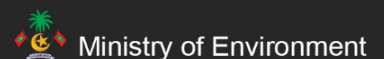




NATIONAL CERTIFICATE IV

Utility Laboratory Technician Services

Student
Learning
Materials



ACKNOWLEDGEMENT

TVET Authority wishes to thank Ministry of Environment for facilitating development of the Occupational Standard and Instructional Materials for Water & Sewerage Courses through the Green Climate Fund.

Table of Contents

1. WRITE TECHNICAL REPORTS.....	13
2. APPLY AND MAINTAIN OCCUPATIONAL HEALTH AND SAFETY	32
3. CARRY OUT DATA ENTRY AND RETRIEVAL PROCEDURES	42
4. APPLY MATHEMATICS FOR WATER OPERATIONS	62
5. APPLY PRINCIPLES OF CHEMISTRY TO WATER SYSTEMS AND PROCESSES	100
6. COMPLY WITH WATER INDUSTRY STANDARDS, GUIDELINES AND LEGISLATIONS....	118
7. PERFORM MICROBIOLOGICAL WATER CONTAMINANT ANALYSIS	152
8. PERFORM CALIBRATION CHECKS ON EQUIPMENT AND ASSIST WITH MAINTENANCE	184
9. APPLY QUALITY SYSTEM IN LABORATORY	195
10. UNDERTAKE WASTE DISPOSAL IN LABORATORY SETTING.....	231
11. CONTRIBUTE TO CONTINUOUS IMPROVEMENT OF QUALITY SYSTEMS.....	254
12. PROCESS AND INTERPRET DATA	260
13. PERFORM LABORATORY TESTING	288
14. CONTROL STOCK.....	318
15. REFERENCES.....	352

INSTRUCTION TO TRAINERS

Competency Based Training (CBT) and assessment - An introduction for trainers

Learning Materials presented here can be used to deliver competency based training using the National Competency Standard developed for the respective occupation.

Competency

Competency refers to the ability to perform particular tasks and duties to the standard of performance expected in the workplace. It requires the application of specified knowledge, skills and attitudes relevant to effective participation, consistently over time and in the workplace environment. The essential skills and knowledge are either identified separately or combined.

Knowledge identifies what a person needs to know to perform the work in an informed and effective manner.

Skills describe the application of knowledge to situations where understanding is converted into a workplace outcome.

Attitude describes the founding reasons behind the need for certain knowledge or why skills are performed in a specified manner. Competency covers all aspects of workplace performance and involves:

- Performing individual tasks
- Managing a range of different tasks
- Responding to contingencies or breakdowns
- Dealing with the responsibilities of the workplace
- Working with others.

Unit of Competency

Like with any training qualification or program, a range of subject topics are identified that focus on the ability in a certain work area, responsibility or function. Each manual focuses on a specific unit of competency that applies in the hospitality workplace. In this manual a unit of competency is identified as a "unit". Each unit of competency identifies a discrete workplace requirement and includes:

- Knowledge and skills that underpin competency
- Language, literacy and numeracy
- Occupational health and safety requirements.

Each unit of competency must be adhered to in training and assessment to ensure consistency of outcomes.

Element of Competency

An element of competency describes the essential outcomes within a unit of competency. The elements of competency are the basic building blocks of the unit of competency. They describe in terms of outcomes the significant functions and tasks that make up the competency. In this manual elements of competency are identified as an "element".

Performance criteria

Performance criteria indicate the standard of performance that is required to demonstrate achievement within an element of competency. The standards reflect identified industry skill needs. Performance criteria will be made up of certain specified skills, knowledge and attitudes.

Learning

For the purpose of this manual learning incorporates two key activities:

- Training
- Assessment.

Both of these activities will be discussed in detail in this introduction.

Today training and assessment can be delivered in a variety of ways. It may be provided to participants:

- On-the-job – in the workplace
- Off-the-job – at an educational institution or dedicated training environment
- As a combination of these two options.

No longer is it necessary for learners to be absent from the workplace for long periods of time in order to obtain recognized and accredited qualifications.

Learning Approaches

Student learning materials developed here can support delivery of training and the expected learning can be facilitated through the following avenues:

Competency Based Training (CBT)

This is the strategy of developing a participant's competency. Educational institutions utilize a range of training strategies to ensure that participants are able to gain the knowledge and skills required for successful:

- Completion of the training program or qualification
- Implementation in the workplace.

The strategies selected should be chosen based on suitability and the learning styles of participants.

Competency Based Assessment (CBA)

This is the strategy of assessing competency of a participant. Educational institutions utilize a range of assessment strategies to ensure that participants are assessed in a manner that demonstrates validity, fairness, reliability, flexibility and fairness of assessment processes.

Flexibility in Learning

Even with the use of this book, it is important to note that flexibility in training and assessment strategies is required to meet the needs of participants who may have learning difficulties. The strategies used will vary, taking into account the needs of individual participants with learning difficulties. However they will be applied in a manner which does not discriminate against the participant or the participant body as a whole.

Catering for Participant Diversity

Participants have diverse backgrounds, needs and interests. When planning training and assessment activities to cater for individual differences, trainers and assessors should:

- Consider individuals' experiences, learning styles and interests
- Develop questions and activities that are aimed at different levels of ability

- Modify the expectations for some participants
- Provide opportunities for a variety of forms of participation, such as individual, pair and small group activities
- Assess participants based on individual progress and outcomes.

The diversity among participants also provides a good reason for building up a learning community in which participants support each other's learning.

Participant Centered Learning

This involves taking into account structuring training and assessment that:

- Builds on strengths – Training environments need to demonstrate the many positive features of local participants (such as the attribution of academic success to effort, and the social nature of achievement motivation) and of their trainers (such as a strong emphasis on subject disciplines and moral responsibility). These strengths and uniqueness of local participants and trainers should be acknowledged and treasured
- Acknowledges prior knowledge and experience – The learning activities should be planned with participants' prior knowledge and experience in mind
- Understands learning objectives – Each learning activity should have clear learning objectives and participants should be informed of them at the outset. Trainers should also be clear about the purpose of assignments and explain their significance to participants
- Teaches for understanding – The pedagogies chosen should aim at enabling participants to act and think flexibly with what they know
- Teaches for independent learning – Generic skills and reflection should be nurtured through learning activities in appropriate contexts of the curriculum. Participants should be encouraged to take responsibility for their own learning
- Enhances motivation – Learning is most effective when participants are motivated. Various strategies should be used to arouse the interest of participants
- Makes effective use of resources – A variety of teaching resources can be employed as tools for learning
- Maximizes engagement – In conducting learning activities, it is important for the minds of participants to be actively engaged
- Aligns assessment with learning and teaching – Feedback and assessment should be an integral part of learning and teaching
- Caters for learner diversity – Trainers should be aware that participants have different characteristics and strengths and try to nurture these rather than impose a standard set of expectations.

Active Learning

The goal of nurturing independent learning in participants does not imply that they always have to work in isolation or solely in a classroom. On the contrary, the construction of knowledge in tourism and hospitality studies can often best be carried out in collaboration with others in the field. Sharing experiences, insights and views on issues of common concern, and working together to collect information through conducting investigative studies in the field (active learning) can contribute a lot to their eventual success.

Active learning has an important part to play in fostering a sense of community in the class. First, to operate successfully, a learning community requires an ethos of acceptance and a sense of trust among participants, and between them and their trainers. Trainers can help to foster acceptance and trust through encouragement and personal example, and by allowing participants to take risks

as they explore and articulate their views, however immature these may appear to be. Participants also come to realize that their classmates (and their trainers) are partners in learning and solving. Trainers can also encourage cooperative learning by designing appropriate group learning tasks, which include, for example, collecting background information, conducting small-scale surveys, or producing media presentations on certain issues and themes. Participants need to be reminded that, while they should work towards successful completion of the field tasks, developing positive peer relationships in the process is an important objective of all group work.

Competency Based Training (CBT)

Principle of Competency Based Training

Competency based training is aimed at developing the knowledge, skills and attitudes of participants, through a variety of training tools.

Training Strategies

The aims of this curriculum are to enable participants to:

- Undertake a variety of subject courses that are relevant to industry in the current environment
- Learn current industry skills, information and trends relevant to industry
- Learn through a range of practical and theoretical approaches Be able to identify, explore and solve issues in a productive manner
- Be able to become confident, equipped and flexible managers of the future
- Be „job ready“ and a valuable employee in the industry upon graduation of any qualification level.
- To ensure participants are able to gain the knowledge and skills required to meet competency in each unit of competency in the qualification, a range of training delivery modes are used.

Types of Training

In choosing learning and teaching strategies, trainers should take into account the practical, complex and multi-disciplinary nature of the subject area, as well as their participant's prior knowledge, learning styles and abilities. Training outcomes can be attained by utilizing one or more delivery methods:

Lecture/Tutorial

This is a common method of training involving transfer of information from the trainer to the participants. It is an effective approach to introduce new concepts or information to the learners and also to build upon the existing knowledge. The listener is expected to reflect on the subject and seek clarifications on the doubts.

Demonstration

Demonstration is a very effective training method that involves a trainer showing a participant how to perform a task or activity. Through a visual demonstration, trainers may also explain reasoning behind certain actions or provide supplementary information to help facilitate understanding.

Group Discussions

Brainstorming in which all the members in a group express their ideas, views and opinions on a given topic. It is a free flow and exchange of knowledge among the participants and the trainer. The

discussion is carried out by the group on the basis of their own experience, perceptions and values. This will facilitate acquiring new knowledge. When everybody is expected to participate in the group discussion, even the introverted persons will also get stimulated and try to articulate their feelings.

The ideas that emerge in the discussions should be noted down and presentations are to be made by the groups. Sometimes consensus needs to be arrived at on a given topic. Group discussions are to be held under the moderation of a leader guided by the trainer. Group discussion technique triggers thinking process, encourages interactions and enhances communication skills.

Role Play

This is a common and very effective method of bringing into the classroom real life situations, which may not otherwise be possible. Participants are made to enact a particular role so as to give a real feel of the roles they may be called upon to play. This enables participants to understand the behavior of others as well as their own emotions and feelings. The instructor must brief the role players on what is expected of them. The role player may either be given a ready-made script, which they can memorize and enact, or they may be required to develop their own scripts around a given situation. This technique is extremely useful in understanding creative selling techniques and human relations. It can be entertaining and energizing and it helps the reserved and less literate to express their feelings.

Simulation Games

When trainees need to become aware of something that they have not been conscious of, simulations can be a useful mechanism. Simulation games are a method based on "here and now" experience shared by all the participants. The games focus on the participation of the trainees and their willingness to share their ideas with others. A "near real life" situation is created providing an opportunity to which they apply themselves by adopting certain behaviour. They then experience the impact of their behaviour on the situation. It is carried out to generate responses and reactions based on the real feelings of the participants, which are subsequently analyzed by the trainer.

While use of simulation games can result in very effective learning, it needs considerable trainer competence to analyse the situations.

Individual /Group Exercises

Exercises are often introduced to find out how much the participant has assimilated. This method involves imparting instructions to participants on a particular subject through use of written exercises. In the group exercises, the entire class is divided into small groups, and members are asked to collaborate to arrive at a consensus or solution to a problem.

Case Study

This is a training method that enables the trainer and the participant to experience a real life situation. It may be on account of events in the past or situations in the present, in which there may be one or more problems to be solved and decisions to be taken. The basic objective of a case study is to help participants diagnose, analyse and/or solve a particular problem and to make them internalize the critical inputs delivered in the training. Questions are generally given at the end of the case study to direct the participants and to stimulate their thinking towards possible solutions. Studies may be presented in written or verbal form.

Field Visit

This involves a carefully planned visit or tour to a place of learning or interest. The idea is to give first-hand knowledge by personal observation of field situations, and to relate theory with practice.

The emphasis is on observing, exploring, asking questions and understanding. The trainer should remember to brief the participants about what they should observe and about the customs and norms that need to be respected.

Group Presentation

The participants are asked to work in groups and produce the results and findings of their group work to the members of another sub-group. By this method participants get a good picture of each other's views and perceptions on the topic and they are able to compare them with their own point of view. The pooling and sharing of findings enriches the discussion and learning process.

Practice Sessions

This method is of paramount importance for skills training. Participants are provided with an opportunity to practice in a controlled situation what they have learnt. It could be real life or through a make-believe situation.

Games

This is a group process and includes those methods that involve usually fun-based activity, aimed at conveying feelings and experiences, which are everyday in nature, and applying them within the game being played. A game has set rules and regulations, and may or may not include a competitive element. After the game is played, it is essential that the participants be debriefed and their lessons and experiences consolidated by the trainer.

Research

Trainers may require learners to undertake research activities, including online research, to gather information or further understanding about a specific subject area.

As National Competency Standards require Competency Based Assessment, following paragraphs provide an overview of the Competency Based Assessment.

Competency Based Assessment (CBA)

Principle of Competency Based Assessment

Competency based assessment is aimed at compiling a list of evidence that shows that a person is competent in a particular unit of competency. Competencies are gained through a multitude of ways including:

- Training and development programs
- Formal education
- Life experience
- Apprenticeships
- On-the-job experience
- Self-help programs.

All of these together contribute to job competence in a person. Ultimately, assessors and participants work together, through the „collection of evidence“ in determining overall competence. This evidence can be collected:

- Using different formats
- Using different people
- Collected over a period of time.

The assessor, who is ideally someone with considerable experience in the area being assessed, reviews the evidence and verifies the person as being competent or not.

INSTRUCTIONS TO CANDIDATE

Introduction to trainee manual

Congratulations on joining this course. The “Student Learning Materials” developed and compiled here is a complete resource book developed in alignment to the respective National Competency Standard and hence will support the students to learn and understand comprehensive theoretical aspects related to the standard. This “Student Learning Materials” will be used for student learning and the method of instruction is called Competency Based Skill Training (CBST).

Aim of the training is to enable trainees to perform tasks and duties at a standard expected by employers. CBT seeks to develop the skills, knowledge and attitudes (or recognize the ones the trainee already possesses) to achieve the required competency standard.

While progressing with the training, make sure you participate with ongoing sessions and systematically develop the required theoretical knowledge and make sure to develop the theoretical competencies in all the units prescribed in the relevant National Competency Standard. Once each competency unit is learnt or the full set of competency units are covered, you may register and undertake the assessment. Do note that, formal assessments related to the TVET programs of Maldives are done by the TVET Authority and the assessments are undertaken within the principles of Competency Based Assessment.

CBA (Competency Based Assessment) involves collecting evidence and making a judgment of the extent to which a worker can perform his/her duties at the required competency standard.

What is a competency standard?

Competency standards are descriptions of the skills and knowledge required to perform a task or activity at the level of a required standard. You will find a description of each competency at the beginning of each Unit. The unit descriptor describes the content of the unit you will be studying in the Manual and provides a table of contents which are divided up into ‘Elements’ and its ‘Performance Criteria’

An element is a description of one aspect of what has to be achieved in the workplace. The ‘Performance Criteria’ details the level of performance that needs to be demonstrated to be declared competent. There are other components of the competency standard:

- Unit Title: statement about what is to be done in the workplace
- Unit Number: unique number identifying the particular competency
- Contact hours: number of classroom or practical hours usually needed to complete the competency. We call them ‘nominal’ hours because they can vary e.g. sometimes it will take an individual less time to complete a unit of competency because he/she has prior knowledge or work experience in that area.

Competency based assessment requires trainees to be assessed in at least 2 – 3 different ways, one of which must be practical. Assessments will be carried out and includes work projects, written questions and oral questions. Your trainer and/or assessor may also use other assessment methods including 'Observation Checklist' and 'Third Party Statement'. An observation checklist is a way of recording how you perform at work and a third party statement is a statement by a supervisor or employer about the degree of competence they believe you have achieved. This can be based on observing your workplace performance, inspecting your work or gaining feedback from fellow workers.

Your trainer and/or assessor may use other methods to assess you such as:

- Journals
- Oral presentations
- Role plays
- Log books
- Group projects
- Practical demonstrations.

Remember your trainer is there to help you succeed and become competent. Please feel free to ask them for more explanation of what you have just read and of what is expected from you and best wishes for your future studies and future career

UNIT 01

WRITE TECHNICAL REPORTS

This unit covers the competence to identify and analyse requirements, to plan and conduct research, to evaluate information and findings, and to develop, document and present technical reports

PLAN RESEARCH AND WRITE PROPOSAL

With the planned engineering qualification, it is important that develop the knowledge and skills on undertaking small research projects that could be system of study, or an engineering part and follow the standard process of writing research or project proposal, conducting research and finally writing the report and presenting them.



Purposes of a Proposal

The project or research proposal:

- ✓ Allows the writer to clarify what it is he/she wants to do, why and how he/she wants to do it,
- ✓ Presents what she/he wants to do in the manner and timeframe proposed, and
- ✓ Once approved, provides a written contract between the student and the project supervisor

Components of a Project Proposal

1. Title

The title of the project is very significant. It will go on the spine of the published document when it is bound and becomes accessible in the University of Lethbridge Library. The title is one of the ways that people using the University of Lethbridge electronic search engine will locate the project in the holdings. The title must be clear, appropriate for the topic and less than 45 characters, including spaces and punctuation.

2. Introduction (WHAT is this about?)

The Introduction to the project provides a general introduction to the phenomena or issue of interest, and is usually contained in 2 pages. The issue or problem under investigation is described, and background and/or context for understanding the nature of the issue is provided. In writing this section, students should provide answers to two main questions:



What is the project all about?

Why is the project important or worthwhile?

The Introduction will also typically conclude with a brief description of the structure of the remainder of the document.

3. Research Question (WHAT am I trying to find out? WHY?)

Every project must state a research question or a statement on what is the intent of the project. It is not a "null-hypothesis statement" but rather you are stating the big, overarching question that is guiding your study. Several smaller questions may even be nested in the larger one.

The research question and the title are two required elements of all proposals. The connections between the two must be obvious. (Hopefully, they are obvious to the writer, but they may not be to the audience.)

Where the research question appears in the proposal is something each writer must decide. It could appear in the introduction; it could follow the introduction or the background or the literature review or it could appear within any of the above sections. Just don't leave it until the reference section!

4. Method (HOW? WHO? WHERE?)

(This section must make sense within the context of the document and be linked with the sections preceding it.) In this section provide a clear, explicit and thorough description of how you will complete your project and the timetable for completing each step. For example, what databases will you be using during your literature review? What search terms and exclusion criteria will you be using? When will you be starting your literature review and when will it be finished?

It is the writer's responsibility to ensure that the proposal is clear about what is being proposed, with whom, where and when. (WHY should already have been explained.) Approximately 1-2 paragraphs is suitable for this section.

A project does not involve interviewing people or collecting raw data as this type of collection of data would require ethics approval and a host of other documents would need to be created such as informed consent.

This section needs to include a statement that you will adhere to an approved code of ethics of your selection.



5. Project (What do I do when I'm done doing what I said I would do?)

Describe what the final product will look like. For example, if it is a manual, provide details about the manual's length, formatting style, number of lessons, etc. If the product is to be something creative and other than text, provide examples of what the final product might look like. If the proposal includes writing a series of fictionalized autobiographical accounts, a sample should be included in the proposal. If the proposal includes a website describe it.

Title Page
Acknowledgements Page
Abstract
Table of Contents
Chapter 1: Overview (proposed number of pages:)
Sub headings:
a.
b.
c.
Chapter 2: Review of Literature (proposed number of pages:)
Sub headings:
a.
b.
c.
Chapter 3: Methods (proposed number of pages:)
Chapter 4: Outcome
a.
b.
c.
Chapter 5: Synthesis
a. Strengths
b. Limitations
c. Recommended Future Research
References

6. Timeline Include a draft timeline from start to finish.

Start with the proposed convocation date and work backwards to revising the final draft of project (expect at least two to three rewrites). Availability of the supervisor is also very important to consider and factor in to your timeline.

7. References

References to anything cited in the text of the proposal must adhere to APA guidelines. (As a matter of fact the entire proposal needs to adhere to APA guidelines). APA formatting requires only those materials cited or referred to in the text be listed in the References. A separate section entitled "Bibliography" lists other materials (books, journal articles, etc.) related to the project but not specifically referred to in the document.

CONDUCT RESEARCH AND ANALYSE THE INFORMATION

The research plan shall detail completely the prosecution the research, including the submission of an acceptable final report. The plan ultimately becomes a part of the contract by reference of the proposal; therefore, it should describe, in a specific and straightforward manner, the proposed approach to the solution of the problem described in the project statement. It should be concise, yet include sufficient detail to describe completely the approach to the solution of the problem. Research methodology shall be described in sufficient detail to permit evaluation of the probability of success in achieving the objectives.



The research plan shall be subdivided into the following sections:

Introduction

The introduction to the research plan should provide a concise overview of the proposer’s approach to conducting research. It should describe the manner in which the expertise and experience of the proposed team will be used in the research, and the application of special data, facilities, contacts or equipment should be presented. The Introduction should highlight the linkages of the proposed team’s capabilities to the project tasks and the manner by which the proposed plan will satisfy the objectives.

Research Approach

This section will be used to describe how the objectives will be achieved through a logical, innovative, and rational scientific plan. The plan shall describe each phase or task of the research to be undertaken.

Equipment and Facilities

This section shall include a description of the facilities available to undertake the research and an itemization of the equipment on hand considered necessary to complete the research. In the event that use of the facilities or equipment is conditional, the conditions should be described. In the event that certain facilities or equipment are considered necessary to undertake the research but are not on hand, that fact should be presented. The proposer should identify any arrangements that will be made to borrow or rent necessary equipment. In the case where it is contemplated that additional equipment will be purchased under project funds, be certain that the budget item “capital equipment” indicates this.

Time Requirements

The time required to complete the research project shall be specified. Proposals will not be rejected if the proposed time does not match the time specified in the project statement. However, the agency must justify any difference. In addition, a schedule shall be included that shows each phase or task of the work, when that phase or task will begin, how long it will continue, and when it should end. The timetable should clearly delineate the points in time where project deliverables and reports are planned



Research Work Plan

In the absence of specific requirements for the format and content of the research work plan, the following constitutes a useful outline:

- ✓ Title
- ✓ Introduction
- ✓ Objectives
- ✓ Research Approach
- ✓ Project Team
- ✓ Equipment and Facilities
- ✓ Budget
- ✓ Schedule
- ✓ Anticipated Results
- ✓ Implementation



The introduction provides background information taken from the Problem Statement or the Request for Proposals. It is included because the work plan should be a “stand-alone” document, i.e. the reader should not need to refer to other documents. The objectives also should be a re-statement of the objectives from the earlier documents. The ‘Research Approach’ is the largest section in the work plan. It should present the hypothesis, and describe and justify the strategy, which is being employed to satisfy the objectives. For instance it could be a desk study comprising literature review and analysis, laboratory studies, field studies, or a combination of approaches. It is usual to divide the work into tasks, each of which constitutes a milestone in the completion of the work. For example, if the study involves writing a state-of-the-art report, the tasks might be:

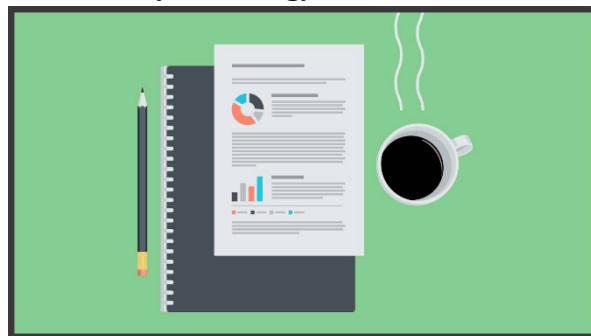
- ✓ Task 1 Literature Survey
- ✓ Task 2 Questionnaire
- ✓ Task 3 Field Visits
- ✓ Task 4 Preparation of First Draft
- ✓ Task 5 Preparation of Second Draft
- ✓ Task 6 Preparation of Final Draft

For each task the activities should be described in detail. In Task 1 the search strategy and the databases should be described. In Task 2 the recipients of the questionnaire should be identified. If it is known which agencies will be included in the field visits in Task 3, they should be identified, otherwise it should be made clear how the decision would be made. In Task 4, the scope and intended audience should be identified, and a tentative outline of the report provided. The work plan should also state who would review each of the drafts.

In the case of a project that involves experimental work and developing the plans for subsequent fieldwork, the tasks might be as follows:

- ✓ Task 1 Literature Survey
- ✓ Task 2 Laboratory Studies
- ✓ Task 3 Exposure Plot Studies
- ✓ Task 4 Development of Field Study Design
- ✓ Task 5 Preparation of Final Report

Task 1 would be described as in the previous example. Task 2 will probably consist of sub-tasks, each comprising a series of experiments. The experiments should be described in detail. This allows the principal investigator to ensure that the necessary people, equipment and laboratory facilities will be available to perform the work, and to calculate the cost of the work. This will usually be an iterative process that involves determining how many experiments can be performed within the available budget. It is essential that the principal investigator be confident that the experiments being performed will be sufficient to satisfy the objectives for the task. It is also good practice to identify a strategy to be followed if the experimental work is not completely successful, e.g. are there other test procedures that could be used? The work plan should describe clearly what would have been accomplished before Task 3 begins, the way in which the work in Task 3 will be influenced by the results obtained in Task 2, and the manner in which the results will be reported. The activities in Task 3 should be described in the



same way as for Task 2, except that they will be more tentative because it is likely that many details cannot be finalized until results from Task 2 become available. Because it is a plan that is being written, it is inevitable that less detail can be provided for the later activities. One of the key roles of the principal investigator is to recognize when changes in the work plan are necessary, and to modify the plan accordingly. The good researcher will maintain flexibility in the work plan to deal with setbacks, and to seize opportunities, while planning in sufficient detail to estimate resources, and to make arrangements for activities which require a long lead time.

In the example given, Task 4 consists of developing a design for a field study to verify the results of Tasks 2 and 3 under real world conditions, not performing the field work itself. The specific details will depend on the results of Tasks 1 to 3, but the plan should contain the following sections:

- ✓ Hypothesis to be tested on field studies
- ✓ Criteria for selection of the study site
- ✓ Potential sites
- ✓ Equipment and other facilities required
- ✓ Data collection and analysis procedures
- ✓ Staffing plan
- ✓ Schedule
- ✓ Budget

The final report prepared in Task 5 should provide full documentation of the problem definition, experimental methods, results, conclusions and future activities, including implementation. Further information on the content and preparation of reports is given in Chapter Five.

In the section describing the project team, the team members should be listed, along with the responsibilities and time commitment for each person. This information is required to ensure that each person will be available to work on the project when required, and to establish costs. The key members of the team should be identified, but for junior positions where the work could be done by one of a number of technicians, it is sufficient to identify the person by rank, e.g. senior technician @ 200 hours, 3 junior technicians @ 300 hours each. The key members must be identified because if a substitution becomes necessary, management and the sponsor will need to satisfy themselves that the replacement has the necessary credentials and experience to perform the research. Curriculum vitae are not required in a work plan.



Equipment and facilities are listed for the same reason as personnel, i.e. to ensure that they will be available when needed and that all the costs are captured in the budget. This also forces the researcher to verify that all the equipment necessary to perform the planned experiments is available, or identify equipment and supplies that must be purchased.

If the research approach, project team, and the equipment are documented in sufficient detail, calculation of the budget for the project is relatively straightforward. Other items such as travel, overhead and profit must, of course, also be included.

A detailed schedule for the work is required to establish a completion date and to provide a mechanism for management to measure the progress of the work. It is also needed to identify when resources will be needed, and to calculate cash flow requirements. For projects that involve no more than about 10 tasks, and about an equal number of sub-tasks, a chart similar to that shown in Figure B-6 is perfectly adequate. Using the second study described above as an example, the chart shows the start and completion dates for each sub-task, and the anticipated progress of each sub-task, as a cumulative percentage. It also shows the interrelationship of the tasks and sub-tasks because it is clear which activities are underway concurrently, and which are sequential. The schedule allows one month for the review of the interim report, and two months to review the final report. The anticipated progress on the overall project can be calculated from a knowledge of the amount of effort required for each task and sub-task. The amount of effort required to complete each sub-task, expressed as a percentage of the effort required to complete the project, is shown in the third column. Taking the end of June 1996 as an example, the anticipated overall completion is:

Task 1 + 25% of sub-tasks 2a, 2b, and 2c

$$= 10\% + 0.25 \times (16\% + 16\% + 16\%)$$

$$= 22\%$$

By plotting the values from the row "Overall Completion" in Figure C-6 against duration of the project, a chart of anticipated progress is developed, as illustrated in Figure B-7. Using the same technique, planned expenditures can be plotted, as shown in Figure B-8, from knowledge of the budget and cash flow projections for each sub-task. Figures C-6 to C-8 are used to measure the progress of the research as described in the section "Execution of the Research".

The Gantt chart provides a powerful visual representation of the work schedule and quite



large research projects, typically up to \$1million budget, can be managed in this way. Larger projects, especially those involving many semi-autonomous contributors, or requiring access to expensive equipment that is used on many projects, may require a more sophisticated work schedule to be developed. This can be done by preparing a critical path analysis or using computer software designed for

project management.

The final section of the work plan, Implementation, describes how the findings of the research will be implemented. This enables the researchers to involve those who will be responsible for implementation in the research, and to allow the plans for the implementation activities to be developed while the research is in progress so that there is no delay between completion of the research and implementation of the findings.

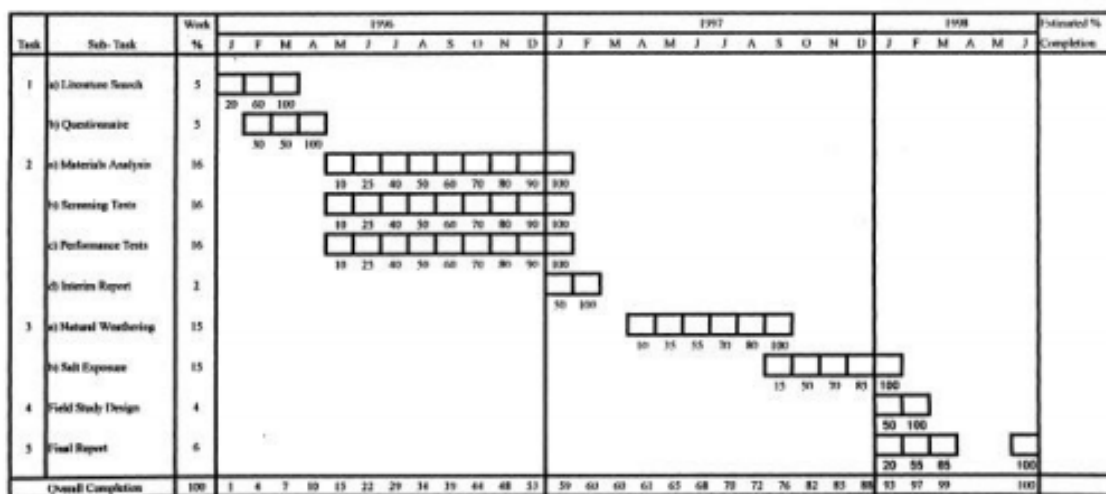


Figure B-6: Example of a Work Schedule Using a Gantt Chart

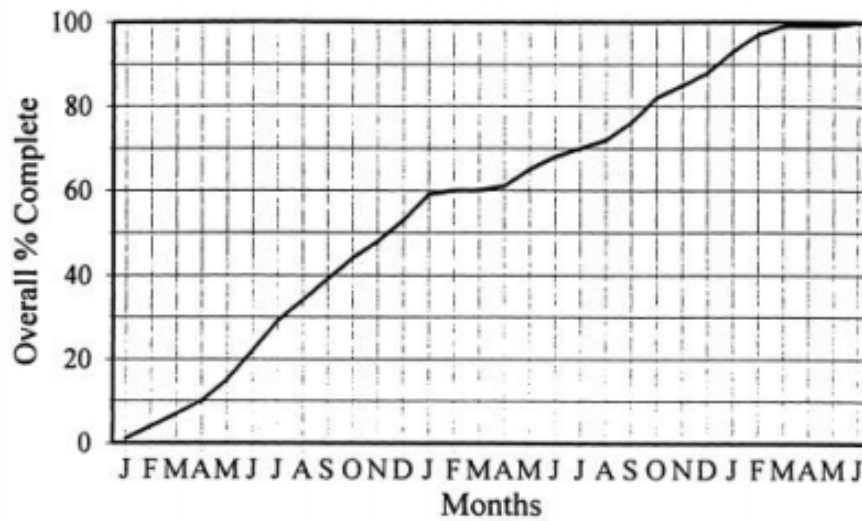


Figure B-7: Planned Progress

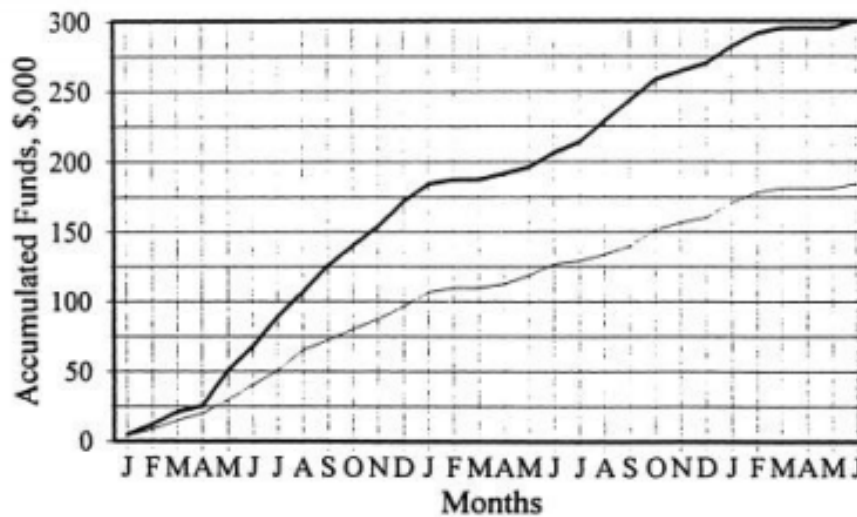


Figure B-8: Anticipated Expenses

Execution of the Research

Technical progress and financial expenditures must be tracked, and monitored, throughout the period of execution of the research. Charts similar to those illustrated in Figures B-6 to B-8 are suitable for this purpose. As an example, Figures B-9 to B-11 illustrate the status of the project described in the previous section as it might have been reported in December 1996. The data indicate that there were delays in beginning Task 2, but, except for work on the performance tests (Task 2c), the project was back on schedule.

Where a greater level of detail is required, as for example, where different budget codes must be reconciled, comparisons between planned and actual expenditures can be made by category, e.g. salaries, travel, and equipment. In this way, variations can be detected early in

the process, and steps taken to bring the project under control.

Task	Sub-Task	Week %	1996												1997												1998					Estimated % Completion
			J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	
1	a) Literature Search	5	[Progress bars]																													100
	b) Questionnaire	5	[Progress bars]																													100
2	a) Materials Analysis	16	[Progress bars]																													90
	b) Screening Tests	16	[Progress bars]																													90
	c) Performance Tests	16	[Progress bars]																													60
	d) Interim Report	2	[Progress bars]																													
3	a) Natural Weathering	15																														
	b) Salt Exposure	15																														
4	Field Study Design	4																														
5	Final Report	6																														
Overall Completion		100	1	4	7	10	13	22	29	34	39	44	48	53	59	60	60	64	65	68	70	72	76	82	83	89	93	97	99	100	49	

Figure B-9: Completed Progress Schedule for December, 1996

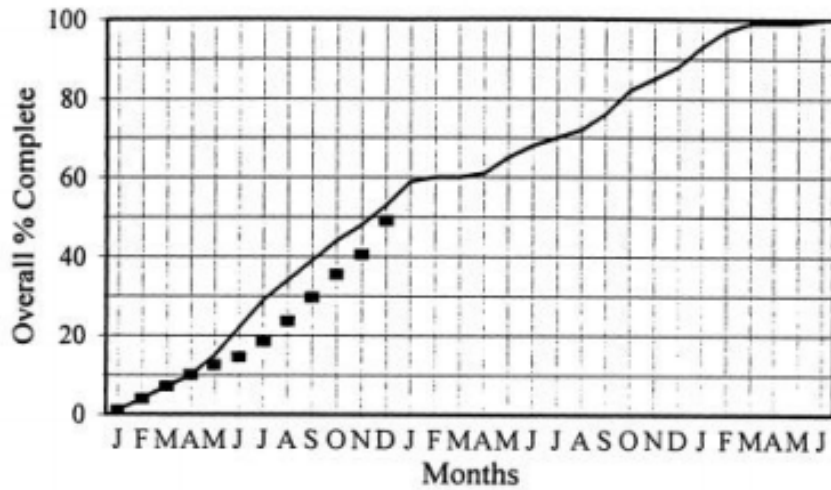


Figure B-10: Overall Progress to December, 1996

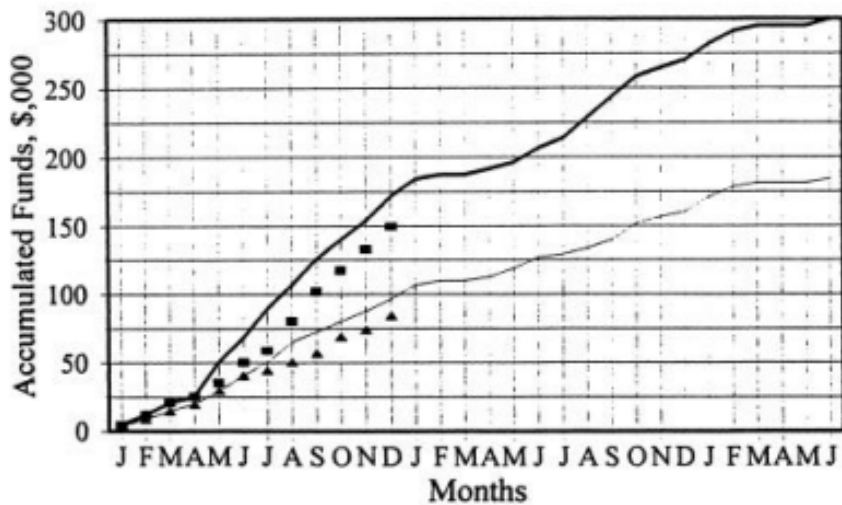


Figure B-11: Expenditures to December, 1996

Implementation and Dissemination of Research Results

An NCHRP study of technology transfer methods and implementation practices included a survey of transportation agencies and an analysis of case studies (10). Much of the information in this section is based on the data collected in the study, and from which the recommendations presented in Chapter Three were developed. Implementation “success” was defined in terms of timeliness, effectiveness, and scope of use. The study examined success from three perspectives:

- ✓ Characteristics of the research results
- ✓ Characteristics of the implementing organization
- ✓ Characteristics of the implementation process

From each perspective, the relative importance of factors that promote implementation, and those which act as barriers to implementation were rated, by participants in a workshop, on a scale of 1 to 5. The results are given in Tables B-1 to B-3 (the data were obtained from figures contained in reference 10). Barriers to implementation have been expressed on a scale of -1 to -5 (-5 being the greatest barrier).

Characteristics of Research Results



Some attributes of the research output can impede implementation. Most obviously, if the research does not meet the needs of potential users, the results will not be put into practice. Also, if users do not see evidence that a new product or process has been adequately tested, they may not want to be guinea pigs.

On the other hand, research results are more likely to be put into practice rapidly and effectively, if the researchers have accounted for real-world situations. In many cases, pilot or demonstration projects are useful steps toward full implementation. Their purpose is to evaluate the new products or processes under operational conditions, and make any necessary improvements, before full implementation on the in-service system. This is important to reduce the risk of failures. Even when full-scale implementation is adopted, the product or process may be designated experimental for a prescribed period to ensure that there is a systematic evaluation of the how well the changes are working.



Site selection for demonstration projects is much more complex than it might appear to be. The objective is to evaluate the new product or process under conditions, which are representative (with respect to site conditions, difficulty of work, contractor expertise, time of year) of the anticipated future applications while minimizing the risk of delay or failure. Frequently the work must be incorporated in contracts already awarded, or about to be tendered. Each has its disadvantages. Changes to existing

contracts are often expensive and the contractor may not have the necessary expertise. Contracts not yet awarded are subject to shifts in award schedules, often resulting in projects being moved from one construction season to another. Rarely will there be an ideal candidate and the selection must be based on compromises between ideal and available conditions. The longer the time available to plan a demonstration project, the greater are the chances of locating site meeting a larger number of the selection criteria.

Positive Factors	Rating	Barriers	Rating
Pilot projects in real settings	4.2	Mismatch between research and user needs	-4.3
Implementation package with research output	4.0	Research output not sufficiently tested	-3.8
Research adaptable to varied contexts	3.3	Research output does not fit work procedures	-3.6
Research designed for commercialization	2.5	Allocation of patents etc. not settled	-3.1

Table B-1: Factors Pertaining to the Characteristics of Research Results

Positive Factors	Rating	Barriers	Rating
Management commitment	4.8	Risk aversion	-4.2
Long-term innovation champions	4.1	Organizational inertia	-4.2
Capability to sustain innovation	4.0	Inflexible contract specifications	-3.9
Incentives for change	4.0	Discomfort with change	-3.9
In-house expertise	3.9	Legal liability	-3.8
On-the-job recognition	3.7	Inadequate resources	-3.8
Performance-oriented specifications	3.4	Skill obsolescence	-3.2
Job rotation assigned	2.7	Political involvement with managers	-3.2
		No local precedents	-2.8
		Inadequate travel budget	-2.6

Table B-2: Factors Pertaining to the Organization

Positive Factors	Rating	Barriers	Rating
Researcher-user pilot collaboration	4.6	User successes unpublicized	-3.7
Users help design research	4.4	Poor quality/relevance filters	-3.6
Targeted funding	3.6	One-way dissemination	-3.6
Easy access to researchers	3.4	Costliness	-3.6
Effective training	3.2	Unknown information source	-3.2
Mandatory innovation use	2.5	Researchers not market-oriented	-2.5

Table B-3: Factors Pertaining to the Implementation Process

Characteristics of the Organization

The most important institutional barriers to implementation include organizational inertia, risk-averse behavior, management discomfort with change, and inadequacy of resources. As noted in the section describing the characteristics of research results, new products and processes entail a degree of risk. Some will prove not worth their cost, and some may not function effectively. The organization must be prepared to encourage staff to innovate, and to support them even when new ventures are not successful. This includes a commitment on the part of senior management to provide resources for implementation efforts and the willingness of senior officials to champion innovation.

Characteristics of the Implementation Process

Collaboration between the researchers and the users throughout the research and implementation phases is the key to the successful use of research results. Many agencies involve the researchers, in-house or contract staff, in the implementation efforts and technology transfer. Commonly, this involves giving seminars or training sessions to agency staff. Depending upon the circumstances, it could also involve evaluating the success of demonstration projects or results designated experimental. However, some agencies deliberately limit the involvement of researchers in the implementation process. The main reasons for doing so are that the contractor is not familiar with the internal process of the agency, and not necessarily expert in implementation efforts. It is also recognized that the implementation effort is substantial, and often different disciplines from those needed to conduct the research. In cases where the researchers are not involved directly in the implementation efforts, it is important that they be accessible.



Cost is frequently a major impediment in implementing new products, and procurement rules that prohibit sole-sourcing can be a major obstacle. Targeted funding for implementation, and flexibility to incorporate experimental features in construction contracts are effective ways of dealing with these problems.

Evaluation of Research Projects

Expert Opinion

This method involves obtaining the opinions of people who are knowledgeable about the subject of the research and the impact of the project being evaluated. The experts can be

internal or external to the agency.

Expert opinion is often solicited in the project selection phase. The opinion can be provided on an unstructured basis, or structures using performance indicators such as the quality of the research, level of innovation, or economic impact.

User or Client Opinion

This method involves obtaining the opinions of clients, often through technical advisory committees or project panels. Like expert opinion, client opinion is most commonly sought when problem statements or proposals for research projects are reviewed. Surveys are a useful method of obtaining client or user input in situations where there are numerous users, or the users are widely separated geographically.

Cost-Benefit Methods

Cost-benefit analysis seeks to assess the project in terms of the economic and social benefits generated for a particular “referent group” (e.g. an agency, a region or society as a whole) as well as the economic and social costs incurred by the referent group to carry out the research and implement the results. The definition of the referent group is important because it defines the bounds for the analysis. There are a number of general principles associated with conducting cost benefit analyses of transportation-related research projects.

- ✓ There are three main types of costs associated with a research project that must be taken into account in the analysis. These are the costs of generating the research results, the costs of introducing and supplying the results to the end users, and the costs incurred by the end users to implement the results.
- ✓ The benefits of the research project are valued at the price society is willing to pay for them. The assessment of benefits includes not only those for which prices are paid, but also benefits associated with, for example, reduced environmental damage, better air quality and improvements in health and safety, even though such benefits may be difficult to quantify.
- ✓ Once they have been identified, all the benefits and costs associated with the project are compared using a common measuring system of constant dollar values. Allowances can be made for future changes in relative real prices, but no adjustments are made for the future changes in the general price level as a result of inflation or deflation. All costs and benefits must be discounted to their present values through a social discount rate before they can be compared to determine the net benefit of the project to society. The selection of the discount rate is controversial, and has a major impact on the results of the analysis. The discount rate is intended to be the social discount rate, which represents the



present generation's weighting of benefits and costs to be borne by future generations. In the private sector, the discount rate is sometimes taken to be the difference between the prime interest rate and the rate of inflation.

- ✓ The net present value is given by the formula:

$$NPV = \sum_{i=1}^N \frac{(B_i - C_i)}{(1+r)^i}$$

where B_i = the benefits attributable to the project in year i

C_i = the costs attributable to the project in year i

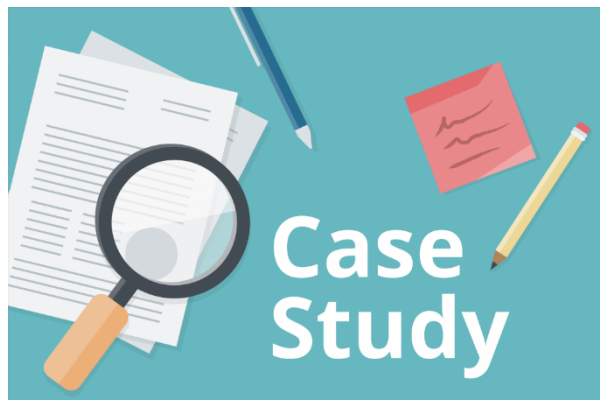
r = the discount rate

N = the number of years over which benefits and costs (compared to the "base case") can be estimated, usually 5 to 10 years.

- ✓ The research project being analyzed must be incremental, and the benefits must be attributable to the results of the research. "Incremental" means that the results would not have been available in the absence of the project. "Attribution" deals with the extent to which the benefits are actually due to the research results. This is extremely important in defining the "base case" which is rarely the situation before the project was undertaken, but more properly it reflects benefits that would have occurred even if the project had not been undertaken. This includes the incorporation of developments made elsewhere, and changes that would have occurred from sound management strategies. Given the uncertainty of research, many evaluators find cost-benefit analysis impractical, except possibly for projects which have been completed for some time, and which have well-defined benefits. On the other hand, cost benefit analysis can be a useful method for deciding which potential projects are most attractive, and for demonstrating the value of investing in research.

Case Studies

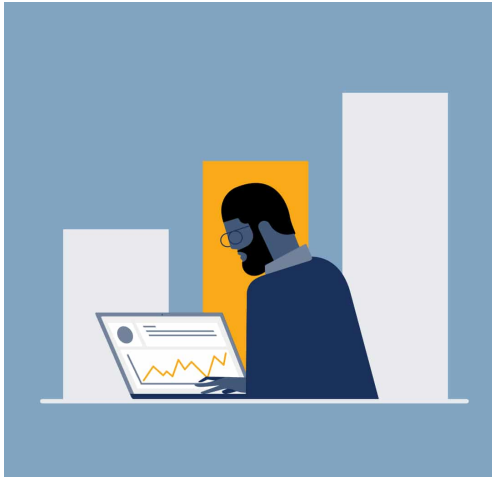
Case studies involve a detailed and thorough analysis of research projects, and seek to track and document the evolution of the impacts associated with the research. The advantage of



case studies is that they afford the best opportunity of identifying the relationship between the research study and the impact of the research results. They are particularly useful for evaluating projects that benefit the public good, rather than using cost-benefit analyses that assign dubious values to some impacts such as the value of a human life. Because the results are usually qualitative, it is difficult to use case studies to compare the value of projects, or to aggregate the results to

demonstrate the value of research programs.

Performance Indicators



There are two main categories of performance indicator methods, partial indicators and integrated partial indicators. The first method involves the collection of information items, each of which provides some insight into the project such as cost, time, risk and potential outputs. The method of integrated partial indicators involves the collection of the same kinds of information, except that it is integrated in some way. The method usually involves summing the partial indicators to arrive at a “bottom line score”. The most common approach is to

evaluate each project with reference to a specific set of criteria (e.g. cost, feasibility or risk, likely impact, relevance to the agency mandate), assign a score and a weight to arrive at an overall score for the project. This method is often used to select individual projects, and to evaluate responses to requests for proposals.



PREPARING AND PRESENTING REPORTS

What is a report?

A report is a written presentation of factual information based on an investigation or research. Reports form the basis for solving problems or making decisions, often in the subjects of business and the sciences. The length of reports varies; there are short memorandum (memo) reports and long reports. Most often you will be asked to write a long report.

What makes an effective report?

- ✓ Clear, concise and accurate
- ✓ Easy for the audience to understand
- ✓ Appropriate for the audience
- ✓ Well organized with clear section headings

Report structure:

Reports follow a standardized format. This allows the reader to find the information easily and focus on specific areas. Most reports follow the following structure, but please look at your assignment question and marking guide carefully, as the format and terminology required in your report may vary from this guide. If so, check with your tutor. Please check your marking guide to determine the word limit and how marks are allocated to each section

A report must have:

- ✓ Title Page

- ✓ Table of Contents
- ✓ Abstract or Executive Summary
- ✓ Introduction (or Terms of Reference and Procedure)
- ✓ Findings and/or Discussion
- ✓ Conclusions
- ✓ Recommendations
- ✓ References

A report may also contain:

- ✓ Cover letter
- ✓ Bibliography
- ✓ Glossary
- ✓ Appendices

The table below summarizes the main headings used in reports and outlines the purpose of each section. Please note: Further headings or subheadings may be used depending on the report's content, and are specific to the individual report.

Section	Purpose
Title Page (Not part of the word count)	Gives the title of the report, the student name/number, the name of the person the report is being submitted to, and the completion date.
Table of Contents (Not part of the word count)	Shows the sections of the report. Gives the headings, subheadings and page numbers.
Abstract or Executive Summary	Gives a summary of the whole report. Outlines the report's purpose, methodology, findings, main conclusions and recommendations. Mainly written in past tense, and prepared last.
Terms of Reference	Briefly states the purpose and scope of the report. This includes who requested the report, the main issues or problems to be identified, the reason for undertaking the report and the due date of the report.
Procedure	Outlines the methods used to collect information e.g. interviews, questionnaires, observations and/or research.
Introduction (May be used instead of the Terms of Reference and Procedure)	Outlines the context, background and purpose of the report. Defines terms and sets limits of the investigation. The reader/audience can easily identify what the report is about, how

	<p>information was gathered, and why the report is needed.</p> <p>Mainly uses past tense and can be written last – but is presented first.</p>
<p>Findings and/or Discussion For this section, avoid using the headings “Findings” or “Discussion”. Instead, create headings and sub-headings that identify the main issues or problems.</p>	<p>Findings: What was found during the research or investigation? Gives the facts only – no interpretation by the writer of the report. Tables, graphs or diagrams can be used. Must be relevant to the issues and problems identified in the Terms of Reference. Arranged in a logical order with headings and sub-headings.</p> <p>Discussion: You may also be required to analyses, interpret and evaluate the findings. The discussion draws together different parts of the findings and may refer to findings of other studies and/or theories.</p>
<p>Conclusions</p>	<p>Brief statements of the key findings of the report (full explanation is given in the Findings and/or Discussion). Arranged so the major conclusions come first. Should relate directly to the objectives set out in the Terms of Reference or Introduction. Follow logically from the facts in the Findings and/or Discussion. Must be complete enough for recommendations to be made from them.</p>
<p>Recommendations (note: not all reports give recommendations)</p>	<p>The opinions of the writer of the report about possible changes, or solutions to the problems, including who should take action, what should be done, when and how it should be done.</p>
<p>References (Not part of the word count)</p>	<p>A list of the sources that are used in and referred to in the report. Use APA referencing style.</p>
<p>Bibliography (Not always required)</p>	<p>Lists any sources that were read for the research but were not cited in the report. (Bibliography is not included in the word count).</p>
<p>Appendices (Not always required)</p>	<p>Additional relevant information. May include interview questions, surveys, glossary etc. (Appendices are not included in the word count).</p>

UNIT 02

APPLY AND MAINTAIN OCCUPATIONAL HEALTH AND SAFETY

This unit of competency describes the skills and knowledge to monitor and maintain work health and safety (WHS) within a work area where the person has supervisory responsibility for others

PERFORM ALL WORK SAFELY

Regardless of your job, there are some basic safe work practices that should be observed by everyone working on the job site. The objective of the safety program is to prevent injuries and to allow you to do your job efficiently and safely. It takes an effort on your part to support the safety program but, after all, that's what it's all about.

Right now, let's review some basic safe work practices. All persons must follow these safe practices and render every possible aid to safe operations and be a part of the program by reporting all unsafe conditions or practices to your supervisor or superintendent. The vast majority of work-related injuries are the result of unsafe acts of workers. That means, when you take shortcuts, you violate safety regulations or simply don't take safety seriously, injuries are more likely to occur. Your company has a responsibility and obligation to make sure that all employees observe and obey all applicable company, or national regulations and order as is necessary to the safe conduct of the work and must take such action as necessary to obtain compliance.



If you violate company safety rules, or you work in an unsafe manner, you will be provided a written safety counselling. This counselling will explain what the unsafe behaviour was and how to correct it. If it's a minor violation, then the counselling will serve as a reminder for the proper procedure. If it's a serious violation, or you continue to exhibit unsafe behaviour, disciplinary action may be warranted. The purpose of safety rule enforcement is the protection of all employees. One employee's unsafe behaviour can affect the safety of other employees and safety is too important to allow unsafe behaviour or unsafe conditions.



In the construction industry, frequent accident prevention instructions or training is provided at least every ten days. However, it is each employee's responsibility to work and act safely every day on every job. Training is simply making you more aware of safety and safety rules and it's your job to work safe and act safely every day.

Anyone known to be under the influence of drugs or intoxicating substances which impair the employee's ability to safely perform the assigned duties shall not be allowed on the job while in that condition. If you are taking medication prescribed by a physician or taking

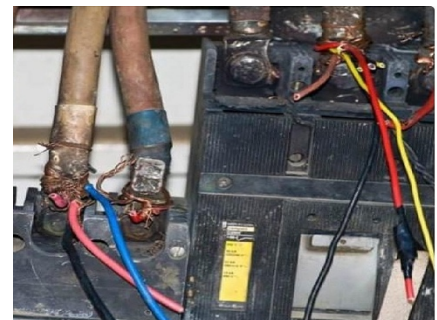
over-the-counter medication, be sure to tell your supervisor before you begin work. Some medications may impair your ability to work or operate equipment safely. We discussed unsafe behaviour and how it leads to injuries on the job. Unsafe behaviour includes horseplay. Scuffling, practical jokes and other acts which tend to have an adverse influence on the safety or wellbeing of other employees. No one shall knowingly be permitted or required to work while the employee's ability or alertness is so impaired by fatigue, illness, or other causes that they might unnecessarily expose the employee or others to injury.

Work shall be planned and supervised to prevent injuries in the handling of materials and in working together with equipment. Employees shall not enter manholes, underground vaults, chambers, tanks, silos, or other similar places that receive little ventilation unless it has been determined that it is safe to enter. Confined spaces can be quite hazardous from toxic fumes, gas, and other hazards can gather in the spaces creating a dangerous hazard.

Machine guards and other protective devices must be in their proper place before machinery and equipment is used and employees must report any deficiencies or hazards to the supervisor when they are detected. If the equipment is unsafe to operate, do not operate the equipment until it has been replaced or repaired.

Crowding or pushing when boarding or leaving any vehicle or other conveyance is prohibited.

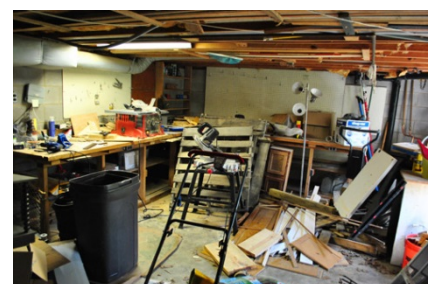
Employees must not handle or tamper with any electrical equipment, machinery, or air or water lines in a manner not within the scope of their duties unless they have received instructions and authorization from their supervisor.



If you are injured on the job, report the injury immediately. Don't wait. Report the injury when it occurs, even if you believe that medical treatment is not necessary. If medical treatment is required, it will be provided.

When lifting anything, use the power of your legs and not your back. If you keep your back in its natural curvature by bending your legs, it's difficult to suffer a back injury.

Inappropriate footwear or shoes with thin or badly worn soles must not be worn. Wear proper footwear and clothing on the job. Materials, tools, and other objects shall not be thrown from structures until proper precautions are taken to protect others from the falling objects.



Housekeeping is important to everyone's safety so take time to keep your work area clean. If you see a hazard, correct it. If you can't correct the hazard yourself, report it so it can be corrected.

When handling chemicals or hazardous substances be sure to use personal protective equipment as necessary and follow the instructions provided on the chemical label. Never use gasoline for any type of cleaning purposes. Wash your hands and skin after handling chemicals and hazardous materials.



When using ladders, inspect the ladder before using it to make sure it is in good condition and will carry the load. Using the proper ladder on the job is equally important. Never stand on the top two steps of a ladder, and when using straight ladders, make sure the ladder extends at least 3 feet above the landing, or where the ladder is positioned on the structure.

Any damage to scaffolds, false work, or other supporting structures shall be immediately reported to your supervisor and repaired before use.

No source of ignition shall be applied to any enclosed tank or vessel, even if there are some openings, until it has been first determined that no possibility of explosion exists. An authority for the work is obtained from your supervisor. Persons using welding equipment must always be concerned in starting fires from the sparks or flash. Never weld around combustible or flammable material and, if necessary, have someone standing by with a fire extinguisher during welding operations.

When using tools and equipment, maintain these tools and equipment in good serviceable condition. Damaged tools or equipment must be removed from service and tagged "defective." Pipe or Stilson wrenches must not be used as substitute for other wrenches. Only appropriate tools shall be used for a specific job.



Vices must be equipped with handles and not used to punch or pry. A screwdriver should not be used as a chisel. Portable electric tools shall not be lifted or loaded by means of a power cord. Use ropes, not the power cord for lifting or lowering electrical tools. Before electrical tools are used, they must be inspected to make sure the power cord and plugs are in good condition. Cords with cuts or fray must be replaced. You cannot simply wrap electrical tape over a cut or frayed cord.

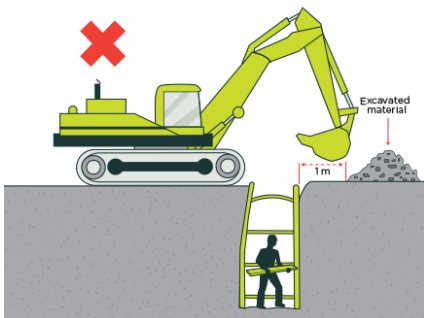
Only those persons who are trained and authorized may operate machinery or equipment. Loose or frayed clothing, long hair, dangling ties, finger rings, necklaces, and other potentially hazardous items may not be worn around moving machinery or other areas where they become entangled. Machinery shall not be serviced, repaired or adjusted while in operation, or shall oiling of moving parts be attempted, except when equipment that is



designed or fitted with safeguards to protect the person performing the work. Where appropriate, lockout-tagout procedures must be used. If you see a piece of equipment or a machine that is locked out and tagged out, do not attempt to operate this equipment. A lock and tag means that someone is working on that machine and could possibly be injured if the equipment were to be inadvertently started.

Employees shall not work under vehicles or other equipment supported by jacks or chain hoists without protective blocking that will prevent injury if jacks or hoists should fail.

Air hoses shall not be disconnected at compressors until the hose line has been bled and is free of any air pressure.



All excavations must be visually inspected before backfilling to ensure it is safe to backfill. Excavating equipment must not be operated near tops of cuts, banks or cliffs if employees are working below. Tractors, bulldozers, scrapers, and carryalls must not operate where there is a possibility of overturning in dangerous areas, like edges of deep fills, cut banks and steep slopes.

Watch out for moving vehicles and equipment on the job site. Often this equipment is noisy and the operator may not be able to hear or see you. You have the responsibility for watch out for moving equipment.

There are many more safe practices and rules that could be listed, but it's impossible to list them all. Actually, safety is simply using common sense and good judgment. If something appears to have the potential for injury, then that's the time to take steps to make sure the injury doesn't occur.

Teamwork - everyone's cooperation and a special effort can result in a safe and helpful work environment. If you take safety seriously, you'll have a much better attitude about yourself and your job. Take time for safety, because safety really does make a difference.



The meaning of key terms

Hazard means a situation or thing that has the potential to harm a person. Hazards at work may include: noisy machinery, a moving forklift, chemicals, electricity, working at heights, a repetitive job, bullying and violence at the workplace.

Risk is the possibility that harm (death, injury or illness) might occur when exposed to a hazard.

Risk control means taking action to eliminate health and safety risks so far as is reasonably practicable, and if that is not possible, minimising the risks so far as is reasonably practicable. Eliminating a hazard will also eliminate any risks associated with that hazard.

ASSIST OTHERS TO OBSERVE AND PRACTICE SAFE WORK PRACTICES

It is important that all work towards apply safety within the work practices and this section summarizes work to be performed by different stakeholders in implementing the risk management across the workplace.

Management Commitment

Effective risk management starts with a commitment to health and safety from those who operate and manage the business or undertaking. You also need the involvement and cooperation of your workers, and if you show your workers that you are serious about health and safety they are more likely to follow your lead.

To demonstrate your commitment, you should:

- ✓ Get involved in health and safety issues
- ✓ Invest time and money in health and safety
- ✓ Ensure health and safety responsibilities are clearly understood.

A Step-By-Step Process

A safe and healthy workplace does not happen by chance or guesswork. You have to think about what could go wrong at your workplace and what the consequences could be. Then you must do whatever you can (in other words, whatever is 'reasonably practicable') to eliminate or minimise health and safety risks arising from your business or undertaking.

This process is known as risk management and involves the four steps set out in this Code (see Figure 1 to the right):

- ✓ Identify hazards – find out what could cause harm
- ✓ Assess risks if necessary – understand the nature of the harm that could be caused by the hazard, how serious the harm could be and the likelihood of it happening
- ✓ Control risks – implement the most effective control measure that is reasonably practicable in the circumstances
- ✓ Review control measures to ensure they are working as planned.

Many hazards and their associated risks are well known and have well established and accepted control measures. In these situations, the second step to formally assess the risk is unnecessary. If, after identifying a hazard, you already know the risk and how to control it effectively, you may simply implement the controls.

Risk management is a proactive process that helps you respond to change and facilitate continuous improvement in your business. It should be planned, systematic and cover all reasonably foreseeable hazards and associated risks.

MONITOR AND OBSERVE OF SAFE WORK PRACTICES

Inspect the Workplace

Regularly walking around the workplace and observing how things are done can help you predict what could or might go wrong. Look at how people actually work, how plant and equipment is used, what chemicals are around and what they are used for, what safe or unsafe work practices exist as well as the general state of housekeeping.



Things to look out for include the following:

- ✓ Does the work environment enable workers to carry out work without risks to health and safety (for example, space for unobstructed movement, adequate ventilation, lighting)?
- ✓ How suitable are the tools and equipment for the task and how well are they maintained?
- ✓ Have any changes occurred in the workplace which may affect health and safety?

Hazards are not always obvious. Some hazards can affect health over a long period of time or may result in stress (such as bullying) or fatigue (such as shiftwork). Also think about hazards that you may bring into your workplace as new, used or hired goods (for example, worn insulation on a hired welding set).

As you walk around, you may spot straightforward problems and action should be taken on these immediately, for example cleaning up a spill. If you find a situation where there is immediate or significant danger to people, move those persons to a safer location first and attend to the hazard urgently.

Make a list of all the hazards you can find, including the ones you know are already being dealt with, to ensure that nothing is missed. You may use a checklist designed to suit your workplace to help you find and make a note of hazards.

PARTICIPATE IN RISK MANAGEMENT PROCESSES

A risk assessment involves considering what could happen if someone is exposed to a hazard and the likelihood of it happening. A risk assessment can help you determine:

- ✓ How severe a risk is
- ✓ Whether any existing control measures are



effective

- ✓ What action you should take to control the risk
- ✓ How urgently the action needs to be taken.

A risk assessment can be undertaken with varying degrees of detail depending on the type of hazards and the information, data and resources that you have available. It can be as simple as a discussion with your workers or involve specific risk analysis tools and techniques recommended by safety professionals.

When should a risk assessment be carried out?

A risk assessment should be done when:

- ✓ There is uncertainty about how a hazard may result in injury or illness
- ✓ The work activity involves a number of different hazards and there is a lack of understanding about how the hazards may interact with each other to produce new or greater risks
- ✓ Changes at the workplace occur that may impact on the effectiveness of control measures.

A risk assessment is mandatory under the WHS Regulations for high risk activities such as entry into confined spaces, diving work and live electrical work. Some hazards that have exposure standards, such as noise and airborne contaminants, may require scientific testing or measurement by a competent person to accurately assess the risk and to check that the relevant exposure standard is not being exceeded (for example, by using noise meters to measure noise levels and using gas detectors to analyse oxygen levels in confined spaces). A risk assessment is not necessary in the following situations:

- ✓ Legislation requires some hazards or risks to be controlled in a specific way – these requirements must be complied with.
- ✓ A code of practice or other guidance sets out a way of controlling a hazard or risk that is applicable to your situation and you choose to use the recommended controls. In these instances, the guidance can be followed.
- ✓ There are well-known and effective controls that are in use in the particular industry, that are suited to the circumstances in your workplace. These controls can simply be implemented.

IMPLEMENTING EMERGENCY PROCEDURES

How to do a risk assessment

All hazards have the potential to cause different types and severities of harm, ranging from minor discomfort to a serious injury or death.

For example, heavy liquefied petroleum gas (LPG) cylinders can cause muscular strain when they are handled manually.



However, if the cylinder is damaged causing gas to leak which is then ignited, a fire could result in serious burns. If that leak occurs in a store room or similar enclosed space, it could result in an explosion that could destroy the building and kill or injure anyone nearby. Each of the outcomes involves a different type of harm with a range of severities, and each has a different likelihood of occurrence.

Work out how severe the harm could be

To estimate the severity of harm that could result from each hazard you should consider the following questions:

- ✓ What type of harm could occur (e.g. muscular strain, fatigue, burns, laceration)? How severe is the harm? Could the hazard cause death, serious injuries, illness or only minor injuries requiring first aid?
- ✓ What factors could influence the severity of harm that occurs? For example, the distance someone might fall or the concentration of a particular substance will determine the level of harm that is possible. The harm may occur immediately something goes wrong (e.g. injury from a fall) or it may take time for it to become apparent (e.g. illness from long-term exposure to a substance).
- ✓ How many people are exposed to the hazard and how many could be harmed in and outside your workplace? For example, a mobile crane collapse on a busy construction site has the potential to kill or injure a large number of people.
- ✓ Could one failure lead to other failures? For example, could the failure of your electrical supply make any control measures that rely on electricity ineffective? „ Could a small event escalate to a much larger event with more serious consequences? For example, a minor fire can get out of control quickly in the presence of large amounts of combustible materials.

Workout how hazard may cause harm

In most cases, incidents occur as a result of a chain of events and a failure of one or more links in that chain. If one or more of the events can be stopped or changed, the risk may be eliminated or reduced.

One way of working out the chain of events is to determine the starting point where things begin to go wrong and then consider: 'If this happens, what may happen next?' This will provide a list of events that sooner or later cause harm. See the case study in Appendix A.

In thinking about how each hazard may cause harm, you should consider:

- ✓ The effectiveness of existing control measures and whether they control all types of harm,



- ✓ How work is actually done, rather than relying on written manuals and procedures
- ✓ Infrequent or abnormal situations, as well as how things are normally meant to occur.

Consider maintenance and cleaning, as well as breakdowns of equipment and failures of health and safety controls.

Work Out the Likelihood of Harm Occurring

The likelihood that someone will be harmed can be estimated by considering the following:

- ✓ How often is the task done? Does this make the harm more or less likely?
- ✓ How often are people near the hazard? How close do people get to it?
- ✓ Has it ever happened before, either in your workplace or somewhere else? How often?

You can rate the likelihood as one of the following:

- ✓ Certain to occur - expected to occur in most circumstances
- ✓ Very likely - will probably occur in most circumstances
- ✓ Possible - might occur occasionally
- ✓ Unlikely - could happen at some time
- ✓ Rare - may happen only in exceptional circumstances

Table 1: Risk matrix

Probability	High			
	Med.			
	Low			
		Low	Med.	High
		Severity		

The level of risk will increase as the likelihood of harm and its severity increases.

UNIT 03

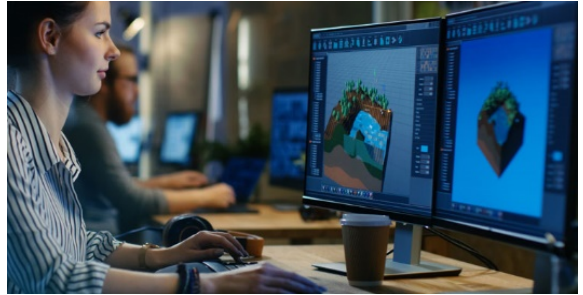
CARRY OUT DATA ENTRY AND RETRIEVAL PROCEDURES

This unit deals with the skills and knowledge required to operate computer to enter, manipulate, and retrieve and to access data and communicate via the Internet

INITIATE COMPUTER SYSTEM

Introduction to computers

While the computer has been with us for) only about half a century, its use dates all the way back to the fourth Century B.C. The first known apparatus was a simple counting aid called the abacus, and may have been invented in Babylonia (now Iraq). Throughout the centuries, computers have changed the way we act, think and view the world. In short, it has revolutionized the world. Today's personal computer, which has been around for only fifteen years, has surpassed its earlier predecessor.

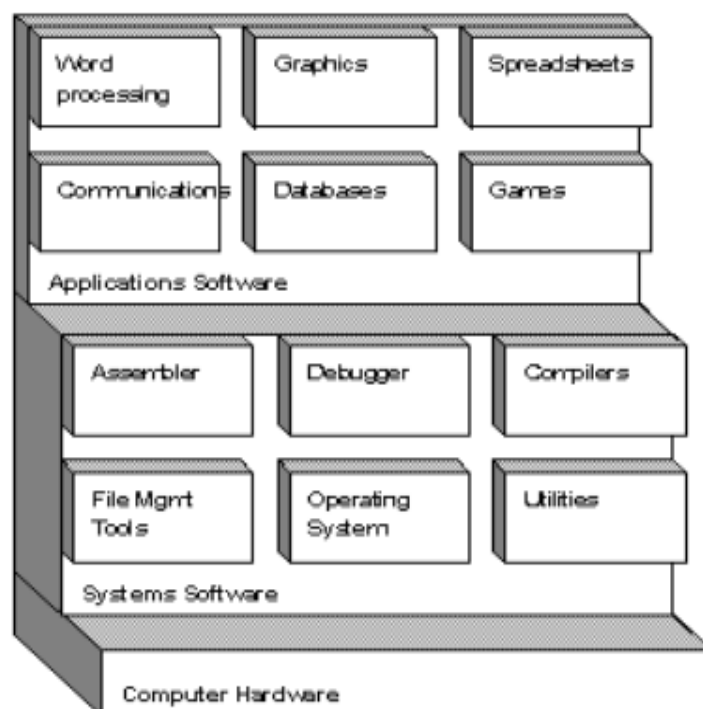


Although computers are used to schedule airlines, predict the weather, play music, control space stations and keep the wheels of the world economy turning; essentially computers do only four things:

- ✓ Receive input
- ✓ Process information
- ✓ Produce output
- ✓ Store information

These four basic functions are responsible for everything computers do.

Computer System:



There are three essential ingredients of any computer system:

- ✓ Hardware
- ✓ Peripherals
- ✓ Software

Hardware - Consists of the microprocessor (the computer's brain), the memory and the input or output connections which get data in and out of the microprocessor.

Peripherals - Are the devices that allow us to communicate with the computer. . Peripheral devices can be external -- such as a mouse, keyboard, printer, external zip drive or scanner -- or internal, such as a CD-Rom, CD-R or internal modem. Internal peripheral devices are often referred to as integrated peripherals

Software – Also called computer program, is essential to make the system work. Without software a computer can do nothing

Software is often divided into two categories:

- ✓ Systems software: Includes the operating system and all the utilities that enable the computer to function.
- ✓ Applications software: Includes programs that do real work for users. For example, word processors, spreadsheets and database management systems.

NOTE: It is very important to distinguish between the Operating System and Application Software.

Check Equipment and Work Environment for Readiness

Checking your equipment and work environment for readiness to perform scheduled tasks involves checking that your computer and its peripherals are installed and functional. Your check must also include ensuring that the layout of your work space minimizes potential hazards. You should note the following:



- ✓ The lighting must be sufficient for the task and there should be sufficient contrast between the screen and the background
- ✓ Distracting noises should be minimized
- ✓ There should be sufficient leg room for you to change positions easily
- ✓ Windows should have blinds or curtains
- ✓ The software should be appropriate for the task

- ✓ The screen must have a stable image, without glitter, glare or reflections
- ✓ The keyboard must be usable, adjustable, detachable and legible
- ✓ The work surface must allow a flexible arrangement of objects, with sufficient space for documents, keyboard, etc
- ✓ The chair should be adjustable in height and have an adjustable backrest in both height and tilt
- ✓ Cables should be properly installed that is, they should be kept as short as possible and be fastened in place or routed through cable ducts. Check to make sure the system is safe before you turn it on
- ✓ The power supply must be adequate. Is there Uninterrupted Power Supply (U.P.S.)?

TIP: Advise the computer technician or another responsible person if you find faults with your system. Do not poke around inside the system as this may cause serious damage to both you and your computer.

When working with computers, seating is particularly important. Your seat must provide the following posture requirements:

- ✓ Adjustable back support
- ✓ Good lumbar support
- ✓ Adjustable seat height
- ✓ No excess pressure under the thighs or back of the knees
- ✓ Space to change position when needed
- ✓ Adjustable screen position in height and angle to allow a comfortable head position
- ✓ Spaces in front of the keyboard to support the hands and wrists during pauses in work

Identify hardware components and their functions

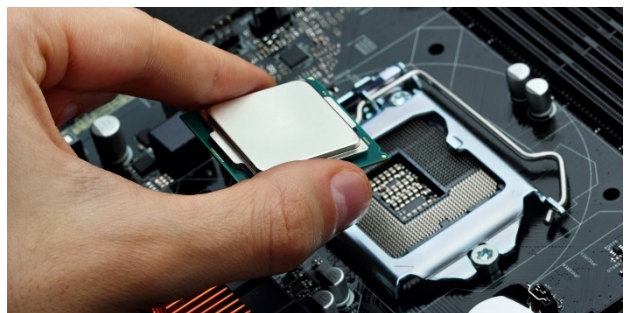
Every computer system contains hardware components that specialise in each of these four functions:

Input devices - feed data into the computer. The keyboard is the most common input device. Other input devices include pointing devices like the mouse and trackball.

Output devices - produce output through two main types of devices: monitor screens for immediate visual output and printers for permanent paper output.

A processor or central processing unit (CPU) - processes information, performs all the necessary arithmetic calculations and make decisions based on information values. The CPU is, in essence, the computer's "brain."

Memory and storage devices - used to store information, but they serve different purposes. The computer's memory (sometimes called primary storage) is used to store programmes and data that need to be instantly accessible to the CPU. Storage devices (sometimes called secondary storage), including disks and tape drives, serve as long-term repositories for data. A storage device such as disk drive can be considered as a combination of input and output device because the computer sends information out to the storage device (output), and later retrieves that



information from it (input).

These four components, when combined make up the hardware of the computer system.

Power up the computer System

To power up the computer simply means to turn it on. You may also see the word 'initialize' which refers to the process of starting up a program or system. The key word is process. Computers first need time to warm up before they are put to use. Once the power switch has been activated, the computer will automatically go through a series of "self-checks". These are critical before the system is booted so that the computer operates efficiently. Once the checks are complete, you may be prompted for login details. After this, the next screen you will see, featuring a number of icons, is called the desktop

TIP: Ensure that you use the correct start up and shut down procedures that are recommended by your computer manufacturer.

Apply access code

If you are connected to a network, you are likely to need a password which allows you access when you type it in using the keyboard. If this is the case, ensure that you log on using the correct username and password.

Examine System Information

When a computer is switched on, one of the first things it does is to read instructions from one of its disks. These instructions tell it how to operate and are known as the Operating System (OS). This process happens quite quickly and is called booting up.

Information about your computer system (processor speed and amount of installed memory), are available on the system itself. Ask your learning facilitator to show you how to access this information.

Customize Desktop Configuration

Simply put, your desktop is what you are looking at when your computer is on and no programs are open. You can arrange the icons on this electronic desktop just as you can arrange real objects on a real desktop. You can:

- ✓ Move them around
- ✓ Put one on top of another
- ✓ Reshuffle them
- ✓ Throw them away

This flexibility allows you to customise your desktop to suit your individual requirements and/or special needs in accordance with organisational guidelines.

The advantages of customising your desktop configuration is that the most used programs are easily accessible in one area, and if you plan to run more than one program at a time, it is

better to have them in the same group window.

Each programme, such as word processor, spreadsheet or database appears as an icon with its name under it, and many computers already come with some of these icons already loaded.

Use help functions

Many programs come with the instruction manual, or a portion of the manual, integrated into the program. Should you encounter a problem or forget a command while running the program, you can bring up the documentation by pressing the Help key or entering a HELP command. In Windows, the Help key is the function key labelled F1.

Once you summon the Help system the program often displays a menu of Help topics. Choose the appropriate topic for the problem you are experiencing. The program will then display a help screen that contains the desired documentation.

Some programs are more sophisticated, displaying different Help messages depending on where you are in the program. Such systems are said to be context sensitive.

ENTER DATA

Types of Data

Data Types are an important concept of statistics, which needs to be understood, to correctly apply statistical measurements to your data and therefore to correctly conclude certain assumptions about it. This blog post will introduce you to the different data types you need to know, to do proper exploratory data analysis (EDA), which is one of the most underestimated parts of a machine learning project.



Introduction to Data Types

Having a good understanding of the different data types, also called measurement scales, is a crucial prerequisite for doing Exploratory Data Analysis (EDA), since you can use certain statistical measurements only for specific data types.

You also need to know which data type you are dealing with to choose the right visualization method. Think of data types as a way to categorize different types of variables. We will discuss the main types of variables and look at an example for each. We will sometimes refer to them as measurement scales.

Categorical Data

Categorical data represents characteristics. Therefore it can represent things like a person's gender, language etc. Categorical data can also take on numerical values (Example: 1 for female and 0 for male). Note that those numbers don't have mathematical meaning.

Nominal Data

Nominal values represent discrete units and are used to label variables, that have no quantitative value. Just think of them as „labels“. Note that nominal data that has no order. Therefore if you would change the order of its values, the meaning would not change. You can see two examples of nominal features below:

Are you married?

- Yes
- No

What languages do you speak?

- Englisch
- French
- German
- Spanish

The left feature that describes if a person is married would be called "dichotomous", which is a type of nominal scales that contains only two categories.

Ordinal Data

Ordinal values represent discrete and ordered units. It is therefore nearly the same as nominal data, except that it's ordering matters. You can see an example below:

What Is Your Educational Background?

- 1 - Elementary
- 2 - High School
- 3 - Undegraduate
- 4 - Graduate

Note that the difference between Elementary and High School is different than the difference between High School and College. This is the main limitation of ordinal data, the differences between the values is not really known. Because of that, ordinal scales are usually used to measure non-numeric features like happiness, customer satisfaction and so on.

Numerical Data

Discrete Data

We speak of discrete data if its values are distinct and separate. In other words: We speak of discrete data if the data can only take on certain values. This type of data can't be measured but it can be counted. It basically represents information that can be categorized into a classification. An example is the number of heads in 100 coin flips.

You can check by asking the following two questions whether you are dealing with discrete data or not: Can you count it and can it be divided up into smaller and smaller parts?



Continuous Data

Continuous Data represents measurements and therefore their values **can't be counted but they can be measured**. An example would be the height of a person, which you can describe by using intervals on the real number line.

Interval Data

Interval values represent **ordered units that have the same difference**. Therefore we speak of interval data when we have a variable that contains numeric values that are ordered and where we know the exact differences between the values. An example would be a feature that contains temperature of a given place like you can see below:

Temperature?

- 10
- 5
- 0
- + 5
- + 10
- + 15

The problem with interval values data is that they don't have a "true zero". That means in regards to our example, that there is no such thing as no temperature. With interval data, we can add and subtract, but we cannot multiply, divide or calculate ratios. Because there is no true zero, a lot of descriptive and inferential statistics can't be applied.

Ratio Data

Ratio values are also ordered units that have the same difference. Ratio values are the same as interval values, with the difference that they do have an absolute zero. Good examples are height, weight, length etc.

Why Data Types are important?

Datatypes are an important concept because statistical methods can only be used with certain data types. You have to analyze continuous data differently than categorical data otherwise it would result in a wrong analysis. Therefore knowing the types of data you are dealing with, enables you to choose the correct method of analysis.

Statistical Methods

Nominal Data

When you are dealing with nominal data, you collect information through:

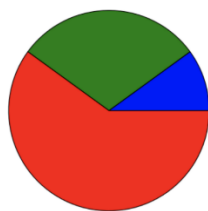
Frequencies: The Frequency is the rate at which something occurs over a period of time or within a dataset.

Proportion: You can easily calculate the proportion by dividing the frequency by the total number of events. (e.g how often something happened divided by how often it could happen)

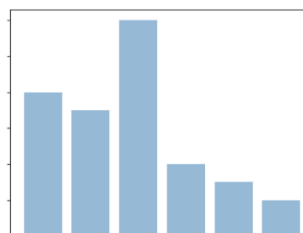
Percentage.

Visualisation Methods: To visualise nominal data you can use a pie chart or a bar chart.

Pie Chart



Bar Chart



Ordinal Data

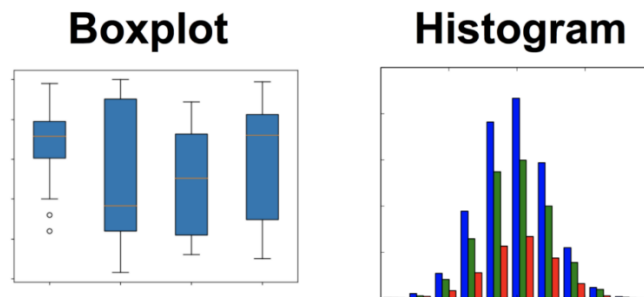
When you are dealing with ordinal data, you can use the same methods like with nominal data, but you also have access to some additional tools. Therefore you can summarise your ordinal data with frequencies, proportions, percentages. And you can visualise it with pie and bar charts. Additionally, you can use percentiles, median, mode and the interquartile range to summarize your data.

Continuous Data

When you are dealing with continuous data, you can use the most methods to describe your data. You can summarise your data using percentiles, median, interquartile range, mean, mode, standard deviation, and range.

Visualization Methods:

To visualise continuous data, you can use a histogram or a box-plot. With a histogram, you can check the central tendency, variability, modality, and kurtosis of a distribution. Note that a histogram can't show you if you have any outliers. This is why we also use box-plots.



RETRIEVE AND AMENDA DATA

Information has become the most significant source of our day-to-day life. Information available on internet may create some confusion among its users because of its diversity. In order to get proper and exact information from internet, users need to know the effective techniques and strategies. This paper focuses on the different information retrieval processes and techniques which help users to get the required information and also to save their valuable time.

Keywords: Information retrieval, Search process, Search strategies, Retrieval techniques.

Introduction:

Data is an observed fact and when any meaning is assign to data or when it is processed, it becomes information. Information reduces uncertainty and it is communicable. Information leads to confirmation but when information is processed and internalized it becomes knowledge. Today, plenty of information available in print and non-print format which leads to information overload. Internet is one of the vital sources of information. Sometimes it becomes impossible for the users to understand the available information or they do not understand where to find it or they are unable to access the right information. These factors leads to their stress, delay in decision making, waste of time etc.

Information Retrieval One of the best examples of information retrieval system (IRS) is library system where information is stored, processed, organized and retrieved on demand of its users.

Different types of information retrieval systems have been developed since 1950's to meet

in different kinds of information needs of different users. Information retrieval system offers different search approaches those deals with three basic aspects. These aspects are as follows.

- ✓ Information storage and organization.
- ✓ Information representation.
- ✓ Information access.



Objectives of and Retrieval/Information Retrieval System (ISAR/IRS):

- ✓ To provide information to the user in least time with least efforts.
- ✓ To act as facilitator between information and user.
- ✓ To provide non-ambiguous search results through proper indexing.
- ✓ User friendliness.

Functions of Information Storage and Retrieval/Information Retrieval System (ISAR/IRS):

To identify sources of information relevant to the areas of the target user community,

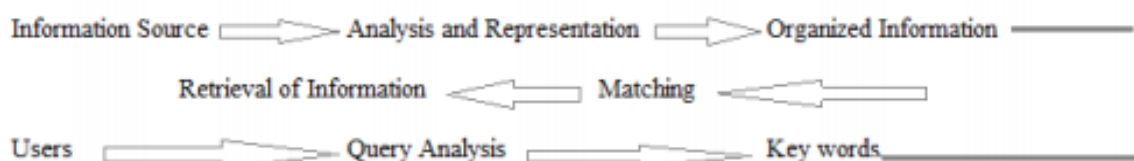
- ✓ To analyze the contents of the sources.
- ✓ Represents contents of analyze sources that will match queries.
- ✓ Analyze user queries that will match with database.
- ✓ Retrieve the information that is relevant.
- ✓ Necessary adjustments in system based on feedback from the user.

Components of Information Storage and Retrieval/Information Retrieval System (ISAR/IRS):

According to Lancaster the major components of an information retrieval system are....

- ✓ Document selection sub-system.
- ✓ Indexing sub-system.
- ✓ Vocabulary sub-system.
- ✓ Searching sub-system.
- ✓ Matching sub-system.

Outline of Information Storage and Retrieval/Information Retrieval System (ISAR/IRS):



Kinds of information retrieval system:

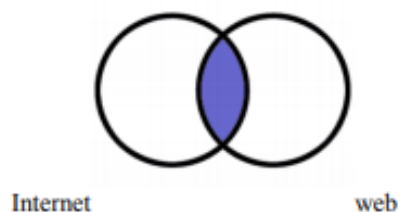
1. Offline Search: In offline search, users can get the required information with or without the help of computer and internet for example: libraries, CD-ROM etc.
- ✓ Online Search: means the search of a remotely located database through interactive communications with the help of computer and communication channel. Online databases can be access through vendor or directly. For example: OPAC, Databases, Internet etc.

Retrieval Techniques:

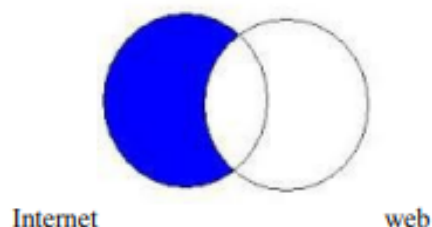
Retrieval techniques are designed to help users to locate the information they need effectively and efficiently. These techniques help users to find out the required information easily. There are two types of retrieval techniques.

1. Basic Retrieval Techniques:

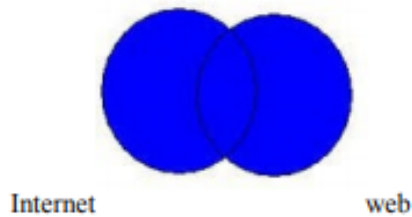
- a. Boolean Searching George Boole (1815-1864) developed AND, OR, NOT Boolean operators. By using these techniques user can narrow down their search to get the required information.
 - i. AND: It includes addition of two different concepts for narrowing down the search. It retrieves all those items where all the constituent terms occur.



- ii. NOT: It is separation of complex concepts into individual simpler ones. It allows users to specify those terms that they do not want to occur in the retrieval records. It excludes unwanted results. Search output will decrease with increase in NOT term.



- iii. OR: The inclusion of more concepts to expand their connotation. It is used for broadening a search. It allows users to combine two or more search terms that system will retrieve all those terms that contain either one or all of the constituent terms.



b. Truncation Search :

It is also known as wildcard, stemming, term masking, conflation algorithm etc...

There are three types of truncation.

- i. Right truncation: truncation is on right side of the term. For example...
Lib*
- ii. Left truncation: truncation is on left side of the term. For example...
*rary
- iii. Simultaneous with left and right side. For example...
polymer

c. Proximity search :

This search facility allows users to specify...

- i. Whether two search terms should occur adjacent to each other.
- ii. Whether one or more words occur in between the search terms.
- iii. Whether the search terms should occur in some paragraph irrespective of the intervening words. Proximity search is as good as AND. It searches for the occurrence of two or more search terms but it specifies the distance between the search terms. For example...

Sun within four words after moon (sun # 2 # after moon)

d. Field Searching :

Document is presented by attributes such as Author, Title, Publication date, Document type, File type etc. these attributes are called as field searching. Search is possible with the help of these fields also.

e. Case Sensitive Searching :

For languages such as English, French, Spanish upper and lower cases makes a difference. Case sensitive searching allows pinpointing exactly how a term is represented in a query and the system. For example...

Web - World Wide Web.

Web - web woven by spiders.

f. Range Searching :

It is very useful in numerical searching. It is important in selecting records within certain data ranges. For example...

Greater than (>)

Less than (<)

Equal to (=)

Not equal to (1=0 or <>)

Greater than or equal to (>=)

Less than or equal to (<=)

2. Advanced Retrieval Techniques :

g. Fuzzy Search :

It sounds related to truncation search but with a major difference. Truncation is intended to retrieve different forms of terms when they share some parts in common. Fuzzy searching is designed to find terms that are spelled incorrectly at data entry or query point.

h. Weighted Search :

For weighted searching, weights are assigned to terms when a search query is composed to indicate proportionally their significance or the emphasis the user placed upon. For example,...internet 3 AND web 5

MONITOR OPERATION OF EQUIPMENT

Preventive maintenance

Preventive maintenance includes measures such as systematic and routine cleaning, adjustment and replacement of equipment parts at scheduled intervals. Manufacturers generally recommend a set of equipment maintenance tasks that should be performed at regular intervals: daily, weekly, monthly or yearly. Following these recommendations will ensure that the equipment performs at maximum efficiency and will increase the lifespan of the equipment. This will also help to prevent:



- ✓ Inaccurate test results due to equipment failure
- ✓ Delays in reporting results
- ✓ Low productivity
- ✓ Large repair costs.

Maintenance plan

A maintenance plan will include preventive maintenance procedures as well as provision for inventory, troubleshooting and repair of equipment. When implementing an equipment maintenance program, some of the initial steps will include:

- ✓ Assigning responsibility for providing oversight;
- ✓ Developing written policies and procedures for maintaining equipment, including routine maintenance plans for each piece of equipment that specify the frequency with which all maintenance tasks should be performed;
- ✓ Developing the format for records, creating logs and forms, and establishing the processes to maintain records;
- ✓ Training staff on the use and maintenance of the equipment, and ensuring that all staff understand their specific responsibilities

Equipment inventory

It is recommended that a label is attached to the instrument indicating when the next maintenance or service should be performed.

The laboratory should keep an inventory log of all equipment in the laboratory. The log should be updated with information on new equipment and include documentation of when old equipment is retired. For each piece of equipment, the equipment inventory log should have a record of:

- ✓ Instrument type, make and model number, and serial number so that any problems can be discussed with the manufacturer;
- ✓ Date the equipment was purchased, and whether it was purchased new, used or reconditioned;
- ✓ Manufacturer/vendor contact information;
- ✓ Presence or absence of documentation, spare parts and maintenance contract;
- ✓ Warranty's expiration date;
- ✓ Specific inventory number indicating the year of acquisition (this is especially useful for larger laboratories); for example, use the style "yy-number" (04- 001, 04-002, etc.) Where "yy-number" equals the last two numbers of the year followed by a number attributed in the year.



An inventory process must be conducted if the laboratory does not have an existing inventory system for equipment. This could be conveniently organized following a model grid, room by room; for example, conduct an inventory of equipment in the reception area, then the sample collection area, the serology testing area, and the parasitology testing area. During the inventory, the condition of the equipment should be documented as functional, partially functional or nonfunctional. Equipment that is not functioning needs to be evaluated as to whether or not it can be repaired. Nonrepairable equipment should be retired, and work should be scheduled for equipment needing repair

Inventory of spare parts

To ensure that the laboratory does not run out of spare parts, an inventory record of those used most frequently should be kept for each piece of equipment. The record should include:

- ✓ Part name and number;
- ✓ Average use of the part, and the minimum to keep on hand;
- ✓ Cost;
- ✓ Date when the part is placed into storage and when it is used (in and out stock log);
- ✓ Quantity of each part remaining in inventory.

ACCESS AND TRANSMIT INFORMATION VIA THE INTERNET

In order to work with the Internet we need to know certain related terms like www, web browsers, web pages, websites, etc. We should know how to get connected to the Internet. Once connected – how to use it.

Most of the terms on the Internet are prefixed with the term web. The electronic pages seen on the Internet are known as web pages. A web page can be defined as the document that we see on the Internet. Many web pages linked with each other combine to form a website. A



web page can be written in the language known as HTML (Hyper Text Markup Language). HTML is a very simple language having a number of options to represent text. Many other scripting languages have now been developed which can be embedded into HTML, giving it the power to interact with the users. (These are discussed in detail in the next Unit). These dynamic web pages can take inputs from users and give information

accordingly – taking in the location of the user before displaying the weather forecast. For example, a protocol called Hyper Text Transfer Protocol (HTTP) is used to transmit and receive the web pages.

Connecting to the Internet

In order to activate Internet services on any computer, it requires an Internet connection from an Internet Service Provider. There are several Internet Service Providers (ISPs) in India like VSNL, BSNL, Airtel, Reliance, etc. They charge some nominal fee for installation and connection. Depending on the requirement we can get an Internet connection in any of the following ways:

- ✓ Dial-up connection: We can get connected to the Internet by dialing the ISP's number. This is useful if the network is either confined to small group of computers or for a single PC.
- ✓ Leased lines : A dedicated line is laid specifically for the connection. This provides a fairly high speed, but is expensive. This is suitable for an organisation requiring uninterrupted, high speed Internet connection.
- ✓ Broadband : This also provides a good speed. While leased line requires a separate telephone line, broadband can be delivered using an existing telephone line. This is ideal for home and small businesses requiring high speed Internet.
- ✓ WiFi Broadband : These days even wireless connections are available. For this we need to have a Wi Fi card attached to the computer and a wireless modem.

- ✓ When we connect to the Internet we must know its speed parameters. The speed of the Internet is measured in the number of bits transferred per unit time. Generally, the speed of the Internet is measured in kbps (kilo bits per second), but these days some organisations are providing high speed connections in Mbps (Mega bits per second).

In order to have a connection we need a device called the modem. This device converts the digital signal from the computer into an analogue signal that can travel through the telephone line. On the other end, this analogue signal is again converted back to digital form by the modem at the destination end. Some computer systems have internal modems (built-in within the motherboard) while in some systems there might be a need to have an external modem to have an Internet connection.

Another device called a router can be attached to the computer to access the Internet. The router is a device used for connecting two different networks.

Uses of the Internet

The Internet is extensively used for a wide variety of purposes. Some of these are mentioned below:

Search for Information

A number of programs called search engines are available to search for the information on any topic. Some famous search engines are provided by: www.google.com, wikipedia.com, webopedia.com, MSN.com, Yahoo.com, etc.

E-mail (Electronic Mail) Services

The Internet is commonly used for sending and receiving e-mails. We can send a message electronically to any person on the globe, provided that person has an e-mail-id. This service is fast and economical.



Chatting

Chatting involves textual exchange of message in real time. Chat servers provide facility to create virtual chat rooms and only the members associated with these rooms are allowed to share messages. Chat works best if the time is scheduled by both the parties who are willing to chat – as both the parties must be connected to the Internet while chatting. Some common chat engines are: Yahoo Messenger, Google Talk, Rediff Bol, etc.

Instant Messenger Service

These tools can be used to send messages instantly. It also allows us to talk to anyone anywhere in the world. This is a cheaper and quicker method compared to other services.

Unlike chatting, it is not necessary to have an account with the same provider. Additionally, both the users need not be connected while sending messages. We can easily download the messenger software from Internet e.g. MSN Messenger, Yahoo Messenger, etc

Newgroups

Newsgroup is an e-service hosted by many newsgroup organisations. One can become a member of a newsgroup and read and share current affairs and messages. Newsgroups cover a broad domain of interests including education, science and technology, medicine, arts, sports, etc. USENET is one such example.

Teleconferencing

People can have a conference or meeting sitting at different locations with a microphone attached to their computers.

Video Conferencing

In teleconferencing we are able to talk to each other sitting at different places but in video-conferencing we can also see what is happening at the other side. We have observed that the anchor, panelists and experts sitting at different locations across the globe communicate and share their views in many news channels. For this, we need a web-camera and a microphone connected to the computer system, high bandwidth connection, and video-conferencing software.



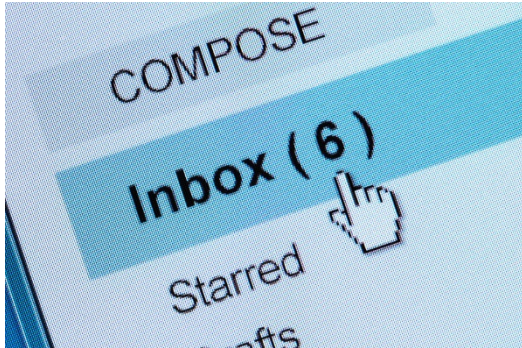
E-Commerce

E-commerce or Electronic-Commerce means online transactions of business. In this, the vendor and customer conduct a transaction sitting at different geographical locations, connected through the Internet. The customer need not strain himself by visiting a number of shops outside in scorching heat or heavy rains. He can do shopping by sitting at home, visiting the desired e-commerce site and placing an order online. E.g. <http://shopping.indiatimes.com>, <http://ebay.com>, <http://shopping.rediff.com>, etc.

M-Commerce

It is an acronym for mobile commerce. It is an upcoming technology after e-commerce. It involves buying and selling of goods and services electronically through wireless handheld devices at any place. We can do transactions through our mobile phones also.

Managing Email Accounts



To see the mails received, click on Inbox. A number against the Inbox indicates the number of unread mails. Once the Inbox is open, we shall see all the mails listed there. To read a mail, we need to just click on the mail that we wish to read.

After going through the mails we can either let them remain in our account for future reference or we can also delete the same. There are options for

deleting or transferring them to trash. Trash is a folder where we keep the mails to be deleted.

To send an e-mail, both the sender and receiver must have an e-mail account. To send an e-mail, follow the steps listed below:

- ✓ Click on the 'Compose' option.
- ✓ Enter the e-mail address of the receiver against any of the three options - To , CC and BCC.
 - To: Address(es) mentioned in this box are visible to every receiver.
 - CC: stands for Carbon Copy. The mail will be sent to the To address as well as CC address. The addresses typed in To as well as in CC are visible to all other receivers.
 - BCC: Stands for Blind Carbon Copy. Each user whose addresses are typed in BCC is unaware of the fact that the same message has also been sent to others.

Instead of typing in the address, we can also insert the same from the address book (Section 7.5.7):

- Click Insert Address or Address Book.
 - Select the addresses by Checking (ticking) them.
 - Click OK or Insert option to insert the address in the recipient mailbox.
- ✓ Write in the message in the text box as indicated in the figure
 - ✓ After typing in the message click on send option as indicated

In order to close the e-mail session, we can click on options like logout or sign out.

CLOSE DOWN COMPUTER SYSTEM

Shutting down a computer safely closes all the programs that are open and exits the Operation System in order to keep the hardware from damage and to prevent the computer from corrupted systems.

Shutting down a computer using Windows 7:

1. Click the Windows Icon at the lower left side of the screen.
2. Click the Shutdown button.

or Press Ctrl+Alt+Del and click the power button in the bottom-right corner of the screen.

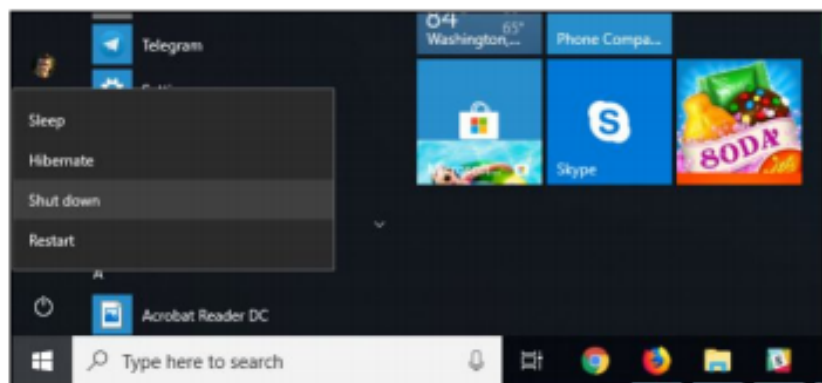
From the Windows desktop, press Alt+F4 to get the Shut down Windows screen and select Shut down.

Shutting down a computer using Windows 10:

1. Click the Windows Icon at the lower left side of the screen.
2. Click the Shutdown button to properly shutdown a computer

or Press Ctrl+Alt+Del and click the power button in the bottom-right corner of the screen.

3. From the Windows desktop, press Alt+F4 to get the Shut down Windows screen and select Shut down.



UNIT 04

APPLY MATHEMATICS FOR WATER OPERATIONS

The aim of this module is to enable the candidate to: Use calculation to solve simple problems, construct plane figures, and develop patterns

PERFORM SIMPLE MATHEMATIC CALCULATIONS

Definition of Fractions

There are two types of fractions, both of which describe less than a whole object. The object can be an inch, a foot, a mile, a ton, a bundle of weld rods, other measurements, etc. The two types of fractions are:

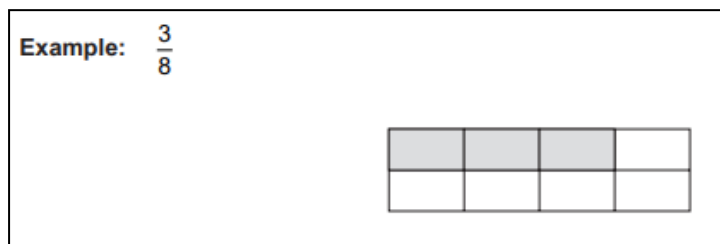
1. Common fractions (fractions)
2. Decimal fractions (decimals)

Common fraction examples are: $\frac{1}{2}$, $\frac{3}{4}$, $\frac{5}{8}$

Decimal fraction examples are: .50, .75, .625

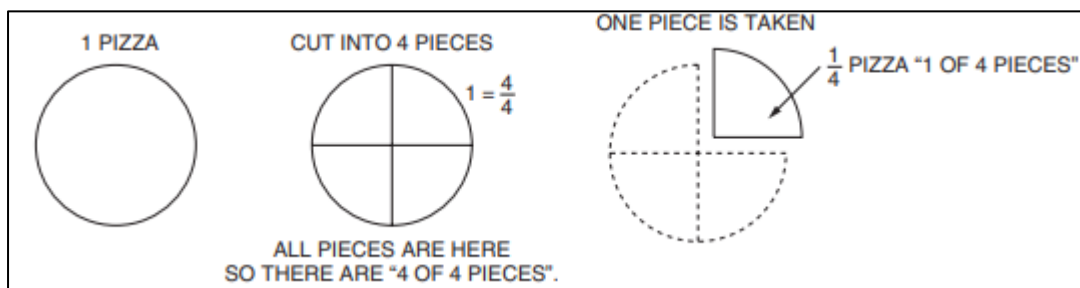
Basic principles

The bottom number (the denominator) of every fraction shows the number of pieces any one whole object is divided into; all pieces are of equal size. The top number (the numerator) shows information about that divided object.



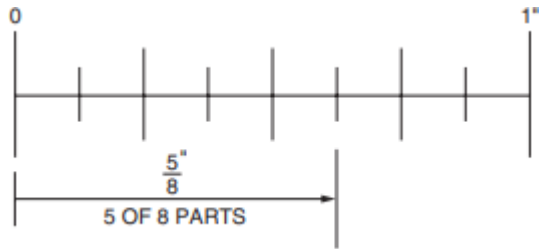
3 is the numerator, and 8 is the denominator. This fraction shows that an object has been divided into 8 equal pieces, and that 3 of those 8 pieces are shaded.

Let's work with other simple examples. If we have one whole unsliced pizza, we can divide it into pieces, and then make fractions about the pizza. This example is cut into 4 pieces (quarters). Fractions concerning this pizza will have the bottom number 4. To describe 1 of those pieces, the fraction is written $\frac{1}{4}$, ("1 of 4 pieces").

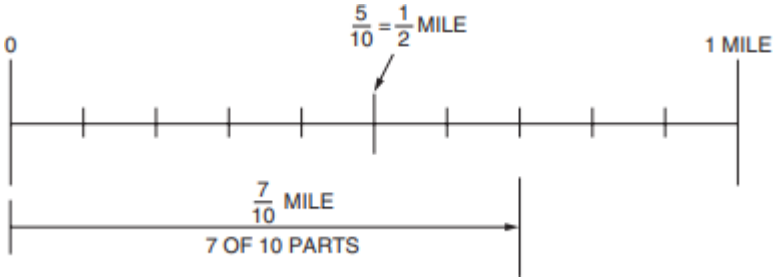


$\frac{3}{4}$ indicates that "3 of 4 pieces" are still available.

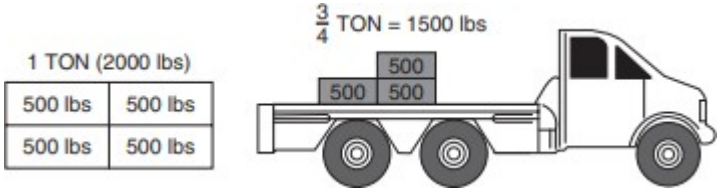
3. $\frac{5}{8}$ " (five-eighths inch) shows that an inch is divided into 8 parts and that 5 of those 8 parts have been measured.



4. $\frac{7}{10}$ of a mile (seven-tenths mile) shows that a mile is divided into 10 parts, and we've measured 7 of those 10 parts.



5. $\frac{3}{4}$ ton (three-fourths, or three-quarters of a ton) shows that a ton of hay (2,000 pounds) has been divided into 4 parts, and 3 of those 4 parts can be hauled on a flat-bed truck.



The fractions $\frac{5}{8}$, $\frac{7}{10}$, and $\frac{3}{4}$ and their verbal descriptions "5 of 8 pieces," "7 of 10 parts," and "3 of 4 parts," give your mind a clear picture of each object, how many pieces it was cut up into, and how many of those pieces are being described. With this, you can give accurate information to anyone: a customer, a fellow worker, your foreman, or on a test you may be taking to get into an apprenticeship.

Decimal fractions are similar to common fractions in that they describe part of a whole object.

In decimals, an object is divided into tenths, hundredths, thousandths, etc. Welders, however, primarily work with tenths and hundredths.

Note: For all decimal problems in this workbook, round to hundredths (two “places” unless otherwise noted. You may round to three, or four, places if that place number is a 5 (i.e., .125 or .0625). Greater accuracy is achieved if only the final answer is rounded off, not the numbers used to arrive at the answer.

A decimal point separates the whole numbers from the parts, and the whole numbers are always to the left of the decimal point.

The first place after the decimal point is called tenths. The second place is called hundredths; and the third place is called thousandths.

1. Example:

Tenths	Hundredths	Thousandths
.758	.7 5	8

Tenths describes 1 whole object divided into 10 parts. Hundredths describes 1 whole object divided into 100 parts.

Rounding Off Decimals

“Rounding off” helps express measurements according to the needs of our trade. Welders generally round off to the nearest tenths or hundredths.

Rounding to tenths:

If the number directly to the right is 5 or more, increase the tenth-place number by 1. If the number directly to the right is 4 or less, the tenth-place number stays the same.

2. Examples:

.68 rounded to tenths is .7.

.64 rounded to tenths is .6.

Rounding to hundredths:

If the number directly to the right is 5 or more, increase the hundredth-place number by 1. If the number directly to the right is 4 or less, the hundredth-place number stays the same.

3. Examples:

.357 rounded to hundredths is .36.

.351 rounded to hundredths is .35

0s placed at the end of a decimal have no effect on the value. Examples:

.5 = .50

.50 = .500

0s placed in front of the decimal point have no effect on the value, as long as there are no whole numbers.

Example: $.25 = 0.25$

Significant figures

The significant figures of a number are digits that carry meaning contributing to its measurement resolution.

Not significant: zero for "cosmetic" purpose

Not significant: zeros used only to locate the decimal point

Significant: all zeros between nonzero numbers

Significant: all nonzero integers

Significant: zeros at the end of a number to the right of decimal point

0 . 0 0 4 0 0 4 5 0 0

One significant figure	Two significant figures
0.08 N 70 m	1.1 s 0.026 mm
Three significant figures	
23.7 m 0.310 L	

Estimation

To **estimate** means to find something close to the correct answer. In other words, you are approximate

$$9411 \rightarrow 9000$$

$$3849 \rightarrow 4000$$

$$9000 + 4000 = 13,000$$

Identify and use the multiples and sub-multiples of units

Formally agreed by the 11th General Conference on Weights and Measures (CGPM) in 1960, the SI is at the centre of all modern science and technology. The definition and realization of the base and derived units is an active research topic for petrologists with more precise methods being introduced as they become available.

Base units

Physical Quantity	Name of Unit	Abbreviation
Mass	Kilogram	kg
Length	Meter	m
Time	Second	s ^a
Temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Ampere	A
Luminous intensity	Candela	cd

Some prefixes

Prefix	Abbreviation	Meaning	Example
Giga	G	10^9	1 gigameter (Gm) = 1×10^9 m
Mega	M	10^6	1 megameter (Mm) = 1×10^6 m
Kilo	k	10^3	1 kilometer (km) = 1×10^3 m
Deci	d	10^{-1}	1 decimeter (dm) = 0.1 m
Centi	c	10^{-2}	1 centimeter (cm) = 0.01 m
Milli	m	10^{-3}	1 millimeter (mm) = 0.001 m
Micro	μ^a	10^{-6}	1 micrometer (μm) = 1×10^{-6} m
Nano	n	10^{-9}	1 nanometer (nm) = 1×10^{-9} m
Pico	p	10^{-12}	1 picometer (pm) = 1×10^{-12} m
Femto	f	10^{-15}	1 femtometer (fm) = 1×10^{-15} m

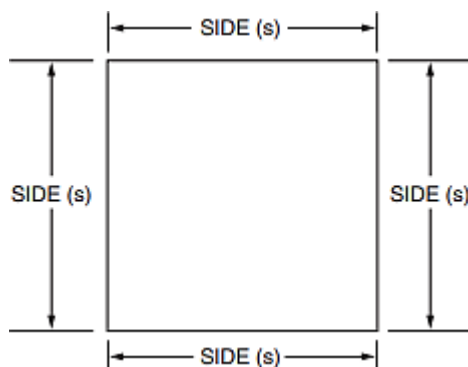
Table 1.2 Derived quantities and their units

Physic Quantity	Expression	Unit
Area	length \times breadth	m^2
Volume	area \times height	m^3
Velocity	displacement / time	m s^{-1}
Acceleration	velocity / time	m s^{-2}
Density	mass / volume	kg m^{-3}
Pressure	force / area	N m^{-2} or Pa

Perform calculations on: Perimeter and Area

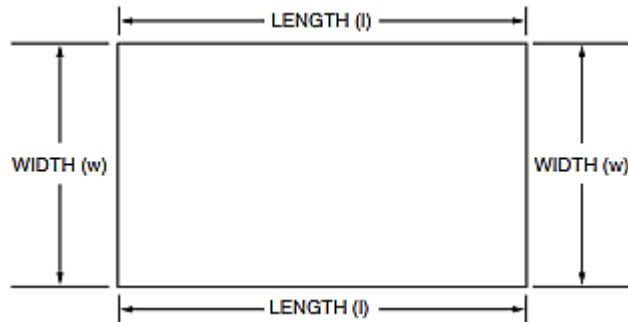
The distance around a figure is called the “perimeter.” Square

A four-sided figure, as shown below. All four sides are of equal length, and all four angles are 90° .



Rectangle

A four-sided figure, as shown below. The lengths are equal only to each other and the widths are equal only to each other. All four angles are 90° .

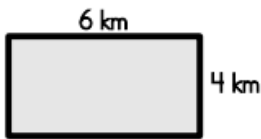


Area of Square

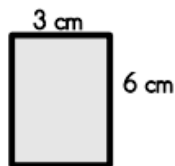
Formula: $A = \text{Side} \times \text{Side}$

Area of Rectangle Formula: $A = L \times H$

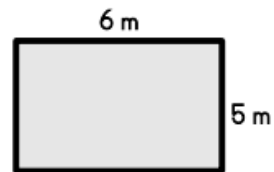
Find the area of each rectangle by multiplying.



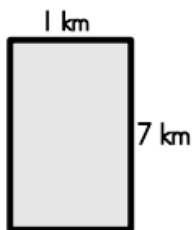
area = _____



area = _____



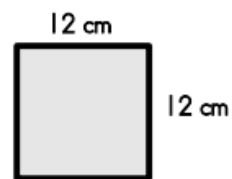
area = _____



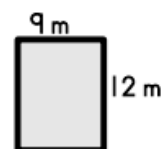
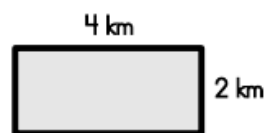
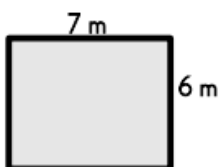
area = _____



area = _____



area = _____



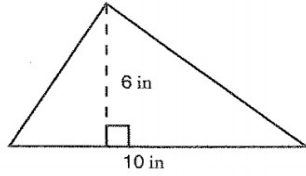
Area of triangle

$$A = \frac{1}{2}bh$$

For

Examples: Find the area.

(a)

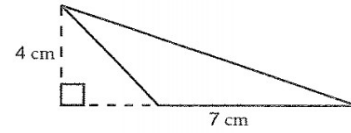


$$A = \frac{1}{2}bh$$

$$A = \frac{1}{2}(10)(6)$$

$$A = 30 \text{ in}^2$$

(b)



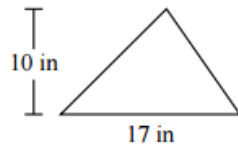
$$A = \frac{1}{2}bh$$

$$A = \frac{1}{2}(7)(4)$$

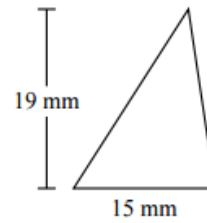
$$A = 14 \text{ cm}^2$$

Find the area of each triangle. Units are not to scale.

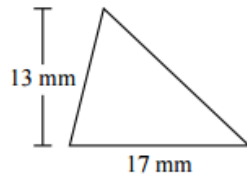
1)



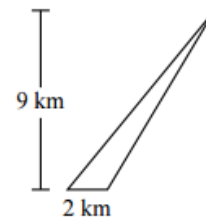
2)



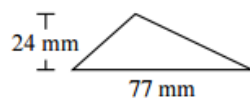
3)



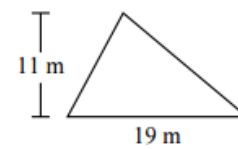
4)



5)

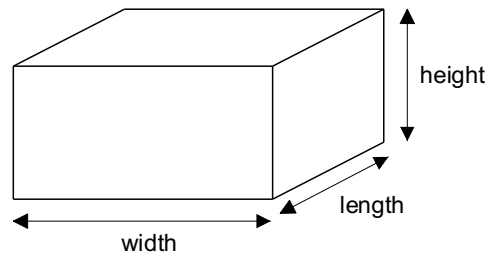


6)

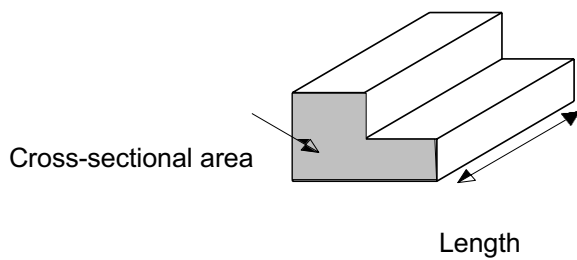


Volume and Surface Area

Volume of **cuboid** = length \times width \times height

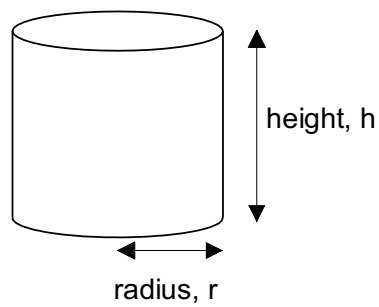


Volume of **prism** = cross-sectional area \times length



Volume of cylinder = $\pi r^2 h$,

Where r is the radius and h is the height of the cylinder.



4. Example: 1

A cuboid measures 15 cm by 12 cm by 8 cm. Find the capacity of the cuboid. Give your answers in liters.

Solution:

$$\text{Volume} = 15 \times 12 \times 8 = 1440 \text{ cm}^3.$$

As 1 litre = 1000 cm³, the capacity of the cuboid = 1.44 litres.

5. Example: 2

A cylinder has a volume of 965 cm³. If the height of the cylinder is 16 cm, find the radius.

Give your answer to 2 significant figures.

Solution:

Substitute the information from the question into the formula for the volume of a cylinder:

$$\text{Volume of cylinder} = \pi r^2 h$$

$$965 = \pi \times r^2 \times 16$$

$$965 = \pi \times 16 \times r^2$$

$$965 = 50.26548 \times r^2$$

$$19.198 = r^2$$

$$4.38156 = r$$

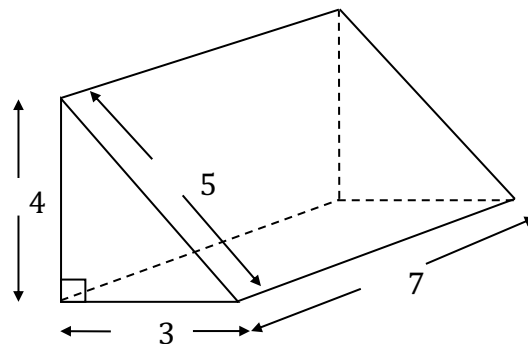
So the radius of the cylinder is 4.4 cm (to 2 SF)

6. Exercise question

A can of drink has the shape of a cylinder. The can has a radius of 4 cm and a height of 15 cm. Calculate the volume of the cylinder. Give your answer correct to three significant figures.

7. Exercise question

Calculate the volume of the triangular prism.



Diagram

NOT

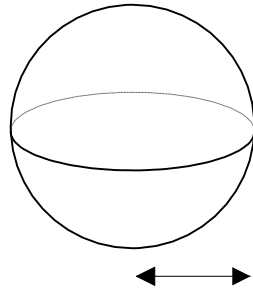
accurately

drawn

Volume of a sphere

Volume of a **sphere**

$$= \frac{4}{3} \pi r^3$$



radius, r

8. Example: 3

A sphere has a volume of 86.5 cm^3 . Find the radius of the sphere. Solution:

A **hemisphere** is half a sphere. Example
The radius of a sphere is 6.7 cm . Find the volume.

Solution:

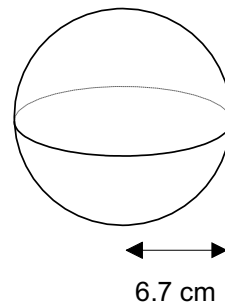
Substitute $r = 6.7 \text{ cm}$ into the formula

$$\text{Volume} = \frac{4}{3} \pi r^3$$

$$V = \frac{4}{3} \times \pi \times 6.7^3$$

$$V = 1259.833 \text{ (remember to use the cube button on your calculator)}$$

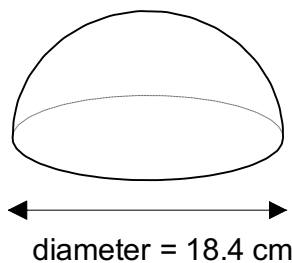
$$V = 1260 \text{ cm}^3 \text{ (to 3 SF)}$$



6.7 cm

9. Example: 2

Find the volume of the hemisphere shown in the diagram.



diameter = 18.4 cm

10. Solution:

The diameter of the hemisphere is 18.4 cm .

Therefore, the radius is 9.2 cm.

$$\begin{aligned}
 \text{Volume of the hemisphere} &= \frac{1}{2} \times \text{volume of sphere} \\
 &= \frac{1}{2} \times \frac{4}{3} \pi r^3 \\
 &= \frac{1}{2} \times \frac{4}{3} \times \pi \times 9.2^3 \\
 &= \frac{1}{2} \times 3261.76 \\
 &= 1630 \text{ cm}^3 \quad (\text{to 3 SF})
 \end{aligned}$$

11. Example 3:

A sphere has a volume of 86.5 cm³. Find the radius of the sphere.

Solution:

Substitute into the formula for the volume of a sphere: $\text{Volume} = \frac{4}{3} \pi r^3$

$$86.5 = \frac{4}{3} \pi r^3$$

So $86.5 = 4.18879r^3$

i.e. $20.65035 = r^3$

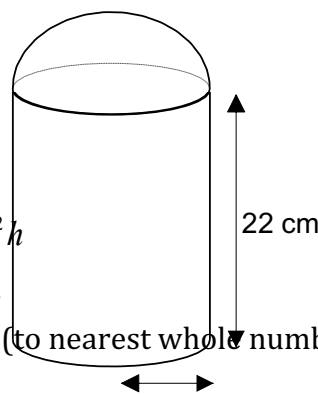
So $r = 2.74 \text{ cm}$ (to 3 SF) (cube rooting)

The sphere has radius 2.74 cm.

12. Examination style question

The object shown is made up from a cylinder and a hemisphere.

The cylinder has radius 5.0 cm and height 22 cm. Find the volume of the object.



13. Solution:

$$\begin{aligned}
 \text{Volume of cylinder} &= \pi r^2 h \\
 &= \pi \times 5^2 \times 22 \\
 &= 1728 \text{ cm}^3 \quad (\text{to nearest whole number})
 \end{aligned}$$

The hemisphere must also have radius 5.0 cm

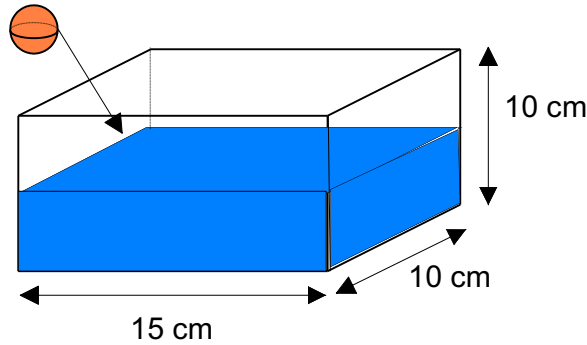
$$\begin{aligned}
 \text{Volume of the hemisphere} &= \frac{1}{2} \times \text{volume of sphere} \\
 &= \frac{1}{2} \times \frac{4}{3} \pi r^3
 \end{aligned}$$

$$\begin{aligned} &= \frac{1}{2} \times \frac{4}{3} \times \pi \times 5^3 \\ &= 262 \text{ cm}^3 \end{aligned}$$

Therefore total volume of the object = 1728 + 262 = 1990 cm³.

14. Example

A tank measures 15 cm by 10 cm by 10 cm. The tank is half-full of water.



A solid metal sphere with radius 2 cm is placed into the tank. Assuming that the sphere sinks to the bottom of the tank, calculate the amount by which the water level in the tank rises.

Solution

As the sphere will be completely submerged, it will displace its volume of water.

$$\text{Volume of sphere} = \frac{4}{3} \pi r^3 = \frac{4}{3} \times \pi \times 2^3 = 33.51 \text{ cm}^3.$$

Therefore, the water displaced is 33.51 cm³.

The water displaced has the form of a cuboid with measurements 15 cm by 10 cm by h cm, where h is the height by which the water level rises.

$$\text{So } 15 \times 10 \times h = 33.51$$

$$\text{i.e. } h = 0.22 \text{ cm}$$

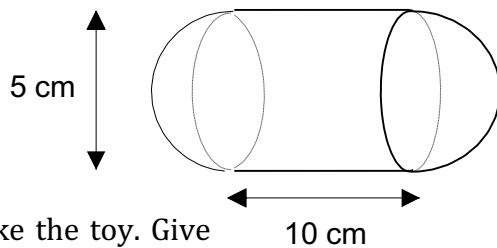
The water rises by 0.22 cm.

15. Examination question

A solid plastic toy is made in the shape of a cylinder which is joined to a hemisphere at both ends.

The diameter of the toy at the joins is 5 cm.

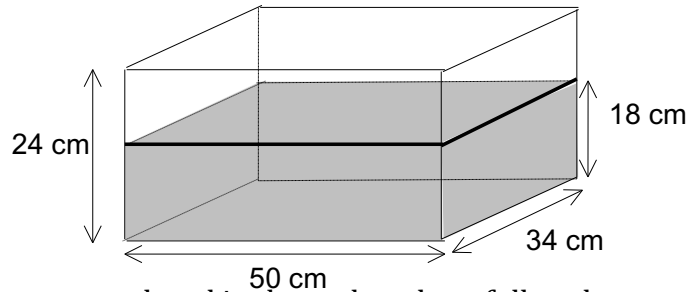
The length of the cylindrical part of the toy is 10 cm.



Calculate the volume of plastic needed to make the toy. Give your answer correct to three significant figures.

16. Examination question

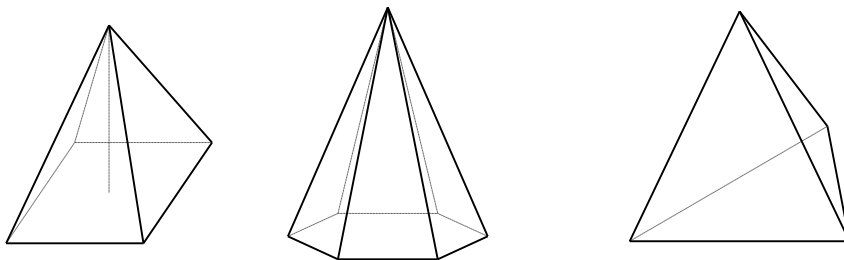
A water tank is 50 cm long, 34 cm wide and 24 cm high. It contains water to a depth of 18 cm.



Four identical spheres are placed in the tank and are fully submerged. The water level rises by 4.5 cm. Calculate the radius of the spheres.

Volume of a pyramid

Pyramids come in a range of shapes. They can have bases which are any shape e.g. triangular, square, rectangular, circular etc.



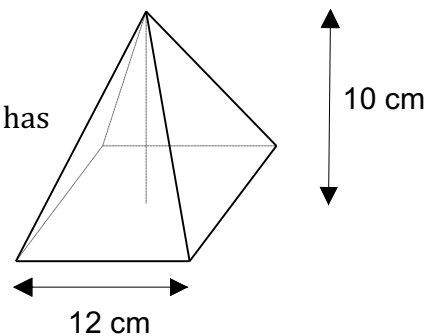
The volume of any **pyramid** can be found using the formula:

$$\text{Volume of pyramid} = \frac{1}{3} \times \text{base area} \times \text{height}$$

Example:

The pyramid shown has a square base. The square has sides of length 12 cm.

The height of the pyramid is 10 cm. Find the volume.

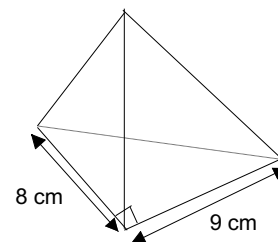


Solution:

The area of the square base is $12 \times 12 = 144 \text{ cm}^2$

So, the volume of the pyramid is:

$$\begin{aligned} \text{Volume} &= \frac{1}{3} \times 144 \times 10 \\ &= 48 \times 10 \\ &= 480 \text{ cm}^3. \end{aligned}$$



17. Example: 2

The diagram shows a triangular-based pyramid. The base of the pyramid is a right-angled triangle. The volume of the pyramid is 325 cm^3 . Find the height of the pyramid.

18. Solution:

The base of the pyramid is as shown:

The area of the base is $\frac{1}{2} \times 9 \times 8 = 36 \text{ cm}^2$.

Substitute information into the formula for the volume of a pyramid.

$$\text{Volume of pyramid} = \frac{1}{3} \times \text{base area} \times \text{height}$$

$$325 = \frac{1}{3} \times 36 \times \text{height}$$

$$325 = 12 \times \text{height.}$$

So, height = $325 \div 12 = 27.08 \text{ cm}$ (to 4 SF).

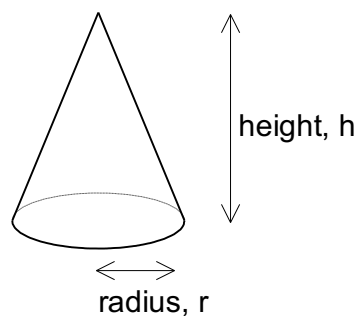
Volume of a cone

A cone is a pyramid with a circular base. Volume of cone = $\frac{1}{3} \pi r^2 h$

The formula for the volume of a cone is:

$$\text{Volume of cone} = \frac{1}{3} \pi r^2 h$$

Where r is the radius of the cone and h is the height of the cone.



Where r is the radius of the cone and h is the height of the cone.

19. Example 1

The base of a cone has a radius of 4 cm. The height of the cone is 6 cm. Find the volume of the cone. Leave your answer in terms of π .

Solution:

Substitute the information into the formula for the volume of a cone

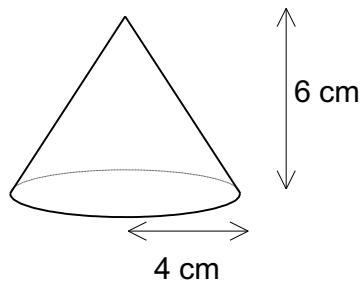
$$\text{Volume of cone} = \frac{1}{3} \pi r^2 h$$

$$= \frac{1}{3} \times \pi \times 4^2 \times 6$$

$$= 2 \times \pi \times 16$$

$$\text{volume} = 32\pi \text{ cm}^3.$$

(start by finding 1/3 of 6)



20. Example 2:

A cone has a volume of 1650 cm^3 . The cone has a height of 28 cm. Find the radius of the cone. Give your answer correct to 2 significant figures.

Solution:

Substitute information into the formula:

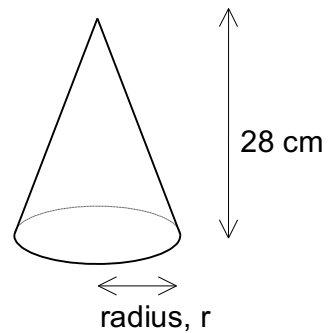
$$\text{Volume of cone} = \frac{1}{3} \pi r^2 h$$

$$1650 = \frac{1}{3} \times \pi \times r^2 \times 28$$

$$1650 = 29.32153r^2 \quad (\text{evaluating } \frac{1}{3} \times \pi \times 28)$$

$$r^2 = 56.2726$$

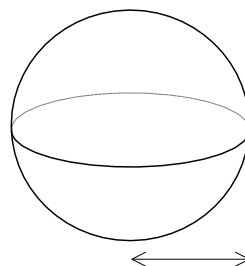
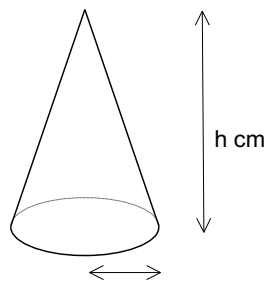
i.e. $r = 7.5 \text{ cm}$ (to 2 SF)



The radius of the cone is therefore 7.5 cm.

21. Problem solving:

The radius of the base of a cone is $x \text{ cm}$ and its height is $h \text{ cm}$. The radius of a sphere is $2x \text{ cm}$.



Diagrams NOT accurately drawn

The volume of the cone and the volume of the sphere are equal.

Express h in terms of x .

Give your answer in its simplest form.

22. Solution:

The volume of the cone is $\frac{1}{3} \pi x^2 h = \frac{1}{3} \pi x^2 h$

The volume of the sphere is $\frac{4}{3}\pi^3 = \frac{4}{3}\pi(2x)^3$ (note: the brackets around $2x$ are important)

$$= \frac{4}{3}\pi \times 8x^3 \quad (\text{cubing both 2 and } x)$$

$$= \frac{32}{3}\pi x^3$$

As the sphere and the cone have the same volume, we can form an equation:

$$\frac{1}{3}\pi x^2 h = \frac{32}{3}\pi x^3$$

$$\pi x^2 h = 32\pi x^3 \quad (\text{Multiplying both sides by 3})$$

$$x^2 h = 32x^3 \quad (\text{Dividing both sides by } \pi)$$

$$h = 32x \quad (\text{Dividing both sides by } x^2)$$

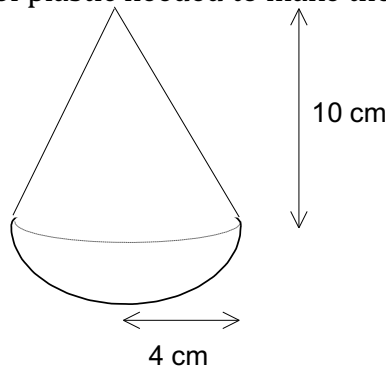
23. Past examination question

A child's toy is made out of plastic. The toy is solid.

The top of the toy is a cone of height 10 cm and base radius 4 cm.

The bottom of the toy is a hemisphere of radius 4 cm.

Calculate the volume of plastic needed to make the toy.



Geometry

Geometry is essential to welding. Several welding projects require you to understand, calculate and measure welds at different angles accurately. Moderate knowledge of geometrical measurements will make it easier for you to connect metals together while advanced knowledge will make it possible to work on complex projects.

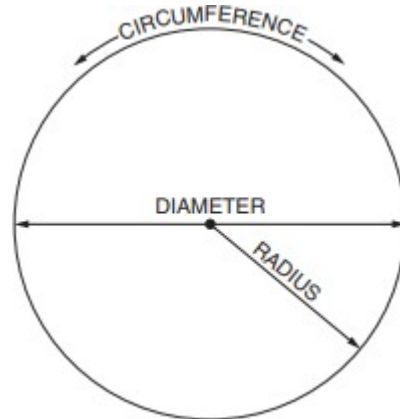
Welders also use geometrical knowledge for calculating the length and size of various shapes and calculate the radius, diameter, and circumference for pieces that have a round shape.

In order to use geometrical angles, welders will also need to have the right drafting tools such as triangles. The triangles make it easier to connect 90, 45 & 60 degree angles together. A compass is also used for precise measurements and calculation of points between different angles. Both tools are helpful when creating joints and help

ensure that they're square. They can also be used to determine the radius, diameter and circumference of a circle.

Identify the elements of a circle Parts

Circle: A circle is a closed curved object, all parts of which are equally distant from the center



Circumference: Circumference is the distance around a circle: it is similar in meaning to perimeter.

Symbol used is C.

Radius: The radius is a straight line measurement from the center, to the edge, of the circle: it is one-half the diameter. Symbol used is r.

Diameter: The diameter is a straight line through the center of the circle, traveling from edge to edge. It divides the circle in half, and is equal in length to 2 radii. Symbol used is (D).

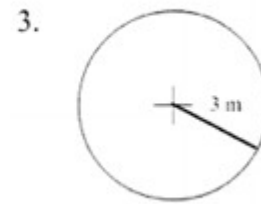
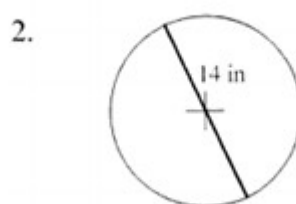
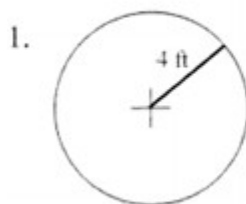
Diameter is designated on blueprints with the symbol \emptyset .

Pi: The circumference of any circle is 3.1416 times the diameter of that circle. The number 3.1416 is represented by the Greek letter "pi". The symbol used is π . Welding shops round π to 3.14.

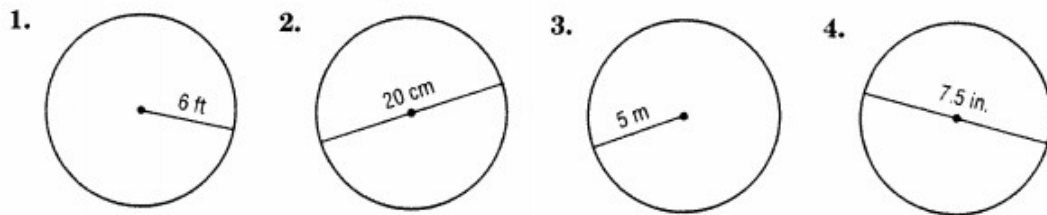
The formula for calculating the circumference of a circle is:

$$\text{Area} = \pi r^2$$

Examples: Find the area of the circle. Remember $\pi = 3.14$



Find the circumference of each circle. Use 3.14 or $\frac{22}{7}$ for π . Round to the nearest tenth if necessary.



5. diameter = 15 km

6. radius = 21 mi

7. radius = 50 m

8. diameter = 600 ft

9. radius = 62 mm

10. diameter = 7 km

Identify and use the ratio of sides of 45° and 60° right angled triangles.

Trigonometry

Speaking of angles, welders must also possess a good understanding of trigonometry for creating angled structures. Trigonometry helps welders determine the area of the weld and the angle it should be created at for handling pressure under various environmental conditions.

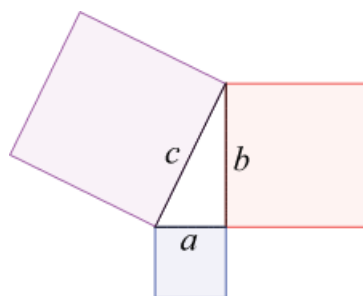
Trigonometry helps welders determine the strength of the weld and how joints should be made to ensure that they will not break with usage. The welder can test the strength of the joint without breaking it by applying module testing methods such as ultrasonic waves based on tangents, signs and cosigns. Testing methods help the welder determine imperfection in the weld and adjust it to create a durable structure.

Trigonometry is one of the more complex mathematical skills and takes time to master. It can be difficult to understand it if you aren't already good at geometry. The good part is that you can learn and improve your understanding of angled joints by taking a course in trigonometry.

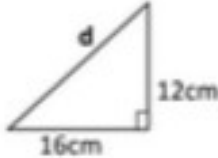
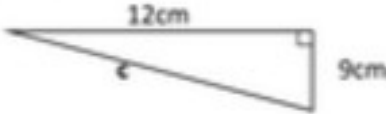
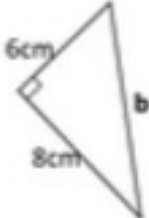
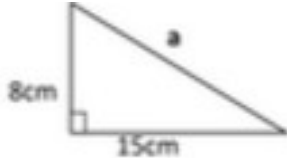
Pythagoras' Theorem

It states that the square of the hypotenuse (the side opposite the right angle) is equal to the sum of the squares of the other two sides.

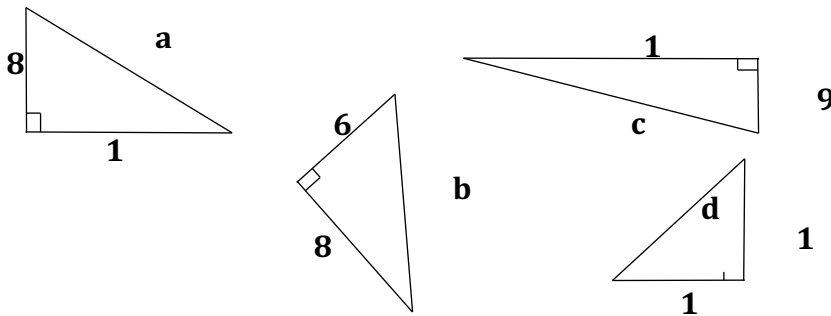
$$a^2 + b^2 = c^2$$



Find hypotenuse of following



Using Pythagoras, find the length of the side labeled with letters.

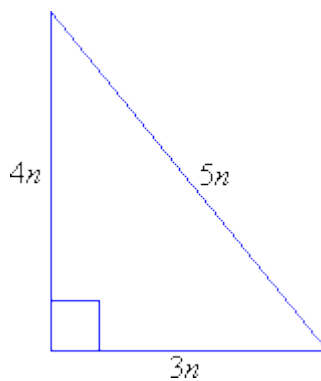


6.

3-4-5 Right Triangle

A 3-4-5 triangle is right triangle whose lengths are in the ratio of 3:4:5. When you are given the lengths of two sides of a right triangle, check the ratio of the lengths to see if it fits the 3:4:5 ratio.

$$\text{Side1} : \text{Side2} : \text{Hypotenuse} = 3n : 4n : 5n$$



24. Example 1:

Find the length of the hypotenuse of a right triangle if the lengths of the other two sides are 6 inches and 8 inches.

25. Solution:

Step 1: Test the ratio of the lengths to see if it fits the $3n : 4n : 5n$ ratio. $6 : 8 : ? = 3(2) : 4(2) : ?$

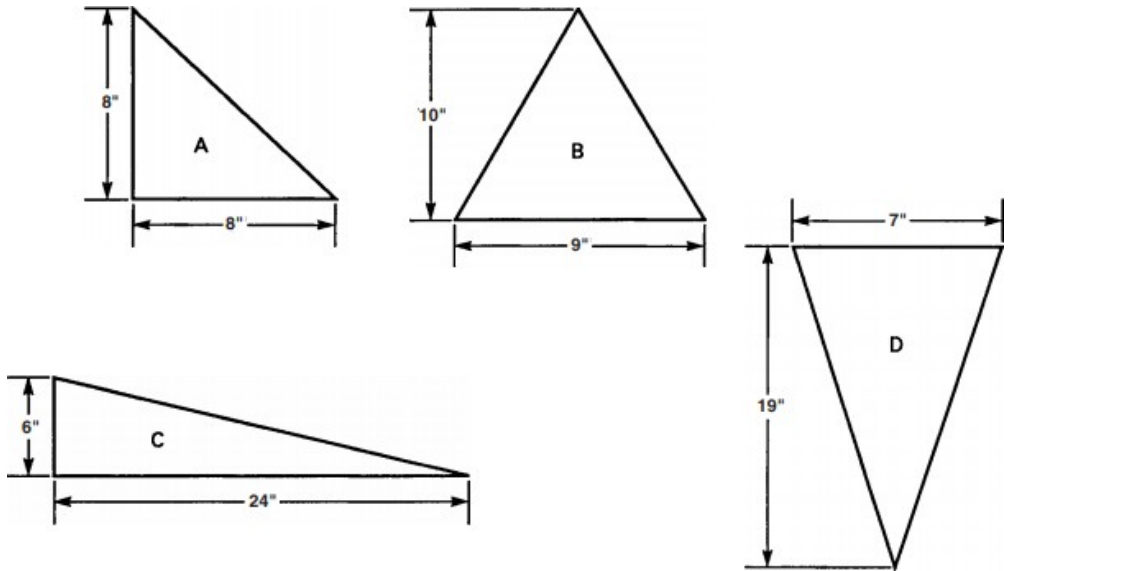
Step 2: Yes, it is a 3-4-5 triangle for $n = 2$.

Step 3: Calculate the third side $5n = 5 \times 2 = 10$

26. Answer:

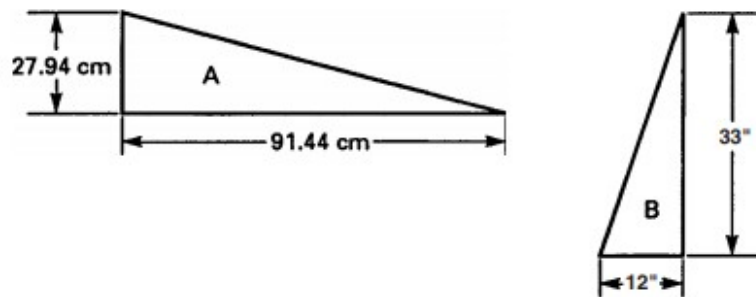
The length of the hypotenuse is 10 inches.

Solve simple workshop problems involving Pythagoras and right-angled triangles. These four triangular shapes are cut from sheet metal. What is the area of each piece in square inches?



- 1. Triangle A _____
- 2. Triangle B _____
- 3. Triangle C _____
- 4. Triangle D _____

Two pieces of sheet metal are cut into triangular shapes.



- 5. Find, in square centimeters, the area of triangle A. _____
- 6. Find, in square inches, the area of triangle B. _____

Convert Degrees Minutes Seconds to Decimal Degrees

Latitude and Longitude coordinates are often presented in degrees, minutes, and seconds, such as 39° 45' 30" (39 degrees, 45 minutes, 30 seconds). However, we can only plot values in decimal degrees. So, for example, 39° 45' is referred to as 39.75°

Converting from degrees, minutes, and seconds is actually quite easy. Consider the latitude value 39° 25' 30". This value needs to be converted to use it in Strater. There are 60 minutes in one degree and 3600 seconds in one degree. To convert minutes and seconds to decimal degrees, divide minutes by 60, divide seconds by 3600, and then add the results to obtain the decimal equivalent. Use the following formula to make the conversion:

$$\text{Decimal degrees} = \text{Degrees} + (\text{Minutes}/60) + (\text{Seconds}/3600)$$

For Example, to convert 39° 25' 30" to decimal degrees

7. First, convert minutes and seconds to their degree equivalents and add the results
 $25'/60=0.4167^\circ$
 $30"/3600=.0083^\circ$
8. and $0.4167^\circ + 0.0083^\circ = 0.425^\circ$
9. Then, add this number to the number of degrees. $39^\circ + 0.425^\circ = 39.425^\circ$
So, the final result is: $39^\circ 25' 30" = 39.425^\circ$

APPLY KNOWLEDGE OF MATHEMATICS IN WATER OPERATIONS

Water Measurement Units

There are two conditions under which water is measured—water at rest and water in motion. Water at rest is measured in units of volume. Water in motion is measured in units of flow— unit of volume for a convenient time unit. It is important that the difference between a unit of volume and a unit of flow be kept in mind.

Volume Units

Water at rest; i.e., ponds, lakes, reservoirs, and in the soil, is measured in units of volume — gallon, cubic foot, acre-inch, and acre-foot.

Cubic Foot – The volume of water that would be held in a container one foot wide by one foot long by one foot deep.

Acre-Inch – The volume of water that would cover one acre (43,560 square feet) one inch deep.

Acre-Foot – The volume of water that would cover one acre one foot deep.

Flow Units

Water in motion; i.e., flowing in streams, canals, pipelines, and ditches, is measured in units of volume per unit of time—gallons per minute (gpm), cubic feet per second (cfs), acre-inches per hour and acre feet per day. Cubic feet per second, sometimes written second-feet (sec. ft. or cusec) is most commonly used for measuring flow of irrigation water moving by gravity from streams and reservoirs. Gallons per minute is most commonly used for measuring flow from pumps.

Cubic foot per second – The quantity of water equivalent to a stream one foot wide by one foot deep flowing with a velocity of one foot per second.

Gallon per minute – The quantity of water equivalent to a stream which will fill a gallon measure once each minute.

A flow of one cfs is approximately equal to either 450 gpm, one acre-inch per hour, or two acre-feet per day (24 hours).

Conversion Factors

The following equivalents are useful for converting from one unit to another and for calculating volumes from flow units.

Volume Units

One gallon

= 231 cubic inches

= 0.13368 cubic foot weighs approximately 8.33 pounds

One cubic foot

= 1,728 cubic inches

= 7.481 gallons (7.5 for ordinary calculations) weighs 62.4 pounds (62.5 for ordinary calculations)

One acre-inch

= 3,630 cubic feet

= 27,154 gallons (27,200 for ordinary calculations)

= 1/12 acre-foot weighs approximately 113.1 tons

One acre-foot

= 43,560 cubic feet

= 325,851 gallons

= 12 acre-inches weighs approximately 1,357 tons

Flow Units

One gallon per minute

= 0.00223 (approximately 1/450) cubic foot per second

= 0.00221 acre-inch per hour

= 0.00442 acre-foot per (24 hour) day

= 1 acre-inch in 452.6 hours (450 for ordinary calculations)
= 1 acre-foot in 226.3 days

One cubic foot per second

= 448.83 gallons per minute (450 for ordinary calculations)
= 1 acre-inch in 1 hour and 30 seconds (1 hour for ordinary calculations)
= 1 acre-foot in 12 hours and 6 minutes (12 hours for ordinary calculations)
= 1.984 acre-feet per (24 hours) day (2 acre-feet for ordinary calculations)

Million gallons per day (mgd)

= 694.4 gallons per minute (695 for ordinary calculations)
= 1.547 cubic feet per second (1.5 for ordinary calculations)

Conversion Table.

To convert from: To: Multiply by:

Cubic-ft Gallons 7.5

Acre-in Cubic-ft 3,630

Acre-ft Cubic-ft 43,560

Acre-ft Acre-in 12 cfs gpm 450

Acre-in per hr cfs 1

Acre-ft per hr cfs 12

Conversion between English and Metric Units

Agricultural producers in many parts of the world use Metric (also called SI) units in their routine water measurements. The most commonly-used volume units in Metric system include liter, cubic meter, and hectare-millimeter, while common flow units are liter per minute (lpm) and cubic meter per second (cms). The following conversion table can be used to convert between English and Metric units.

Irrigation water management does begin with knowing how much water is available and involves some arithmetic. The most common mistake when working with water measurement units is to accidentally substitute one flow unit or volume unit for another without proper conversion. Usually the final answer appears obviously wrong; however, this is not always true. When checking your arithmetic, also check the measurement unit to see they are correct.

English/Metric Conversion Table.

To convert from: To: Multiply by:

Gallons Liters 3.8

Cubic-meter Cubic-ft 35.3

Cubic-ft Liters 28.3

Acre-in Hectare-mm 10.3

gpm lpm 3.8

cfs lpm 1700
cms cfs 35.3

Flow Units

Water in motion; i.e., flowing in streams, canals, pipelines, and ditches, is measured in units of volume per unit of time—gallons per minute (gpm), cubic feet per second (cfs), acre-inches per hour and acre feet per day. Cubic feet per second, sometimes written second-feet (sec. ft. or cusec) is most commonly used for measuring flow of irrigation water moving by gravity from streams and reservoirs. Gallons per minute is most commonly used for measuring flow from pumps.

Cubic foot per second - The quantity of water equivalent to a stream one foot wide by one foot deep flowing with a velocity of one foot per second.

Gallon per minute - The quantity of water equivalent to a stream which will fill a gallon measure once each minute of time.

A flow of one cubic foot per second is approximately equal to either 450 gallons per minute, one acre-inch per hour, or two acre-feet per day (24 hours).

Conversion Formulas

The following formulas are handy for computing the approximate depth of water applied to a field.

$$\frac{\text{Cubic feet per second} \times \text{hours}}{\text{acres}} = \text{acre-inches per acre, or average depth in inches.}$$
$$\frac{\text{Gallons per minute} \times \text{hours}}{450 \times \text{acres}} = \text{acre-inches per acre, or average depth in inches.}$$

Calculating the

Weight of Water

The challenge of calculating the weight of water really comes down to exactly what it means to find the *weight* of water, and whether the use of the term is for a specific reason or is simply a colloquial way of asking for the *mass* of water. In any case, you can easily find the result using the general formula for density and the value of the density of water.

Mass vs. Weight

The most important thing to understand before you try to calculate the weight of water is the difference between mass and weight. The mass of a substance is a measure of how much matter is present, and it's measured in kilograms or pounds. Most of the time, this is the most useful measure when you want to see how much of a substance is present.

The weight of a substance or an object is the *force* that gravity exerts on it due to its mass. For this reason, weight is technically measured in newtons or pounds-force. When most

people say “weight” in real life, they are actually referring to the mass of the substance, because in colloquial language the words are basically interchangeable. However, in physics they have very specific meanings, and as such, you have to be careful to ensure you’re using the right words and calculating the right quantities.

Water Measurement Calculator – mL to g

The metric system has a lot of advantages when it comes to converting between masses and volumes of water. This really comes down to the convenient value for the density of water, but if you just want to calculate the weight or mass of water without going into much detail, this is the simplest approach to use.

In short, 1 mL (milliliter) of water has a mass of 1 g, so 1 liter has a mass of 1 kg. You can use this fact to work out the mass of water from any volume: for example, 450 mL is 450 g, and 1.35 liters is 1.35 kg.

Volume to Mass in General

You should learn the general formula for density to convert the mass of anything to the volume, or vice-versa, and of course you can also use this for water. Density ρ is defined as the mass m divided by the volume V , or (equivalently) the mass per unit volume of a substance. The formula is:

$$\rho = \frac{m}{V}$$

However, if you’re looking to calculate the mass or weight of water (or another substance) you can re-arrange the formula to:

$$m = \rho V$$

Then all you need to find is the volume of water you’re trying to measure and the density of water. Make sure that the units match before making the calculation. For example, if you have the density of water in kg/m³, you need to measure the volume in m³, and if you’ve measured the volume in ft³, you’ll need the density in lb/ft³. The density of water in kg/m³ is 1,000 kg/m³, and in lb/ft³ it is 62.4 lb/ft³.

So if you have 0.01 m³ of water, this is:

$$\begin{aligned} m &= \rho V \\ &= 1000 \text{ kg/m}^3 \times 0.01 \text{ m}^3 \\ &= 10 \text{ kg} \end{aligned}$$

Mass to Weight of Water

Finally, you can convert between mass and weight (if you really do need the weight rather than the mass) using the formula:

$$W = mg$$

Where W is the weight, m is the mass and $g = 9.81 \text{ m/s}^2 = 32.17 \text{ ft/s}^2$, the acceleration due to gravity. So continuing from the previous example gives:

$$\begin{aligned} W &= mg \\ &= 10 \text{ kg} \times 9.81 \text{ m/s}^2 \\ &= 98.1 \text{ N} \end{aligned}$$

Again, you need to make sure the units match up, so if you have the mass in lb, you'll need the acceleration due to gravity in ft/s^2 to ensure the answer makes sense.

Wastewater Conversion Table

$$\text{Alkalinity, as mg CaCO}_3/\text{L} = \frac{(\text{Titrant Volume, mL})(\text{Acid Normality})(50,000)}{\text{Sample Volume, mL}}$$

$$\text{Amps} = \frac{\text{Volts}}{\text{Ohms}}$$

$$\text{Area of Circle} = (0.785) (\text{Diameter}^2) \text{ or } (\pi) (\text{Radius}^2)$$

$$\text{Area of Cone (lateral area)} = (\pi) (\text{Radius}) \sqrt{\text{Radius}^2 + \text{Height}^2}$$

$$\text{Area of Cone (total surface area)} = (\pi) (\text{Radius}) (\text{Radius} + \sqrt{\text{Radius}^2 + \text{Height}^2})$$

$$\text{Area of Cylinder (total outside surface area)} = [\text{Surface Area of End \#1}] + [\text{Surface Area of End \#2}] + [(\pi) (\text{Diameter}) (\text{Height or Depth})]$$

$$\text{Area of Rectangle} = (\text{Length}) (\text{Width})$$

$$\text{Area of a Right Triangle} = \frac{(\text{Base})(\text{Height})}{2}$$

$$\text{Average (arithmetic mean)} = \frac{\text{Sum of All Terms}}{\text{Number of Terms}}$$

$$\text{Average (geometric mean)} = [(X_1)(X_2)(X_3)(X_4)(X_n)]^{1/n} \text{ The } n\text{th root of the product of } n \text{ numbers}$$

$$\text{Biochemical Oxygen Demand (unseeded), in mg/L} = \frac{(\text{Initial DO, mg/L}) - (\text{Final DO, mg/L})}{\frac{\text{Sample Volume, mL}}{\text{Final Diluted Volume, mL}}}$$

$$\text{Chemical Feed Pump Setting, \% Stroke} = \frac{(\text{Desired Flow})(100\%)}{\text{Maximum Flow}}$$

$$\text{Chemical Feed Pump Setting, mL/min} = \frac{(\text{Flow, MGD})(\text{Dose, mg/L})(3.785 \text{ L/gal})(1,000,000 \text{ gal/MG})}{(\text{Liquid, mg/mL})(24 \text{ hr/day})(60 \text{ min/hr})}$$

Circumference of Circle = (π) (Diameter)

Composite Sample Single Portion = $\frac{(\text{Instantaneous Flow})(\text{Total Sample Volume})}{(\text{Number of Portions})(\text{Average Flow})}$

Cycle Time, min. = $\frac{\text{Storage Volume, gal}}{\text{Pump Capacity, gpm} - \text{Wet Well Inflow, gpm}}$

Degrees Celsius = (Degrees Fahrenheit - 32) $(\frac{5}{9})$ or $\frac{(F - 32)}{1.8}$

Degrees Fahrenheit = [(Degrees Celsius) $(\frac{9}{5})$ + 32] or [(Degrees Celsius) (1.8) + 32]

Detention Time = $\frac{\text{Volume}}{\text{Flow}}$ Note: Units must be compatible.

Electromotive Force (E.M.F), volts = (Current, amps) (Resistance, ohms) or $E = IR$

Feed Rate, lbs/day = $\frac{(\text{Dosage, mg/L})(\text{Capacity, MGD})(8.34 \text{ lbs/gal})}{(\text{Purity, decimal percentage})}$

Filter Backwash Rate, gpm/sq ft = $\frac{\text{Flow, gpm}}{\text{Filter Area, sq ft}}$

Filter Backwash Rise Rate, in/minute = $\frac{(\text{Backwash Rate, GPM/sq ft})(12 \text{ in/ft})}{(7.48 \text{ gal/cu ft})}$

Filter Yield, lbs/hr/sq ft = $\frac{(\text{Solids Loading, lbs/day})(\text{Recovery, \%} / 100\%)}{(\text{Filter Operation, hr/day})(\text{Area, sq ft})}$

Flow Rate, cfs = (Area, sq ft) (Velocity, ft/sec) or $Q = AV$ where: Q = flow rate, A = area, V = velocity

Food/Microorganism Ratio = $\frac{\text{BOD}_5, \text{ lbs/day}}{\text{MLVSS, lbs}}$

Force, pounds = (Pressure, psi) (Area, sq in)

Gallons/Capita/Day = $\frac{\text{Volume of Wastewater Produced, gpd}}{\text{Population}}$

Hardness, as mg CaCO_3/L = $\frac{(\text{Titrant Volume, mL})(1,000)}{\text{Sample Volume, mL}}$ Only when the titration factor is 1.00 of EDTA

Horsepower, Brake (bhp) = $\frac{(\text{Flow, gpm})(\text{Head, ft})}{(3,960)(\text{Decimal Pump Efficiency})}$

Horsepower, Motor (mhp) = $\frac{(\text{Flow, gpm})(\text{Head, ft})}{(3,960)(\text{Decimal Pump Efficiency})(\text{Decimal Motor Efficiency})}$

$$\text{Horsepower, Water (whp)} = \frac{(\text{Flow, gpm})(\text{Head, ft})}{3,960}$$

$$\text{Hydraulic Loading Rate, gpd/sq ft} = \frac{\text{Total Flow Applied, gpd}}{\text{Area, sq ft}}$$

$$\text{Leakage, gpd} = \frac{\text{Volume, gallons}}{\text{Time, days}}$$

$$\text{Mass, lbs} = (\text{Volume, MG})(\text{Concentration, mg/L})(8.34 \text{ lbs/gal})$$

$$\text{Mass Flux, lbs/day} = (\text{Flow, MGD})(\text{Concentration, mg/L})(8.34 \text{ lbs/gal})$$

$$\text{Mean Cell Residence Time (MCRT) or Solids Retention Time (SRT), days} = \frac{\text{Aeration Tank TSS, lbs} + \text{Clarifier TSS, lbs}}{\text{TSS Wasted, lbs/day} + \text{Effluent TSS, lb/day}}$$

$$\text{Molarity} = \frac{\text{Moles of Solute}}{\text{Liters of Solution}}$$

$$\text{Normality} = \frac{\text{Number of Equivalent Weights of Solute}}{\text{Liters of Solution}}$$

$$\text{Number of Equivalent Weights} = \frac{\text{Total Weight}}{\text{Equivalent Weight}}$$

$$\text{Number of Moles} = \frac{\text{Total Weight}}{\text{Molecular Weight}}$$

$$\text{Organic Loading Rate} = \frac{\text{Organic Load, lbs BOD}_5/\text{day}}{\text{Volume}}$$

$$\text{Organic Loading Rate-RBC, lbs BOD}_5/\text{day}/1,000 \text{ sq ft} = \frac{\text{Organic Load, lbs BOD}_5/\text{day}}{\text{Surface Area of Media, 1,000 sq ft}}$$

$$\text{Organic Loading Rate-Trickling Filter, lbs BOD}_5/\text{day}/1,000 \text{ cu ft} = \frac{\text{Organic Load, lbs BOD}_5/\text{day}}{\text{Volume, 1,000 cu ft}}$$

$$\text{Oxygen Uptake Rate/Oxygen Consumption Rate, mg/L/minute} = \frac{\text{Oxygen Usage, mg/L}}{\text{Time, minute}}$$

$$\text{Population Equivalent, Organic} = \frac{(\text{Flow, MGD})(\text{BOD, mg/L})(8.34 \text{ lbs/gal})}{\text{lbs BOD/day/person}}$$

$$\text{Recirculation Ratio-Trickling Filter} = \frac{\text{Recirculated Flow}}{\text{Primary Effluent Flow}}$$

$$\text{Reduction in Flow, \%} = \frac{(\text{Original Flow} - \text{Reduced Flow})(100\%)}{\text{Original Flow}}$$

$$\text{Reduction of Volatile Solids, \%} = \frac{(\text{In} - \text{Out})(100\%)}{\text{In} - (\text{In} \times \text{Out})}$$
 All information (In and Out) must be in decimal form

$$\text{Removal, \%} = \frac{(\text{In} - \text{Out}) (100)}{\text{In}}$$

$$\text{Return Rate, \%} = \frac{(\text{Return Flow Rate}) (100\%)}{\text{Influent Flow Rate}}$$

$$\text{Return Sludge Rate-Solids Balance} = \frac{(\text{MLSS}) (\text{Flow Rate})}{\text{Return Activated Sludge Suspended Solids} - \text{MLSS}}$$

$$\text{Slope, \%} = \frac{\text{Drop or Rise}}{\text{Distance}} \times 100$$

$$\text{Sludge Density Index} = \frac{100}{\text{SVI}}$$

$$\text{Sludge Volume Index, mL/g} = \frac{(\text{SSV}_{30}, \text{mL/L}) (1,000 \text{ mg/g})}{\text{MLSS, mg/L}}$$

$$\text{Solids, mg/L} = \frac{(\text{Dry Solids, grams}) (1,000,000)}{\text{Sample Volume, mL}}$$

$$\text{Solids Concentration, mg/L} = \frac{\text{Weight, mg}}{\text{Volume, L}}$$

$$\text{Solids Loading Rate, lbs/day/sq ft} = \frac{\text{Solids Applied, lbs/day}}{\text{Surface Area, sq ft}}$$

Solids Retention Time (SRT): *see* Mean Cell Residence Time (MCRT)

$$\text{Specific Gravity} = \frac{\text{Specific Weight of Substance, lbs/gal}}{\text{Specific Weight of Water, lbs/gal}}$$

$$\text{Specific Oxygen Uptake Rate/Respiration Rate, (mg/g)/hr} = \frac{\text{OUR, mg/L/min (60 min)}}{\text{MLVSS, g/L (1 hr)}}$$

$$\text{Surface Loading Rate or Surface Overflow Rate, gpd/sq ft} = \frac{\text{Flow, gpd}}{\text{Area, sq ft}}$$

Three Normal Equation = $(N_1 \times V_1) + (N_2 \times V_2) = (N_3 \times V_3)$, where $V_1 + V_2 = V_3$

Two Normal Equation = $N_1 \times V_1 = N_2 \times V_2$, where N = concentration (normality), V = volume or flow

$$\text{Velocity, ft/second} = \frac{\text{Flow Rate, cu ft / sec}}{\text{Area, sq ft}} \text{ or } \frac{\text{Distance, ft}}{\text{Time, second}}$$

$$\text{Volatile Solids, \%} = \frac{(\text{Dry Solids, g} - \text{Fixed Solids, g}) (100)}{\text{Dry Solids, g}}$$

$$\text{Volume of Cone} = (1/3) (0.785) (\text{Diameter}^2) (\text{Height})$$

$$\text{Volume of Cylinder} = (0.785) (\text{Diameter}^2) (\text{Height})$$

$$\text{Volume of Rectangular Tank} = (\text{Length}) (\text{Width}) (\text{Height})$$

$$\text{Waste Milliequivalent} = (\text{mL}) (\text{Normality})$$

$$\text{Watts (DC circuit)} = (\text{Volts}) (\text{Amps})$$

$$\text{Watts (AC circuit)} = (\text{Volts}) (\text{Amps}) (\text{Power Factor})$$

$$\text{Weir Overflow Rate, gpd/ft} = \frac{\text{Flow, gpd}}{\text{Weir Length, ft}}$$

$$\text{Wire-to-Water Efficiency, \%} = \frac{\text{Water Horsepower, HP}}{\text{Power Input, HP or Motor HP}} \times 100$$

$$\text{Wire-to-Water Efficiency, \%} = \frac{(\text{Flow, gpm}) (\text{Total Dynamic Head, ft}) (0.746 \text{ kw/hp}) (100)}{(3,960) (\text{Electrical Demand, kilowatts})}$$

Temperature Conversion

The three common temperature scales are Celsius, Fahrenheit, and Kelvin. Each scale has its uses, so it's likely you'll encounter them and need to convert between them. Fortunately, the conversion formulas are simple:

Celsius to Fahrenheit	$^{\circ} \text{F} = 9/5 (^{\circ} \text{C}) + 32$
Kelvin to Fahrenheit	$^{\circ} \text{F} = 9/5 (\text{K} - 273) + 32$
Fahrenheit to Celsius	$^{\circ} \text{C} = 5/9 (^{\circ} \text{F} - 32)$
Celsius to Kelvin	$\text{K} = ^{\circ} \text{C} + 273$
Kelvin to Celsius	$^{\circ} \text{C} = \text{K} - 273$
Fahrenheit to Kelvin	$\text{K} = 5/9 (^{\circ} \text{F} - 32) + 273$

Population Equivalent

A means of expressing the strength of organic material in wastewater. In a domestic wastewater system, microorganisms use up about 0.2 pound (90 grams) of oxygen per day for each person using the system (as measured by the standard BOD test). May also be expressed as flow (100 gallons/person/day or 378 liters/person/day) or suspended solids (0.2 lb SS/person/day or 90 grams SS/person/day).

Density and Specific Gravity

Density and specific gravity have very similar, but not quite identical definitions.

Density is the mass of material per unit volume.

Specific gravity is a ratio of the mass of a material to the mass of an equal volume of water at 4 °C. Because specific gravity is a ratio, it is a unitless quantity. For example, the specific gravity of water at 4°C is 1.0 while its density is 1.0 gcm⁻³.

Detention Time

Detention time is the length of time water is retained in a vessel or basin or the period from the time the water enters a settling basin until it flows out the other end. When calculating unit process detention times, we are calculating the length of time it takes the water to flow through that unit process. Detention times are normally calculated for the following basins or tanks:

Flash mix chambers (seconds)

Flocculation basins (minutes)

Sedimentation tanks or clarifiers (hours)

Wastewater ponds (days)

Oxidation ditches (hours)

To calculate the detention period of a basin, the volume of the basin must first be obtained with the formula: $V = L \times W \times D$

Detention time is calculated in units of time. The most common are seconds, minutes, hours and days. If detention time is desired in minutes, then the flow rate used in the calculation should have the same time frame (cfm or gpm, depending on whether tank volume is expressed as cubic feet or gallons). If detention time is desired in hours, then the flow rate used in the calculation should be cfh or gph.

The simplest way to calculate detention time is to divide the volume of the container by the flow rate into the container. The theoretical detention time of a container is the same as the amount of time it would take to fill the container if it were empty. For volume, the most common units used are gallons; however, on occasion, cubic feet may also be used. Time units will be in whatever units are used to express the flow. For example, if the flow is in gpm, the detention time will be in days. If, in the final result, the detention time is in the wrong time unit, simply convert to the appropriate units.

Detention time can be determined using the following formula:

$$\text{Detention Time} = \frac{\text{Volume}}{\text{Flow}} \quad * \text{Units must be compatible}$$

UNDERTAKE WATER/WASTEWATER CALCULATIONS

Service Line Flushing Time

General Service Connection Flushing Procedures

4. Flushing a service connection should not be started until after the water main serving the service connection has been thoroughly flushed by the public water supply system's operating staff.
5. Once the waterline/water main has been thoroughly flushed, begin the process of flushing the service connection by locating the outside spigot/faucet that is closest to the water main.
6. Run the water with the outside spigot/faucet open for at least 10-15 minutes to flush the service line. Lengthy or complex service lines may require flushing for more than 10-15 minutes.
7. A hose may be attached to the outside spigot/faucet to redirect the water to avoid ponding. In doing so, make sure the flow is high and nothing is attached to the end of the hose. Additional flushing time may be necessary to compensate for any restrictions imposed by the attached hose.
8. Wait 30 – 60 minutes without using any water, if possible, to allow the water in the water main to settle.
9. Open the outside spigot/faucet again and check water clarity.
10. If necessary, flush the service line through the outside spigot/faucet for another 10-15 minutes. Depending on the flushing of the water main, it may be necessary to repeat the flushing of the service line checking water clarity each time.
11. After the water from the outside spigot/faucet appears clear, begin the general process of flushing the service connection's interior pipes and faucets.
12. If possible, begin flushing at a cold water faucet that is both on the lowest level of the service connection's structure and closest to its water meter.
13. Fully open each cold water faucet one at a time and run for at least five minutes. Prior to flushing remove all faucet attachments such as aerators, screens, etc. to maximum flow.
14. Flush remaining cold water faucets moving upwardly in the service connection's structure and away from its water meter. Be sure to include tubs and showers.
15. Individually open each remaining outside spigot/faucet and similarly flush as above.
16. Flush hot water heaters according to the manufacturer's instructions for flushing. Disconnect power to the hot water heater at the circuit breaker box and allow the hot water heater to sufficiently cool before flushing to avoid being burned. Begin flushing hot water taps on the lowest level of the service connection's structure. Individually open the hot water faucets and run until the warm water turns to cold

water. Restore power to the hot water heater once all hot water faucets have been thoroughly flushed.

17. Flush items such as in-line filters, treatment systems, water softeners, refrigerator water dispensers (direct or tanked) with enough water to replace at least 1-2 volumes of all connecting lines and tanks. To avoid contamination, consider replacing all filters, especially if they are at the end of their useful service life.
18. Refer to owner's manuals for flushing water softening systems, reverse osmosis systems, and other types of filtering systems. To avoid contamination, consider replacing all filters, especially if they are at the end of their useful service life.
19. Other items that utilize water such as coffee makers, pitcher type water filters, and dental cleaning appliances should be cleaned and their filters replaced.
20. If water from taps is not clear, repeat steps 2 through 16.
21. Once flushing has been completed, verify that all spigots and faucets are closed.

Composite Sampling

Wastewater sampling is generally performed by one of two methods, grab sampling or composite sampling. Grab sampling is just what it sounds like; all of the test material is collected at one time. As such, a grab sample reflects performance only at the point in time that the sample was collected, and then only if the sample was properly collected. Composite sampling consists of a collection of numerous individual discrete samples taken at regular intervals over a period of time, usually 24 hours. The material being sampled is collected in a common container over the sampling period. The analysis of this material, collected over a period of time, will therefore represent the average performance of a wastewater treatment plant during the collection period.

Numerous industry references list various parameters for wastewater testing and whether samples should be collected using grab sampling or composite sampling methods. For example, grab sampling allows the analysis of specific types of unstable parameters such as pH, dissolved oxygen, chlorine residual, nitrites and temperature. However, the most widely used indicators of treatment plant performance, including CBOD5 (five day carbonaceous biochemical oxygen demand), TSS (total suspended solids) and TN (total nitrogen) require the use of composite sampling techniques. STANDARD METHODS (20th Edition, Section 1060 § B, "Collection and Sampling") states "A sample can represent only the composition of its source at the time and place of collection." Grab samples may be used to represent "some well-mixed surface waters, but rarely, wastewater streams" for water quality evaluation. The widely varying flow patterns of residential treatment plants make it impossible to evaluate performance by analyzing a single grab sample of effluent. Residential treatment plants receive a frequent number of short hydraulic surges throughout the day followed by intermittent periods of no flow whatsoever.

Routine variations in the volume and strength characteristics of incoming wastewater create fluctuations in the quality of treatment plant effluent. Therefore, an effluent grab sample taken at one specific time throughout the daily flow pattern will not be representative of system performance over the entire day.

While the limitations of determining system performance by grab sampling are apparent, the use of grab samples for the evaluation of a residential treatment unit is further compromised if the sample is collected from a location where the effluent does not have sufficient velocity to keep the effluent solids in suspension.

While the limitations of determining system performance by grab sampling are apparent, the use of grab samples for the evaluation of a residential treatment unit is further compromised if the sample is collected from a location where the effluent does not have sufficient velocity to keep the effluent solids in suspension. WASTEWATER SAMPLING FOR PROCESS AND QUALITY CONTROL (Manual of Practice No. OM-1, § “Representative Sampling”) directs that samples be collected “at points where the sample stream or tank is well mixed.” The manual goes on to say “avoid taking samples at points where solids settling occurs or floating debris is present. These situations occur normally in quiescent areas, where the velocity of the flow has decreased.” For this reason, plant performance can never be evaluated by a sample of effluent taken from a pump chamber, distribution box, sump, roadside ditch or any device that contains effluent below the flow line. The intermittent flow pattern of an individual residence intensifies this problem by allowing effluent solids to settle out within a sump during low flow periods. Even the few solids present in a high quality effluent will settle out when retained within a sump. If only a very few solids settle within a sump during a low flow period today, they remain and accumulate with additional solids settling out over successive days. Any sample drawn from a sump will contain effluent suspended solids combined with days, weeks, months or years worth of accumulated solids. A sample of liquid from such a sump cannot be analyzed for overall system performance, as it is scientifically impossible to determine what portion of the solids were suspended in the effluent and what portion of the solids had accumulated in the sump over a period of time. Using any sample drawn from a sump to evaluate the performance of a residential wastewater treatment plant is simply inappropriate. Samples must be taken from a location where the effluent is free-flowing and has sufficient velocity to keep the effluent solids in suspension.

Composite samples of effluent collected, stored, analyzed, tabulated and averaged over an extended period of time provide the only verifiable indication of treatment plant performance. Collecting and analyzing these composite samples is often an expensive and time-consuming process. For these reasons, most regulatory organizations recognize independent third-party certifiers, who use composite sampling methods to conduct performance evaluation and accurately measure system performance in a standardized, reproducible setting. Attempting to evaluate a residential treatment system in the field by analyzing a grab sample taken from a sump or any other containment vessel provides a compound degree of error and will yield erroneous conclusions about system performance.

Biochemical Oxygen Demand

To determine the value of the BOD in mg/L, use the following formula:

$$\text{BOD, mg/L} = [(\text{Initial DO} - \text{Final DO}) \times 300] / \text{mL sample}$$

For example:

Initial DO = 8.2 mg/L

Final DO = 4.4 mg/L

Sample size = 5 mL

$$\text{BOD mg/L} = [(8.2 - 4.4) \times 300]/5 = (3.8 \times 300)/5 = 1140/5 = 228 \text{ mg/L}$$

Whenever a sample is dechlorinated, it must be seeded. If the sample is seeded, a correction factor must be calculated to determine the effects that the seed material has on the DO depletion. A number of BOD's must be run on the seed material to determine the seed correction factor.

UNIT 05

APPLY PRINCIPLES OF CHEMISTRY TO WATER SYSTEMS AND PROCESSES

This unit describes the skills required to identify and apply to water systems and processes the principles of chemistry, and to select the relevant and effective chemicals required for specific processes

APPLY CHEMISTRY TO WATER PROCESSES

Apply relevant chemistry principles to improve performance of specific water processes.

We take for granted the water that comes out of the taps in our home when we turn them on – but a lot of work goes into getting it there. Chemistry, too, has a hand in making sure that the water is safe to drink. Here, we take a look at the water treatment process, and in particular the chemicals used to get clean drinking water to your tap.

The water that ends up in our homes can begin in a number of places. Much of it is groundwater – water beneath the Earth’s surface, trapped between the pores and cracks in rocks. This water can actually be relatively pure, due to natural filtration through chalk and similar rock types, and as such can sometimes skip through some of the treatment steps we’ll detail here, as it contains little by way of debris and organic material.

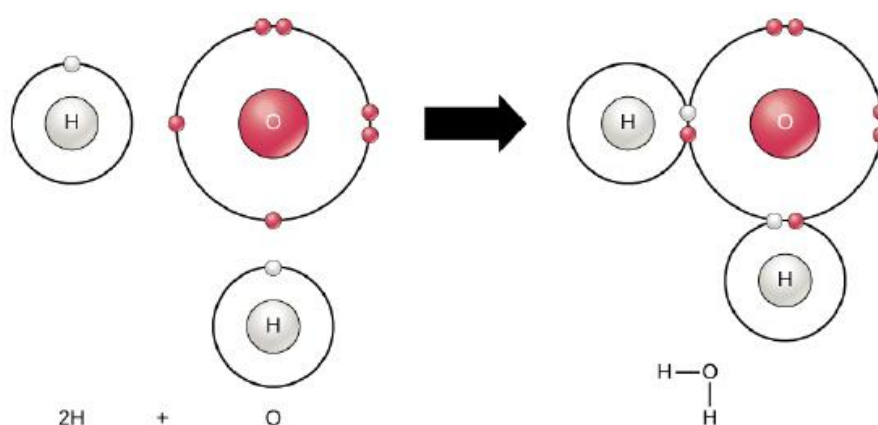
Chemical Structure and Properties of Water

You are probably already familiar with many of the water’s properties. For example, you no doubt know that water is tasteless, odorless, and transparent. In small quantities, it is also colorless. However, when a large amount of water is observed, as in a lake or the ocean, it is actually light blue in color. The blue hue of the water is an intrinsic property and is caused by selective absorption and scattering of white light. These and other properties of water depend on its chemical structure.

The transparency of water is important for organisms that live in water. Because water is transparent, sunlight can pass through it. Sunlight is needed by water plants and other water organisms for photosynthesis.

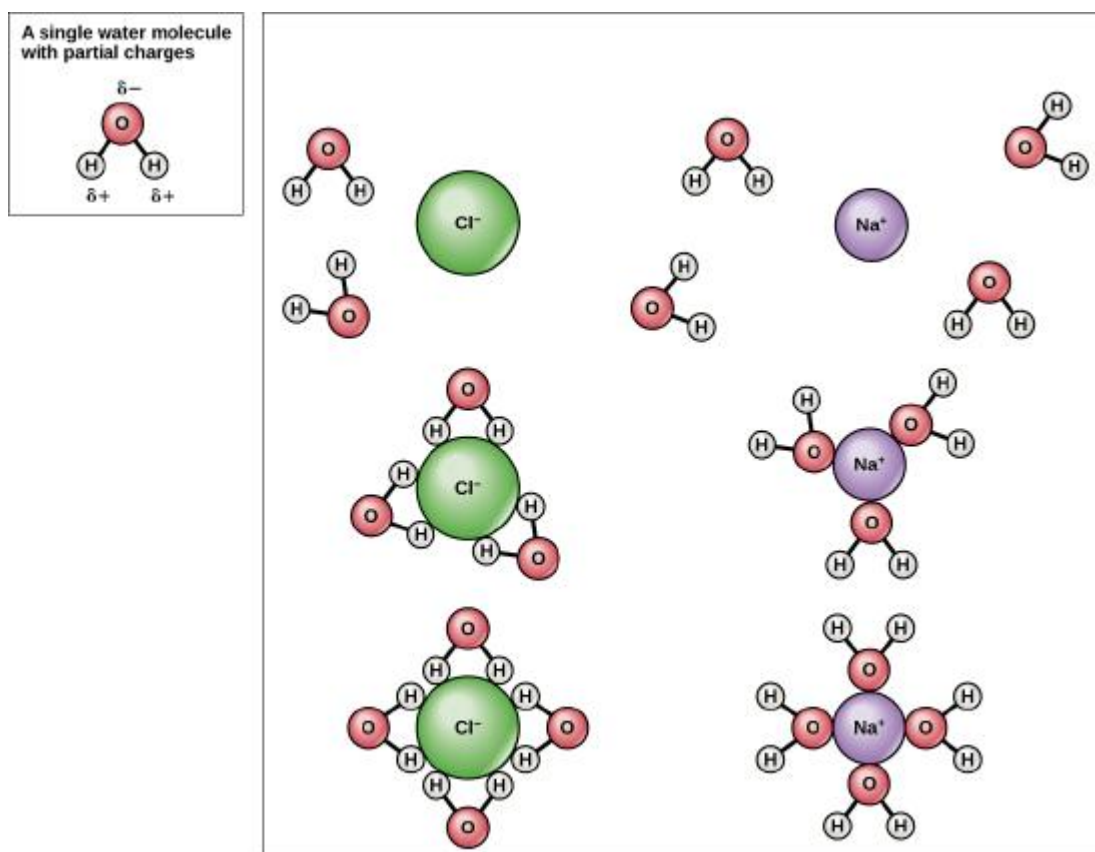
Chemical Structure of Water

Each molecule of water consists of one atom of oxygen and two atoms of hydrogen, so it has the chemical formula H₂O. The arrangement of atoms in a water molecule, shown in Figure, explains many of the water’s chemical properties.



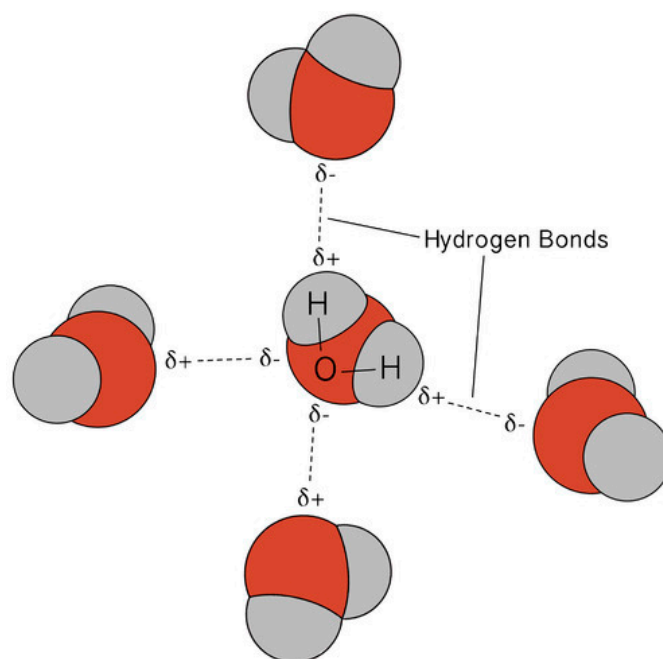
This model is an atomic diagram of water, showing the two hydrogen atoms and an oxygen atom in the center. The electrons circle each nucleus.

In each water molecule, the nucleus of the oxygen atom (with 8 positively charged protons) attracts electrons much more strongly than do the hydrogen nuclei (with only one positively charged proton). This results in a negative electrical charge near the oxygen atom (due to the "pull" of the negatively charged electrons toward the oxygen nucleus) and a positive electrical charge near the hydrogen atoms. A difference in electrical charge between different parts of a molecule is called polarity. A polar molecule is a molecule in which part of the molecule is positively charged and part of the molecule is negatively charged. Due to polarity in charge within the water molecule, it can dissolve salts. Following Figure illustrates how water dissolves ionically bonded sodium chloride. Therefore, water is considered a very good solvent in the biochemical reactions.



This diagram shows the positive and negative parts of a water molecule. It also depicts how a charge, such as on an ion (Na or Cl, for example) can interact with a water molecule.

Hydrogen Bonding



Hydrogen bonds form between positively and negatively charged parts of water molecules. The bonds hold the water molecules together. How do you think this might affect water's properties?

Opposite electrical charges attract one another. Therefore, the positive part of one water molecule is attracted to the negative parts of other water molecules. Because of this attraction, bonds form between hydrogen and oxygen atoms of adjacent water molecules, as demonstrated in Figure. This type of bond always involves a hydrogen atom, so it is called a **hydrogen bond**.

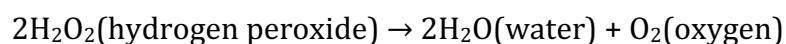
Hydrogen bonds can also form within a single large organic molecule. For example, hydrogen bonds that form between different parts of a protein molecule bend the molecule into a distinctive shape, which is important for the protein's functions. Hydrogen bonds also hold together the two nucleotide chains of a DNA molecule.

Identify and describe chemical reactions specific to water processes.

Chemical reactions

Chemical reactions occur when chemical bonds between atoms are formed or broken. The substances that go into a chemical reaction are called the reactants, and the substances produced at the end of the reaction are known as the products. An arrow is drawn between the reactants and products to indicate the direction of the chemical reaction, though a chemical reaction is not always a "one-way street," as we'll explore further in the next section.

For example, the reaction for breakdown of hydrogen peroxide (H_2O_2) into water and oxygen can be written as:



In this example hydrogen peroxide is our reactant, and it gets broken down into water and oxygen, our products. The atoms that started out in hydrogen peroxide molecules are rearranged to form water molecules (H₂O) and oxygen molecules (O₂).

You may have noticed extra numbers in the chemical equation above: the 2s in front of hydrogen peroxide and water. These numbers are called coefficients, and they tell us how many of each molecule participate in the reaction. They must be included in order to make our equation balanced, meaning that the number of atoms of each element is the same on the two sides of the equation.

Equations must be balanced to reflect the law of conservation of matter, which states that no atoms are created or destroyed over the course of a normal chemical reaction.

Reversibility and equilibrium

Some chemical reactions simply run in one direction until the reactants are used up. These reactions are said to be irreversible. Other reactions, however, are classified as reversible. Reversible reactions can go in both the forward and backward directions.

In a reversible reaction, reactants turn into products, but products also turn back into reactants. In fact, both the forward reaction and its opposite will take place at the same time. This back and forth continues until a certain relative balance between reactants and products is reached—a state called equilibrium. At equilibrium, the forward and backward reactions are still happening, but the relative concentrations of products and reactants no longer change.

Each reaction has its own characteristic equilibrium point, which we can describe with a number called the equilibrium constant. To learn where the equilibrium constant comes from and how to calculate it for a specific reaction, check out the equilibrium topic.

When a reaction is classified as reversible, it is usually written with paired forward and backward arrows to show it can go both ways. For example, in human blood, excess hydrogen ions (H⁺) bind to bicarbonate ions (HCO₃⁻), forming carbonic acid (H₂CO₃):



Since this is a reversible reaction, if carbonic acid were added to the system, some of it would be turned into bicarbonate and hydrogen ions to restore equilibrium. In fact, this buffer system plays a key role in keeping your blood pH stable and healthy.

IDENTIFY THE USE OF CHEMICALS IN WATER INDUSTRY PROCESSES

Assess the functions of the range of industry chemicals in relation to their use in water processes.

Chemicals used in treatment

Disinfectants and disinfection by-products

The three chemicals most commonly used as primary disinfectants are chlorine, chlorine dioxide and ozone. Monochloramine, usually referred to as chloramine, is used as a residual disinfectant for distribution.

Chlorine

Chlorine is the most widely used primary disinfectant and is also often used to provide residual disinfection in the distribution system. Monitoring the level of chlorine in drinking water entering a distribution system is normally considered to be a high priority (if it is possible), because the monitoring is used as an indicator that disinfection has taken place. Residual concentrations of chlorine of about 0.6 mg/l or more may cause problems of acceptability for some consumers on the basis of taste. Monitoring free chlorine at different points in the distribution system is sometimes used to check that there is not an excessive chlorine demand in distribution that may indicate other problems in the system, such as ingress of contamination.

Chlorine reacts with naturally occurring organic matter in raw water to form a range of unwanted by-products. Guideline values have been established for a number of these byproducts. The compounds most widely considered as representatives of chlorination byproducts for the purposes of setting standards and monitoring are the trihalomethanes (thms) which include chloroform, bromodichloromethane, chlorodibromomethane and bromoform. Haloacetic acids (haas), such as monochloroacetate, dichloroacetate and trichloroacetate, can also be formed as the result of reaction of chlorine with organic matter contained in raw water. Some countries monitor haas as well as thms, but haas are much more difficult and expensive to analyse than thms.

Thms and haas continue to develop within the distribution system; thus, monitoring can be complex. Optimizing coagulation and filtration is most important in helping to remove the precursors of these by-products and will, in turn, reduce the formation of thms, haas and other unwanted by-products.

In order to ensure the microbial safety of drinking-water, disinfection should never be compromised in trying to meet guidelines for any disinfection by-products.

Chlorine dioxide

Chlorine dioxide breaks down to leave the inorganic chemicals chlorite and chlorate. These are best managed by controlling the dose of chlorine dioxide applied to the water. Chlorite can also be found in hypochlorite solution that has been allowed to age. There is no guideline value for chlorate because of limited data on its toxicology, but this chemical has

been shown to be less toxic than chlorite and is present at lower concentrations. Controlling chlorite will generally also adequately control chlorate.

Ozone

Ozone, used as a primary disinfectant, cannot be monitored in drinking-water, because it leaves no residual. Ozonation in the presence of inorganic bromide, which can occur naturally in raw water, can give rise to low concentrations of bromate. The analysis of bromate is difficult and expensive, because a number of other inorganic substances that interfere with the analysis may be present. It is considered, therefore, that bromate monitoring is a low priority, and that management should instead involve controlling the conditions of ozonation.

Monochloramine

Monochloramine, used as a residual disinfectant for distribution, is usually formed from the reaction of chlorine with ammonia. Careful control of monochloramine formation in water treatment is important to avoid the formation of di- and trichloramines, because these can cause unacceptable tastes and odours. The formation of nitrite as a consequence of microbial activity in biofilms in the distribution system is a possibility when monochloramine is used as a residual disinfectant, particularly if ammonia levels are not sufficiently controlled.

Identify and describe factors influencing the effectiveness of chemical use.

A number of other chemicals may be added in treatment. These include substances such as sodium hydroxide for adjusting pH and, in certain circumstances, chemicals for fluoridation of drinking-water. In all cases it is appropriate to specify the quality of the chemicals added so that the final water does not contain unacceptable concentrations of unwanted contaminants. Ensuring that chemicals used are of an appropriate quality is generally best managed by product specification rather than by monitoring drinking-water. The WHO Guidelines for Drinking-water Quality (WHO, 2004) has a section on approval and control of chemicals and materials for use in contact with drinking-water that provides guidance on product specification.

Ion-exchange resins and more advanced treatment processes based on membranes are increasingly used in drinking-water treatment. It is possible that chemicals can leach from the materials used in the manufacture of these systems; therefore, these too should be managed by appropriate product and materials specifications.

The most widely used metal for pipes and fittings in distribution systems is iron, which may give rise to corrosion products. These products can cause discoloration at the tap if the distribution system is not managed correctly. Monitoring for corrosion products is not appropriate; instead, it is necessary to manage the problem of corrosion and the accumulation of corrosion products in distribution. In some circumstances, iron hand pumps can give rise to discoloured water if they are corroded by water that is too acid. In such cases, it may be appropriate to screen the raw water for low pH and, where a low pH is

detected, consider using alternative materials for the pumps. The corrosivity of water is a function of many factors, including pH, low alkalinity, chloride and sulfate ions, sediment and microbial activity; this topic is covered in more detail in the WHO Guidelines for Drinking-water Quality (WHO, 2004).

Lead, copper and sometimes zinc may be present in drinking-water, as a consequence of the use of these metals in pipework in public, commercial and domestic buildings. Monitoring is complicated by the fact that both occurrence and concentration will vary from building to building and at different times of the day. Concentrations will usually be greater the longer the water is standing in the pipe, so first-draw water will usually have higher levels than water from a fully flushed system. Copper and zinc are less likely than lead to occur at levels of concern, except in very new buildings or where highly corrosive water is supplied; however, concentrations may be increased in some circumstances when copper piping is used as a means of earthing the electrical system in a building. Lead frequently occurs at concentrations greater than the guideline value in situations where lead pipes and solders are present. Lead is also a component of brass, bronze and gun-metal, which are used in fittings in plumbing systems. In some circumstances, fittings made of these metals can be a significant contributor to the concentrations of lead at the tap.

Monitoring of metals from plumbing is difficult because of variations in concentration with time and the fact that the levels are frequently property specific. Where lead pipes are present in a large number of buildings, the most important requirements are public health surveillance (to ensure that there is no significant public health problem) and identification of the buildings that have lead piping. Consideration of lead in drinking-water should be part of an overall lead-reduction strategy, because lead exposure from other sources may be more significant. There are a number of possible approaches to reducing lead levels in drinkingwater, ranging from targeted replacement of lead pipes to central control of corrosion to reduce the possibility that lead will dissolve in water.

Lead can also arise if lead solder is used in the installation of copper piping. A control measure in this case would normally be to avoid the use of lead solders for applications involving drinking-water.

Polyvinyl chloride (PVC) plastic pipe is also widely used in distribution systems. Lead has been used as a stabilizer in unplasticised PVC pipe, and may give rise to elevated lead levels in drinking-water for a time after a new installation. Such pipe is normally of large diameter; thus, the dilution effect of the water flowing through the pipe will reduce the concentration of lead and may result in lead concentrations below the guideline value. There have been cases where the levels of vinyl chloride monomer remaining in the plastic have been higher than desirable. However, chemical monitoring of drinking-water is not normally considered to be appropriate and the most suitable method of management is by product specification, as indicated above for other materials.

Store, handle and prepare chemicals.

Hazardous chemicals can destroy health, cause severe injury, harm the environment and damage property. Knowledge on the safe handling of chemicals is key for any teams who

work with, supply, or store hazardous materials.

Protective equipment.

Educate your employees on selecting the correct PPE (personal protective equipment) to use when handling different chemicals. Required PPE may include gloves, footwear, facemasks and goggles.

PPE should only be selected after all hazards of a specific chemical or task have been identified. Safety equipment also needs to be comfortable to prevent incidents from occurring. For example, if touch sensitivity is essential for a task, textured and thin gloves are required to ensure agile movement.

Handling practices.

Each chemical used within water treatment plant should have a specific procedure for safe handling.

Essential aspects of safe handling practices are:

- ✓ Reading & re-reading each chemical SDS to minimize the risk of mishandling.
- ✓ Wearing PPE.
- ✓ Disposing of hazardous chemicals appropriately.
- ✓ Being prepared for emergencies with first aid.
- ✓ Not working with or handling chemicals while alone.
- ✓ Using all precautions to avoid spillage, leakage or dropping chemicals during transportation. Use specialized carriers and carts, such as a transportable gas bottle trolley.

The Globally Harmonized System of Classifying and Labelling Chemicals (GHS).

At the start of 2017 GHS labelling for primary and secondary containers became mandatory in most countries. The GHS provides a universal standard for the labelling of hazardous goods, and includes information on chemical hazards, as well as storage instructions, placards, and Safety Data Sheets (SDS).

Manufacturers and suppliers should always have the correct GHS labelling on hazardous goods, so it's important to ensure everyone understands how to read GHS labels, and is familiar with the requirements for labelling.

Storage of dangerous goods.

Some chemicals can pose serious health hazards if they come into contact with, or are stored

with, one another. For example, oxygen and acetylene cylinders have to be stored in separate gas bottle cages with a non-flammable shield in between them to prevent a reaction.

On top of this, some chemicals need to be stored out of direct sunlight, or below a certain temperature. Storage information can be found on each chemical's Safety Data Sheet.

Transportation of dangerous goods.

Whether you're transporting hazardous materials within a work site, or between worksites, it's essential that your team is familiar with the state or territory regulations.

Each state or territory has different regulations, including no-go transport zones where chemicals can't be transported, and specific transport documentation requirements. Be sure to contact your local transport regulator to understand your state's requirements - and relay this information to your team.

There are also key elements to be aware of when transporting dangerous goods, including the flash points of flammable liquids, the storage temperatures of goods, and the transportation of goods on work sites. Incorporate these into your training so that your team knows what to keep in mind when moving chemicals in and around the workplace.

Educate on risk management policies and practices.

As part of Health and Safety Regulations, businesses have specific duties to manage risks associated with chemicals in the workplace. This means having clear risk management policies and processes in place.

The team should be trained on all procedures and policies, including:

- ✓ Emergency plans if any unexpected accidents or reactions occur.
- ✓ Information on where fire safety and first aid equipment is stored.
- ✓ The correct way to decommission any chemical storage or handling systems.
- ✓ Spill containment systems for hazardous chemicals.
- ✓ How to assess risk surrounding dangerous goods.

SELECT CHEMICALS FOR SPECIFIC WATER INDUSTRY PROCESSES

Identify the range of chemicals available for specific water industry processes.

For the chemical treatment of water, a great variety of chemicals can be applied. Following are the different types of water treatment chemicals.

- ✓ Algaecides
- ✓ Antifoams

- ✓ Biocides
- ✓ Boiler water chemicals
- ✓ Coagulants
- ✓ Corrosion inhibitors
- ✓ Disinfectants
- ✓ Defoamers
- ✓ Flocculants
- ✓ Neutralizing agents
- ✓ Oxidants
- ✓ Oxygen scavengers
- ✓ Ph conditioners
- ✓ Resin cleaners
- ✓ Scale inhibitors

Algaecides

Algaecides are chemicals that kill algae and blue or green algae, when they are added to water. Examples are copper sulphate, iron salts, rosin amine salts and benzalkonium chloride. Algaecides are effective against algae, but are not very usable for algal blooms for environmental reasons.

The problem with most algaecides is that they kill all present algae, but they do not remove the toxins that are released by the algae prior to death.

Antifoams

Foam is a mass of bubbles created when certain types of gas are dispersed into a liquid. Strong films of liquid than surround the bubbles, forming large volumes of non-productive foam.

The cause of foam is a complicated study in physical chemistry, but we already know that its existence presents serious problems in both the operation of industrial processes and the quality of finished products. When it is not held under control, foam can reduce the capacity of equipment and increase the duration and costs of processes.

Antifoam blends contain oils combined with small amounts of silica. They break down foam thanks to two of silicone's properties: incompatibility with aqueous systems and ease of spreading. Antifoam compounds are available either as powder or as an emulsion of the pure product.

Powder

Antifoam powder covers a group of products based on modified polydimethylsiloxane. The products vary in their basic properties, but as a group they introduce excellent antifoaming in a wide range of applications and conditions.

The antifoams are chemically inert and do not react with the medium that is defoamed. They

are odourless, tasteless, non-volatile, non-toxic and they do not corrode materials. The only disadvantage of the powdery product is that it cannot be used in watery solutions.

Emulsions

Antifoam Emulsions are aqueous emulsions of polydimethylsiloxane fluids. They have the same properties as the powder form, the only difference is that they can also be applied in watery solutions.

Biocides

Biocides are usually slug fed to a system to bring about rapid effective population reductions from which the microorganisms cannot easily recover. There are various different biocides, some of which have a wide range of effect on many different kinds of bacteria. They can be divided up into oxidising agents and non-oxidising agents.

Oxidising agents:

- ✓ Chlorine
- ✓ Chlorine dioxide
- ✓ Chloroisocyanurates
- ✓ Hypochlorite
- ✓ Ozone

Non-oxidising agents:

- ✓ Acrolein
- ✓ Amines
- ✓ Chlorinated phenolics
- ✓ Copper salts
- ✓ Organo-sulphur compounds
- ✓ Quaternary ammonium salts

Boiler water chemicals

Boiler water chemicals include all chemicals that are used for the following applications:

- ✓ Oxygen scavenging;
- ✓ Scale inhibition;
- ✓ Corrosion inhibition;
- ✓ Antifoaming;
- ✓ Alkalinity control.

Coagulants

When referring to coagulants, positive ions with high valence are preferred. Generally aluminium and iron are applied, aluminium as $Al_2(SO_4)_3$ - (aluin) and iron as either $FeCl_3$ or $Fe_2(SO_4)_3$ -. One can also apply the relatively cheap form $FeSO_4$, on condition that it will be

oxidized to Fe^{3+} during aeration. Coagulation is very dependent on the doses of coagulants, the pH and colloid concentrations. To adjust pH levels $\text{Ca}(\text{OH})_2$ is applied as co-flocculent. Doses usually vary between 10 and 90 mg Fe^{3+}/L , but when salts are present a higher dose needs to be applied.

Corrosion inhibitors

Corrosion is a general term that indicates the conversion of a metal into a soluble compound.

Corrosion can lead to failure of critical parts of boiler systems, deposition of corrosion products in critical heat exchange areas, and overall efficiency loss.

That is why corrosion inhibitors are often applied. Inhibitors are chemicals that react with a metallic surface, giving the surface a certain level of protection. Inhibitors often work by adsorbing themselves on the metallic surface, protecting the metallic surface by forming a film.

There are five different kinds of corrosion inhibitors. These are:

1. Passivity inhibitors (passivators). These cause a shift of the corrosion potential, forcing the metallic surface into the passive range. Examples of passivity inhibitors are oxidizing anions, such as chromate, nitrite and nitrate and non-oxidizing ions such as phosphate and molybdate. These inhibitors are the most effective and consequently the most widely used.
2. Cathodic inhibitors. Some cathodic inhibitors, such as compounds of arsenic and antimony, work by making the recombination and discharge of hydrogen more difficult. Other cathodic inhibitors, ions such as calcium, zinc or magnesium, may be precipitated as oxides to form a protective layer on the metal.
3. Organic inhibitors. These affect the entire surface of a corroding metal when present in certain concentration. Organic inhibitors protect the metal by forming a hydrophobic film on the metal surface. Organic inhibitors will be adsorbed according to the ionic charge of the inhibitor and the charge on the surface.
4. Precipitation inducing inhibitors. These are compounds that cause the formation of precipitates on the surface of the metal, thereby providing a protective film. The most common inhibitors of this category are silicates and phosphates.
5. Volatile Corrosion Inhibitors (VCI). These are compounds transported in a closed environment to the site of corrosion by volatilization from a source. Examples are morpholine and hydrazine and volatile solids such as salts of cyclohexylamine, cyclohexylamine and hexamethylene-amine. On contact with the metal surface, the vapor of these salts condenses and is hydrolyzed by moist, to liberate protective ions.

Disinfectants

Disinfectants kill present unwanted microorganisms in water. There are various different types of disinfectants:

- ✓ Chlorine (dose 2-10 mg/L)
- ✓ Chlorine dioxide
- ✓ Ozone
- ✓ Hypochlorite

Chlorine dioxide disinfection

Cl₂ is used principally as a primary disinfectant for surface waters with odor and taste problems. It is an effective biocide at concentrations as low as 0.1 ppm and over a wide pH range. Cl₂ penetrates the bacterial cell wall and reacts with vital amino acids in the cytoplasm of the cell to kill the organisms. The by-product of this reaction is chlorite.

Chlorine dioxide disinfects according to the same principle as chlorine, however, as opposed to chlorine, chlorine dioxide has no harmful effects on human health.

Hypochlorite disinfection

Hypochlorite is applied in the same way as chlorine dioxide and chlorine. Hypo chlorination is a disinfection method that is not used widely anymore, since an environmental agency proved that the Hypochlorite for disinfection in water was the cause of bromate consistence in water.

Ozone disinfection

Ozone is a very strong oxidation medium, with a remarkably short life span. It consists of oxygen molecules with an extra O-atom, to form O₃. When ozone comes in contact with odor, bacteria or viruses the extra O-atom breaks them down directly, by means of oxidation. The third O-atom of the ozone molecules is than lost and only oxygen will remain.

Disinfectants can be used in various industries. Ozone is used in the pharmaceutical industry, for drinking water preparation, for treatment of process water, for preparation of ultra-pure water and for surface disinfection. Chlorine dioxide is used primarily for drinking water preparation and disinfection of piping.

Every disinfection technique has its specific advantages and its own application area. In the table below some of the advantages and disadvantages are shown:

Flocculants

To promote the formation of flocs in water that contains suspended solids polymer flocculants (polyelectrolytes) are applied to promote bonds formation between particles. These polymers have a very specific effect, dependent upon their charges, their molar weight and their molecular degree of ramification. The polymers are water-soluble and their

molar weight varies between 10^5 and 10^6 g/mol. There can be several charges on one flocculent. There are cationic polymers, based on nitrogen, anionic polymers, based on carboxylate ions and polyampholytes, which carry both positive and negative charges.

Neutralizing agents (alkalinity control)

In order to neutralize acids and basics we use either sodium hydroxide solution (naoh), calcium carbonate, or lime suspension ($\text{Ca}(\text{OH})_2$) to increase ph levels. We use diluted sulphuric acid (H_2SO_4) or diluted hydrochloric acid (hcl) to decline ph levels. The dose of neutralizing agents depends upon the ph of the water in a reaction basin. Neutralization reactions cause a rise in temperature.

Oxidants

Chemical oxidation processes use (chemical) oxidants to reduce COD/BOD levels, and to remove both organic and oxidizable inorganic components. The processes can completely oxidize organic materials to carbon dioxide and water, although it is often not necessary to operate the processes to this level of treatment. A wide variety of oxidation chemicals are available. Examples are:

- ✓ Hydrogen peroxide;
- ✓ Ozone;
- ✓ Combined ozone & peroxide;
- ✓ Oxygen.

Hydrogen peroxide

Hydrogen peroxide is widely used thanks to its properties; it is a safe, effective, powerful and versatile oxidant. The main applications of H_2O_2 are oxidation to aid odour control and corrosion control, organic oxidation, metal oxidation and toxicity oxidation. The most difficult pollutants to oxidize may require H_2O_2 to be activated with catalysts such as iron, copper, manganese or other transition metal compounds.

Ozone

Ozone cannot only be applied as a disinfectant; it can also aid the removal of contaminants from water by means of oxidation. Ozone then purifies water by breaking up organic contaminants and converting inorganic contaminants to an insoluble form that can then be filtered out. The Ozone system can remove up to twenty-five contaminants. Chemicals that can be oxidized with ozone are:

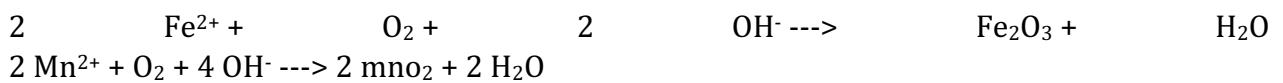
- ✓ Absorbable organic halogens;
- ✓ Nitrite;
- ✓ Iron;
- ✓ Manganese;

- ✓ Cyanide;
- ✓ Pesticides;
- ✓ Nitrogen oxides;
- ✓ Odorous substances;
- ✓ Chlorinated hydrocarbons;
- ✓ PCB's.

Oxygen

Oxygen can also be applied as an oxidant, for instance to realize the oxidation of iron and manganese. The reactions that occur during oxidation by oxygen are usually quite similar.

These are the reactions of the oxidation of iron and manganese with oxygen:



Oxygen scavengers

Oxygen scavenging means preventing oxygen from introducing oxidation reactions. Most of the naturally occurring organics have a slightly negative charge. Due to that they can absorb oxygen molecules, because these carry a slightly positive charge, to prevent oxidation reactions from taking place in water and other liquids.

Oxygen scavengers include both volatile products, such as hydrazine (N₂H₄) or other organic products like carbohydrazide, hydroquinone, diethylhydroxyethanol, methylethylketoxime, but also non-volatile salts, such as sodium sulphite (Na₂SO₃) and other inorganic compounds, or derivatives thereof. The salts often contain catalysing compounds to increase the rate of reaction with dissolved oxygen, for instance cobalt chloride.

pH conditioners

Municipal water is often pH-adjusted, in order to prevent corrosion from pipes and to prevent dissolution of lead into water supplies. During water treatment pH adjustments may also be required. The pH is brought up or down through addition of basics or acids. An example of lowering the pH is the addition of hydrogen chloride, in case of a basic liquid. An example of bringing up the pH is the addition of sodium hydroxide, in case of an acidic liquid.

The pH will be converted to approximately seven to seven and a half, after addition of certain concentrations of acids or basics. The concentration of the substance and the kind of substance that is added, depend upon the necessary decrease or increase of the pH.

Resin cleaners

Ion exchange resins need to be regenerated after application, after that, they can be reused. But every time the ion exchangers are used serious fouling takes place. The contaminants that enter the resins will not be removed through regeneration; therefore, resins need

cleaning with certain chemicals. Chemicals that are used are for instance sodium chloride potassium chloride, citric acid and chlorine dioxide.

Chlorine dioxide cleansing serves the removal of organic contaminants on ion exchange resins. Prior to every cleaning treatment resin should be regenerated. After that, in case chlorine dioxide is used, 500 ppm of chlorine dioxide in solution is passed through the resin bed and oxidizes the contaminants.

Scale inhibitors

Scale is the precipitate that forms on surfaces in contact with water as a result of the precipitation of normally soluble solids that become insoluble as temperature increases. Some examples of scale are calcium carbonate, calcium sulphate, and calcium silicate. Scale inhibitors are surface-active negatively charged polymers. As minerals exceed their solubility's and begin to merge, the polymers become attached. The structure for crystallization is disrupted and the formation of scale is prevented. The particles of scale combined with the inhibitor will then be dispersed and remain in suspension. Examples of scale inhibitors are phosphate esters, phosphoric acid and solutions of low molecular weight polyacrylic acid.

Evaluate the factors affecting the selection of chemicals for particular water industry applications.

Following are the factors affecting the selection of chemicals for particular water industry applications.

- ✓ Environmentally friendly
- ✓ Byproducts
- ✓ Effectivity
- ✓ Investment
- ✓ Operational costs
- ✓ Fluids
- ✓ Surfaces

Select suitable chemicals and calculate correct usage for a range of specific water industry processes.

Technology	Environmentally friendly	Byproducts	Effectivity	Investment	Operational costs	Fluids	Surfaces
Ozone	+	+	++	-	+	++	++
UV	++	++	+	+/-	++	+	++
Chlorine dioxide	+/-	+/-	++	++	+	++	--

Chlorine gas	--	--	-	+	++	+/-	--
Hypochlorite	--	--	-	+	++	+/-	--

UNIT 06

COMPLY WITH WATER INDUSTRY STANDARDS, GUIDELINES AND LEGISLATIONS

This unit describes the skills required to ensure compliance with the risk management principles established in the Environment Protection Agency (EPA) guidelines which contribute to the improved management of water supply systems and the reduction of water quality risks for water supplies

INTERPRET KEY LEGISLATION AND GUIDELINES OF THE WATER INDUSTRY

Access and interpret the relevant guidelines and legislative requirements.

Effective programmes to control drinking-water quality depend ideally on the existence of adequate legislation, standards, and codes. One of the functions of the basic legislation is to define the functions, authority, and responsibilities of the water-supply agency and the surveillance agency. Standards and codes should specify the quality of the water to be supplied to the consumer, the practices to be followed in selecting and developing water sources and in treatment processes and distribution systems, and procedures for approving water systems in terms of water quality.

The precise nature of the legislation in each country will depend on national, constitutional, and other considerations. Experience has shown that the basic legislation should be limited to general principles and to specifying offences and penalties for its contravention. The authority to establish and revise drinking-water standards, codes of practice, and other technical regulations should be delegated to the appropriate government minister—preferably the minister of health—who is responsible for ensuring the quality of water supplies and the protection of public health. The authority to establish and enforce quality standards and regulations may be vested in a ministry other than that usually responsible for public and/or environmental health. Consideration should then be given to requiring that water-quality standards are promulgated only after approval by the public health or environmental health authority so as to ensure their conformity with health-protection principles.

Such legislation commonly makes provision for the establishment and amendment of drinking-water quality standards and guidelines, as well as regulations for the development of drinking-water sources, and the production, maintenance, and distribution of safe drinking-water. It also generally establishes the legal functions and responsibilities of the water-supply agency, and states clearly that, as an organization that sells and/or supplies water to the consumer, this agency has a legal duty to supply safe and wholesome water that meets legally established water-quality standards. In addition, the agency is responsible for providing continuous and effective quality assurance and quality control of water supplies, including inspection, supervision, preventive maintenance, routine testing of water quality, and remedial actions as required.

The water-supply agency should be deemed responsible for the safety and quality of the water supply up to a defined point in the distribution system, generally the house connection or public standpost.

A country-wide or regional water-supply company or governmental organization often supplies drinking-water to a municipal water-supply agency or a local water-distribution company or group. As the “wholesaler”, the primary supplier should be legally responsible for the water quality up to the point of connection to the pipelines of the local supplier; the

organization that supplies the public directly then becomes the “retailer”. In other words, each organization should

Carry legal responsibility for the quality of the water supply up to the point of delivery to the “customer”.

Governments should also consider introducing legislation that would enable individuals or community organizations to take legal action to enforce water quality standards and regulations. They should consider making legal provisions for water-supply agencies to initiate legal action to protect their water sources and distribution systems from sources of pollution. This is particularly important in areas where no effective government programme is in operation to control pollution.

The surveillance agency should be given the necessary powers to administer and enforce laws, regulations, standards, and codes concerned with water quality. It should also be able to delegate those powers to other specified agencies such as municipal councils, local health departments, regional authorities, nongovernmental (community) organizations, universities, and qualified, government-authorized private testing services.

Many countries lack basic legislation of this sort, and in others the existing legislation is seriously outdated. However, many interim measures to ensure drinking-water quality can be enforced under existing general health, food, and welfare legislation. Implementation of programmes to provide safe drinking water should not be delayed because of a lack of appropriate legislation.

Even where legally binding guidelines or standards for drinking-water have yet to be promulgated it may be possible to encourage, and even enforce, the supply of safe drinking-water through educational efforts or commercial, contractual arrangements between customer and supplier based on civil law.

1.2 Analyse the key features or elements.

Surveillance is an investigative activity undertaken to identify and evaluate factors associated with drinking-water which could pose a risk to health. Surveillance contributes to the protection of public health by promoting improvement of the quality, quantity, coverage, cost, and continuity of water supplies. It is also both preventive—detecting risks so that action may be taken before public health problems occur—and remedial—identifying the sources of outbreaks of waterborne disease so that corrective action may be taken promptly.

Surveillance requires a systematic programme of surveys that combine analysis, sanitary inspection, and institutional and community aspects. Sanitary inspection should cover the whole of the water-supply system including sources, conduction lines, treatment plants, storage reservoirs, and distribution systems.

Surveillance is indispensable for the development of rational strategies for the improvement of the quality of water-supply services.

Quality control is designed to ensure that water services meet agreed national standards and institutional targets.

Water suppliers are responsible at all times for the quality and safety of the water that they produce, and they achieve this by a combination of good operating practice and preventive maintenance, supported by quality control. Water quality control is the responsibility of the water supplier and involves the establishment of safeguards in the production and distribution of drinking-water as well as the routine testing of water quality to ensure compliance with national Standards.

Quality control is distinguished from surveillance on the basis of institutional responsibilities and the frequency of the monitoring activities conducted. The surveillance agency is responsible for an independent (external) and periodic audit of all aspects of safety, whereas the water supplier is responsible at all times for regular quality control, and for monitoring and ensuring good operating practice.

1.3 Establish the relationships between the guidelines and the state and territory requirements.

The main role of surveillance in the management of community water supplies is to assess the safety and acceptability of the water distributed to the public so that consumers are consistently and reliably protected from the health hazards of contaminated supplies. Surveillance therefore adds considerably to the value of water, especially for domestic use. It facilitates the recovery of its cost and increases its health benefits.

Water-quality surveillance requires an institutional framework that reflects its objectives and functions and gives key responsibilities to the relevant bodies—not just the agencies in charge of supplying water and promoting health but all institutions with relevant normative, developmental, educational, and control functions.

At the center of this framework major responsibility for surveillance is shared between two agencies whose activities should be both mutually exclusive and complementary. The water-supply agency is responsible for the quality and safety of the water that it produces and distributes, while the surveillance agency has overall responsibility for ensuring that all drinking-water supplies under its jurisdiction are free from health hazards. Indirectly, however, health hazards related to the ingestion or other utilization of contaminated water from unprotected sources may be the fault of the water-supply agency if it has failed to fulfil its mandate, thus causing the public to use unsafe supplies.

The water-supply agency also differs from the surveillance agency in the sense that it carries out routine testing and monitoring of the quality of the water that it produces, while the public health protection agency conducts independent surveillance audits of water quality to determine whether the water-supply agency is fulfilling its responsibility.

The key basic principle in the implementation of a reliable program of surveillance of drinking-water quality is that this two-tier system is absolutely necessary. It is imperative that the public health protection agency is adequately equipped to fulfil its regulation functions. If it is not, surveillance tasks can be subcontracted by the surveillance agency to a third party, such as a private company, at a cost that can be recovered, e.g. In the selling price of water. Monitoring by the water-supply agency of the quality of its own product, or that of an affiliated company, should never be considered as a satisfactory substitute for independent surveillance.

Another important principle is that the institutional and legal arrangements for water-quality surveillance should lend themselves to both decentralization and intersectoral cooperation. Like all water-related activities, water-quality promotion and control are fragmented horizontally between a large number of producers, users, and planning, financing, and monitoring agencies, as well as vertically between national and regional agencies with limited potential for decentralization, Numerous local authorities with scarce resources, and a very large number of consumption points, especially in developing countries.

Intersectoral cooperation is required in all activities related to the promotion and surveillance of water quality, from the normative functions to the actual supply of water, the surveillance of water quality, and the implementation of preventive and remedial measures. At the normative stage, those agencies responsible for the protection of public health and for the supply of water should, in consultation with one another, agree on safe and feasible water-quality standards. To ensure that these standards are also acceptable to consumers, the communities served should always be involved, together with the major water users, including industrial or agricultural concerns that may compete for the same water source or public supply.

Other normative and regulatory functions belong to such ministries as those responsible for public works, housing, natural resources, or the environment, which are concerned with the design of water-supply and waste-disposal systems, equipment standards, plumbing codes and rules, water allocation, protection and conservation, and waste collection, treatment, and disposal. The economic planning unit (for resources allocation), the ministries and agencies in charge of

Internal affairs and local government (for community issues), and the ministry of finance (in relation to water tariffs) should be consulted on issues within their respective areas of competence. Private autonomous water suppliers should also be involved in drawing up standards if this is justified by their individual or collective size and importance; the national regulations, adjusted as necessary, should always be applicable to such water suppliers. Successful intersectoral coordination requires the involvement of agencies responsible for community development and hygiene education in all activities and at all levels; these agencies are usually more easily decentralized than the water authorities. Public health agencies are often closer to the community than those responsible for its water supply. At local level, they also interact with other sectors, e.g. Education, and their combined action is essential to ensure active community involvement.

Public health surveillance teams operate at national, provincial, and district levels, as well as in cities or at rural health centres. However, public health laboratories may be available only in large cities, in which case the use of field kits for water-quality testing (see pp. 65–66) by mobile surveillance teams may help to bridge the gap between fixed laboratories and remote communities.

Where they are able to operate in remote areas with widely scattered populations, surveillance teams can also provide essential epidemiological information that can be used in planning, and information on major faults that is valuable in the organization of maintenance. Where water-quality surveillance teams cannot operate, nongovernmental organizations can help, and community volunteers can also be trained. In some countries, religious missions, aid agencies, and scientific institutes play important roles in water-quality surveillance.

MIX TRIAL BATCH FOR EVALUATION

Interpret organization standards and processes for reporting compliance

It is the responsibility of the surveillance agency to generate and summarize surveillance data and to promote improvements, it is the water-supply sector that will carry out many of the actions designed to improve supplies. In addition, supply and construction agencies are responsible for quality control of the service they provide. However, there may not always be a clear division of responsibilities between the health and water-supply sectors. In some cases, the range of professional, governmental, nongovernmental, and private institutions may be wider and more complex than that discussed above. Whatever the existing framework, it is important that clear strategies and structures are developed for implementing surveillance and quality control, collating and summarizing data, reporting and disseminating the findings, and taking remedial action. Similarly, clear lines of accountability and communication are essential.

The organizational arrangements for carrying out surveillance and quality control activities may be modified as programmes move from the pilot stage to regional and then national implementation. It is important that basic local, regional, and national frameworks should be in place from the outset in order to avoid subsequent confusion, but they may well be refined and improved in the light of experience during the implementation of activities. It is preferable to develop and build on existing frameworks than to impose radical changes immediately before or during a programme.

Integrate legislative requirements into organisation water quality management plan.

- ✓ Establishing national priorities

When the commonest problems and shortcomings in water-supply systems have been identified, national strategies can be formulated for improvements and remedial measures; these might include changes in training (of managers, administrators, engineers, or field staff), rolling programmes for rehabilitation or improvement, or changes in funding

strategies to target specific needs.

- ✓ Establishing regional priorities

Regional offices of water-supply agencies can decide which communities to work in and which remedial activities are priorities; public health criteria should be considered when priorities are set.

- ✓ Establishing hygiene education

Not all of the problems revealed by surveillance are technical in nature, and not all are solved by supply and construction agencies; surveillance also looks at problems involving private supplies, water collection and transport, and household treatment and storage. The solutions to many of these problems are likely to require educational and promotional activities coordinated by the health agency.

- ✓ Enforcement of standards

Many countries have laws and standards related to public water supply. The information generated by surveillance can be used to assess compliance with standards by supply agencies. Corrective action can be taken where necessary, but its feasibility must be considered, and enforcement of standards should be linked to strategies for progressive improvement.

- ✓ Ensuring community operation and maintenance

Support should be provided by a designated authority to enable community members to be trained so that they are able to assume responsibility for the operation and maintenance of their water supplies. Water-quality control programmes, but it is then likely that greater emphasis will be placed on the setting of investment priorities at regional and national levels than on hygiene education and enforcement. Each of the mechanisms is discussed in greater detail in subsequent chapters.

Information alone does not lead to improvement. It is the effective management and use of the information generated by surveillance that makes possible the rational improvement of water supplies—where “rational” implies that available resources are used for maximum public health benefit.

Provide advice on the links between the regulatory framework and work practices.

Initial phase

- ✓ Establish requirements for institutional development
- ✓ Provide training for staff involved in Programme
- ✓ Start inventories of supply systems
- ✓ Undertake sample surveys to identify priority areas
- ✓ Develop methodologies suitable for the area
- ✓ Commence routine surveillance in priority areas
- ✓ Limit water-quality analysis to critical parameters and known problem substances
- ✓ Establish reporting, filing, and communications systems (paper-based, rather than computerized)
- ✓ Make improvements according to identified priorities

- ✓ Establish reporting to local suppliers, communities, and regional authorities
- ✓ Establish liaison with communities; identify community roles in surveillance and means of promoting community participation

Intermediate phase

- ✓ Train staff involved in programme
- ✓ Complete inventories of supply systems
- ✓ Establish and expand systematic routine surveillance
- ✓ Expand analytical capability (often by means of regional laboratories, national laboratories being largely responsible for analytical quality control and training of regional laboratory staff)
- ✓ Undertake surveys for chemical contaminants using wider range of analytical methods
- ✓ Evaluate all methodologies (sampling, analysis, etc.)
- ✓ Use draft standard methods (e.g. Analytical methods, fieldwork procedures)
- ✓ Establish (and possibly computerize) database archive
- ✓ Identify common problems, improve activities to address them at regional and national levels
- ✓ Expand reporting to include interpretation at national level
- ✓ Draft or revise national standards and legislation
- ✓ Use legal enforcement where possible
- ✓ Involve communities routinely in surveillance implementation

Advanced phase

- ✓ Train staff involved in programme
- ✓ Establish routine surveillance for all health and acceptability parameters at defined frequencies
- ✓ Use full network of central, regional, and local laboratories (including analytical quality control)
- ✓ Use national standards and legislation
- ✓ Improve water services on the basis of national and local priorities, hygiene education, and enforcement of standards
- ✓ Disseminate data at all levels (local, regional, and national)
- ✓ Involve communities routinely in surveillance implementation

Convey importance of multiple barrier principles and their general function to team.

The Multi-barrier approach is a key paradigm for ensuring safe drinking water.

An integrated system of procedures, processes and tools that collectively prevent or reduce the contamination of drinking water from source to tap in order to reduce risks to public health.

- ✓ **Source water protection**—Taking action to minimize adverse impacts on source waters reduces the risk from pathogens and chemical pollutants in that water, and can also reduce the degree of treatment required.

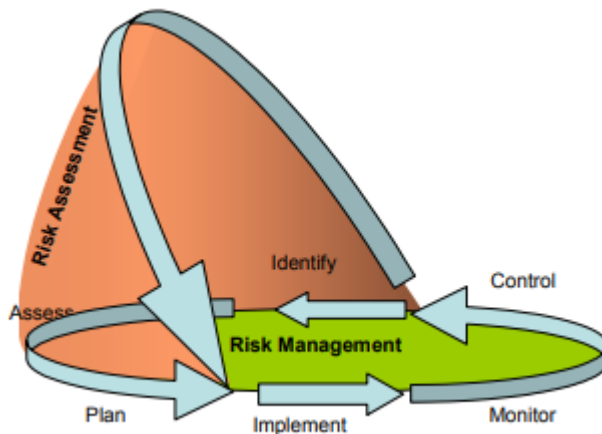
- ✓ **Robust water treatment**—Having treatment trains with more than one step provides redundancy against treatment failure.
- ✓ **A secure water supply network**—Providing a disinfectant residual to the extreme points of the distribution system protects against water quality degradation and microbial intrusion.
- ✓ **Monitoring programs**—Monitoring water quality at each of the above points (source, treatment plant, and tap) allows the treatment process to be adjusted to deal with fluctuations in water quality and ensures that the drinking water is safe at the point of human consumption.
- ✓ **Prepared responses to adverse conditions**—Having response plans (for example, issuing a boil-water advisory) in place provides a final barrier to protect the public if harmful contaminants should make it through the other barriers.

The holistic perspective of the multi-barrier approach also incorporates many players into the goal of keeping drinking water safe. These include managers, researchers, regulators, legislators, and the public.

Manage risks utilising the organisation’s risk management principles.

Risk Management and Risk Assessment are major components of Information Security Management (ISM). Although they are widely known, a wide range of deviating definitions of Risk Management and Risk Assessment are found in the relevant literature [ISO13335-2], [NIST], [ENISA Regulation]. In this chapter a consolidated view of Risk Management and Risk Assessment is presented. For the sake of this discussion, two approaches to presenting Risk Management and Risk Assessment, mainly based on OCTAVE [OCTAVE] and ISO 13335-2 [ISO13335-2] will be considered. Nevertheless, when necessary, structural elements that emanate from other perceptions of Risk Management and Risk Assessment are also used (e.g. Consideration of Risk Management and Risk Assessment as counterparts of Information Security Management System, as parts of wider operational processes, etc. [WG-Deliverable 3], [Ricciuto]).

It seems to be generally accepted by Information Security experts, that Risk Assessment is part of the Risk Management process. After initialization, Risk Management is a recurrent activity that deals with the analysis, planning, implementation, control and monitoring of implemented measurements and the enforced security policy. On the contrary, Risk Assessment is executed at discrete time points (e.g. Once a year, on demand, etc.) And – until the performance of the next assessment - provides a temporary view of assessed risks and while parameterizing the entire Risk Management process. This view of the relationship of Risk Management to Risk Assessment is depicted in Figure



The relationship between Risk Management and Risk Assessment

Collate relevant collected data to support compliance and review for completeness

If an organization is considering whether to collect data on its own or get help from an external consultant, it will need to have enough information to make an informed decision about how to proceed.

This section outlines some of the key considerations that may arise during various steps in the data collection process. There is no requirement that these steps be followed or pursued in the order that they are written. The model presented is offered as a reference tool. How data is gathered and analyzed depends on many factors, including the context, the issue that needs to be monitored, the purpose of the data collection, and the nature and size of the organization.

The main consideration is to make sure that any information collected is done in a way and for a purpose that is consistent with the *Code* and complies with freedom of information and privacy protection legislation. In the interest of effectiveness and efficiency, it is recommended that efforts be made to collect data that will shed light on issues or opportunities. To protect the credibility and reliability of data, information should be gathered using accepted data collection techniques.

Step 1: Identify issues and/or opportunities for collecting data

The first step is to identify issues and/or opportunities for collecting data and to decide what next steps to take. To do this, it may be helpful to conduct an internal and external assessment to understand what is happening inside and outside of your organization.

Some organizations, like FCP and Legislated Employment Equity Plan (LEEP)^[21] employers, are given specific direction on what issues should be explored and how data must be collected. Other organizations may have more flexibility to decide when and how to collect information to achieve certain goals. Some of the non-exhaustive questions identified below may apply to a diverse range of organizations and audiences, including employees and service users. Depending on the organization, these questions may be considered at Step 1, or at different stages in a data collection process.

Conduct a review of all policies, practices and procedures applicable to employees, service users or another appropriate audience:

- ✓ Does the organization have human resources and human rights policies, practices and procedures that are accessible to all employees or to the people they serve?
- ✓ Does the organization have clear, transparent and fair complaint procedures in place to deal with allegations of discrimination, harassment or systemic barriers?
- ✓ Have any claims, grievances or allegations been made or received relating to discrimination, harassment or systemic barriers?
- ✓ Do any signal barriers to persons protected under the *Code* and/or other individuals/groups in society based on a non-*Code* ground?
- ✓ Have any been dealt with appropriately and in accordance with existing policies, practices and procedures?

Explore organizational culture from a human rights, diversity and equity-inclusion lens:

- ✓ What are the organization's mandate, goals and core values?
- ✓ What is the history of the organization?
- ✓ Are equity, diversity and inclusiveness supported, reflected and promoted by senior leaders throughout the organization?
- ✓ Are performance measures in place to motivate the achievement of an organization's strategic human resources, human rights, equity and diversity goals?
- ✓ Do employees feel that the organization is diverse, inclusive, and provides equal opportunity for learning and advancement?
- ✓ How are decisions made?
- ✓ How are employment, programming or service delivery opportunities advertised?
- ✓ Does the organization have formal, transparent and fair processes in place to recruit, hire, promote, terminate and retire staff?
- ✓ Does the organization have a clear system of discipline?
- ✓ Is this system perceived to be applied fairly and consistently?
- ✓ Do service users feel that they are welcome, valued, and able to use the services offered by the organization?

Assess external context:

- ✓ Are there best practices in the industry/sector or among similar organizations that can be learned from?
- ✓ Are there objective data or research studies showing that discrimination or systemic barriers exist or do not exist in the organization, industry/sector or similar organizations?
- ✓ Is there evidence from other organizations or jurisdictions that a policy, program or practice, similar to one in place at the organization, has had a positive or negative impact on Code-protected persons or other marginalized persons in society?
- ✓ How is the organization perceived by the community it operates in?

- ✓ Have the media or advocacy groups complimented or criticized the organization about human rights, human resource or equity issues?
- ✓ What are the demographics of the people the organization serves or the community it operates in?
- ✓ Are the demographics changing or projected to change in the future?
- ✓ Is the organization proactively looking at ways to make sure that it has the skills and knowledge to meet the potential needs and concerns of this changing demographic?

Check representation:

- ✓ Compare the organization's workforce makeup to the availability of labour or the demographics of the service users in the community, city, region, province and/or country it operates in.
- ✓ Is the organization representative of and responsive to the needs of the community it serves?
- ✓ At this stage, a detailed comparison is not needed. The goal here is to identify key issues and/or opportunities that may need further study by noting obvious gaps, disparities or trends.
- ✓ Organizations can:
- ✓ Estimate how people or groups identified by *Code* grounds and other persons/groups are represented and distributed among their employees or service users by levels of responsibility, occupation, branch, department or other appropriate measure.
- ✓ Are there any areas in the organization or in service delivery where the persons or groups seem to be obviously over-represented or under-represented?
- ✓ Finding the above information can be challenging for smaller organizations, but the internet offers a wealth of resources to choose from. Media reports may offer insights, as well as on-line resources offered by the OHRC, Statistics Canada,^[22] the City of Toronto,^[23] government agencies, and community organizations that focus on *Code* and non-*Code* ground-related topics. Information may also be gathered from various sources using accepted data collection research methodologies discussed in Step 3.
- ✓ It is to be expected that an internal and external assessment of the organization, in light of the questions listed above, may result in a number of potential issues and/or opportunities for exploring data collection. Before proceeding to Step 2, organizations may wish to consider whether there are any preliminary actions that can be taken to address these issues and/or opportunities, without collecting data (*e.g.* Training, policy development).
- ✓ **Example:** The review in Step 1 may have identified the following issues and/or opportunities for collecting data:
- ✓ Positive public feedback received about a pilot community policing project in high-crime neighborhoods
- ✓ Unclear and inconsistent human rights policies and procedures in place to address sexual harassment.
- ✓ The above examples present a potential opportunity or problematic human rights issue, respectively, and could lend themselves to data collection. Decisions need to be made about how best to address the identified opportunities and/or issues and whether it would be appropriate to act, based on the assessments in Step 1 (either instead of or together with further data collection).

If the results of the internal and external assessment seem to show that the organization does not have any pressing problems with discrimination and/or systemic barriers, and is generally in compliance with the *Code* and OHRC policies, consider whether the organization could still benefit from proactively implementing a data collection initiative (for example, to help monitor the ongoing effectiveness and suitability of policies, programs and intervention strategies).

Step 2: Select issue(s) and/or opportunity(ies) and set goals

The focus of Step 2 is choosing a priority issue(s) and/or opportunity (ies) for collecting data, and then setting goals and objectives.

The organization reviews the issues and/or opportunities identified from the internal and external assessment done in Step 1, and picks one or more specific issues and/or opportunities for starting a data collection project from among the list of priorities. Some of the questions an organization can consider when deciding to prioritize an issue and/or opportunity for gathering data include:

- ✓ Is there a fundamental reason or opportunity to collect data from which other issues and/or opportunities seem to arise?
- ✓ **Example:** An aging taxpayer base provides a government body with a pressing reason to collect data on this group's projected size, needs and revenue base. This changing demographic also presents an opportunity for the government body to ensure that it is proactively developing policies, programs and services that are accessible and appropriate to meet the needs and concerns of these taxpayers.
- ✓ Did the internal and external assessment of the organization in Step 1 reveal any critical gaps or trends that are apparent in the organization, industry/sector or similar organizations?
- ✓ Is there one particular area that has drawn positive/negative media attention or been subject to multiple complaints, internal rumours and concerns?
- ✓ Does there seem to be a greater diversity or lack of diversity in one area compared to others?

Goal-setting

While the organization may intend to collect data relating to multiple issues and/or opportunities at the same time, the next steps, including goal-setting, should be individualized for each issue and/or opportunity.

The specific goal(s) defined for each issue and/or opportunity may depend on a hypothesis or guess about what is happening that can be tested using data collection techniques and analysis.

Example: A downtown Toronto hotel receives complaints from guests, who self-identify as being gay, about the unwelcome treatment they received from staff. A hypothesis might be that hotel staff lack sufficient awareness and training about how to deal respectfully with guests who are gay, or are perceived to be from the larger LGBT community. The goal is to get enough evidence to test this hypothesis.

Step 2 can also involve an organization brainstorming a smaller set of questions that may be answered by collecting data. Rather than asking a general question like, "Is there any

evidence of discrimination on the basis of sexual orientation or gender identity in this hotel?” One might ask, “What percentage of hotel guests self-identify as being part of the LGBT community?” And “What are the perceptions of the service received by self-identified LGBT patrons?” Ultimately, data that is collected should be rationally connected to the goals set and the overall purpose for collecting the data.

Step 3: Plan an approach and methods

In Step 3, organizations will make decisions about who will be surveyed, how data will be collected, the sources of data that will be used, and the duration of the data collection project, among other questions. These decisions may be made in consultation with an expert. The methods and approaches will flow from the goals set in Step 2, and will vary significantly depending on a number of factors, including the organization’s context, size, resources, and the purpose and complexity of the issue(s) or opportunity(ies) selected.

Some of the questions to consider at this stage include:

Who will the data be collected about?

The “group of interest” (e.g. Youth service users of a local community centre who cannot read and speak English as a second language) will be the focus of the study, and the data collection methods used will refer to this group, or the persons within it, depending on the goals of the project.

Understanding discrimination

- ✓ When thinking about who the data will be collected about, it is important to consider who you think will be most affected by, for example, the discrimination or inequities that you wish to measure. Is it a broad category (e.g. All service users who *cannot* read), or a sub-set of that category (e.g. *Youth* service users who *cannot* read)? The italicized words refer to a unique characteristic about a broader group that an organization may wish to gather information about.
- ✓ Depending on factors like the goals of the data collection project, the organization’s size, resources and time, data may be gathered about many sub-sets within a broader group of interest (e.g. *Youth* service users who *cannot read* and who *speak English as a second language*).
- ✓ Collecting data about a group of interest that shares characteristics, based on several *Code* or *non-Code* grounds, can help an organization understand the behaviour, perceptions, values and demographic makeup of services users and other subjects of interest. Generally speaking, gathering data that reflects more than one *Code* and/or *non-Code* ground can allow for richer, nuanced information and more complex analysis.
- ✓ It is important to recognize that based on their unique combination of identities, people may be exposed to particular forms of discrimination. Multiple forms of discrimination can intersect and compound to form a unique experience of discrimination. This perspective is referred to as an “intersectional” analysis of discrimination.

- ✓ **Example:** A South Asian male youth service user, who cannot read and speaks limited English, may face discrimination on any of the grounds of age, race, colour, ancestry, ethnic origin, place of origin, gender, disability or perceived disability (*e.g.* Could be seen as having a learning disability). However, he may also be exposed to discrimination on intersecting grounds based on being identified as a “young, illiterate Indian male from a foreign country,” based on the various assumptions or stereotypes that are uniquely associated with this socially significant interaction of multiple identity factors.

To better understand the potential impact of multiple identity factors, or intersectionality, when collecting and analyzing data about a group of interest, it may be helpful to consult with communities, and review applicable research and other relevant documents that highlight how the dynamic of discrimination and disadvantage can play out in a practical way for persons identified by Code and non-Code grounds. The OHRC’s recent edition of *Human Rights at Work* is a useful reference for this purpose. The OHRC has also developed policies and guidelines that provide a more detailed outline of how the Code applies to the various grounds (see Appendix G for a list of OHRC guides, policies and guidelines).

Who will the group of interest be compared to?

The “comparator group”^[24] should be persons who share one or more characteristics with the persons in the group of interest, but differ in the key characteristic(s) being studied (*e.g.* Youth service users who cannot read but *can* speak English fluently). The experiences of youth service users who cannot read and who speak English as a second language can then be compared to youth service users who cannot read but can speak English fluently.

What locations or geographical areas will the data be gathered from?

Some data collection initiatives require gathering data from multiple sizes, groups or communities located in different locations and geographical areas. When determining where to collect information from, key factors to consider include who the data will be collected about and who the data will be compared to.

Example: A local community centre is interested in making its current youth literacy program more responsive to the needs of an increased number of youth in the surrounding area who cannot read and who speak English as a second language. The community centre plans to gather information about the community it serves and the geographical region it is located in. Data is gathered from the community centre’s pre-existing records relating to its service users, including people who attend the youth literacy program or have expressed an interest in it. Publicly available information about the characteristics of the surrounding neighbourhood is also explored, among other data sources.

What categories will be used to identify the group of interest and comparator group?

Choosing categories provides a way to organize the information that is collected. This can be done either before collecting data, as discussed in this step, or after data is collected (see Step 5).

In some cases, although it is not required, it is preferable to use pre-determined categories

such as those developed by Statistics Canada. There are certain benefits to this approach.

Example: Organizations can be confident that the 12 racial groups used by Statistics Canada will represent how the majority of Canadians racially classify themselves. In addition, use of these categories is most likely to produce reliable and valid results and enable researchers to directly compare the results of their studies to Census data collected by Statistics Canada.[\[25\]](#)

The limitations are that if these categories are used, some respondents may not identify with them or may object to them. Another limitation is that Statistics Canada does not produce Census data on all grounds (for example, on sexual orientation).[\[26\]](#)

For a fee, Statistics Canada will customize its data. For example, it can break it down to “disaggregated” data for a local labour market or for a particular occupational category.[\[27\]](#)

Another limitation is that the Statistics Canada categories may be too broad depending on the goals selected in Step 2.

Example: Using a broad category such as “racialized” can mask important differences between racialized groups, since racialized groups are not subject to exactly the same experiences, racial stereotypes and types of discrimination.[\[28\]](#) However, when it is necessary to describe people collectively, the term “racialized person” or “racialized group” is preferred over terms like “racial minority,” “visible minority,” “person of colour” or “non-White” as it expresses race as a social construct rather than as a description based on perceived biological traits. Also, these other terms treat “White” as the norm that racialized persons are to be compared to, and have a tendency to group all racialized persons in one category, as if they are all the same.[\[29\]](#)

Consider other categories to describe the groups selected (for example, relating to job or service categories). Organizations may ultimately choose the categories that best reflect where the organization is at in terms of achieving its human rights, equity and diversity goals.

How should data be collected?

In the context of human rights, social-science researchers[\[30\]](#) are commonly asked to lead or help with data collection projects. Two types of data are used in social science research: qualitative and quantitative. A good research effort involves the use of both types. Both approaches, while distinct, can overlap and rely on the other to produce meaningful data, analysis and results.

Qualitative data:

- ✓ Typically, data is called “qualitative” if it is in the form of words, but may also include any information that is not numerical in form, such as photographs, videos and sound recordings.

- ✓ Qualitative methods are aimed at describing a specific context, event, people or relationship in a broad contextual way, by trying to understand the underlying reasons for behaviour, thoughts and feelings.
- ✓ Common qualitative research methods include observation, one-on-one interviews, focus groups and intensive case studies.
- ✓ **Example:** A restaurant chain wants to improve service and access to customers with disabilities. Management decides to collect qualitative information using focus groups consisting of a range of stakeholders, including customers and representatives of organizations from the disability community.
- ✓ **Potential strengths:**
- ✓ Qualitative data excels at "telling the story" from the participant's viewpoint (it helps participants feel like they have been heard)
- ✓ Can help others better understand the issue or problem by providing the rich descriptive detail that explains the human context of numerical results

Potential weaknesses:

- ✓ Perceived that the accuracy of qualitative data can be influenced by false, subjective or manipulated testimonies. Good qualitative data, checked by a professional researcher and gathered using accepted data collection research methods, can address the impact of such factors
- ✓ Depending on the nature and size of the project, as well as the sophistication of the methods and analysis used, can take a significant amount of time, be very labour-intensive, and yield results that may not be general enough for policy-making and decision-making purposes.

Quantitative data:

- ✓ Typically, data is called "quantitative" if it is in the form of numbers.
- ✓ A quantitative approach can be used to count events or the number of people who represent a particular background.
- ✓ Common quantitative tools include surveys, questionnaires and statistical data (such as Statistics Canada census information).
- ✓ It is important to note that all quantitative data is based on qualitative judgment. In other words, numbers cannot be interpreted by themselves, without understanding the assumptions that underlie them.
- ✓ **Example:** A simple 1- 5 rating variable for the survey statement, "My union handles human rights grievances in a sensitive and efficient manner" gives respondents the option of circling: 1 (Strongly Disagree), 2 (Disagree), 3 (Neutral) 4 (Agree) and 5 (Strongly Agree).

A respondent circles "2 = Disagree." To understand the value of "2" here, a researcher must consider some of the judgments and assumptions that are behind this choice. Did the respondent understand the term "human rights grievance"? Has the respondent had experience filing a grievance with the union? Does the respondent like unions generally?

Potential strengths:

- ✓ Perceived to be more credible and reliable than qualitative data because of the use of numbers, which are seen as an objective source of data. This is not necessarily the case. The accuracy of quantitative data can be influenced by manipulation and bias of the researcher, among other factors, unless checked by the researcher's professionalism and the use of accepted data collection research methods
- ✓ Quantitative data excels at summarizing, organizing and comparing large amounts of information, and drawing general conclusions about a research topic of interest
- ✓ Can help measure progress and success
- ✓ Good at identifying trends and determining the magnitude of a research topic of interest.

Potential weaknesses:

A focus on numbers and rankings alone can overly simplify or lead to an inaccurate understanding of complex situations and realities, unless a broader context is provided

Example: An employment data survey of the Custodial Services Division of a large organization reveals that 80% of the cleaning staff are women and that 6 of 7 Custodial Services supervisors are men. A comparison between these figures and gap data from Human Resources and Skills Development Canada (HRSDC) shows that, while there is an overrepresentation of women in the ranks of cleaners, there is no gap for women in the ranks of supervisors.

The reason for the seeming discrepancy is that HRSDC gap data is based on availability. Nationally, so few women are Custodial Services supervisors that there is a statistically insignificant availability, giving rise to the conclusion that there is no numerical gap with respect to women supervisors. This conclusion, however, does not make sense since the organization knows that the 200:40 women to men cleaning staff ratio is supervised by a 6:1 male to female supervisory staff ratio. The organization decides to ignore the HRSDC data and apply common sense by setting up career advancement mentoring and other policies and programs to increase the number of female supervisors in its workforce.

- ✓ Subject to multiple interpretations of what the numbers actually mean, which can lead to a distorted understanding of a research topic of interest. This potential weakness can be minimized by using accepted quantitative research methods and identifying appropriate warnings to explain the parameters and assumptions underlying the research
- ✓ Depending on the nature and size of the project, as well as the sophistication of the methods and analysis used, it can be costly to gather the required information
- ✓ In areas of research that are relatively new or where tools, indicators, procedures and sources are far from settled, statistical data can be lacking or of unequal quality, causing problems for comparisons. These difficulties are often compounded by other issues, like definition problems (e.g. The meaning of the word "freedom" – depending on the interpretation of the word chosen, it may produce different issues and results).

What sources of data should be used to collect information?

Qualitative and quantitative data are generally gathered from more than one source. Where possible, two or more of the following sources should be used together to strengthen reliability and consistency in results.

Pre-existing or official data

Pre-existing or official data is information that has already been documented (e.g. Newspaper clippings, case law, Statistics Canada census data, photographs) or is created by an organization during its routine business operations (e.g. Employee personnel files, student registration forms, annual reports, occurrence reports). This data may contain information that directly relates to specific *Code* grounds like race, but more commonly will relate only indirectly (for example, in the form of names, place of origin or ethnicity). This type of information could be used as proxies or stand-ins for race, but would be less reliable than actually having self-reported racial data.

Potential strengths:

- ✓ Is efficient. Avoids the time, energy, expense and disruption involved in collecting data as a separate step from running daily operations

Example: Outcomes of workplace recruitment, hiring, promotions and terminations can be recorded, as can events such as interventions by security guards and customer complaints. When recording these events, relevant *Code* ground and non-*Code* classifications could also be included. This data could then be examined for trends over time to show whether discrimination or systemic barriers exist, may exist or do not exist.

Potential weaknesses:

- ✓ To be a useful source of information, organizations need to be willing to collect the data as part of their ordinary record-keeping procedures
- ✓ The reliability of this data will depend on the diligence and accuracy of the reporting done by the people collecting it.

Survey data

Survey research is a broad area and generally includes any measurement procedures that involve asking respondents questions. A "survey" can range from a short paper-and-pencil questionnaire to an in-depth one-on-one interview (interviews will be discussed further below).

In designing a survey, it is important to consider the specific characteristics of the respondents, to make sure that the questions are relevant, clear, accessible and easy to understand. Some practical considerations to keep in mind are whether the respondents can read, have language or cultural barriers, have disabilities, and can be easily reached.

Potential strengths:

- ✓ Very useful for documenting an individual’s perceptions and perceived experiences of an organization’s work culture, service delivery or other areas of interest
- ✓ **Example:** The TDSB’s 2006 Student Census, Grades 7-12 System Overview included a component on how senior and secondary school students generally perceived their schooling and out-of-school experiences in 10 areas, including school safety and home support and involvement.
- ✓ Can contain questions that are quantitative or qualitative in nature, or a combination of both
- ✓ Can be conducted on a small or large scale.

Potential weaknesses:

- ✓ Quality and reliability of survey data depends on factors like the expertise of the people conducting them, the design and appropriateness of the questions asked, and the credibility of the methods used to analyze and interpret the results
- ✓ May not provide an accurate measure of how others perceive a person’s background or experience.
- ✓ **Example:** A transgender employee may self-identify as female but a third party may identify her as male.

Focus groups and interviews

Interviews and focus groups (also referred to as “group interviews”) allow for information to be provided orally, either individually or in a group setting. The data can be recorded in a wide variety of ways including written notes, audio recording and video recording.

Focus groups:

In focus groups, the interviewer facilitates the session. A select group of people are brought together, asked questions, encouraged to listen to each other’s comments, and have their answers recorded. The same set of questions may be used for a number of different groups, each of which is constituted slightly differently, and for a range of purposes.

Focus groups may be facilitated by professionals, but this is not always needed. The decision to hire a professional facilitator may depend on the goals of the focus group research, the nature of the questions asked, the skills and experience of staff taking part, and the need for confidentiality or anonymity.

Example: To get the unique perspective of each group, an organization may wish to hold separate focus groups for representatives of each of the organization’s internal and external stakeholder groups, such as senior management, front-line employees, service users, union representatives and community groups. Or, it may be of greater value to organize a group that includes people representing all key internal and external stakeholders, to allow for contrasting ideas to be expressed and discussed.

Whatever format is chosen, it is important that the focus group is structured and managed in a way that cultivates a “safe space” for people to share their experiences. In some cases, this may not be possible without setting up separate focus groups or hiring a professional

facilitator who is not connected to the organization.

Potential strengths:

- ✓ Focus groups allow for multiple narratives to be voiced in one “interview” about a research topic of interest
- ✓ Act as tools for education because discussion among participants can illuminate the participants’ and the researcher’s views, helping to further refine research about a particular topic of interest.

Potential weakness:

- ✓ Does not allow participants to fully express their individual opinions and narratives, or ask questions when they immediately come to mind, because of the need to hear and accommodate other voices.

Interviews:

Typically, interviews involve a set of standard questions being asked of all respondents, on a one-on-one basis, so that accurate trends and gaps can be drawn from the data. Interviews are commonly conducted face-to-face, but for more rapid results, can also be done over the telephone, or, as technology advances, through video-conferencing and other means.

Potential strengths:

- ✓ Interviews can provide a rich, detailed perspective, impression or story on a research topic of interest
- ✓ The interviewer generally has the opportunity to probe more deeply or ask follow-up questions than when in a focus group setting
- ✓ Data from both focus groups and interviews can provide valuable context for understanding and informing research, numbers, events, behaviour and other research goals
- ✓ Depending on the size of the organization, the purpose of the data collection, the internal expertise available and other factors, focus groups and interviews can be done with relatively little expense.

Potential weaknesses:

- ✓ One-on-one interviews allow for just one narrative or perspective on a research topic of interest
- ✓ Can be very time consuming and resource intensive
- ✓ Respondents in interviews and focus groups generally want to “look good” in the eyes of others. Depending on the questions asked, they might “spin” their response to avoid being embarrassed, particularly in a face-to-face setting. Skilled interviewers may be able to address this potential weakness by doing a few things, like designing good questions, being perceptive, asking follow-up questions and cross-checking responses with other credible sources of information

- ✓ Interviewers, in both individual and focus group settings, may distort an interview by not, for example, asking questions that make them uncomfortable or not listening carefully to respondents on topics that they have strong opinions on. The impact of this potential weakness can be addressed by taking steps like making sure that interviewers are properly trained and using standard interview questions.

Observed data

Trained staff or external experts can gather data by identifying and recording the characteristics and behaviour of research subjects through observation, either within or outside of an organization. Observed data can include information gathered using all of the senses available to the researcher, including sight, hearing, smell, taste and touch.

Example: A human rights organization that offers a mediation service hires a mediation expert to observe mediators and service users and provide feedback about any issues of concern related to human rights. To minimize potential stress and anxiety experienced by the people being observed, staff and service users are informed in advance of the purpose and goals of the exercise. Service users' consent is sought. Staff is advised that the observed data gathered will only be used for research purposes and not shared with their managers. The expert maintains access to the data, and the results are reported on an aggregated and summarized basis to prevent individuals from being identified.

Hiring experts, while potentially expensive, can add validity and credibility to research analysis because they are often perceived as having no vested interest in the research results.

Information gathered using observation techniques differs from interviewing, because the observer does not actively ask the respondent questions. Observed data can include everything from field research, where someone lives in another context or culture for a period of time (participant observation), to photographs that show the interaction between service providers and service users (direct observation). The data can be recorded in many of the same ways as interviews (taking notes, audio, video) and through pictures, photos or drawings.

Potential strengths:

- ✓ An effective and capable observer can provide an objective third viewpoint on what is going on, and draw out implications that are not obvious or that people are unaware of
- ✓ Can be relatively inexpensive depending on factors like the size of the project, its goals, the organization's resources and the duration of the project.

Potential weaknesses:

- ✓ An observer, trained or otherwise, can influence the behaviour of the people being observed (for example, people could be motivated to behave better while under observation), which may ultimately affect the accuracy of observed results
- ✓ Can cause potential stress and anxiety for the people being observed, more than the use of other data collection methods. Efforts can be made to minimize stress and anxiety by using effective communication strategies to inform participants, in advance, of the purpose, goals, confidentiality measures, duration of the project and other key information
- ✓ An observer, trained or otherwise, may not always be able to accurately differentiate within or between certain groups of people, particularly when an identity (ies) is/are non-evident (e.g. Religion, mental illness, sexual orientation). A survey requesting self-identification information might be more effective in this regard.
- ✓ Each source of data used to collect information has its strengths and weaknesses. Some of the more common potential strengths and weaknesses identified above have been highlighted. Analyzing data from multiple perspectives and relying on data from different sources can strengthen the conclusions drawn from research. A combination of statistical analysis, observational data, legal analysis, documentary analysis, in-depth interviews and external and/or internal consultation can help maximize understanding of a given situation.[31] Organizations should choose the sources of data that best suit their program goals, context, resources and organizational culture.

How long will the data be collected (the scope of data collection)?

Data can be collected and analyzed on a short-term or project basis in response to situations or needs that arise from time to time. A short-term data collection project would include a start and a finish date, with set deliverables to be carried out over a certain period of time.

The best practice is to collect data on an ongoing, permanent basis, and to analyze this data as often as is needed to identify, address and monitor barriers to Code-protected persons or other persons based on non-Code grounds.

Data collected in a time-limited study may be less complete than data collected through ongoing monitoring. This is because short-term studies do not allow for the assessment of trends, patterns or changes over time. However, where costs, time and resources are a factor, short-term studies may be the preferred choice to fulfil a need and project goals.

Other factors may also influence the reliability of the data. For example, people may modify behaviour while under scrutiny during the data collection period.

Step 4: Collect data

When planning on how best to collect data in Step 4, it is important to be aware of the practical considerations and best practices for addressing logistical challenges organizations often face at this stage of the process. Implementing a data collection plan requires attention to matters such as:

- ✓ Getting buy-in from senior leadership and key stakeholders, in or outside of the organization. This group could include boards of directors, management committees,

union representatives, employees, community groups, tenants, customers and service users.

- ✓ Establishing a steering committee or selecting a person(s) to be consulted and held accountable for all major decisions about the data collection process, such as design, logistics, communication management, coordination and finances.
- ✓ Determining who will collect the data (e.g., experts or trained employees).
- ✓ Identifying the logistics, resources, technology and people needed to develop and implement a data collection initiative.
- ✓ Anticipating and addressing key stakeholder concerns and questions about the project.
- ✓ Designing a communication and consultation strategy that will explain the data collection initiative and encourage the highest possible participation rate.
- ✓ Protecting privacy and personal information by using carefully controlled procedures for collecting, storing and accessing data that comply with privacy, human rights and other legislation. Dignity and confidentiality must be respected.
- ✓ Minimizing the impact and inconvenience for the people affected in the workplace or service environment, which includes choosing the best time to collect the data.
- ✓ Aiming for flexibility to allow for changes without great expense or inconvenience.
- ✓ Considering a test period or a pilot phase to allow you to improve and modify data collection methods, as may be needed.

Step 5: Analyze and interpret data

Step 5 involves analyzing and interpreting the data collected. Whether quantitative and/or qualitative methods of gathering data are used, the analysis can be complex, or less so, depending on the methods used and the amount of data collected.

Explaining the technical steps involved in analyzing and interpreting data is beyond the scope of this guide. An organization will have to determine whether it has the internal capacity and expertise to analyze and interpret data itself, or whether it will need the help of an external consultant.

A smaller organization that has basic data collection needs may be able to rely on internal expertise and existing resources to interpret the meaning of gathered data.

Example: An organization with 50 employees wants to find out if it has enough women working in management positions, and if there are barriers to equal opportunity and advancement. The organization counts the number of female employees it has (25), and determines how many of these employees are working in supervisory and management positions (two). A few motivated employees identify some issues of concern, like gender discrimination, that may have broader implications for the organization as a whole.

After deciding to do an internal and external assessment (Step 1), and gather qualitative data using focus groups and interviews with current and past employees, senior leadership decides that barriers exist for women in the organization's recruitment, hiring, promotion and human resources policies, processes and practices. Efforts are made to work with female employees, human resources and other staff to address these barriers. The organization makes a commitment to foster a more equitable, inclusive work environment for all employees.

Step 6: Act on results

Once an organization has analyzed and interpreted the results of the data collected, it may decide to act on the data, collect more of the same type of data or modify its approach.

Quantitative and qualitative information can provide a solid basis for creating an effective action plan designed to achieve strategic organizational human resources, human rights, equity and diversity goals identified through the data collection process. If an organization feels it has enough information to develop an action plan, it should consider including the following elements:

- ✓ A summary of the results of the analysis and interpretation of the data
- ✓ Identification of the barriers, gaps and opportunities that exist or may exist for Code-protected persons and other individuals/groups based on non-Code grounds
- ✓ Steps that will be taken to address these barriers, gaps or opportunities now and in the future
- ✓ Realistic, attainable goals with short-term and longer-term timelines
- ✓ Input sought from stakeholders and affected communities
- ✓ How progress in meeting these goals will be monitored, evaluated and reported.

In some cases, an organization may decide that it needs to collect more information because there are gaps in the data collected, or areas where the data is unclear or inconclusive. This may prompt them to conduct a more detailed internal and external assessment (go back to Step 1) or try another approach.

In the end, there is no one or “right way” to conduct a data collection initiative. The experiences of Mount Sinai Hospital, KPMG Canada, the Keewatin-Patricia District School Board, TD Bank Financial Group, the University of Guelph and the *diversecity Counts* project and featured in the Appendices reflect this statement, yet also show some similarities in terms of the best practices and lessons learned.

COMMUNICATE COMPLIANCE WITH LEGISLATION TO TEAM MEMBERS

Establish steps to monitor compliance and reporting function.

Monitoring allows for early identification and correction before a problem festers and causes the company to be in non-compliance.

Examples of Monitoring

- ✓ Pre-activity approvals
- ✓ Transaction reviews, such as travel expense reports
- ✓ Reviews of in-process quality checks and outcome data
- ✓ Review of staff-completed checklists

- ✓ Listening to or reviewing recorded customer service intake calls
- ✓ Attending sales presentations

Monitoring and auditing are essential to verify that a business activity actually works and continues to do so. A process's design should consider both monitoring and auditing in process design and improvement to ensure the most effective overall internal control solution, while still making certain of an independent, objective audit.

So, a distinction between monitoring and auditing is important to ensure that operational management cannot improperly bias or overrule the audit of an activity; in this regard, higher leadership provides an effective check to ensure that while the audit remains independent, monitoring and auditing function in tandem efficiently and effectively.

Monitoring of a process's external environment (i.e., the organization's external and internal changes) helps to ensure that the process can adjust to these changes.

Timing

Monitoring can occur prior to, during or after a business activity takes place. Common pre-activity monitoring includes, for example, a management approval, such as for high-risk activities like offering expensive gifts to customers. After-the-event monitoring may be reserved for activities that are less risky and/or that occur frequently; while it cannot head off problems specific to a single transaction, such monitoring stresses that management is watching over the activity, especially when management regularly queries staff about how transactions were conducted.

Monitoring may occur during an activity, such as a complex set of procedures where management previews certain intended actions while it reviews just-completed ones. For instance, during a prospective consultant due diligence process, management may review the outcome of staff's initial screening while previewing staff's evaluation of the consultant's response to a questionnaire. Or management may sit in on a sales presentation to ensure accuracy of presented data.

Comprehensiveness

Monitoring includes some portion of an activity's occurrences. For the most sensitive activities, monitoring may involve each transaction. Or it may act as a 'spot check' in looking only at randomly selected transactions. Management may determine to review process exceptions with the assumption that they pose the greatest risk. Or it may develop a more sophisticated way to evaluate higher-risk transactions, such as those that occur in certain demographics, by certain staff members or with other select parameters.

For example, management may decide to more closely monitor hotline calls from staff with a pattern of errors. A complex monitoring program may include a variety of these approaches.

Monitors

While operational management needs to assume accountability for an activity's oversight, who actually conducts the monitoring can vary, largely based on the activity's sensitivity and staff's requisite competence. For instance, management may delegate monitoring to staff not directly involved in an activity, who then report results back to the manager. This is more likely to occur for routine transactions with lesser risk and where staff can be appropriately trained. In the most sensitive situations, management will want to reserve monitoring for itself.

What is important is ensuring that the choice of who monitors still provides effective oversight of the activity. COSO indicates that good process management includes "an effective organizational structure that assigns monitoring roles to people with appropriate capabilities, objectivity and authority."⁸

Metrics

Metrics are an important part of any business process and critical to monitoring. The monitor must be able to determine whether an activity meets, comes close to or fails to meet its goals, and the responsible staff should be able to do the same. If an activity fails, the monitor needs to know the extent of the failure and, if possible, the reason why.

Also, metrics help the monitor to know whether an activity is improving when the metrics improve (or visa versa). Even results that achieve but come close to missing objectives provide value, and monitoring of these metrics ensures that management can take appropriate action with this data.

Outcomes

Monitoring helps management to affect changes when an activity does not meet or is at risk of not meeting its intended results. This step is pivotal in process management. Unaddressed failures or other deficiencies not only weaken a process, they also can create unexpected liability if regulators or others determine that the company did not take reasonable measures to achieve compliance.

This means that the outcome of monitoring must be more than identifying actual or potential non-compliance; it must lead to management taking actions that correct the non-compliance risks. Knowing that it will report results of monitoring its activity also encourages a company to both monitor and make appropriate changes.

A monitoring outcome also may include identifying changes to the underlying activity or external environment that may require changes to the activity to ensure continued compliance. Take the situation where the number of calls to a company's hotline quickly decreases in a given month. This change may signal a shift in demographics, employee opinions or other issues that may require a change in the hotline communication or call intake process.

Factors

What monitoring steps should be included and how they should be designed and conducted depend on various determinants, including:

- ✓ ***The number of an activity's transactions.*** The fewer the transactions, the easier that monitoring the activity becomes.
- ✓ ***The cost of monitoring*** per transaction in money, staffing and other resources.
- ✓ ***The ease of monitoring.*** For example, where management can employ technology to automate and expedite monitoring, this bodes well for the overall process.
- ✓ ***The risk of non-compliance*** – both its seriousness and likelihood. Serious consequences of non-compliance may encourage pre-transaction approval; non-compliance that is more likely to occur can suggest a need for monitoring of more transactions.
- ✓ ***Motives for operating staff not to comply.*** Where staff may benefit from non-compliance, it behooves management to consider more stringent monitoring. For example, if sales staff can earn more commission from increased product sales by bypassing important paperwork, it may be important to monitor to ensure the paperwork's timely and accurate completion.

Other determinants may also be appropriate depending on the underlying activity.

Finally, monitoring should work hand in hand with auditing. It should benefit from the outcome of internal or external audits. Audit findings are intended to correct or improve a process, and part of this correction can include a process's monitoring steps. Just as monitoring provides a valuable benefit to an activity's correction and improvement, process audits provide the same benefits to monitoring steps.

Putting it All Together

Given all of this information, the challenge then is for management to implement monitoring steps that best meet an activity's needs. The intent is to develop, implement, maintain and improve monitoring practices so that they provide effective oversight of an activity as efficiently as possible. For starters, a process may not need a sophisticated monitoring plan at the beginning; it likely can start with basic monitoring steps as the process gets underway. In fact, a new process may be best served by very basic but active monitoring in the early stages to ensure that the basic process steps are followed and to identify glaring variations. Management also can simplify development of monitoring steps by using standardized templates and other materials that can then be customized to a process to train employees, serve as reporting tools and invoke correction actions.

Other Monitoring Techniques

Some ways that monitoring may be modified include the following:

Self-Monitoring

This is a means by which a responsible individual or group – such as operations staff – monitors and reports on its own performance. Self-monitoring seeks to create greater accountability among the responsible parties and, in turn, reduce the need for monitoring by others, like management. Auditing can be used as a check to ensure that the self-monitoring actions are performed as expected and not otherwise compromised. Still, even with self-monitoring, it is reasonable that management will want to perform some monitoring to provide greater assurance that the self-monitoring efforts are working, or for high-risk activities.

Continuous Monitoring

This is a means by which monitoring is made an ongoing activity versus a periodic, discrete one. According to KPMG, “Continuous monitoring (CM) is a feedback mechanism used by management to ensure that controls operate as designed and transactions are processed as prescribed. This monitoring method is the responsibility of management and can form an important component of the internal control structure.”

Continuous monitoring is likely to employ automated technology in order to simply and mechanize it. Continuous monitoring is a concept that is perhaps most helpful to those companies that conduct only occasional process monitoring. KPMG also discussed how continuous monitoring seeks to review disparate data from multiple processes to weave together an otherwise unknown perspective on potential risk to the business activity.

3.2 Address identified areas of non-compliance and take corrective action.

When a deviation/noncompliance event is discovered, study teams should take immediate measures (also referred to as Corrections) to mitigate risk and protect rights, safety and welfare of the subject(s) and others should be taken. This may be in the form of a phone call or an office/clinic visit between the subject and a member of the research team, or other tests and procedures to ensure the subject's safety. Corrections alone may resolve minor deviations but they will not effectively resolve more significant or systematic noncompliance, which generally also require corrective and preventive action.

Corrective and Preventive Actions are developed and implemented for more significant or systematic noncompliance, once the root cause is known. Corrective and Preventive Actions are implemented to prevent the occurrence and recurrence of an event. To avoid the need for a CAPA, study teams should have prevention and quality assurance procedures in place to proactively avoid problems. However, if a CAPA needs to be developed, the following approach will be helpful.

State the problem, event, or issue identified

Briefly outline the problem, event, or issue identified. This outline should be as objective as possible and include a description of:

- ✓ What occurred
- ✓ Where and when the event occurred
- ✓ What should have occurred instead
- ✓ What the source of the information was
- ✓ Who discovered the information/event

Examine the issue and identify the cause(s) of the event (i.e. Root Cause Analysis)

a) Collect data: Analyze the situation fully before you can move on to look at factors that contributed to the problem. To maximize the effectiveness of this step, talk to everyone with knowledge of the problem and process. You may become aware of additional information that you were not aware of at the time the event was initially discovered. Data collection should provide you with information on:

- ✓ Whether the problem truly exists, including the evidence indicating that a problem occurred
- ✓ What the true scope and magnitude of the problem is, including:
 - ✓ How many times the event occurred
 - ✓ How many subjects were affected
- ✓ Whether this event occurred in one or multiple studies under this PI's purview, with similar study team members, and/or within the program
- ✓ How long the problem has existed, including:
 - ✓ When the event first occurred and how long it continued
- ✓ What the effect or impact of the problem is and who was affected

b) Identify Possible Causes: The goal of this step is to identify and document as many factors contributing to the problem as possible. There can be multiple reasons or causes that contribute to one single problem. This list may include human error, and/or process or equipment/space related factors. The focus should be on identifying underlying problems that contribute to error rather than on mistakes made by individuals.

Root cause analysis tools, including many common types of charts and graphs, can be helpful during this process. A Why Chart can be particularly helpful in determining a root cause, as it helps analyze the different layers of causes.

During the Root Cause Analysis, ask at least the following questions:

- ✓ What sequence of events lead to the problem or allowed the problem to occur?
- ✓ What conditions allowed the problem to occur?
- ✓ What other problems surround the occurrence of the central problem?
- ✓ What were the contributing factors that led to this event? (i.e. All the items in the causal chain)
- ✓ What is the underlying, root cause of the event? (i.e. The first item in the causal chain)

Propose and Implement a Corrective and Preventive Action (CAPA) Plan

Create simple, measurable solutions that address the root cause(s). These solutions should take the form of durable corrective and preventive actions that eliminate the cause and prevent it from recurring in the future, instead of just resolving the issue at hand.

When developing a CAPA, consider at least the following:

- ✓ What are the available solutions to prevent the event from occurring or recurring?

- ✓ Are the solutions feasible?
- ✓ How will the solution(s) be implemented?
- ✓ What are the available resources (internal and external to the study team) to implement and monitor the CAPA plan?
- ✓ Who will be responsible and accountable for implementing and monitoring the CAPA Plan?
- ✓ Are the deadlines reasonable and achievable?
- ✓ Can it be monitored?

Monitor the progress and effectiveness of the CAPA Plan

Despite best efforts to identify root causes and solutions, the identified root causes may be incorrect and/or the solutions ineffective. Therefore, it is important that any CAPA be periodically assessed for effectiveness and modified as needed. Modifying an ineffective CAPA may require reexamining the causes of the initial event and restarting the root cause analysis process.

When monitoring a CAPA, consider at least the following:

- ✓ How will the CAPA plan be monitored (i.e. How will problems with the CAPA be identified and reported)?
- ✓ When will you review the progress and effectiveness of the CAPA Plan?
- ✓ At what intervals or frequency will you review the progress and effectiveness of the plan?
- ✓ When and to whom should the outcome of the CAPA Plan be reported?

Assistance with CAPA Development: Individuals not involved in day-to-day study conduct can provide valuable objective feedback on the potential causes of and solutions to events. It may be beneficial to engage others in your department or unit/program in this process. The Post-Approval Monitoring and FDA Regulated Research Programs are also available to provide consultation at any point during the CAPA development process.

Reporting Noncompliance: When noncompliance is discovered, submit the reportable event to the reviewing IRB as soon as possible within their required timelines as well as any other applicable oversight bodies (e.g. Sponsor, FDA if the PI is sponsor-investigator). If you believe more time is necessary to conduct a full assessment of the event, contact the IRB to determine the next steps.

Provide feedback on compliance issues to team members.

Ensuring that your team understands the importance of compliance to your business is key. How do you make sure everyone is onboard in meeting compliance controls and processes? A mindset of proper management is the first step.

Achieving compliance is no easy task; your team must be prepared to do the following:

Fully Understand the Requirements

Each compliance standard has its own set of requirements. In order to make sure your business passes all levels of an audit, it's important to understand what the requirements really mean. Additionally, you must make sure every element has security standards in place to protect your consumers and their data. You must have knowledgeable team members

who can fully decipher what is needed, not leaving anything subject to interpretation. The best thing is to work on meeting all the required regulations while adopting an actionable framework that can be used for future reference.

Set a Budget

Meeting compliance standards may have significant related expenses. There are direct, indirect, and opportunity costs involved. The key is in having a workable budget in place to meet those expenditures without jeopardizing business operations. Consider the cost of an analysis, which could climb upwards of \$20,000, while certification costs could range between \$40,000 and \$60,000. Personnel, training, and implementation are also considerations that involve some form of budgeting.

Form the Right Team

You must make the investment to get the best results. That includes having the right team in place to ensure you meet compliance standards. The compliance process could take up to a year. It requires input from members across the organization. The team charged with compliance tasks must be adequately prepared and have enough time to see the project through to completion. Below are some key roles which will need to be defined within the compliance team:

- ✓ A dedicated project manager, or more than one, can help keep things in order. They should be detail-oriented and ready to address hard facts. They should be intimately involved with the business on all levels and understand the rules of compliance.
- ✓ You should also have human resources personnel who can assist in reviewing current policies and procedures and adjust them to meet any new requirements. This role will be time-consuming, and all supervisors should be aware and in agreement on the time commitment.
- ✓ The CFO, or a designated person from the finance department, should be on board to ensure the costs of compliance are met on all levels.

Make recommendation for preventative measures.

Build a Framework to Verify Compliance Controls & Processes

Once you have those key elements in place, you'll be able to put together a working model on verifying your compliance controls and processes. Here are a few tips:

1. Weekly Reporting

This is a MUST. Every person on the team involved in the process should regularly present their findings and timelines for implementation, being accountable for their role. One of the best ways to do this is by holding a weekly compliance meeting to ensure issues won't linger, concerns are addressed quickly, progress is being made, and everyone is on the same page as it relates to changes.

2. Internal Spreadsheet

A working document that outlines each element of the framework to its specific controls, including the systems and processes will help keep everyone on the same page. There should be a system in place to update this document on a regular basis and determine

which systems and processes address each requirement, their effectiveness, and the person responsible for that area.

3. Automated Reporting

Relying on a platform that automatically reports on the effectiveness of your compliance controls and processes helps keep everyone on schedule. At the same time, automation assists with monitoring the activities that directly affect compliance standards.

By taking a holistic approach, the company will be able to better manage the compliance process, utilize the right people and create an effective solution that works.

Drive continuous improvement of work practices to achieve water quality outcomes.

Legislation should clearly specify that the water-supply agency is legally responsible at all times for the quality of the water sold and/or supplied to the consumer and for the proper supervision, inspection, maintenance, and safe operation of the water-supply system. It is the water-supply agency which actually provides water to the public—the “customer”—usually on a commercial basis, and which should, as the supplier or vendor of the finished product, be legally responsible (under both criminal and civil law) for its quality and safety from a public health point of view. However, it should be held responsible for the quality of the water only up to a defined point in the distribution system, and not for any deterioration of water quality within the household as a result of poor plumbing or unsatisfactory storage tanks. It should be the long-term policy of the health and water authorities to place the legal burden of the primary level of water-quality control testing on the supply agency. These authorities should develop the infrastructure necessary for quality control, the costs involved forming part of the price of the water. This form of transfer of responsibility, in a decentralized manner, to the producer/supplier provides a system of independent surveillance coupled with strict enforcement by an authority with the power to determine whether the supplier is fulfilling its responsibilities, and is based on the principles of sound administration.

The legislation should empower the appointed surveillance agency to enforce compliance with water-quality standards and regulations by carrying out independent periodic surveillance of all aspects of water quality and safety, including sanitary inspections and spot checks. The results of this surveillance should be reported to the water-supply agency, which should be required to take remedial action, where necessary.

Surveillance should primarily be a support and advisory function and only secondarily one of enforcement and the imposition of penalties. However, appropriate penalties should be specified in the law, including fines for violations, and continuing fines for continuing violations. Consideration should be given to holding water-supply agency management personally responsible for serious offences involving personal neglect and mismanagement, something that has been found to be effective in certain countries. The surveillance agency should be required by law to publish annual reports on its work or at least to provide free public access to all water-quality surveillance results in a form that is both meaningful and

comprehensible to the general public.

While remedial action to ensure the timely correction of faults should be an aim of the surveillance programme, there may at times be a need for penalties to ensure compliance. The surveillance agency must be supported by strong and enforceable legislation if it is to be effective. However, it is important that the agency develops a positive and supportive relationship with suppliers.

The surveillance agency should be empowered by law to compel the supplier to post notices recommending the boiling of water when microbial contamination is detected.

7. PERFORM MICROBIOLOGICAL WATER CONTAMINANT ANALYSIS

INVESTIGATE WATERBORNE MICROORGANISMS

Identify the samples of waterborne microorganisms found in water sources.

Pathogen	Health significance	Persistence in water supplies ^a	Resistance to chlorine ^b	Relative infectivity ^c	Important animal source
Bacteria					
<i>Burkholderia pseudomallei</i>	Low	May multiply	Low	Low	No
<i>Campylobacter jejuni</i> , <i>C. coli</i>	High	Moderate	Low	Moderate	Yes
<i>Escherichia coli</i> – Pathogenic ^d	High	Moderate	Low	Low	Yes
<i>E. coli</i> – Enterohaemorrhagic	High	Moderate	Low	High	Yes
<i>Legionella</i> spp.	High	Multiply	Low	Moderate	No
Non-tuberculous mycobacteria	Low	Multiply	High	Low	No
<i>Pseudomonas aeruginosa</i> ^e	Moderate	May multiply	Moderate	Low	No
<i>Salmonella typhi</i>	High	Moderate	Low	Low	No
Other salmonellae	High	May multiply	Low	Low	Yes
<i>Shigella</i> spp.	High	Short	Low	Moderate	No
<i>Vibrio cholerae</i>	High	Short	Low	Low	No
<i>Yersinia enterocolitica</i>	High	Long	Low	Low	Yes
Viruses					
Adenoviruses	High	Long	Moderate	High	No
Enteroviruses	High	Long	Moderate	High	No
Hepatitis A	High	Long	Moderate	High	No
Hepatitis E	High	Long	Moderate	High	Potentially
Noroviruses and Sapoviruses	High	Long	Moderate	High	Potentially
Rotavirus	High	Long	Moderate	High	No
Protozoa					
<i>Acanthamoeba</i> spp.	High	Long	High	High	No
<i>Cryptosporidium parvum</i>	High	Long	High	High	Yes
<i>Cyclospora cayetanensis</i>	High	Long	High	High	No
<i>Entamoeba histolytica</i>	High	Moderate	High	High	No
<i>Giardia intestinalis</i>	High	Moderate	High	High	Yes
<i>Naegleria fowleri</i>	High	May multiply ^f	High	High	No
<i>Toxoplasma gondii</i>	High	Long	High	High	Yes
Helminths					
<i>Dracunculus medinensis</i>	High	Moderate	Moderate	High	No
<i>Schistosoma</i> spp.	High	Short	Moderate	High	Yes

Identify the general characteristics of different types of microorganisms.

A Colilert test is the routine test to determine if coliforms are absent or present in drinking water. Coliforms are a group of bacteria that are normal inhabitants of the intestinal tract which include *Escherichia* (or *E. Coli.*), *Klebsiella*, *Enterobacter*, and *Citrobacter*. All but *E. Coli.* May also be found in the soil. Coliform bacteria may be accompanied by pathogens (i.e., pathogenic bacteria, viruses, protozoa, and helminths) in sewage and in wastewater. Sewage and wastewater could potentially contaminate a private well and thus contaminate the drinking water. The colilert test allows the use of coliforms as an indicator for routinely

evaluating drinking water for the presence of pathogens. Testing for coliforms as opposed to pathogens is more reliable and less time consuming.

The colilert test first indicates either the presence or absence of total coliforms. Of these four bacteria, only *E. Coli*. Can be specified. The presence of coliforms in the absence of *E. Coli*. Suggests that the naturally occurring bacteria from the soil possibly entered the well through runoff or some other means. The presence of coliforms and *E. Coli* indicates that fecal contamination has occurred and pathogens may be present.

Coliform bacteria are rarely pathogenic, but there are a few exceptions. Certain strains of *E. Coli* have been associated with gastrointestinal infections in adults, known as traveler's diarrhea or Montezuma's revenge, urinary tract infections, and newborn meningitis. Certain strains of *Klebsiella pneumoniae* have been associated with gastrointestinal infections, pneumonia, hospital-acquired urinary tract infections, burn wound infections, or as secondary invaders in other respiratory infections. *Enterobacter* has been associated with hospital acquired urinary tract infections. *Citrobacter* has been associated with hospital-acquired urinary tract infections, superficial wound infections, osteomyelitis, neonatal meningitis, and gastroenteritis. For more information on *E. Coli* look up the EPA fact sheet on the EPA website located in the sidebar.

The principle bacteria pathogens that have been shown to cause human intestinal disease associated with drinking water are: *Salmonella typhi*, Typhoid fever; *Salmonella paratyphi-A*, paratyphoid fever; other *Salmonella* species, salmonellosis, enteric fever; *Shigella dysenteriae*, *S. Flexneri*, and *S. Sonnei*, bacillary dysentery; *Vibrio cholerae*, cholera; *Leptospira* sp., leptospirosis; *Yersinia enterocolitica*, gastroenteritis; *Francisella tularensis*, tularemia; *Escherichia coli*. (specific strains), gastroenteritis; and *Pseudomonas aeruginosa*, various infections. The infecting dose varies with the strain as well as the age and general health of the host. Infants, the aged and the immunocompromised may be particularly susceptible.

The principal viral pathogens that may be transmitted by drinking water from sewage or wastewater are the enteric viruses (i.e., acid stable picornaviruses), reoviruses, adenoviruses, and hepatitis A. People infected by these ingested viruses do not always become ill, but a disease involving the gastrointestinal system, central nervous system, skin, and heart is possible.

The principle protozoa pathogens that may be transmitted by drinking water from sewage or wastewater are *Entamoeba histolytica*, *Giardia lamblia*, and *Cryptosporidium*. *Entamoeba histolytica* is considerably more prevalent in tropical and subtropical areas. *Cryptosporidium* and *G. Lamblia* are most frequently seen in rural and lower socioeconomic areas, but these protozoa may be found in drinking water that has been contaminated by sewage. People infected by these protozoa may not have any symptoms. Symptomatic victims may complain of abdominal cramps and diarrhea.

The principle intestinal worms that are transmitted in drinking water include *Ascaris lumbricoides*, the round worm; *Trichuris trichiura*, the whipworm; *Ancylostoma duodenale*

and *Necator americanus*, the hookworms; and *Strongyloides stercoralis*, the threadworm. It is unlikely that the transmission of helminthic infections into drinking water is significant.

Identify water quality or treatment problems caused by microorganisms.

Chemical disinfection utilizing some form of chlorine remains the choice for disinfecting private wells. Chlorine has been shown to be an effective disinfectant for bacteria and viruses, but standard knowledge of the vulnerability of protozoa and helminths to chlorine is incomplete. It is known that protozoa and helminths are more resistant to chlorine than bacteria. The presence of coliforms or *E. Coli* would warrant chlorination because of the potential risk for infection. The current NC groundwater quality standard for the coliform organisms is 1 per 100 milliliters (15NCAC 2L.0202), and a new standard is proposed at zero. The EPA maximum contaminant goal (MCG) for *Cryptosporidium*, *Giardia lamblia*, viruses, and total coliforms is 0 mg/L

Identify microorganisms causing problems specific to water treatment processes.

There is a group of nuisance organisms collectively designated as iron, sulfur bacteria, and sulfate-reducing bacteria that may be found in drinking water. These bacteria are not pathogenic and are naturally found in the soil. These nuisance bacteria are responsible for various transformations of iron usually in the form of slime and often cause a bad odor and/or taste in the water. In addition, iron bacteria may cause plugging of well AND A REDDISH TINGE TO THE WATER. Sulfur and sulfate reducing bacteria may cause rusty water and corrosion of pipes.

Iron bacteria are most likely to appear in water with relatively high iron concentrations (i.e., 10 to 30 mg/L), but may develop in water with low iron concentrations (0.1 to 0.3 mg/L) if the supply of iron is continuously renewed. Iron bacteria oxidize ferrous iron to ferric iron and cause the precipitation of ferric hydrate. The precipitation of ferric hydrate causes a foul odor and taste and reddish tinge to the water.

Sulfur bacteria oxidize sulfur to sulfate while sulfate-reducing bacteria reduce sulfate to hydrogen sulfide. These products cause a foul odor and taste to the water. Sulfur bacteria may bring large amounts of iron into solution under conditions favorable for its development. The hydrogen sulfide produced from the sulfate-reducing bacteria reacts with dissolved iron to form black insoluble iron sulfide. Chlorination is used to control these nuisance organisms as well as decreasing the iron, sulfide, and/or sulfur content for the water.

Identify the characteristics of, and diseases caused by, pathogenic microorganisms.

Water-borne diseases are caused by water that is contaminated with microorganisms. The microbes—typically bacteria, viruses, protozoa, and parasites—are usually found in the intestinal tracts of humans and other creatures. In most cases, the water becomes contaminated by feces that carry the microbes.

Over 1 billion people worldwide do not have access to safe drinking water, and 3.4 million people die each year due to water-borne diseases, according to the World Health Organization (WHO). Indeed, water-borne diseases are the most common cause of disease and death in the world, according to the WHO. While this is largely a problem in developing and underdeveloped countries, developed nations, are not immune.

As noted above, water-borne diseases are caused by a wide range of pathogens, including bacteria, viruses, parasites, and protozoa. Examples of bacteria that are important water-borne pathogenic organisms include *Vibrio cholerae* (the bacteria that causes cholera), various species *Campylobacter*, *Salmonella*, *Shigella*, and a type of *Escherichia coli* designated O157:H7.

An example of a pathogenic water-borne virus is the norovirus, which has become notorious in causing disease outbreaks on cruise ships, and in day care centers and universities. In the winter of 2007, classes were interrupted at two universities in the Canadian province of Nova Scotia because of simultaneous outbreaks of water-borne norovirus diarrhea. Viruses that normally dwell in the intestinal tract are also capable of causing disease if they contaminate water. Just one example is hepatitis (several forms of hepatitis are caused by several types of hepatitis virus).

Waterborne diseases are often the result of drinking or bathing in contaminated freshwater. Saltwater-borne microbial diseases also exist, and bacteria, viruses, and algae are typically associated with these illnesses. Explosive growth of certain algal species in ocean water can lead to the accumulation of these algae in oysters and other shellfish that feed by filtering water. If people eat the affected shellfish, various diseases can result. Some of these can be serious, producing paralysis and death.

Amebiasis is a common water-borne disease that is caused by the parasite *Entamoeba histolytica*. This parasite is normally found in feces, and can cause disease when fecal-contaminated water is consumed. About one of every 10 people who consume *E. Histolytica*—which translates to millions of people worldwide—becomes ill. Their symptoms can be mild (diarrhea, stomach ache, and cramping), but, in some people, a severe form of amebiasis called amebic dysentery develops. The destruction of cells lining the intestinal tract produces bloody diarrhea. More rarely, the parasite can spread to the liver, lungs, or the brain.

Cryptosporidiosis is another water-borne disease caused by a parasite. This illness is caused parasites of the genus *Cryptosporidium*, especially *C. Parvum*. The organism's life cycle consists of a small, inert form and an actively growing form. The inert form can pass through

the filters used in water treatment plants and can survive exposure to chlorine. Once inside a person, the resulting infection can persist for months despite treatment.

Once relatively rare, cryptosporidiosis increased in prevalence beginning in the 1980s, as expansion of urban areas brought more people into contact with the animals that naturally harbor the parasite in their intestinal tracts. Symptoms of cryptosporidiosis include dehydration, persistent stomach upset, weight loss, nausea, and vomiting. The parasite can be passed from person to person. As of 2007, cryptosporidiosis is one of the most common causes of water-borne disease in the United States. A well-known outbreak occurred in Milwaukee, Wisconsin, in 1993; over 200,000 people were sickened during this outbreak.

Yet another parasite-mediated water-borne disease is cyclosporiasis, which is caused by *Cyclospora cayetanensis*. A hallmark of this infection is the sudden and explosive diarrhea that repeatedly occurs. Other symptoms include weight loss, dehydration, stomach upset, and fatigue.

Giardiasis is a disease caused by an intestinal parasite called *Giardia lamblia* (sometimes called *Giardia intestinalis*). Over the past 20 years, this disease has become one of the most common water-borne human diseases in the United States. In North America, it is sometimes known as beaver fever, since the beaver is one of the animals that naturally harbor the parasite in their intestinal tracts. Symptoms of giardiasis include diarrhea, intestinal gas, stomach cramps, upset stomach, and nausea. The lingering intestinal upset of giardiasis can be debilitating.

Water-borne diseases caused by microorganisms occur worldwide. Virtually every country experiences water-borne illnesses, although the diseases tend to be more prevalent in tropical countries where the warmer climate favors the persistence of bacteria and viruses that enter the water from the intestinal tract. Water-borne diseases are especially problematic in developing and underdeveloped nations, where adequate water treatment facilities may be lacking and safe drinking water may be in short supply. For example, in 2000, about 140,000 cases of cholera were reported to the WHO, and these infections resulted in 5,000 deaths.

IDENTIFY PROCESS TO REMOVE MICROORGANISMS

Assess the effectiveness of a range of filtration processes for physically removing pathogenic microorganisms according to organisational and legislative requirements. This unit considers various processes for removal of microbes from water. In particular, it discusses:

- ✓ ***Pretreatment*** — broadly defined as any process to modify microbial water quality before, or at the entry to, a treatment plant;
- ✓ ***Coagulation, flocculation and sedimentation*** — by which small particles interact to form larger particles and settle out by gravity;
- ✓ ***Ion exchange*** — used for removal of calcium, magnesium and some radionuclides;

- ✓ **Granular filtration** — in which water passes through a bed of granular materials after coagulation pretreatment;
- ✓ **Slow sand filtration** — in which water is passed slowly through a sand filter by gravity, without the use of coagulation pretreatment.

Assess the effectiveness of a range of disinfection processes for inactivating pathogenic microorganisms according to organisational and legislative requirements.

Pretreatment

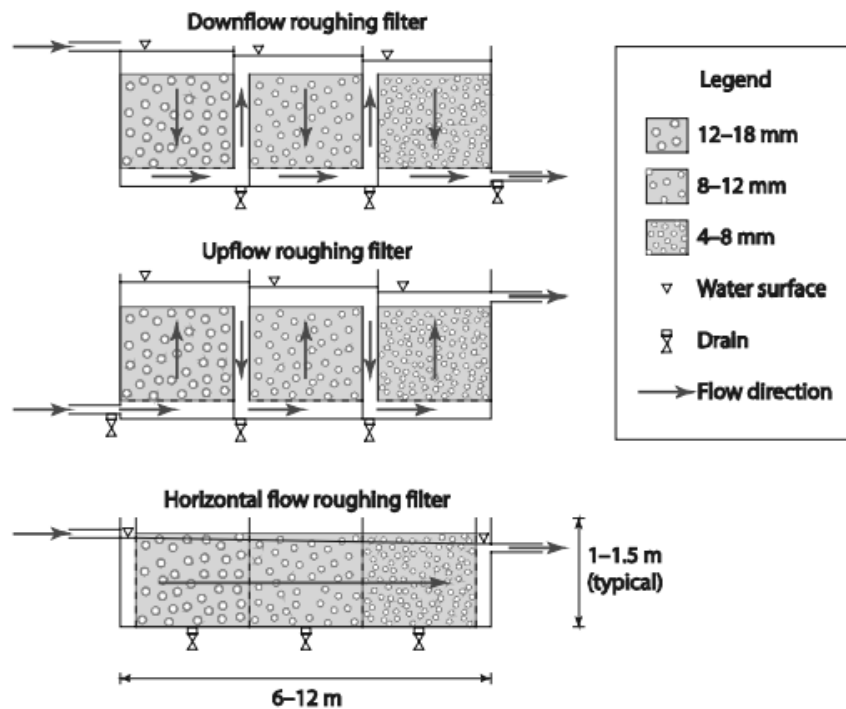
This section describes some of the processes that can be used in pretreatment of water (roughing filters, microstrainers, off-stream storage and bank infiltration), each of which has a particular function and water quality benefit. Applications of pretreatment include removal of algal cells, high levels of turbidity, viruses and protozoan cysts. The various options for pretreatment may be compatible with a variety of treatment processes, ranging in complexity from simple disinfection to membrane filtration.

Roughing filters

A roughing filter is a coarse media (typically rock or gravel) filter used to reduce turbidity levels before processes such as slow sand filtration, diatomaceous earth (DE) or membrane filtration. Such filters typically have a filter box divided into multiple sections containing gravel beds of decreasing particle size, inlet and outlet structures, and flow-control devices. Examples of common configurations are shown in Figure

Roughing filters have achieved peak turbidity removals ranging from 60 to 90%; generally, the more turbid the water initially, the greater the reduction that can be achieved (Galvis, Fernandez & Visscher, 1993; Collins et al., 1994; Ahsan, Alaerts & Buiteman, 1996). These filters can achieve similar reductions of coliform bacteria. Pilot studies of various roughing filter configurations (horizontal-flow, up-flow and down-flow) reduced faecal coliform bacteria by 93–99.5% (Galvis, Fernandez & Visscher, 1993). These filters were also combined with a dynamic roughing filter (which contains a thin layer of fine gravel on top of a shallow bed of coarse gravel, with a system of underdrains) to pretreat high turbidity events, and achieved faecal coliform removal of 86.3%.

When followed by slow sand filtration, the removal reached 99.8%, with an overall combined treatment efficiency of 4.9–5.5 log units. In a five-month pilot study of a medium gravel (5.5 mm) horizontal roughing filter in Texas City, United States of America (USA), the filter removed on average 47% of total bacteria (as measured by epifluorescence microscopy), 37% of the source water algal cells and 53% of the total chlorophyll (Collins et al., 1994). The researchers found that the roughing filters removed clay particles more effectively when the filter was ripened with algal cells. Addition of alum coagulant before treatment with a horizontal roughing filter improved the filter's performance for turbidity, colour, organic carbon, head loss and filter run length (Ahsan, Alaerts & Buiteman, 1996).



Typical roughing filter configurations

Microstrainers

Microstrainers are fabric meshes woven of stainless steel or polyester wires, with apertures ranging from 15 to 45 μm (usually 30–35 μm). Such meshes are useful for removing algal cells and large protozoa (e.g. *Balantidium coli*), but have no significant impact on bacteria or viruses. Microstrainers generally remove about 40–70% of algae and, at the same time, about 5–20% of turbidity (Mouchet & Bonnellye, 1998). The performance of microstrainers for specific applications varies, depending on the type of algae present, as summarized in Table below. Although microstrainers can reduce the amount of coagulant needed, they do not remove smaller species or reproductive forms of algae.

Performance of microstrainers for various algae

Organism	Type	Percentage removal
Diatoms		
<i>Cyclotella</i>	Unicellular	10–70
<i>Stephanodiscus</i>	Unicellular	10–60
<i>Melosira</i>	Filamentous	80–90
<i>Synedra</i>	Unicellular	40–90
<i>Asterionella</i>	Colonial	75–100
<i>Fragilaria</i>	Filamentous	85–100
Chlorophyceae		
<i>Chlorella</i>	Unicellular	10–50
<i>Scenedesmus</i>	Cenobia (4–8 cells)	15–60
<i>Pediastrum</i>	Cenobia (4–64 cells)	80–95
Blue-green algae		
<i>Oscillatoria</i>	Filamentous	40–50
<i>Anabaena</i>	Filamentous	50–70

Off-stream storage

In this discussion, off-stream storage refers to a storage reservoir that directly or indirectly feeds a potable water intake. The effects of off-stream storage are difficult to generalize because important physical, biological and chemical processes are influenced by hydrological and limnological characteristics of the reservoir. For example, 'round' reservoirs and lowland impoundments influenced by strong winds can be represented as homogeneous biotypes because they are mixed effectively. On the other hand, long reservoirs whose depth increases with length are best represented as a series of interconnected individual basins (Bernhardt, 1995). The characteristics of reservoirs created by construction of a dam will differ from those of a natural or artificial lake.

Oskam (1995) summarized the self-purification processes that improve water quality in off-stream reservoirs (Table 2.2). The major factors that influence these processes are the degree of compartmentalization, the hydraulic residence time, the shape and flow through the reservoir, and the quality of the source water. Certain processes can also degrade water quality; for example, poorer quality of the impounded water can result from failure to:

- ✓ Manage algal growth;
- ✓ Control influx of nitrogen, phosphorus or other contaminants;
- ✓ Limit faecal contamination from run-off of surrounding areas or roosting birds.

Type of process	Effects
Physical	Equalization of peak concentrations (e.g. chemicals, microbes) Exchange of oxygen and carbon dioxide with the atmosphere Evaporation of volatile substances (e.g. solvents) Settling of suspended solids and adsorbed substances (e.g. turbidity, heavy metals)
Biological	Biodegradation of organic substances Die-off of faecal bacteria and viruses Nitrification of ammonium to nitrate Denitrification of nitrate to nitrogen Phosphorus elimination by phytoplankton uptake (in pre-reservoirs)
Chemical	Oxidation of divalent iron and manganese Hydrolysis of polyphosphates and organic esters (e.g. phthalates) Photolysis of humic substances and polynuclear aromatic hydrocarbons

Self-purification processes that improve off-stream reservoir water quality

In a study by Bernhardt (1995), coliform bacteria in dammed reservoirs were reduced by 80–99% when residence times were greater than 40 days, and allochthonous bacteria were reduced by 90–99% when retention times exceeded about 100 days. Kors & Bosch (1995) reported reductions of enteroviruses (1.5 logs), Kjeldahl nitrogen (50%), total phosphorus (60%) and ammonium (70%) for a pumped, off-stream reservoir after about 100 days retention time. Stewart et al. (1997) examined storm events that washed high levels of *Giardia* cysts (up to 17 000 cysts/100 l) and *Cryptosporidium* oocysts (up to 42 000 oocysts/100 l) into receiving reservoirs. Only one of 29 reservoir effluent samples was positive, suggesting that the cysts and oocysts had become trapped in sediments that settled to the bottom of the reservoir, because unattached organisms settle slowly (Medema et al., 1998). Hawkins et al. (2000) reported complete elimination of *Cryptosporidium* spikes (i.e. High concentrations) within three weeks in the 2 million megalitre Lake Burragorang reservoir that provides source water for Sydney (Australia). The authors calculated a settling rate of 5–10 metres/day and postulated that sedimentation was accelerated by oocysts clumping with other suspended particles. In a study of three reservoirs in Biesbosch (Netherlands), storage with long residence times (average 24 weeks) resulted in reductions of 2.3 logs for *Giardia*, 1.4–1.9 logs for *Cryptosporidium*, 2.2 logs for *Escherichia coli* and 1.7 logs for faecal streptococci (Ketelaars et al., 1995; van Breemen & Waals, 1998).

The die-off kinetics for microbes can be modelled as a first-order reaction dependent on the residence time and short-circuiting (i.e. The decrease in hydraulic residence time in a vessel) (Oskam, 1995). For relatively rapid removal rates (k values > 0.05/day), the degree of compartmentalization has a positive effect on water quality. Therefore, a series of three or four smaller reservoirs would be better than one large impoundment. With estimated k -values of 0.07/day for removal of *Giardia* and *Cryptosporidium*, and 0.13/day for enteric viruses,

Compartmentalization in three or four reservoirs would increase the removal effect to

15–230 times that achieved by a single basin (Oskam, 1995).

For reservoirs with short retention times (and therefore limited self-purification), the raw water pumping schedule can be used to improve water quality, by avoiding periods of source water contamination. For example, in a study of the Delaware River (USA), peak levels of microbial contaminants were associated with high levels of turbidity following rainfall events (lechevallier et al., 1998). By operating the source water pumps to avoid these peak events, levels of *Giardia* and *Cryptosporidium* 12–16 times higher than normal were avoided.

Bank infiltration

Bank infiltration refers to the process of surface water seeping from the bank or bed of a river or lake to the production wells of a water treatment plant. During the water's passage through the ground, its quality changes due to microbial, chemical and physical processes, and due to mixing with groundwater. The process can also be described as 'induced infiltration,' because the well-field pumping lowers the water table, causing surface water to flow into the aquifer under a hydraulic gradient.

Bank infiltration can be accomplished through natural seepage into receiving ponds, shallow vertical or horizontal wells placed in alluvial sand and gravel deposits adjacent to surface waters, and infiltration galleries. Bank infiltration has been widely used in European countries and is of increased interest in many other countries. Variations on the underground passage concept include soil aquifer treatment, injection of surface water for underground passage and aquifer recharge.

The advantages of bank infiltration are summarized in Table 2.3. The efficiency of the process depends on a number of factors: the quality of the surface water (turbidity, dissolved organic matter, oxygen, ammonia and nutrients), the composition and porosity of the soil, the residence time of the water in the soil and the temperature. This efficiency can vary over time, depending on the difference in level between the source water (e.g. River stage) and groundwater. This difference can influence the degree of groundwater mixing and the residence time of the infiltrated surface water.

A natural pretreatment step requiring little chemical addition
Reduced turbidity and particles
Removal of biodegradable compounds
Reduction of natural organic matter and less formation of disinfection by-products
Reduction of bacteria, viruses and protozoa
Equalization of concentration peaks (e.g. moderation of spills, temperature, etc.)
Dilution with groundwater

Advantages of bank infiltration

Concern about groundwater under the direct influence of surface water has caused some confusion about how to regard bank infiltration. Clearly, this process is under the direct influence of surface water; however, in the USA, the Surface Water Treatment Rule (USEPA,

1989a) does not consider the infiltration process as contributing to water treatment.

In a study of the Grand River in Ontario (Canada), removal of algae and diatoms ranged from 4.8 to 7.2 logs when the quality of the collection well was compared to the raw water (Clancy & Stendahl, 1997). No *Giardia* or *Cryptosporidium* were detected in the collector wells, although these protozoa were frequently detected in the river water. Figure 2.2 shows the relationship between the concentration of algae and the theoretical flow-path distance for wells along the Great Miami River at Cincinnati (USA), with approximately 1 log reduction for every 8.5 m (28 ft) of separation from the source water (Gollnitz, Cossins & demarco, 1997). Schijven and Rietveld (1997) measured the removal of male-specific coliphage, enteroviruses and reoviruses at three infiltration sites, and compared the measured values to those predicted by a virus transport model. They found a 3.1-log reduction of bacteriophage within 2 m (6.6 ft) and a 4.0-log reduction within 4 m (13.2 ft) of very fine dune sand. Phage levels were reduced by 6.2 logs through riverbank infiltration over 30 m (98 ft) of sandy soil. In all cases, enteroviruses and reoviruses were eliminated to below detection limits (> 2.6 to > 4.8 log removals). The virus transport model corresponded reasonably well with the measured results, producing calculated removals ranging from 2.5 to 15 logs.

In studies being conducted by the American Water Works Service Company and the Johns Hopkins University, monitoring of three river bank infiltration systems along the Wabash, Ohio and Missouri rivers (USA) have shown complete removal of *Clostridium* and bacteriophage indicators (Table 2.4) and substantial reductions in biodegradable dissolved organic carbon (BDOC) and assimilable organic carbon (AOC), which can stimulate bacterial growth in distribution system pipelines (Ainsworth, 2004). These data indicate that bank infiltration can be highly effective for removal of microbial contaminants.

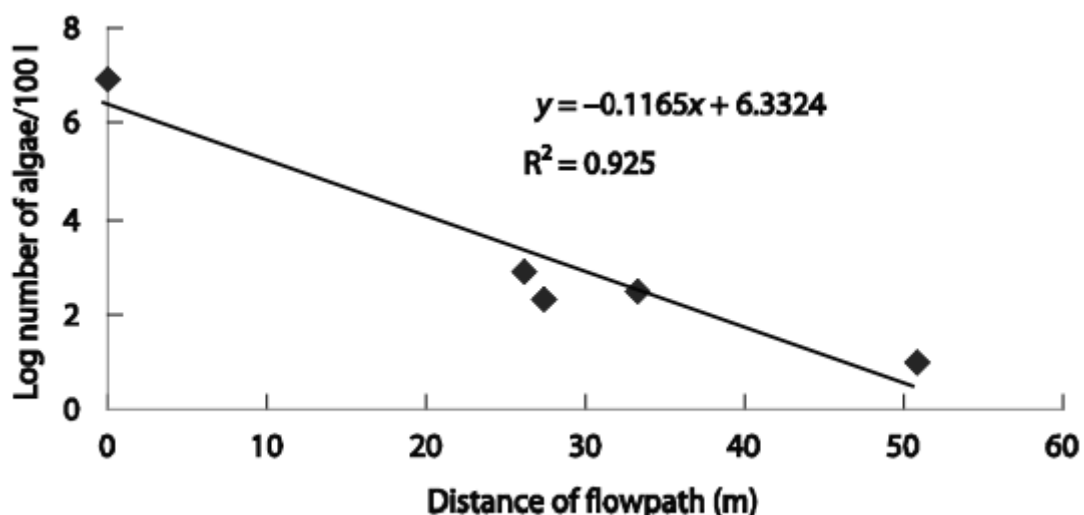


Figure 2.2 Relationship between algae concentration and theoretical flowpath.

Coagulation, Flocculation and Sedimentation

Coagulation, flocculation and sedimentation are used in conjunction with subsequent filtration. These processes are summarized below.

- ✓ Coagulation promotes the interaction of small particles to form larger particles. In practice, the term refers to coagulant addition (i.e. Addition of a substance that will form the hydrolysis products that cause coagulation), particle destabilization and interparticle collisions.
- ✓ Flocculation is the physical process of producing interparticle contacts that lead to the formation of large particles.
- ✓ Sedimentation is a solid–liquid separation process, in which particles settle under the force of gravity.

Excellent reviews of these processes are available (Gregory, Zabel & Edzwald, 1999; Letterman, Amirtharajah & O’Melia, 1999). With respect to coagulation and flocculation, most bacteria and protozoa can be considered as particles, and most viruses as colloidal organic particles.

Sample	Distance from river (m)	BDOC (mg/l)	Total AOC (µg/l)	Clostridium cfu/100 ml	Bacteriophage	
					Somatic pfu/100 ml	Male-specific pfu/100 ml
Site — Terre Haute						
Wabash River	–	1.35	193	253	129	12
Collector	21–27	0.14	23	0.06	< 0.13	< 0.13
Well #3*	122	0.07	15	< 0.13	< 0.13	< 0.13
Site — Jeffersonville						
Ohio River	–	0.35	58	116	46	10
Well #9	61	0.04	32	< 0.13	< 0.13	0.2
Well #2	177	0.03	19	< 0.13	< 0.13	< 0.13
Site — Parkville						
Missouri River	–	0.33	233	132	42	5.5
Well #4	37	0.28	290	< 0.13	< 0.13	< 0.13
Well #5	37	0.25	201	< 0.13	< 0.13	< 0.13

Effects of bank infiltration

Conventional clarification

Efficiency of conventional clarification

Conventional clarification typically refers to chemical addition, rapid mixing, flocculation and sedimentation (usually in a rectangular basin). Removal of particles depends mainly on the terminal settling velocity of the particles and the rate of basin surface loading or overflow. The efficiency of the sedimentation process may be improved by using inclined plates or tubes. For conventional treatment processes, chemical coagulation is critical for effective removal of microbial pathogens. In the absence of a chemical coagulant, removal of microbes is low because sedimentation velocities are low (Medema et al., 1998). A chemical coagulant destabilizes microbial particles (e.g. By neutralizing or reducing their surface

electrical charge, enmeshing them in a floc particle or creating bridges between them) and allows particles to come into contact with one another. Flocculation of microbial particles creates aggregates with sufficient settling velocities to be removed in the sedimentation basin. When properly performed, coagulation, flocculation and sedimentation can result in 1–2 log removals of bacteria, viruses and protozoa. However, performance of full-scale, conventional clarification processes may be highly variable, depending on the degree of optimization. For example, in a report summarizing the performance of treatment plants from various countries, average microbial removals for coagulation and sedimentation ranged from 27 to 74% for viruses, 32 to 87% for bacteria (total coliforms or faecal streptococci) and 0 to 94% for algae (Gimbel & Clasen, 1998). It is difficult to interpret full-scale data for *Cryptosporidium* and *Giardia* because these protozoa are found at very low levels, and methods for their detection have limitations (Iechevallier et al., 1991).

Factors that can result in poor clarification efficiency include variable plant flow rates, improper dose of coagulant, poor process control with little monitoring, shear of formed floc, inappropriate mixing of chemicals, poor mixing and flocculation, and inadequate sludge removal (USEPA, 1991). In addition to metallic coagulants (e.g. Alum or ferric), it may be necessary to use polymeric coagulation, filter aids or both to produce low turbidity levels (< 0.1 nephelometric turbidity unit, NTU) especially for high-rate filtration (> 2.71 l/m²s). Preoxidation with chlorine or ozone can improve particle removal by sedimentation and filtration (Yates et al., 1997; Becker, O'Melia & Croker, 1998). In some cases, treatment plants are being designed with intermediate ozonation, specifically to aid in particle removal by sedimentation and filtration (Langlais, Reckhow & Brink, 1991).

Using jar tests, Bell et al. (2000) reported removal of bacteria (*E. Coli* vegetative cells and *Clostridium perfringens* spores) and protozoa (*Giardia* cysts and *Cryptosporidium* oocysts) as typically of 1–2 logs (Figure 2.3). Overall, iron-based coagulants were slightly more efficient than alum (aluminum hydroxide) or polyaluminium chloride (pacl); however, sitespecific water-quality conditions had a greater effect on removal efficiencies than did the type of coagulant. Coagulation conditions (i.e. Dose, ph, temperature, alkalinity, turbidity and the level and type of natural organic matter) affected the efficiency of removal, with slightly better overall microbial reductions under ph conditions optimal for removal of total organic carbon (i.e. Ph 5–6.5).

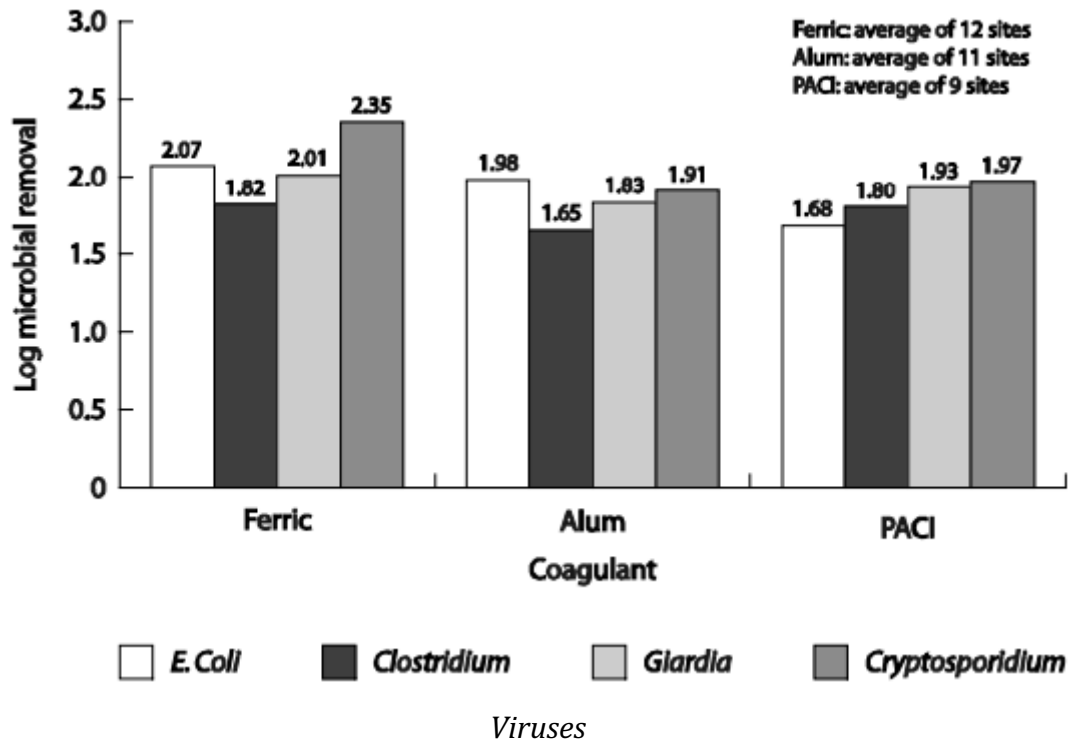
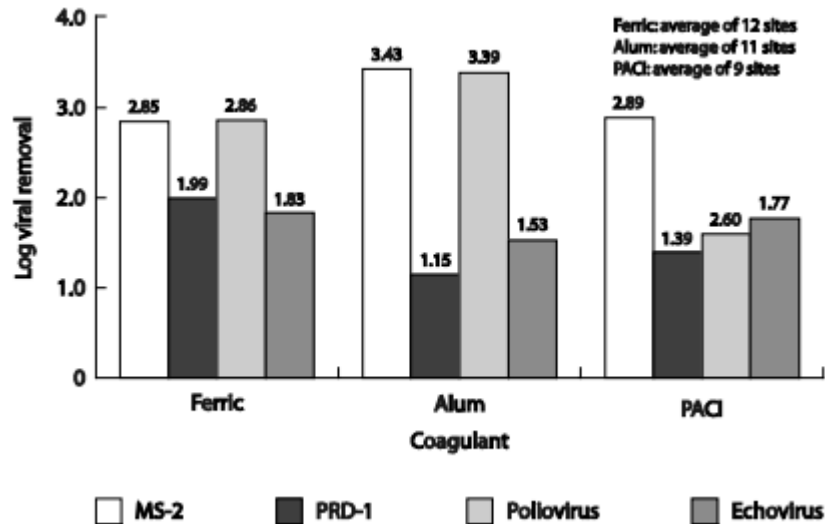


Figure 2.4 shows that different viruses may respond quite differently to coagulation conditions. For example, the bacteriophage MS2 and human enteric poliovirus are removed at a fairly high efficiency (2.6–3.4 logs), whereas the phage PRD-1 and enteric echovirus are removed at a much lower rate (1.1– 1.9 logs). The differences in virus removal are most pronounced for alum. Similar differences in virus adsorption have been observed in granulated gels (Mouillot & Netter, 1977). It is evident that the effect of coagulation differs for various viruses, and that it may be unwise to extrapolate the data on viruses to other, untested viruses.

Protozoa

Haas et al. (2000) reviewed data from four bench-scale or pilot-plant studies for coagulation, flocculation and sedimentation of *Cryptosporidium* oocysts. The authors selected data from studies where the coagulant type, coagulant dose, ph, temperature and mixing conditions were described. Using 24 data points, they found that oocyst removal depended on coagulant concentration, polymer concentration and process ph. The model had an excellent fit to the data (R^2 of 0.94); however, the fit decreased when data from other studies were added to the model. The authors concluded that additional data are needed, especially from studies that fully describe coagulation and flocculation conditions. An optimal coagulation dose is the most important factor for ensuring effective removal of cysts and oocysts by sedimentation and filtration (Logsdon et al., 1985; Al-Ani et al., 1986; Logsdon, 1990; Bellamy et al., 1993). Impaired flocculation was one of the factors in the 1987 outbreak of cryptosporidiosis in Carrollton, Georgia (USA) (Bellamy et al., 1993). In a study of eight water filtration plants, Hendricks et al. (1988) concluded: without proper chemical pretreatment *Giardia* cysts will pass the filtration process. Lack of chemical coagulation or improper coagulation was the single most important factor in the design or

operation of those rapid rate filtration plants where *Giardia* cysts were found in finished water ... with proper chemical coagulation, the finished water should be free of *Giardia* cysts, have few microscopic particles and have turbidity levels less than 0.1 NTU [nephelometric turbidity units].



Removal of viruses under optimized coagulation conditions.

Algae

Coagulation and sedimentation can be effective for removal of algae, although care must be taken to remove these organisms without disrupting the cells, as this may release liver or nerve toxins. Generally, coagulation appears not to cause the release of algal toxins, provided that oxidants are not added (Yoo et al., 1995b). Coagulation and sedimentation are not very effective at removing algal toxins; studies have shown removal levels ranging from 0 to 49%. However, addition of powdered activated carbon to the clarification process can increase removal levels to 90% or more, depending on the carbon dose, type of carbon, toxin level and organic matrix (Yoo et al., 1995b). A natural coagulant derived from shrimp shells (termed chitosan) was shown to be effective, removing more than 90% of the algae *Chlorella* and *Scenedesmus quadricuda* at neutral to alkaline pH conditions, using chitosan doses of more than 10 mg/l (Chen, Liu & Ju, 1996).

High-rate clarification

High-rate clarification was first used in the 1930s, and it grew in popularity during the 1970s and 1980s. It involves using smaller basins and higher surface loading rates than conventional clarifiers, and is therefore referred to as high rate clarification. Processes include floc-blanket sedimentation (also known as 'solids-contact clarification'), ballasted-floc sedimentation, and adsorption or contact clarification.

In floc-blanket sedimentation, a fluidized blanket increases the particle concentration, thus increasing the rate of flocculation and sedimentation. Ballasted-floc systems combine coagulation with sand, clay, magnetite or carbon to increase the particle sedimentation rate. Adsorption or contact clarification involves passing coagulated water through a bed where

particles attach to previously adsorbed material.

High-rate clarifiers can be as effective as or even more effective than conventional basins for removal of microbes. The choice of an appropriate blanket polymer is important for optimal operation (Gregory, Zabel & Edzwald, 1999). Bell, Bienlien & Lechevallier (1998) reported turbidity removals of 98% for a solids-contact, sludge blanket clarifier (raw water turbidity 20–50 NTU, settled water 0.6–0.75 NTU), 89% for internal slurry recirculation (raw water turbidity 4–10 NTU, settled water 0.5–0.9 NTU) and 61% for circular flocblanket purification unit clarification (raw water turbidity 1.2–16 NTU, settled water average 0.97 NTU). Baudin & Lainé (1998) evaluated three full-scale treatment plants and found complete removal (> 2–2.8 logs) of *Giardia* and *Cryptosporidium* by pulsator clarifiers. The units produced a 1.0–2.7 log removal of turbidity. Other investigators (Hall, Pressdee & Carrington, 1994) have reported similar efficiencies for floc-blanket clarifiers. A combination of preozonation and use of a solids-contact sludge blanket reportedly improved clarification of *Giardia* and *Cryptosporidium*-sized particles by about 1.5– 2.5 logs (Wilczak et al., 1991). Pilot plant studies of a sand ballasted-floc system showed effective removal of turbidity and particle counts (Jeschke, 1998). In addition, microscopic particulate analysis of raw and settled water showed an average 3.9-log removal of algae, and 4.5-log removal of diatoms (Jeschke, 1998). Floc formed on magnetic particles can be rapidly removed by using magnets within the sedimentation process (Gregory, Maloney & Stockley, 1988; Bolto, 1990; Anderson et al., 1993). The magnetic particles can be collected and regenerated for reuse.

Dissolved air flotation

In dissolved air flotation (DAF), bubbles are produced by reducing pressure in a water stream saturated with air. The rising bubbles attach to floc particles, causing the agglomerate to float to the surface, where the material is skimmed off (Gregory, Zabel & Edzwald, 1999). DAF can be particularly effective for removal of algal cells and *Cryptosporidium* oocysts. It is most applicable to waters with heavy algal blooms or those with low turbidity, low alkalinity and high color, which are difficult to treat by sedimentation because the floc produced has a low settling velocity.

The effectiveness of DAF for treating algal-laden, humic, coloured water is illustrated by the comments of Kiuru (1998), who indicated that the only type of treatment plants built in Finland since the mid-1960s have been DAF plants. A 1.8-log removal of the algae *Aphanizomenon* and *Microcystis* was achieved by pilot-scale DAF. Similar results (1.4–2.0 log removals) have been obtained in full-scale studies (Mouchet and Bonnelye, 1998). DAF is also effective in the removal of cell-associated algal toxins (Mouchet and Bonnelye, 1998).

Plummer, Edzwald & Kelley (1995) reported that, depending on the coagulant dose, DAF achieved 2–2.6 log removal of *Cryptosporidium* oocysts, whereas conventional sedimentation resulted in 0.6–0.8 log removal. The performance of DAF for oocyst removal depended on the pH, coagulant dose, flocculation time and recycle ratio of the saturated water stream. Other researchers have confirmed the effectiveness of DAF for oocyst removal, particularly when polyelectrolyte coagulant aids are added to help stabilize the floc

(Hall, Pressdee & Carrington, 1994).

Lime softening

Precipitative lime softening is a process in which the pH of the water is increased (usually through the addition of lime or soda ash) to precipitate high concentrations of calcium and magnesium. Typically, calcium can be reduced at pH 9.5–10.5, although magnesium requires pH 10.5–11.5. This distinction is important because the pH of lime softening can inactivate many microbes at the higher end (e.g. pH 10–11), but may have less impact at more moderate levels (e.g. pH 9.5). In precipitative lime softening, the calcium carbonate and magnesium hydroxide precipitates are removed in a clarifier before the water is filtered. The microbial impact of lime softening can, therefore, be a combination of inactivation by elevated pH and removal by settling.

Logsdon et al. (1994) evaluated the effects of lime softening on the removal and disinfection efficiency of *Giardia*, viruses and coliform bacteria. Coliform bacteria in river water (spiked with raw sewage) were inactivated by 0.1 log at pH 9.5, 1.0 log at pH 10.5 and 0.8–3.0 logs at pH 11.5 for 6 hours at 2–8°C. Bacteriophage MS2 was sensitive to lime softening conditions, demonstrating more than 4-log inactivation in the pH range of 11–11.5 within 2 hours. Hepatitis A virus was reduced by 99.8% when exposed to pH 10.5 for 6 hours. Poliovirus was the most resistant virus tested, requiring exposure to a pH level of 11 for 6 hours to achieve a 2.5-log inactivation. Reductions were less than 1 log when exposed for 6 hours to a pH of less than 11. The viability of *Giardia muris* cysts (measured by excystation) was not significantly affected by exposure to pH 11.5 for 6 hours. *Cryptosporidium* viability (measured using dye exclusion) was not affected by exposure to pH 9 for 5 hours (Robert, Campbell & Smith, 1992).

Jar tests of precipitative lime softening at pH 11.5 resulted in 4-log removal of viruses and bacteria, and 2-log removal of *Giardia* and *Cryptosporidium*, due to combined effects of removal by sedimentation and inactivation through high pH (Bell et al., 2000). Limited full-scale data suggest that 2-log removal can be achieved through sedimentation by precipitative lime softening (Logsdon et al. 1994).

In-line coagulation

In-line coagulation can be used with high-quality source waters (e.g. those where turbidity and other contaminant levels are low). The coagulants are added directly to the raw water pipeline before direct filtration. Typically, the coagulants are added before an in-line static mixer, and it is not necessary to use a basin for sedimentation. In-line coagulation permits the particle destabilization necessary for effective particle removal by filtration, but does not remove microbes by sedimentation.

ION EXCHANGE

Ion exchange is a treatment process in which a solid phase presaturant ion is exchanged for an unwanted ion in the untreated water. The process is used for water softening (removal of

calcium and magnesium), removal of some radionuclides (e.g. Radium and barium) and removal of various other contaminants (e.g. Nitrate, arsenate, chromate, selenate and dissolved organic carbon). The effectiveness of the process depends on the background water quality, and the levels of other competing ions and total dissolved solids. Although some ion exchange systems can be effective for adsorbing viruses and bacteria (Semmens, 1977), such systems are not generally considered a microbial treatment barrier, because the organisms can be released from the resin by competing ions. Also, ion exchange resins may become colonized by bacteria, which can then contaminate treated effluents (Flemming, 1987; Parsons, 2000). Backflushing and other rinsing procedures, even regeneration, will not remove all of the attached microbes. Impregnation of the resin with silver suppresses bacterial growth initially, but eventually a silver-tolerant population develops. Disinfection of ion exchange resins using 0.01% peracetic acid (1 hour contact time) has been suggested (Flemming, 1987).

FILTRATION

Various filtration processes are used in drinking-water treatment. Filtration can act as a consistent and effective barrier for microbial pathogens. Following figure shows the most commonly used filtration processes in potable water treatment, the pore size of the filter media and the sizes of different microbial particles. These size spectra are useful for understanding removal mechanisms and efficiencies, and for developing strategies to remove microbes by different filtration processes.

Identify and assess the implications of by-product formation resulting from disinfection processes.

Chemical drinking water disinfection with substances such as chlorine has been applied for more than a century. During the seventies, scientists discovered the possibility of origination of disinfection byproducts by means of gas chromatography testing. Disinfection byproducts can be harmful to human health. After this discovery, extensive research took place on the origination of disinfection byproducts, on the health effects and on procedures to prevent the formation of these products during the disinfection process.

Disinfection byproducts

Disinfection byproducts are chemical, organic and inorganic substances that can form during a reaction of a disinfectant with naturally present organic matter in the water.

How are disinfection byproducts formed?

Disinfection byproducts can form when disinfectants, such as chlorine, react with naturally present compounds in the water. The formation of these products mainly takes place during reactions in which organic substances, such as humic acid and fulvic acid, play a part. These materials end up in water during the decomposition of plant matter.

In 1971 the American scientist Bellar discovered that chloroform was absent in the Ohio

River water which was used for drinking water production. However, chloroform appeared to be present in drinking water originating from drinking water purification plants. This proves the formation of disinfection byproducts during chlorination.

Little information can be found on the chemical structures of humic acids and fulvic acids. The mechanism of formation of disinfection byproducts therefor remains unclear. Research is difficult, because of the extensive number of substances that make up organic matter.

Which factors influence the formation of disinfection byproducts?

The types of disinfection byproducts that are formed depend on a number of influential factors:

- The *type of disinfectant*
- The *disinfection dose*
- The *disinfection residue*

When the dose and residue of the disinfectant are higher, more disinfection byproducts are formed. To prevent halogenic disinfection byproducts from forming, alternative disinfectants are applied today. However, disinfection byproducts may still form.

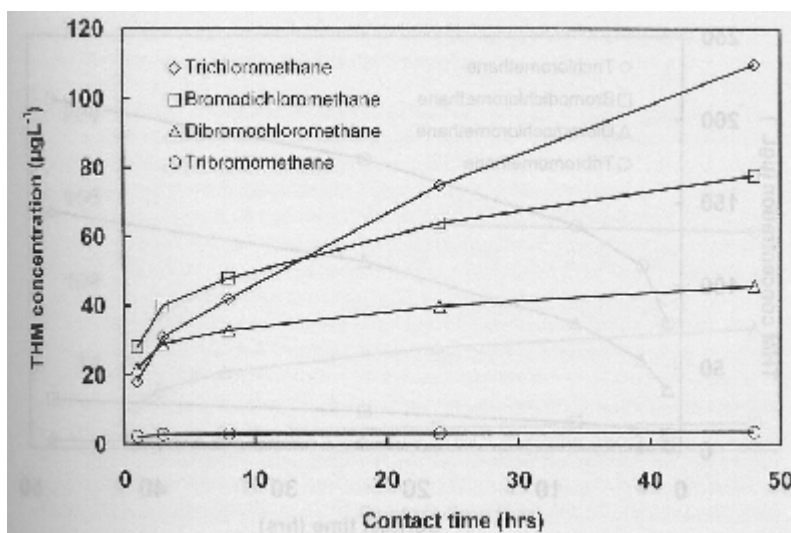
- Circumstances of disinfection: *reaction time, temperature and ph*

When the reaction time is shorter, higher concentrations of trihalomethanes (THM) and halogenic acetic acids (HAA) may be formed. When the reaction time is longer, some temporary forms of disinfection byproducts may become disinfection endproducts, such as tribromine acetic acid or bromoform. Haloacetonitrils (HAN) and halo ketons (HK) are decomposed.

When temperatures increase, reactions take place faster, causing a higher chlorine concentration to be required for a proper disinfection. This causes more halogenic disinfection byproducts to form. An increase in temperatures also enhances the decomposition of tribromine acetic acids, HAN and HK.

When ph values are high, more hypochlorite ions are formed, causing the effectivity of chlorine disinfection to decrease. At higher ph values, more THM is formed, whereas more HAA is formed when ph values are lower. At high ph values HAN and HK are decomposed by hydrolysis, because of an increase in hydrolysis reactions at higher ph values.

The levels of trihalomethanes in drinking water are often higher in the distribution network than at drinking water production companies. When hydrolysis takes place many disinfection byproducts become trihalomethanes.

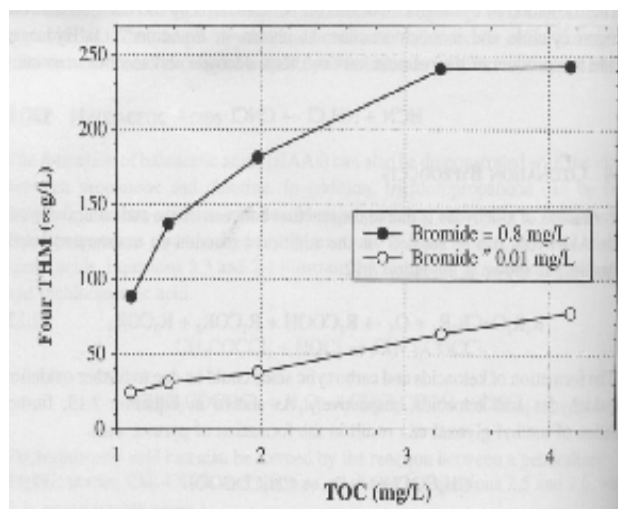


Trihalomethane formation (trichloromethane, brominedichloromethane, dibromomethane and tribromomethane), concequentially to contact time

The constituents of water

- ✓ Concentrations and properties of naturally present organic matter (NOM) in the water

NOM is the predecessor of a disinfection byproduct. The level of organic matter is usually registered as the "total organic carbon" concentration or the "dissolved organic carbon" concentration. The composition and concentration of naturally present organic matter determine the types and concentrations of disinfection byproducts that will eventually be formed. Naturally present organic matter contains compounds, such as humic acids, fulvic acids, hydrophobic acids, hydrofobic neutral substances, transfilic acids, transfilic neutral substances, hydrophilic acids and hydrophilic neutral substances.



Organic carbon concentration influencing the formation of various types of trihalomethanes at various bromine concentrations

Seasons influence the naturally present organic carbon concentration, causing the concentrations of disinfection byproducts to vary.

The concentrations of disinfection byproducts in surface water and groundwater may be different.

Disinfection byproducts of various disinfectants

Disinfectant	Organohalogenic disinfection byproducts	Inorganic disinfection byproducts	Non-halogenic disinfection byproducts
<i>Chlorine (Cl₂)/ underchloric acid (hocl)</i>	Trihalomethanes, halogenic acetic acids, haloacetonnitrils, chlorine hydrates, chloropicrin, chlorophenols, N-chloramines, halofuranones, bromohydrins	Chlorate (particularly the application of hypochlorite)	Aldehydes, alkanic acids, benzene, carboxylic acids
<i>Chlorine dioxide (clo₂)</i>		Chlorite, chlorate	Unknown
<i>Chloramines (NH₃Cl etc.)</i>	Haloacetonnitrils, cyano chlorine, organic chloramines, chloramino acids, chlorohydrates, haloketons		Aldehydes, ketons
<i>Ozone (O₃)</i>	Bromoform, monobromine acetic acid, dibromine acetic acid, dibromine acetone, cyano bromine	Nitrite, nitrate, chlorate, hydrazine	Aldehydes, ketons, ketoacids, carboxylic acids

Assess the effectiveness of various pre- or post-treatment processes for removing microorganisms, or their metabolites, causing nuisance and toxicity problem.

Pretreatment processes include application of roughing filters, micro strainers, off-stream storage, or bank infiltration, each with a particular function and water quality benefit. Filtration can be accomplished using granular media filters, slow sand, precoat filters, membranes, or other filters. Oxidants may be added to water for a variety of purposes, including control of taste and odor compounds, removal of iron and manganese, Zebra Mussel control, and particle removal, among others.

For control of microbes within the distribution system, disinfectants must interact with bacteria growing in pipeline biofilms. Models for removal of particles and microbes by granular media filtration, and equations for predicting microbial inactivation by disinfectants, can aid in the understanding and prediction of the effectiveness of treatment processes for microbial pathogens.

Water Treatment and Pathogen Control is intended to provide a critical analysis of the literature on removal and inactivation of pathogenic microbes in water to aid the water quality specialist and design engineer in making important decisions regarding microbial water quality.

Post-treatment Processes

Depending on the treated water application, the Reverse Osmosis permeate should be conditioned prior to end usage.

Desalination Reverse Osmosis permeate has a slightly acidic ph after Pass-1, a TDS of 70 to 350 mg/L, 2 to 6 mg/L of Ca+ Mg and Boron concentration between 0.5-1.2 mg/L based on the raw water salinity and temperature.

Post treatment technologies vary upon final application:

	Drinking water	Irrigation water	Process water
Sodium chloride	< 450 mg/L	SAR optimization	Minimized
Calcium, Magnesium	Hardness 6-10 ^o d		Minimized
Ph	6.5-8.5		
Boron		Crop dependent	
Sodium chloride	Required	Not required	

Drinking Water

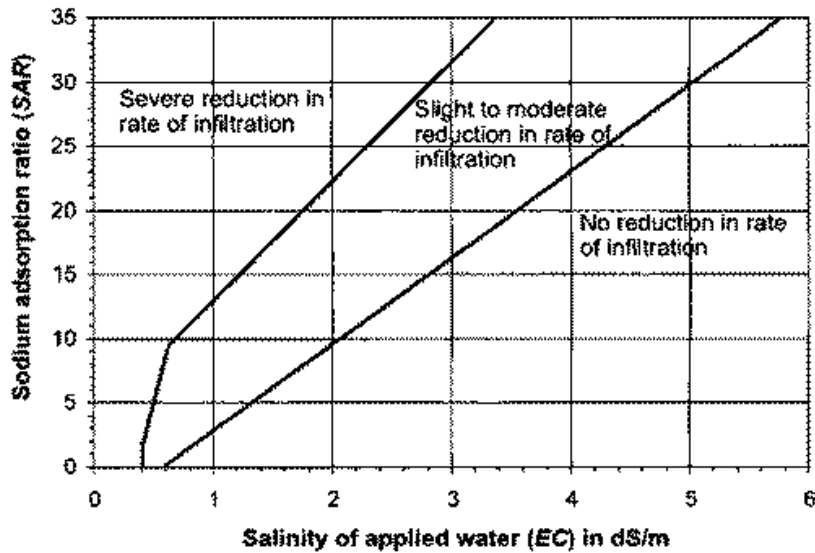
Sodium chloride and Boron can be reduced by adding a second pass RO, with either Brackish water membranes or Seawater membranes. When water passes through a second pass, residual calcium and magnesium concentration are close to zero.

Therefore 2nd-pass Ro permeate should be remineralized to achieve a residual typical hardness of 8^od (100 mg/L CaCO₃).

This solution matches well drinking water requirements in low sodium, high calcium values.

Irrigation water

Irrigation water is more complex, it relies on an equilibrium between sodium, calcium and magnesium that ensure good infiltration in the soil. This equilibrium is measured by the Sodium Adsorption ratio (SAR) and the Electrical conductivity (EC):



Boron should also be removed, as it represents a toxic poison for the plants. In order to keep a minimum EC of 0.3 ds/cm (~200 mg/L TDS), a sufficient calcium and magnesium concentration, the second-pass RO should be avoided or largely by-passed. Therefore, the ideal solution is to use a specific Boron removal ion exchange resin and then to remineralizer.

Process water

Process water is a very generic term that includes all type of water that doesn't need to comply with the WHO guidelines for drinking water. Requirements are usually up to the water consuming apparatus manufacturers guidelines, like a heat exchanger, a boiler, dilution water, etc. In heating/cooling industries, process water should usually have a low mineralization to avoid scale deposit in the pipes or chloride corrosion. For further demineralization visit our Desalination Polishing Step pages

POST TREATMENT SUMMARY

Process	Drinking water	Irrigation water	Process water
To remove Sodium chloride	2nd pass RO (BW or SW)	-	2nd pass RO (BW or SW)
To add Calcium, Magnesium	Remineralisation		-
To neutralize to ph +/-7	Naoh / hcl injection		
To remove Boron	Caustic soda injection + 2nd pass RO (BW or SW)	Specific Boron Removal IX	
To disinfect	Required	Not required	

DETERMINE APPROPRIATE WATER TREATMENT PROCESSES

Identify optimum treatment processes for the range of microorganisms found in water

Maintaining reliable treatment performance is critical for minimizing microbial risk, because health effects associated with microbial contaminants tend to be due to short-term, single dose exposure rather than long-term exposure. However, drinking-water treatment is a dynamic process and the treatment efficiency for removal or inactivation of microbial pathogens is variable. This is illustrated by an on-site survey of 100 water treatment plants across the USA, which found that the removal efficiency of particles greater than 2 μm ranged from 0.04 to 5.5 logs, with a median value of 2.8 logs (Mctigue et al., 1998). The study also found significant variation in the removal efficiencies of *Cryptosporidium* oocysts and *Giardia* cysts, although the removal of these pathogens did not necessarily correlate directly with the removal of particles.

Some process variation is normal and expected; however, too much variability can result in treatment failures, leading to waterborne disease outbreaks. It is the objective of drinking-water standards, therefore, to keep process variability within acceptable limits.

This chapter looks at the possible effects of treatment process variability, how changes in one unit process can affect the efficiency of other processes, the dynamic nature of treatment processes, the effects of changes in raw water quality and the variation that can arise from process measurements.

Effects of process variability

Treatment efficiency for removal of microbes may vary between treatment plants, between unit treatment processes and between microbes. The net result is that removal efficiency may sometimes be low. Figure 5.1 shows hypothetical log removals of a microbe by the conventional water treatment processes of coagulation and clarification, filtration and disinfection, as a cumulative frequency distribution function. An average removal of, for example, 1 log by coagulation and clarification, 2 logs by filtration and 3 logs by disinfection would result in an average removal of 6 logs for the combined processes. However, because of the variability associated with each unit process, the removal efficiency may be as low as 3.4 logs for 10% of the time.

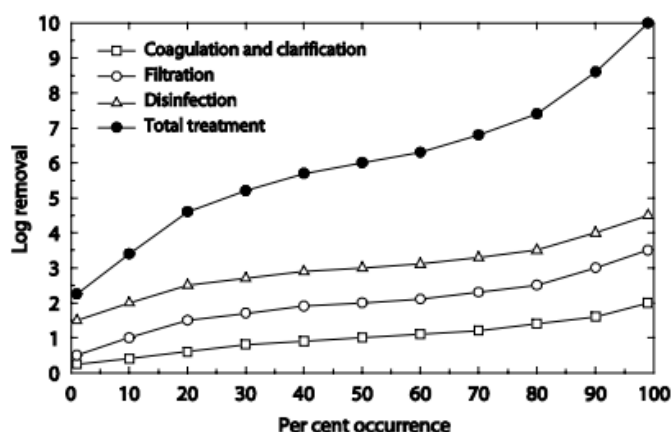
Although it may be possible to offset the reduced performance of removal processes (e.g. Coagulation and clarification, and filtration) with increased disinfection, often the failure of one process affects the performance of other processes. This is because unit processes in water treatment plants are interrelated, as described below.

Relationship between treatment processes

The performance of a treatment unit can affect the efficiency of downstream treatment units. For example, the presence of suspended solids increases the resistance of most microbes to disinfection (Lechevallier, Evans & Seidler, 1981). Therefore, a failure in the

removal efficiency of turbidity or particles by granular filtration processes can decrease the inactivation efficiency of disinfection processes. Similarly, clarification affects filter performance. Clarification removes suspended solids, thus reducing the solid loading to the filters and improving filter performance. If an incorrect dose of coagulant is used and floc is carried over from a sedimentation tank, head loss develops more rapidly, shortening the filter run.

A further example of how treatment processes are related is the effect of preoxidation on the removal of particles and microbes by granular filtration. By affecting the surface properties of particles and microbes, pre-oxidation can improve the performance of granular filters (Au et al., 2002). However, many water utilities are considering delaying or omitting the addition of oxidants such as chlorine and ozone before filtration, in an attempt to reduce the formation of disinfectant by-products. These strategies must be carefully considered because of possible adverse effects on filtration performance (Au & lechevallier, 2000). Possible impacts (either positive or negative) on other unit processes must be evaluated when considering modification of any unit process to achieve a particular microbial goal.



Hypothetical example of log removal as function of per cent occurrence.

Dynamic nature of treatment process

Variation in the efficiency of water treatment processes can be due to the dynamic nature of the processes. For example, removal efficiency of granular media high-rate filtration varies throughout a filter run, which may last from a few hours to several days. As described in Chapter 2 (Section 2.5.1), after a filter is cleaned by backwashing, it performs poorly during the ripening period, before achieving a stable level of performance, which will eventually be followed by degradation and breakthrough of microbes at the end of the run. The effect of the variable performance of an individual filter on the final quality of the filtered water can be reduced by using multiple filters. This concept is similar to that of multiple barriers, where sufficient overlap in treatment systems ensures a reliable finished water quality.

Effects of change in raw water quality

Changes in raw water quality can affect the efficiency of treatment processes. Depending on local and seasonal situations, each water treatment plant encounters different ranges of raw water quality. Data from 67 surface water treatment plants in the USA showed that the variation in particles greater than 3 μm in raw water followed a log-normal distribution pattern; particle concentrations ranged from 28/ml to 11×10^7 /ml, with a geometric mean of 22 800/ml (Arora et al., 1998). A change of any water quality parameter in the source water may affect apparent treatment efficiency, as discussed in Section 5.3. For example, in their study of 67 surface water treatment plants in the USA, Arora et al. (1998) found that the removal efficiency (based on the difference in particle concentrations between raw and filtered waters) increased with increasing particle concentration in raw water. For raw water particle concentrations from 10^3 – 25×10^3 /ml, the median removal efficiency was 2.08 logs; whereas, when concentrations increased to 10^6 – 10^7 /ml, the median removal efficiency increased to 3.2 logs. The greater removal efficiency at higher particle concentrations was due primarily to more efficient clarification. This is to be expected because removal of particles by clarification depends significantly on aggregation efficiency, which is a second-order process with respect to particle concentration (i.e. A higher particle concentration means that particles will collide more frequently and thus be more likely to aggregate).

Variability due to process measurements

With respect to removal of microbes, treatment reliability relates to the expected variation in treatment performance. Monitoring of process performance must include assessment of variability. However, uncertainties in analytical measurements may make this process more complex, particularly when few analyses are performed (Frey et al., 1998). Direct measurements of treatment performance for microbial removal may be difficult due to the time it takes to perform the analysis and the low concentrations of microbes in raw waters. Surrogate measures such as turbidity, particle counts or total coliforms may be used, but these also have limitations (Nieminski & Bellamy, 2000). These difficulties and limitations create uncertainties in estimating treatment performance, meaning that observed (apparent) treatment performance and variability may not reflect the actual (intrinsic) performance. For example, a treatment plant may show 2 logs of particle count removal, resulting in an effluent count of 10 particles/ml. If the source water particle count increases due to a storm event, so that the difference between the source water level and the treated count (which is still 10 particles/ml) is now 4 logs, without any change in treatment parameters, has treatment improved? Using the apparent measure of performance (i.e. Particle counts), the conclusion would be that it has improved. However, the apparent improvement of the performance of the treatment process was influenced by changes in the source water; the intrinsic capability of the plant to provide 4 logs of microbial protection may have been present all along!

A study by Mctigue et al. (1998) illustrates this point (Table 5.1). In pilot plant experiments, the level of *Cryptosporidium* was varied from 26 to 4610 oocysts/l. Monitoring of the plant effluent showed a consistent removal of approximately 4 logs. Turbidity and particle count data, which were limited because of relatively low levels in source water, showed an apparent removal of 1.0–1.6 logs. A plot of *Cryptosporidium* levels in raw water versus

detection of oocyst in filtered effluent suggests that breakthrough occurs at a treatment plant performance level of approximately 4–5 logs given in the following figure.

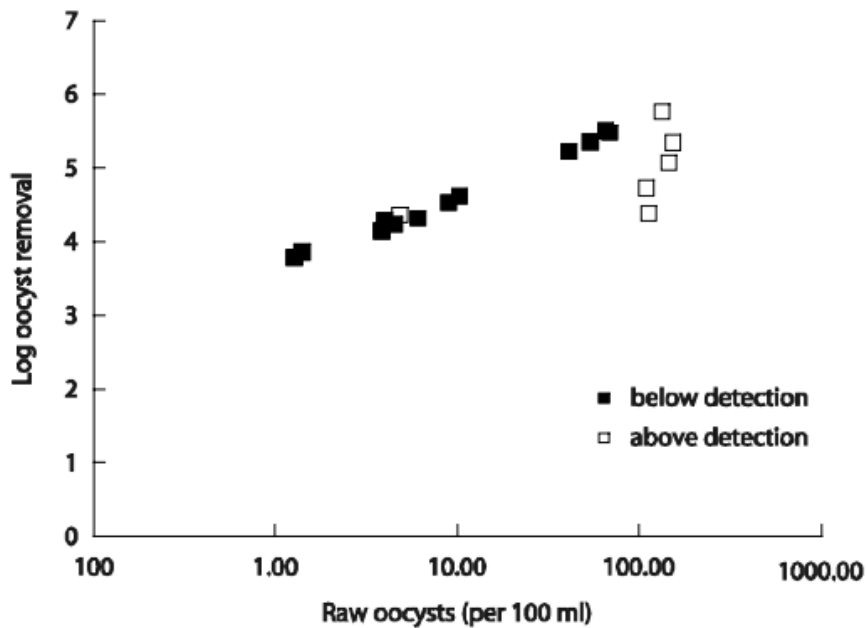


Figure 5.2 Evaluation of a pilot treatment plant performance for removal of *Cryptosporidium* oocysts. Data demonstrate performance of 4–5 log removal. Source: D Cornwell, personal communication (2001).

Table 5.1 Impact of source water concentration on apparent treatment performance (results of three trials)

Oocysts/l			Turbidity (NTU)			Particles > 3 µm/ml		
Raw	Effluent	Log removal	Raw	Effluent	Log removal	Raw	Effluent	Log removal
26	0.0017	4.2	2.5	0.07	1.6	7000	350	1.3
688	0.041	4.2	2.0	0.07	1.5	7700	530	1.2
4610	0.214	4.3	1.3	0.07	1.3	4700	480	1.0

NTU = nephelometric turbidity unit
Source: McTigue et al. (1998)

Report on effective treatment processes and associated sampling and testing requirements required to maintain water quality.

Interpreting a Bacteriological Test

All water has some form of bacteria in it. The presence of bacteria does not mean the water is unsafe to drink. Only disease-causing bacteria known as pathogens lead to disease. Your test results should

include total coliform bacteria. Total coliform bacteria are a group of several kinds of bacteria commonly found in the environment, including soil, vegetation and untreated surface water. They also are found in the intestinal tract of warm-blooded animals, including humans.

A laboratory commonly will report the bacteriological test as positive or negative, indicating the presence or absence of total coliform bacteria. A negative total coliform bacteria result means the water is safe for human consumption from a bacteriological standpoint.

A positive total coliform test would indicate unsanitary conditions and the possible presence of disease-causing organisms. Further testing should include the subgroup fecal coliform and its subgroup, *Escherichia coli* (*E. Coli*). A positive fecal coliform would indicate possible recent sewage or animal waste contamination.

E. coli outbreaks related to food contamination have received media attention. These outbreaks are caused by a specific strain of *E. Coli* known as *E. Coli* 0157:H7. A positive *E. Coli* result does not necessarily mean this specific strain is present. However, it does indicate recent fecal contamination, which should be interpreted as an indication of a greater risk that pathogens are present.

Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches or other symptoms. These pathogens may pose a special health risk for infants, young children and people with severely compromised immune systems.

Shock chlorination should be performed on a well that reports a positive *E. coli* or fecal coliform test. Repeat the bacteria test within seven days to confirm the effectiveness of the chlorination.

Interpreting a Mineral Analysis

Alkalinity

Alkalinity is a measure of the capacity of water to neutralize acids. The predominant chemicals present in natural waters are carbonates, bicarbonates and hydroxides. The bicarbonate ion is usually prevalent. However, the ratio of these ions is a function of pH, mineral composition, temperature and ionic strength. Water may have a low alkalinity rating but a relatively high pH or vice versa, so alkalinity alone is not of major importance as a measure of water quality.

Alkalinity is not considered detrimental to humans but generally is associated with high pH values, hardness and excessive dissolved solids. High-alkalinity waters also may have a distinctly flat, unpleasant taste. Treatment is an ion exchange via the addition of a tank media or reverse osmosis.

Arsenic

Arsenic is a semimetallic element that is odorless and tasteless. It enters drinking water supplies from natural deposits in the earth, or from agricultural and industrial practices.

According to the EPA, long-term exposure to arsenic in drinking water is linked to cancer of the bladder, lungs, skin, kidneys, nasal passages, liver and prostate. Noncancerous effects of ingesting arsenic include cardiovascular, pulmonary, immunological, neurological and endocrinal (for example, diabetes) problems.

Treatment depends on the level of contamination. Typical recommendations include the addition of an anion filter or tank media.

Calcium and Magnesium

Calcium and magnesium are the main contributors to water hardness. When water is heated, calcium breaks down and precipitates out of the solution, forming scale. Maximum limits have not

been established for calcium. Magnesium concentrations greater than 125 mg/l may have a laxative effect on some people. Treatment for calcium is softening (tank media) and reverse osmosis. Magnesium levels can be controlled through distillation.

Chloride

High concentrations of chloride ions can cause water to have an objectionable salty taste and corrode hot-water plumbing systems. High-chloride waters have a laxative effect for some people. An upper limit of 250 mg/l has been set for chloride ions, although noticing the taste at this level is difficult, and even higher concentrations do not appear to cause adverse health effects. An increase in the normal chloride content of water may indicate possible pollution from human sewage, animal manure or industrial wastes.

Color

Color may indicate dissolved organic material, inadequate treatment and high disinfectant demand, and may indicate the potential for the production of excessive amounts of disinfectant byproducts. Inorganic contaminants, such as metals, are also common causes of color. In general, the point of consumer complaint is variable, ranging from 5 to 30 color units, although most people find color objectionable in excess of 10 color units. Other contaminants that may be related to change in water color include aluminum, copper, foaming agents, iron, manganese and total dissolved solids. Treatment is reverse osmosis.

Conductivity

Conductivity is a measure of the conductance of an electric current in water. This is an easy measurement to make and relates closely to the total dissolved solids (mineral) content of water. The maximum contaminant level (MCL) is 0.4 to 0.85 micro Siemens per centimeter. Treatment with reverse osmosis is effective for drinking water purposes.

Fluoride

Fluoride concentrations of 0.7 to 1.2 mg/l in drinking water will protect against dental cavities. However, excessive levels (more than 1.5 mg/l) may cause discoloration, or mottling of the teeth. This occurs only in developing teeth before they push through. Elevated fluoride levels also may cause skeletal damage and bone disease. Because low levels of fluoride are common in groundwater, most municipalities add fluoride to the water.

Iron and Manganese

Iron in concentrations greater than 0.3 mg/l and manganese in concentrations greater than 0.05 mg/l may cause brown and black stains on laundry, plumbing fixtures and sinks. A metallic taste also may be present, and it may affect the taste of beverages made from the water. High concentrations of iron and manganese do not appear to present a health hazard. Treatment includes a water softener or iron filter for iron and reverse osmosis for manganese.

Nitrates

The results reported for nitrates can be confusing because they may be reported as nitrogen (N) or nitrate-nitrogen or as nitrate (NO₃). The following are the maximum levels for each:

- ✓ Nitrogen (N) or nitrate-nitrogen (NO₃-N) should not be higher than 10mg/L.
- ✓ Nitrate (NO₃) should not be higher than 45mg/L.

High nitrate levels may cause methemoglobinemia (infant cyanosis or “blue baby disease”) in infants who drink water or formula made from water containing nitrate levels higher than recommended.

Adults can drink water with considerably higher concentrations than infants without adverse effects. Treatment of such water includes anionic ion exchange, reverse osmosis, distillation and/or deionization.

Ph

The ph of water is a measure of acidity or alkalinity. The ph is a logarithmic scale based on a measure of the free hydrogen ions in the water. The scale runs from 0 to 14, where 7 is considered neutral, 0 to 7 is acidic and 7 to 14 is alkaline. Because ph can be affected by dissolved minerals and chemicals, it is an important indicator of the change in water chemistry.

According to the U.S. Environmental Protection Agency, drinking water with a ph between 6.0 and 9.5 generally is considered satisfactory. Several public water supplies that use the Missouri, James or Red River as their source of water have to maintain the ph above 9 keep them in compliance with the Lead and Copper rule of the Safe Drinking Water Act, which details how to prevent leaching of these elements from piping systems.

Water with a ph below 6 or above 9.5 can be corrosive to metal plumbing pipes and fixtures. The ph of water can affect the performance of pesticides, particularly herbicides.

Potassium

Potassium concentrations in water are generally very small. Although excessive amounts may have a laxative effect, the EPA has not established a maximum limit. Potassium (chloride) is used as a replacement for salt in water softeners when dietary sodium intake is a health issue.

Sodium

Sodium is a very active metal that does not occur naturally in a free state. It always is combined with other substances. In the human body, sodium helps maintain the water balance. Human intake of sodium is mainly influenced by the consumption of sodium as sodium chloride or table salt. The contribution of drinking water is normally small, compared with other sources.

The treatment for certain heart conditions, circulatory or kidney diseases, or cirrhosis of the liver may include sodium restriction. Diets for these people should be designed with the sodium content of their drinking water taken into account.

The National Academy of Sciences has suggested a standard for public water allowing no more than 100 mg/l of sodium. This would ensure that the water supply adds no more than 10 percent of the average person’s total sodium intake.

The American Health Association recommends a more conservative standard of 20 mg/l to protect heart and kidney patients.

Softening by ion exchange or lime-soda ash increases the sodium content approximately 8 mg/l for each gr/gal (grain per gallon) of hardness removed. Treatment includes the use of potassium chloride instead of sodium chloride softener pellets (softener salt) or, alternatively, restricting drinking water from this source.

Sulfates

Water containing high levels of sulfates, particularly magnesium sulfate (Epson salts) and sodium sulfates (Glauber’s salt) may have a laxative effect on people unaccustomed to the water. These

effects vary among individuals and appear to last only until they become accustomed to using the water. High sulfate content also affects the taste of water and forms a hard scale in boilers and heat exchangers. The upper limit recommended for sulfates is 250 mg/l. Treatment includes reverse osmosis.

Total Dissolved Solids (TDS)

High concentrations of TDS may affect taste adversely and deteriorate plumbing and appliances. The EPA recommends that water containing more than 500 mg/l of dissolved solids not be used if other less mineralized supplies are available. However, water containing more than 500 mg/l of TDS is not dangerous to drink. Exclusive of most treated public water supplies, the Missouri River, a few freshwater lakes and scattered wells, very few water supplies in North Dakota contain less than the recommended 500mg/L concentration of total dissolved solids. Many households in the state use drinking water supplies with concentrations up to 2,000 mg/l and greater. Treatment for household use is reverse osmosis.

Total Hardness

Hardness is the property that makes water form an insoluble curd with soap and primarily is due to the presence of calcium and magnesium. Very hard waters have no known adverse health effects and may be more palatable than soft waters. Hard water is primarily of concern because it requires more soap for effective cleaning; forms scum and curd; causes yellowing of fabrics; toughens vegetables cooked in the water; and forms scale in boilers, water heaters, pipes and cooking utensils. The hardness of high-quality water should not exceed 270 mg/l (15.5 grains per gallon) measured as calcium carbonate. Water softer than 30 to 50 mg/l may be corrosive to piping, depending on pH, alkalinity and dissolved oxygen. Water softeners will correct hard water of more than 270 mg/l.

Turbidity

Turbidity is a measure of suspended minerals, bacteria, plankton, and dissolved organic and inorganic substances. Turbidity often is associated with surface water sources. Treatment includes mixing with a substance such as alum that causes coagulation of the suspended materials, which then can be removed by sand filter filtration.

**8. PERFORM CALIBRATION CHECKS ON EQUIPMENT AND ASSIST WITH
MAINTENANCE**

PERFORM SETUP AND PRE-USE CHECKS OF LABORATORY EQUIPMENT

Perform laboratory equipment setup and pre-use checks in accordance with enterprise procedures

Selecting equipment

Selecting the best instrument for the laboratory is a very important part of equipment management. Some criteria to consider when selecting laboratory equipment are listed below.

- ✓ Why and how will the equipment be used? The instrument should be matched against the service the laboratory provides.
- ✓ What are the performance characteristics of the instrument? Is it sufficiently accurate and reproducible to suit the needs of the testing to be done?
- ✓ What are the facility requirements, including the requirements for physical space?
- ✓ Will the cost of the equipment be within the laboratory's budget?
- ✓ Will reagents be readily available?
- ✓ Will reagents be provided free of charge for a limited period of time? If so, for how long?
- ✓ How easy will it be for staff to operate?
- ✓ Will instructions be available in a language that is understood?
- ✓ Is there a retailer for the equipment in the country, with available services?
- ✓ Does the equipment have a warranty?
- ✓ Are there any safety issues to consider?

If the decisions about purchasing are made outside the laboratory, for example by a central purchasing body, the laboratory manager should provide information that will support selecting equipment that will best serve the needs of the laboratory. In areas where there are national programs for purchasing.

Standard equipment, the laboratories of the country should have some input to decisions. In addition, in areas where donors are likely to provide some of the equipment that is used, laboratory management should have input into choice of equipment. If this is not possible, management should consider declining equipment, if inappropriate for laboratory needs.

Acquiring equipment

Is it better to purchase, rent or lease equipment? When making this decision, it is a good idea to factor in repair costs. The initial cost of an instrument may seem reasonable, but it may be expensive to repair. Also consider savings that could be negotiated if the laboratory needs more than one piece of equipment.

The manufacturer should provide all of the necessary information to operate and maintain equipment.

Before purchasing ask if:

- ✓ Wiring diagrams, computer software information, a list of parts needed, and an operator's manual are provided;
- ✓ The manufacturer will install the equipment and train staff (covering travel expenses as necessary) as part of the purchase price;
- ✓ The warranty includes a trial period to verify that the instrument performs as expected;
- ✓ The manufacturer's maintenance can be included in the contract and if so,
- ✓ Whether maintenance is provided on a regular basis.

Determine if the laboratory can provide all the necessary physical requirements, such as electricity, water, and space. There must be adequate room to move the equipment into the laboratory; consider door openings and elevator access.

Perform safety checks in accordance with relevant enterprise and instrumental procedures

Installing equipment

Before equipment is installed, verify that all physical requirements (electrical, space, doors, ventilation, and water supply) have been met. Other things to consider are:

- ✓ The vendor's responsibilities for installation should be confirmed in writing prior to beginning the installation process.
- ✓ A checklist of the expected performance specifications should be developed, so that performance can be quickly verified as soon as the equipment is installed.

Whenever possible, it is best to have the manufacturer install laboratory equipment; this will likely improve the conditions of the warranty, and also may ensure that the installation is done properly and quickly.

If equipment is installed by the laboratory:

- ✓ Check that the package contents contain all of the parts;
- ✓ Make a copy of any software that is part of the system;
- ✓ Do not allow the equipment to be used before it is completely installed, performance is verified, and testing personnel are trained.

Identify faulty or unsafe components and equipment and report to appropriate personnel

If you have concerns about a product due to its design, construction or the manner of supply, you should report the matter to the appropriate market surveillance authority (MSA). The manufacture and supply of most equipment used at work

However, before you report a defective product, it will help in processing and investigating

your concerns if you can also provide the following information:

- ✓ Reasons you consider the product to be defective
- ✓ Details of any injuries or harm resulting from the defect
- ✓ A description of the defect with, where relevant, measurements (such as gaps in safeguards and the distance through such gaps to parts giving rise to danger)
- ✓ Photographs of the product and the defect, if available
- ✓ Details of the markings / information on the product or accompanying documentation (eg type, serial number, date of manufacture, CE or other conformity markings)
- ✓ Full contact details of the manufacturer, any supplier(s) and date of supply
- ✓ A copy of the Declaration of Conformity (or Declaration of Incorporation)
- ✓ Extracts from the user instructions which deal with health and safety
- ✓ Details of the markings / information on the product or accompanying documentation

Complete instrument log books/records to meet enterprise requirements

Record the following details of each piece of equipment:

- ✓ Identity
The name of the piece of equipment, including its type/model where applicable
- ✓ Label
Make this yourself: use a logical label that includes the abbreviated name of the laboratory (to indicate that the equipment is owned by the laboratory) and a unique code for the piece of equipment
- ✓ Serial number
This is a number provided by the manufacturer
- ✓ Manufacturer name
- ✓ Manufacturer's contact person and contact details
- ✓ Date of purchasing
- ✓ Date of putting into service
- ✓ Location
E.g. Room number and, if applicable the building number
- ✓ Condition
E.g. "Functioning properly"/ "In need of calibration"/ "In need of maintenance"/ "Defect"
- ✓ Service provider name
- ✓ Service provider's contact person and contact details
- ✓ Frequency of maintenance
How often per year is maintenance and calibration needed?
- ✓ Date of previous maintenance
- ✓ Date of next scheduled maintenance
- ✓ Remarks
Additional information, if needed.

PERFORM CALIBRATION CHECKS

Startup equipment according to operating procedures

After equipment has been installed, the following details need to be addressed before putting the equipment into service:

- ✓ Assign responsibility for performing the maintenance and operation programs;
- ✓ Develop a system for recording the use of parts and supplies;
- ✓ Implement a written plan for calibration, performance verification, and proper operation of the equipment;
- ✓ Establish a scheduled maintenance program that includes daily, weekly, and monthly maintenance tasks;
- ✓ Provide training for all operators; only personnel who have been trained specifically to properly use the equipment should be authorized as operators.
- ✓ Designate those authorized to use the equipment and when it is to be used.

Use specified standards for calibration check

Follow the manufacturer's directions carefully when performing the initial calibration of the instrument. It is a good idea to calibrate the instrument with each test run, when first putting it into service. Determine how often the instrument will need to be recalibrated, based on its stability and on manufacturer's recommendation. It may be advantageous to use calibrators provided by or purchased from the manufacturer.

Check equipment as per calibration procedures and schedules

Prior to testing specimens, it is important to evaluate the performance of new equipment to ensure it is working correctly with respect to accuracy and precision. In addition, test methods using kits or laboratory instruments need to be evaluated for the ability to detect disease (sensitivity, specificity, positive and negative predictive value), and to determine normal and reportable ranges.

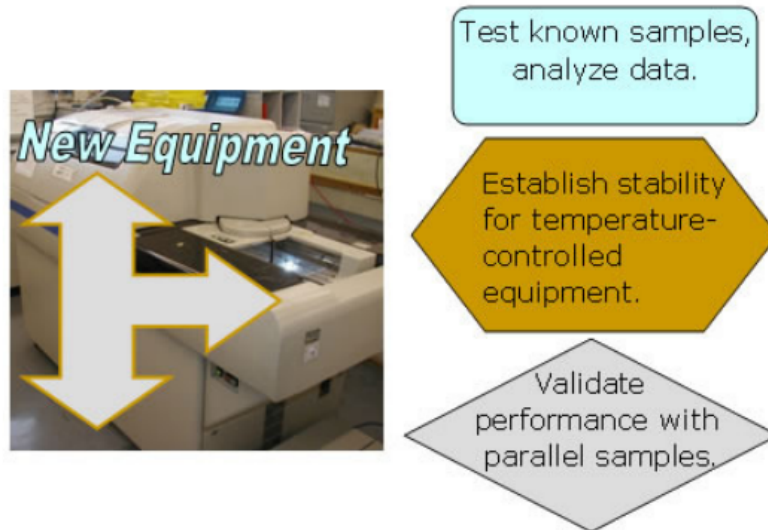
Record all calibration data accurately and legibly

Verification of manufacturers' performance claims—Manufacturers provide performance evaluations for testing methods using their kits or instruments, and include the information in the package inserts or operators' manuals. However, laboratories need to verify the manufacturers' performance claims, and demonstrate they can get the same results using the kits or equipment in their laboratory, with their personnel.

Some of the steps that should be followed to verify performance include:

- ✓ Testing samples with known values and comparing the results to the expected or certified value;

- ✓ If equipment is temperature controlled, establishing the stability and uniformity of the temperature.



Compare data with specifications and/or previous records to identify non-compliant equipment

Validation of new equipment and associated techniques— If the equipment and/or associated techniques are new, validation processes will be important. This can be carried out by running samples in parallel on both previous and new equipment/methods for a period of time to determine that the expected results can be obtained. These validation procedures should be completely recorded.

Function checks

In order to verify that equipment is working according to the manufacturer's specifications, it is necessary to monitor instrument parameters by performing periodic function checks. This should be done before using the instrument initially, then with the frequency recommended by the manufacturer. These function checks should also be done following any instrument repairs. Some examples of function checks are daily monitoring of temperatures and checking the accuracy of wavelength calibration.

ASSIST WITH EQUIPMENT MAINTENANCE

Ensure all equipment work areas are clean during and after equipment use and perform basic maintenance in accordance with enterprise procedures

Preventive maintenance

Preventive maintenance includes measures such as systematic and routine cleaning, adjustment, and replacement of equipment parts at scheduled intervals. Manufacturers generally recommend a set of equipment maintenance tasks that should be performed at regular intervals: daily, weekly, monthly, or yearly. Following these recommendations will ensure that the equipment performs at maximum efficiency and will increase the lifespan of the equipment. This will also help to prevent:

- ✓ Inaccurate test results due to equipment failure
- ✓ Delays in reporting results
- ✓ Lower productivity
- ✓ Large repair costs.

Maintenance plan

A maintenance plan will include preventive maintenance procedures as well as provision for inventory, troubleshooting, and repair of equipment. When implementing an equipment maintenance program, some of the initial steps will include what follows.

- ✓ Assign responsibility for providing oversight.
- ✓ Develop written policies and procedures for maintaining equipment, including routine maintenance plans for each piece of equipment. The plan should specify the frequency with which all maintenance tasks should be performed.
- ✓ Develop the format for records, create logs and forms, and establish the processes to maintain records.
- ✓ Train staff on the use and maintenance of the equipment, and assure that all staff understand their specific responsibilities.

It is recommended that a label be attached to the instrument indicating when the next maintenance or service should be performed.

The laboratory should keep an inventory log of all equipment in the laboratory. The log should be updated with information on new equipment, as it is added, and include documentation of when old equipment is retired.

For each piece of equipment, the equipment inventory log should have a record of:

- ✓ Instrument type, make and model number, and serial number of the instrument, so that any problems can be discussed with the manufacturer;
- ✓ Date the equipment was purchased, and whether it was purchased new, used, or reconditioned;
- ✓ Manufacturer/vendor contact information;
- ✓ Presence or absence of documentation, spare parts, and maintenance contract;
- ✓ Warranty's expiration date;
- ✓ Specific inventory number indicating the year of acquisition; this is especially useful for larger laboratories. For example, use the style "YY-number" (04- 001, 04-002, etc.) Where "YY-number" equals the last two numbers of the year followed by a number attributed in the year.

An inventory process must be conducted if the laboratory does not have an Existing inventory system for equipment.

- ✓ This could be conveniently organized following a model grid room by room, for example, reception, sampling, serology, and parasitology.
- ✓ During the inventory, the condition of the equipment should be documented as:
- ✓ Functional

- ✓ Partially functional, or
- ✓ Non-functional. Equipment that is not functioning needs to be evaluated as to whether or not it can be repaired. Non-repairable equipment should be retired, and work should be scheduled for equipment needing repair.

Inventory of spare parts

To ensure that the laboratory does not run out of spare parts, an inventory record of those used most frequently should be kept for each piece of equipment. The record should include:

- ✓ Part name and number;
- ✓ Average use of the part, and the minimum to keep on hand;
- ✓ Cost;
- ✓ Date when the part is placed into storage, and when it is used (in and out stock log);
- ✓ Quantity of each part remaining in inventory.

Clean and store equipment according to enterprise and/or manufacturer's specifications/procedures

Identify and replace, repair or dispose of damaged/worn equipment as appropriate

What is the source of the problem?

Problems with equipment may present in many ways. The operator may notice subtle changes such as drift in quality control or calibrator values or obvious flaws in equipment function. Sometimes, the equipment fails to operate. It is important to teach operators to troubleshoot equipment problems in order to quickly get the equipment functioning and resume testing as rapidly as possible. When an operator observes instrument drift, it is important to repeat the preventive maintenance procedures as a first step to resolve the problem. If this does not work, proceed with troubleshooting processes.

Troubleshooting

Manufacturers frequently provide a flowchart that can help determine the source of problems. Some of the questions to consider are listed below.

- ✓ Is the problem related to a poor sample? Has the sample been collected and stored properly? Are factors such as turbidity or coagulation affecting instrument performance?
- ✓ Is there a problem with the reagents? Have they been stored properly, and are they still in date? Have new lot numbers been introduced without updating instrument calibration?
- ✓ Is there a problem with the water or electrical supply?
- ✓ Is there a problem with the equipment?

Make one change at a time based on symptoms. If equipment is the problem, review the

manufacturer's instructions to verify that all procedures are being followed correctly.

When problems cannot be corrected

If problems cannot be identified and corrected in-house, attempt to find a way to continue testing until the equipment can be repaired. Some ways to achieve this are as follows.

- ✓ Arrange to have access to back-up instruments. It is often too costly for the laboratory to have its own back-up instruments, but sometimes a central stores agency can maintain back-up instruments to be shared throughout the local area or country.
- ✓ Ask the manufacturer to provide a replacement instrument during repairs.
- ✓ Send the samples to a nearby laboratory for testing.

Be sure to notify the appropriate providers that there are problems and that there will probably be delays in completing the testing.

Do NOT use faulty equipment! Seek help from the manufacturer or other technical expert. Place a note on the equipment so all staff are aware that it is not in use.



Service and repair

Manufacturers may provide service and repair of equipment that is purchased from them. Be sure to set up a procedure for scheduling service that must be periodically performed by the manufacturer. When instruments need repair, remember that some warranties require that repairs be handled only by the manufacturer.

Large facilities sometimes have biomedical service technicians in-house who perform equipment maintenance and repair.

Routine service should be scheduled so as not to interrupt the flow of work.

Retiring and disposing of equipment

It is very important to have a policy and procedures for retiring older laboratory equipment. This will usually occur when it is clear that the instrument is not functioning and is not repairable, or when it is outmoded and should be replaced with new equipment.

Once a piece of equipment is fully retired and it has been determined that it has no further usefulness, it should be disposed of in an appropriate manner. This last step is often neglected in laboratories, and old equipment accumulates, taking up valuable space and sometimes creating a hazard.



When disposing of equipment, salvage any useable parts, particularly if the equipment is being replaced with another similar one. Then consider any potential biohazards, and follow all safety disposal procedures.

MAINTAIN RECORDS

Record and report information on unsafe or faulty equipment according to enterprise procedures

Developing documents and policies for recordkeeping

Equipment documents and records are an essential part of the quality system. The policies and procedures for maintenance should be defined in appropriate documents, and keeping good equipment records will allow for thorough evaluation of any problems that arise. (Module 16: Documents and Records)

Each major piece of equipment will have its own equipment maintenance document. Smaller, commonly used equipment such as centrifuges and pipettes may be managed with an equipment maintenance document or manual that deals with all such equipment in the laboratory.

An equipment maintenance document should include:

- ✓ Step-by-step instructions for routine maintenance, including frequency of performance, and how to keep records of performance;
- ✓ Instructions for carrying out function checks, frequency of performance, and how to record the results;
- ✓ Directions for calibrating the instrument;
- ✓ Guide for troubleshooting;
- ✓ Any required manufacturer's service and repair;
- ✓ List of any specific items needed for use and maintenance, such as spare parts.
- ✓ For major equipment, include identification of the specific instrument, and perhaps information on its performance.

Recording maintenance information

Each piece of equipment should have a dedicated logbook documenting all characteristics and maintenance elements:

- ✓ Preventive maintenance activities and schedule;
- ✓ Recording of function checks and calibration;
- ✓ Any maintenance performed by the manufacturer;
- ✓ Full information on any problem that the instrument develops, the subsequent troubleshooting activity, and follow-up information regarding resolution of the problem. In recording problems, be sure to record:
 - ✓ Date problem occurred, and when equipment was removed from service;
 - ✓ Reason for breakdown or failure;
 - ✓ Corrective action taken; including a note about any service provided by the manufacturer;
 - ✓ Date returned to use;
 - ✓ Any changes to procedure for maintenance or function checks as a result of the problem.



Some of the tools that are helpful for keeping records on equipment management are:

- ✓ Charts
- ✓ Logs
- ✓ Checklists
- ✓ Graphs
- ✓ Service reports.

UNIT 09

APPLY QUALITY SYSTEM IN LABORATORY

9. APPLY QUALITY SYSTEM IN LABORATORY

SATISFY QUALITY REQUIREMENTS IN DAILY WORK

Access information on quality system requirements for own job function

Quality

Quality is a term that is often used inaccurately. The term can cause confusion because it has TWO related but different meanings:

- ✓ High grade, superior excellence
- ✓ A characteristic, property or attribute. (The Macquarie Dictionary)

It is the second meaning of quality that is used in the context of business, manufacturing, and commerce, or in this case, laboratory testing. Note that this second meaning does not specify whether the quality is high or low.

We do not always strive for the best product, service or result, instead we strive for the one that best suits our purpose. Similarly, we always strive for consistency of product. For instance, a haemoglobin measurement in blood is only required to one decimal place and therefore we strive for accuracy to one decimal point even when it is possible to attain greater accuracy. Attempting to measure haemoglobin to four decimal places would be more expensive and wasteful of time and resources.

Joseph M. Juran (one of the founders of quality management) summed up quality in the phrase:

'Fitness for purpose'

W. Edwards Deming (another founder) said: *"Good quality does not necessarily mean high quality. It means a predictable degree of uniformity and dependability at a low cost with quality suited to the market."*

And Armand V. Feigenbaum said: *"Quality is whatever the customer says it is."*

Quality System

A quality system is formally described as 'the organisational structure, responsibilities, procedures, processes and resources for implementing the management of quality'. Said in a simpler way, a quality system concerns the way an enterprise goes about running its business to achieve its goals (effectively or otherwise!). The quality system would usually be documented and is often based around a quality manual that defines and embodies the system.

Many manufacturing and service enterprises have their quality systems certified against a recognised quality management standard, commonly one of the international ISO 9000 standards. Such standards lay down generic elements of good business practice that the

enterprise must implement and follow in order to gain certification.

It is often the case today that organisations are required to be certified against a particular standard for contractual or regulatory reasons. Meat processing companies and nursing homes, for instance, must comply with government-imposed standards in order to demonstrate that the processors produce food that is safe to eat and that the homes provide a caring environment for elderly people.

Having a certified quality system can inspire credibility in the eyes of customers and suppliers as well as helping the organisation to run more efficiently. However, it should be said that a quality system does not need to be certified for it to work well.



Independent bodies are specifically accredited to grant certification. Certification occurs after a thorough assessment or audit of the organisation's quality system and operations. Regular follow-up audits are necessary to demonstrate on-going compliance, otherwise certification may be withdrawn.

Record and report quality control data in accordance with quality system

A very important part of quality system is quality control. We shall now concentrate on this topic.

Quality Control (QC) is defined as being 'the operational techniques and activities that are used to fulfil the requirements for quality'. In effect, these operational techniques and activities mean:

- ✓ Checking a process at appropriate stages to ensure it stays within defined limits (ie to produce the 'right' quality product)
- ✓ Eliminating the causes of any unsatisfactory performance (ie reducing the rework and waste that otherwise cost companies money)
- ✓ Removing or repairing any defective products before they get to the customer.

As this definition implies, QC is not a method of improvement of the quality of products, but rather a method of maintaining a consistent level of quality.

What does QC mean for a laboratory organization where the 'product' is the analytical data that reports to its customers? What are the QC activities that inform the analyst that the analytical process is operating within its defined limits (ie that the product is meeting quality standards or more simply, are the results valid)? The QC activities for laboratories involve more than simply examining the end results of analysis. QC activities for Lab involve

checks that are performed at various stages of the laboratory processes. These include activities such as:

- ✓ Replicate analysis (checks for consistency)
- ✓ Standards analysis (correctness)
- ✓ Alternative methods (method validity)
- ✓ Control charts (abnormal trends)
- ✓ Comparison with other laboratories (independent cross-check).

The data generated from such QC checks is important and must be recorded, reported and stored for possible later reference during audits or if a query arises. This is a requirement of simulab's quality system.

Monitoring the validity of test results is a requirement of the laboratory standard, ISO 17025, and one that simulab must follow if it is to have confidence in the results it provides to its customers.

Document Control

1. The following constitute controlled documents used at simulab:
 - ✓ All policies and procedures contained in the Quality Manual plus the Table of Contents and Amendment Record.
 - ✓ Standard Operating Procedures (sops) and other relevant documents in the Methods Manual, OHS Manual and Staff Manual.
2. Each page of these documents shall contain the following information:
 - ✓ Simulab logo
 - ✓ Controlled document name or number
 - ✓ Version number
 - ✓ Date of version.
3. Amendments to controlled documents shall be made as follows:
 - ✓ Only the Quality Officer, Laboratory Supervisor or delegated senior staff are authorized to make amendments
 - ✓ NO amendment is to be written onto a page
 - ✓ Each amendment will result in the re-issue of the pages involved
 - ✓ All copies of the document shall be amended at the one time
 - ✓ A copy of amendments to manuals is to be recorded in the Amendment Record
 - ✓ All superseded copies of controlled documents are kept in the History File.
4. Working documents such as Laboratory Test Sheets shall not be controlled documents but will use a standardized design.

Data Control

The control of results (both raw and final) and data is vital to the operations of simulab. All results and data will be collated and stored as follows:

QC Data

Where an automated interface exists between an analyzer and a computer, the QC data is to be stored on the hard drive of the computer and backup copies of the data made onto floppy discs or CD roms as appropriate on a daily basis.

Where data is extracted manually, the data is to be transcribed onto a **DATA - Running Sheet** and printouts, graphs etc attached to the running sheet. The running sheets are to be stored in the QC log for the test/machine.

Results

Are to be transcribed onto the Results Data Sheet and all calculations shown on this sheet. Printouts and graphs etc. Are to be attached to the results data sheet. The data sheets are to be stored in the appropriate test folders.

Results are to be transcribed from the Results Data Sheet onto the Laboratory Test Sheet for promulgation to the customer.

Statistical Analysis

Is to follow established procedures for each of the tests performed and may be either according to QC programs in commercially available statistics packages or via manual means.

All calculations, graphs and validation results are to be stored on the computer hard drive (with daily backup copies) or in manual folders.

It was discussed earlier that QC for Lab is about performing activities that give operators confidence that test results are valid and true. Monitoring of test result validity is an important aspect of the Lab quality system. If you have not kept a copy of the Test Result Validation Procedure, use the following link to obtain it. Print it for the following activity, to check you understanding of handling QC data.

Test Result Validation Procedure

The validity of test results is monitored by QC standardization protocols prior to the run and routine testing of standards during the run.

As appropriate, a range of check standards are used to cover low, medium and high ranges of the test samples being measured. This will monitor result accuracy. In addition, standards are employed to check for precision of results.

As relevant, the results of standards are displayed on statistical control charts where out-of-control situations are identified by trends and individual data points.

All out of control situations are investigated, the situation resolved and a record made. The requirement for re-analysis of test samples should be discussed with the Senior Technician.

Only certified or validated materials are used as standards. Instructions are provided in the standard operating procedures (sops) of the Methods Manual for the selection, maintenance and use of such standards.

Wherever possible, standards are diluted in substrates that are identical to, or approximate,

real test samples. The sops provide instruction for standards preparation.

Follow quality control procedures to ensure products or data are of a defined quality as an aid to acceptance or rejection

In the previous step QC was defined as the checking of a process to ensure that it stays within defined limits in order to produce a product of the required quality. We also looked at some examples of how QC procedures are applied at Lab for the analysis of samples.

In this step you will look more closely at QC procedures and, in particular, how the defined limits of quality determine acceptance or rejection.

QC procedures generally involve:

- ✓ Measurement of a parameter
- ✓ The concepts of accuracy and precision regarding that measurement
- ✓ A range of acceptance (ie the defined limits of quality)
- ✓ Recording of raw data, calculations and the decision to accept or reject (see Step 2)
- ✓ Recording of QC parameters to follow patterns over time (Task 2 - Steps 1 and 3).

In this step, you will concentrate on the first three points, beginning with measurement of parameters. Click on the following link to find out more about measurement of parameters in QC procedures.

Measurement of a Parameter

QC always involves the measurement of a parameter. Measurement methods range from very basic to highly sophisticated. For example, measurement of whether the paint on a Crazy Kola can is clean, shiny and unscratched as the can comes off the production line involves the simple method of a visual check by the human eye. Other measurement methods may involve basic measuring equipment, for example measuring whether a 24 can carton of Crazy Kola weighs within an acceptable variance. More sophisticated equipment and more complex procedures would be involved in determining, for example, the shelf life (stability) of Crazy Kola, or whether there is evidence of microbial contamination, or whether the concentration of glucose in Crazy Kola is acceptable.

There is also a range of different types of parameters. Although parameters are often physical, they may also be non-physical. For example, measurement of the percentage of 10 to 14 year old males who like Crazy Kola is a measurement that uses opinion as a parameter.

Testing (ie measuring a parameter) may be non-destructive or destructive. For instance, checking the paint finish or weighing Crazy Kola does not damage the sample. On the other hand, chemical or microbiological testing of Crazy Kola makes it unsuitable for further use. Other testing such as measuring the maximum load a seat belt can withstand before failure, or testing a rifle cartridge for detonation and accuracy under field conditions, leads to the

destruction of the sample.

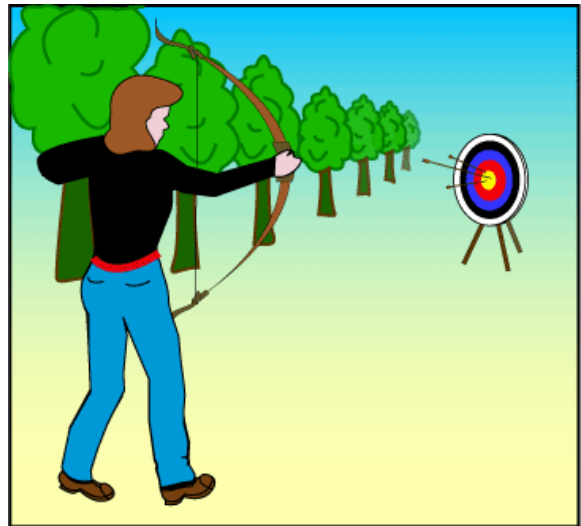
The Concepts of Accuracy and Precision

You will remember that in the glucose analysis of Krazy Kola we touched on the concepts of accuracy and precision. As stated earlier, the concepts of accuracy and precision regarding the measurement of parameters are an important part of QC procedures. These terms have different meanings and it is very important that you fully understand them before proceeding.

The Difference between Accuracy and Precision

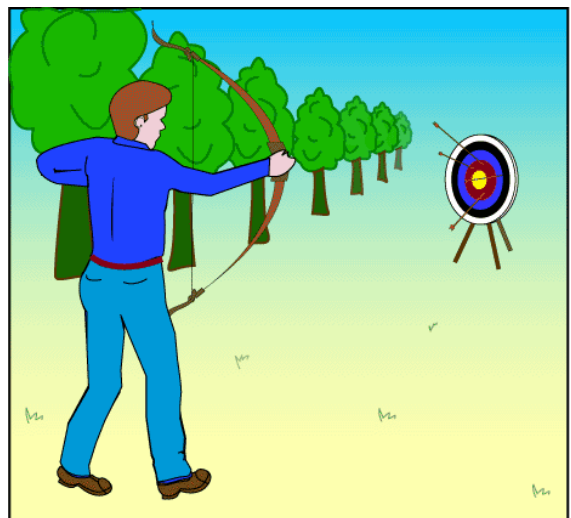
Consider the analogy of four archers who each take turns to shoot at a target using the same bow. Each archer performs quite differently

The most accurate archer is the one with shots landing in or near the middle ring of the target, the bullseye. Thus, accuracy is the ability to get close to a target value, in this case the bullseye.



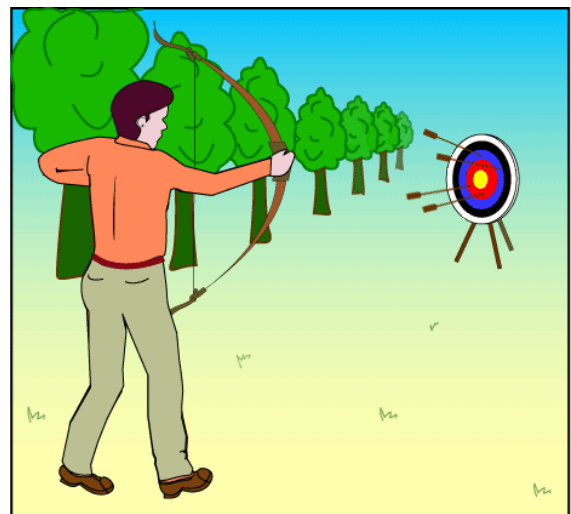
Accurate and precise

For the second archer, we see that the shots are also concentrated close together but away from the bullseye. This archer is not accurate because he hasn't hit the target however we can say that he is at least precise. Precision is about how results are grouped or spread or, said in another way, how repeatable they are.



Precise but not accurate

The third archer is accurate overall but not precise. The average of his shots would lie close to the bullseye but the individual shots are spread out



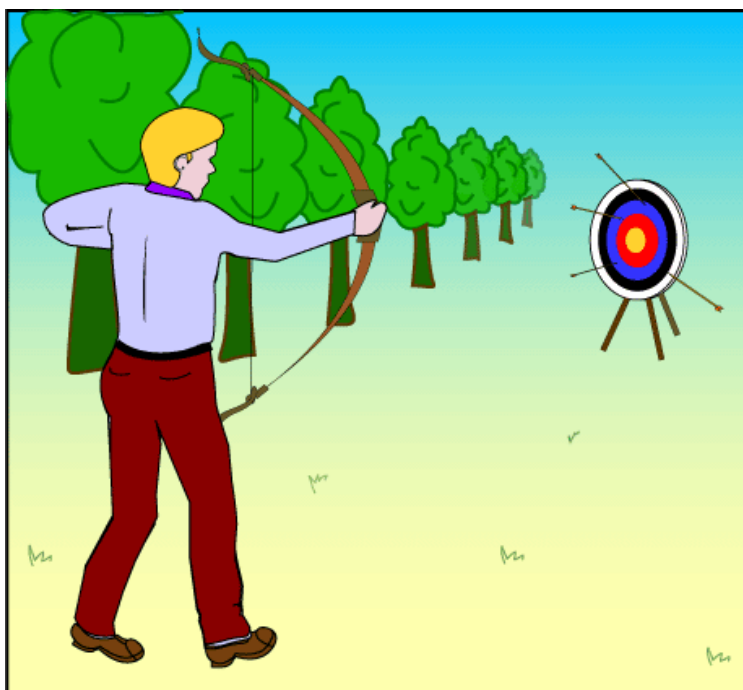
Accurate but not precise

The fourth archer is neither accurate nor precise

because his shots are spread out and have landed away from the bullseye overall.

Not accurate and not precise

Imagine that the first archer in the Study Notes concerning accuracy and precision now uses a different bow with the result that her target looks like that of the second archer. How is it that she is no longer accurate yet she remains precise? The difference in performance can be attributed to some factor to do with the new bow. Perhaps the string was tighter, for example.



When results are precise but not accurate, as in our example above,

we say that a bias exists, ie there is a consistent difference between the measured value and the target value. Bias is a measurement error that can come about as the result of human influences or other influences such as equipment that is set up incorrectly. Bias affects the accuracy of a measurement but not the precision.

Range of Acceptance

The third important part of QC procedures to be discussed is the range of acceptance. You will recall from the Krazy Kola work that each of the QC checks had 'defined limits'. These defined limits are known as the range of acceptance. Click on the following link to find out more about this important aspect of QC procedures.

Range of Acceptance

The range of acceptance is defined as the limits that determine the quality of our analytical results. Figures falling within that range are accepted and figures falling outside the range will cause a run to be rejected.

For example, the Low Check Standard (CS) must give a value in the range **2.00% to 2.10%** for the run to be accepted. There may be exceptions to this rule depending on circumstances. For example, if the Low CS was 1.88% (ie below the acceptable range) but the test samples were 30% to 50% and the other checks were satisfactory, then it could be argued that the run should be passed because the machine was shown to be accurate at the concentrations of the samples despite this not being the case at lower concentrations.

Such decisions about making exceptions to the rule would be left to the Senior Technician or

the Quality Officer and may even be debated by the Quality Management Committee.

How is the range of acceptance for each CS determined?

One simple way is to analyse the CS a large number of times under conditions that are as close to ideal as possible. For example, using the Low CS we measure the % w/v glucose 100 times using good machinery and good operators. We then apply some basic statistics to the readings.

Firstly, we calculate the mean (the mean, also known as the **average**, can be found by adding the values of the individual readings and then dividing this by the number of readings). This figure is 2.05% glucose. Now we calculate the **standard deviation** which we find to be 0.025% glucose. Think of standard deviation as being a measure of how much the results are 'spread' - the wider apart our 100 results are spread, the greater will be the standard deviation. You can see from this that standard deviation is connected to precision - as standard deviation gets smaller, precision improves.

Most statistical QC is based on the notion of a **95% confidence** limit which basically means that 95% or 19 out of 20 measurements of the Low CS would be expected to fall within an acceptable range defined by the confidence limit.

The 95% confidence limit (acceptable range) is derived by subtracting and adding 2 standard deviations to the mean, as in the following example.

$$\begin{aligned} 95\% \text{ confidence limit} &= [2.05 - (2 \times 0.025)] \text{ to } [2.05 + (2 \times 0.025)] \\ &= [2.05 - 0.05] \text{ to } [2.05 + 0.05] \\ &= 2.00 \text{ to } 2.10 = \text{acceptance range} \end{aligned}$$

Think of the acceptance range in this way. If a CS result falls within the acceptance range there is a good chance that the analytical process is operating well and that the test sample result is valid and can be accepted. On the other hand, if the CS result is outside the range, there is the possibility that something has gone wrong with the analysis. In this case, follow up investigation is needed. Can you see now how QC procedures help to give confidence to the analyst about the quality of the test results?

Recognise and report non-conformances or problems

In essence, a non-conformance occurs where a procedure in our quality system has not been followed in some way (ie you are not doing what you should be doing). There can also be times when a problem arises even though we appear to be doing everything correctly. In either case, quality or productivity may be jeopardized.

QC and Non-conformance

Crosby, another proponent on quality management, looks at quality from a slightly different perspective to Deming or Juran mentioned earlier. Crosby reasoned that the way to improve

quality management was to measure the cost of doing things right (the price of conformance) against the cost of doing things wrongly (the price of non-conformance).

The price of conformance includes:

- ✓ Prevention costs - the costs of reducing defects and non-conformances
- ✓ Appraisal costs - at Lab the costs of running the quality system and any accreditations it holds.

The price of non-conformance includes:

- ✓ Appraisal costs - detecting non-conformances (ie QC)
- ✓ Internal failure costs - unsatisfactory quality detected within simulab
- ✓ External failure costs - costs associated with poor quality test results being detected outside the enterprise.

Crosby argued that reducing non-conformances would reduce the overall cost of quality. For example, reducing the number of failed runs at simulab from 5% to 1% would lead to significant savings in time, money and customer confidence as failed runs have to be repeated and this leads to delays and extra costs.

The ability to recognise and report non-conformances or problems at simulab will lead to better productivity and quality. The adage of 'a stitch in time saves nine' holds well here.

Non-conformances or problems occur right across the quality system and can result from issues to do with:

- ✓ People and personalities eg lazy habits
- ✓ QC eg wrong SOP used
- ✓ Equipment eg not calibrated
- ✓ Reagent and chemicals eg used after expiry date
- ✓ Training eg no employee induction
- ✓ Paperwork sops and instructions eg superseded documents used
- ✓ Communication eg client not notified
- ✓ Physical environment eg laboratory temperature too high.

Non-conformances or problems become known through various means such as:

- ✓ Customer complaints
- ✓ Internal audits
- ✓ QC activities
- ✓ Instrument calibrations
- ✓ Staff observations or supervision
- ✓ Management reviews
- ✓ Checking of consumable materials.

Conduct work in accordance with sustainable work practices

The resources of the world are finite. We have only a limited amount of fossil fuels (gas, oil, coal), minerals and water. Resources such as water are recycled through the environment but there is only a finite amount that can be captured and used without affecting other aspects of the ecosystem. For example, consider the environmental problems associated with the Murray and Snowy Rivers.

Energy derived from fossil fuels is limited but energy from the sun is continuous and unlimited (for the next few million years anyway!). Theoretically, timber and plants are unlimited as they capture the sun's energy to grow. But famine still rules the world. Why?

The Western world uses more than its fair share of energy and resources. There is not much that simulab can do to help world poverty, apart from our sponsorship of relief programs, but simulab can have a direct effect on reducing the pollution of the environment.

Reduction in the use of energy and resources always leads to a reduction in waste, emission and pollution. At the same time this saves money. Simulab has committed itself to employ sustainable energy practices.

One fundamental aspect of energy conservation is having an awareness of how energy use contributes to an increase in waste and pollution of the environment.

Click on the following link to access an activity to test your understanding of energy use and pollution.

Assignment - Pollution and You

Can you pick the polluters in the following table? Which of these activities causes increased use of energy and increased emissions and what reason?

Activity	Increases Pollution	If yes, why?
Turning on a light switch		
Driving a V-12 Jaguar		
Replacing light bulbs with fluorescent tubes		
Using solar energy for heating water		
Cleaning filters on pumps		
Insulating simulab		
Recycling		

The audit is designed to identify and reduce energy use in premises of all sizes. Energy audits are investigations of energy use in a defined enterprise or in a defined area or site.

The audit allows the measurement of energy use and costs, which leads to processes for better control of consumption.

Audits can be extremely complex, for example, imagine doing an energy audit at a car manufacturing plant! At simulab the audit will be relatively simple and based on common sense.

1. From your experience and knowledge of simulab operations, answer the following questions:
 - a. What forms of energy are used at simulab?
 - b. What are these forms of energy used for?
 - c. Briefly detail six ideas for saving energy.
 - d. What major resources are used at simulab?
 - e. What are they used for?
 - f. Briefly detail six ideas for saving resources.

2. Consider your own living environment. Use your own experience and understanding to answer the following:
 - a. Briefly, what processes (if any) do you have in place to save energy?
 - b. Briefly, what processes (if any) do you have in place to save resources?

For example, avoiding racing starts and screeching halts in your car will save petrol (resource), money and reduces pollution (exhaust emissions). Turning off a light when not in use will save electricity (energy) and lessen CO₂ emissions at the power plant.

Promote sustainability principles and work practices to other workers

Conducting a safety audit and proposing ways to reduce energy and resource use is only half of the process. The other half involves promoting the acceptance of energy saving principles amongst the staff at simulab. This will involve some marketing and selling of the changes with the intention of changing the behaviour of your workmates.

ANALYSE OPPORTUNITIES FOR CORRECTIVE AND /OR OPTIMIZATION ACTION

Improving quality is an interactive and proactive process. Your ability to analyse quality situations and to apply corrective actions to optimize procedures is important in your role as a Laboratory Technician. This unit of competency will check your ability to assess and apply quality principles.

Compare current work practices, procedures and process or equipment performance with requirements and/or historical data or records

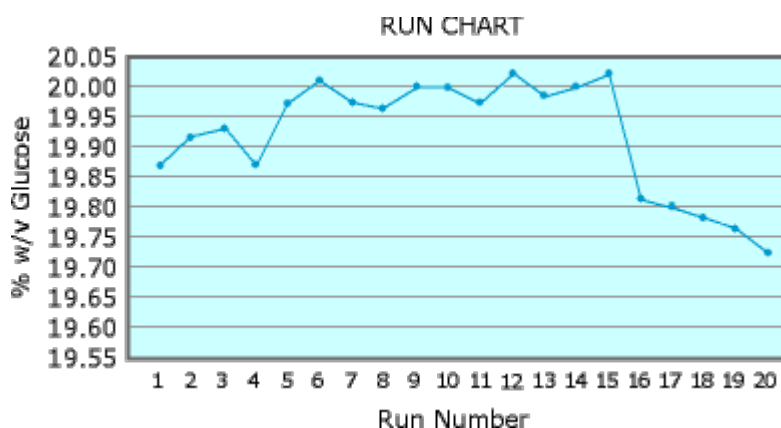
Different charts are often used to enable a laboratory technician to monitor and compare

processes with requirements, historical data and records. One of the simple statistical charts used to monitor processes is the run chart.

A run chart is simply a graphical means of depicting data in chronological order. This chart allows a visual means to see the performance of a particular test parameter and whether there are any trends developing. In this way problems can often be avoided before they occur.

As a simulab laboratory technician, you need to monitor processes and procedures for non-conformances. Today you will monitor the % w/v Glucose results for Krazy Kola over the last 20 runs and look at the performance of the Medium Check Standard. In reality the three check standards would be monitored at the same time but for simplicity you will only look at one here. Remember that the acceptance range for the Medium Check Standard is 19.74 - 20.02 and any values falling outside these limits will cause the run to fail QC. If this happens simulab cannot have confidence that the results for test samples will be valid.

Assignment - Run Chart Evaluation



Look at the % w/v Glucose - Medium Check Standard Run Chart and answer the following questions:

1. Are there any runs that fall outside the acceptable range?
2. If so, what numbers are they?
3. Are there any other areas of the run chart that give cause for concern?
4. If so, what are they and why are you concerned?
5. Was the run chart easy to read or could it be improved?
6. If so, how?

Run charts are useful because they show trends and problem-results however control charts can be even more useful. We will now consider control charts, which are an extension of run charts and are more effective in highlighting how QC data is behaving. Click on the following link to access information on control charts.

Control Charts

Remember that in Task 1, Step 3 we looked at the development of the range of acceptance and found that it was based on 2 standard deviations on each side of the mean value. It was said that this represented the 95% confidence limits, so named because 95% (or 19 out of 20) values will fall within this range under normal circumstances.

A control chart is like the run chart we saw earlier but it has the following features drawn in:

- ✓ A line denoting the mean value
- ✓ A line denoting means plus 2 standard deviations, called the Upper Control Limit
- ✓ A line denoting means minus 2 standard deviations, called the Lower Control Limit.

Let us now again consider the Medium Check Standard and work through the procedure to determine the 95% confidence limits, ie 19.74 - 20.02, so that we can then view a control chart for the Medium Check Standard.

In reality the Medium Check Standard would be measured a large number of times but for this exercise we will only measure it 20 times with the following results:

19.85	19.94	19.87	19.95
19.89	19.97	19.99	19.00
19.90	19.90	19.94	20.00
19.90	19.89	19.94	19.89
19.87	20.00	19.90	19.88

The first step is to calculate the mean:

$$\begin{aligned}\text{Mean} &= \frac{(\text{total of 20 readings})}{(\text{number of readings})} \\ &= \frac{397.52}{20} \\ &= 19.88\end{aligned}$$

The second step is to calculate the standard deviation:

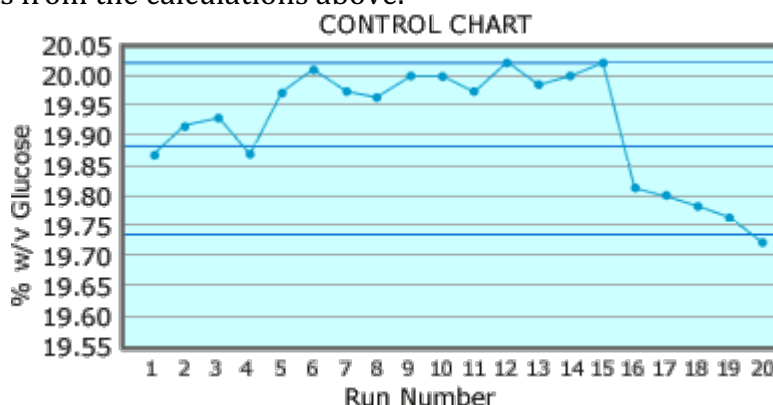
$$\text{Standard Deviation (SD)} = S = \sqrt{\frac{\text{sum of (data value - mean)}^2}{\text{number of data values}}} \text{ or } \sqrt{\frac{\sum(x - M)^2}{N}}$$

The SD for this set of data is calculated to be **SD = 0.07**

And so the 95% confidence limits are:

$$\begin{aligned}
 \text{95\% confidence limits} &= && [\text{mean} - 2\text{SD}] \text{ to } [\text{mean} + 2\text{SD}] \\
 &= && [19.88 - (2 \times 0.07)] && \text{to} && [19.88 + (2 \times 0.07)] \\
 &= && [19.88 - 0.14] && \text{to} && [19.88 + 0.14] \\
 &= && \mathbf{19.74 \text{ to } 20.02}
 \end{aligned}$$

The following shows a control chart that has been set up for the Medium Check Standard using the results from the calculations above.



Plotting the mean and 95% confidence limits makes a control chart very informative since it can clearly show abnormal behaviour in QC data. Abnormal behaviour occurs when:

- ✓ Trends develop (a trend is a pattern that defies our expectation to see values fall randomly on both sides of the mean and to be closer to the mean rather than further away from it)
- ✓ A reading is outside the Upper or Lower Control Limits.

Recognise variances that indicate abnormal or sub-optimal performances

Variations and Variability

Remember in Task 1, Step 3 you investigated the concepts of accuracy and precision with the archers. You also should know that measurements can never be perfectly accurate and precise: there is always variability. Click on the following link to find out how variability affects accuracy and precision.

Variability, Accuracy and Precision

If we could measure with perfect accuracy down to the molecular level we would be able to determine, for example, the exact concentration of glucose in Task 1, Step 2 (position 3), and this figure might look like this - 29.975754302183654000% w/v.

This perfect value is called the True Value. Needless to say, the true value is not measurable as we are unable to measure down to the molecular level for many reasons.

We strive for measurement of the Accepted Value, which approximates the true value and is accurate enough for our purposes. In this case the machine measured 29.98% w/v, which is more than accurate enough for our purposes, as we are only required to give the answer to

one decimal place.

If the Accepted Value is close enough to the True Value for our purposes then we say that the answer is Accurate (just like our archer hitting the bullseye). We check accuracy in a run by using Check Standards that have a verified concentration. We then compare the measurement of the check standard with their verified value (accepted value) and if close enough, the accuracy of the run has been established.

But what about precision? Each time a sample is measured there will be subtle variations in the result. For example, look at the results for the Precision Checks in Task 1, Step 2 (positions 15 to 17).

1.	0.01	BLK
2.	2.04	Low
3.	29.98	
4.	31.33	
5.	30.62	
6.	30.54	
7.	31.18	
8.	19.87	Med
9.	52.15	
10.	51.95	
11.	50.88	
12.	51.07	
13.	51.54	
14.	50.54	High
15.	45.49	SLPC
16.	45.46	SLPC
17.	45.59	SLPC

Notice that although it was the same sample, the same run, the same machine and the same operator, there are small differences in the values obtained each time the check was measured. This range of values reflects the Precision of the run. The larger the range of values the lower the precision and the smaller the range of values the higher the precision.

Think about the first archer shooter in the earlier example. Even with the new bow and poor accuracy, the shooter was able to hit the target with her shots very close together (tight group) and hence her precision was excellent.

Accuracy reflects how close we have come to measuring the true value. Accuracy might also be thought of as correctness.

Precision shows how close a number of replicate measures are to each other, in other words how the individual values are spread or grouped

Errors and Variation

Every time a measurement is taken there is a difference between the True Value (not achievable) and the actual measurement. This difference is called an Error and errors lead to Variation in a product or service.

For example, think of the Krazy Kola assays. What factors would lead to errors in the measured % w/v Glucose? Click on the following link to do an activity to test your understanding of factors leading to errors.

Errors lead to variability. They can be systematic or random.

Systematic errors remain constant or vary in a specific manner. For example, the thermometer might always read 1°C too high or the pipette might deliver 5% below a given volume. Systematic errors are said to arise from a BIAS in the measurement system leading to inaccuracy.

Note that operators can introduce bias, for example, a technician may use a burette in exactly the same manner every time but may be using it incorrectly. Similarly, a technician may not know how to round up/round down correctly.

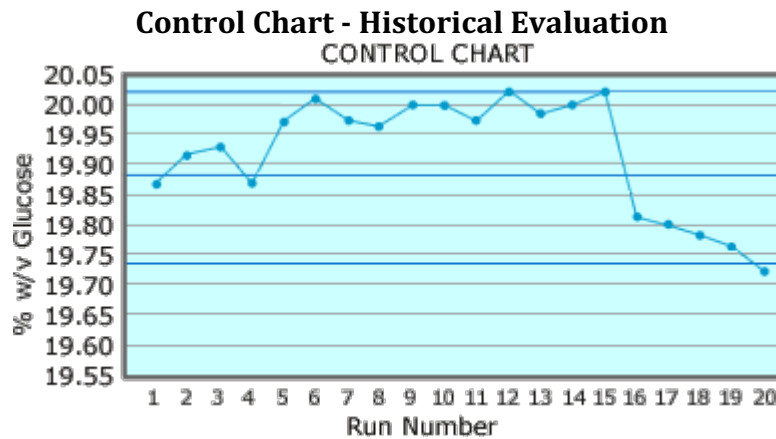
Random errors are unpredictable and lead to imprecision.

Variability is caused by the sum of the errors in a process. Click on the link below to do an activity on identifying errors that lead to variability.

Collect and/or evaluate batch and/or historical records to determine possible causes for sub-optimal performance

In Task 2, Step 1 a control chart was set up for the % w/v Glucose Medium Check Standard using the mean (19.88) and 95% confidence limits (19.74 to 20.02) as the Upper and Lower Control Limits (20.02 and 19.74 respectively) .

You will now use the completed control chart to evaluate historical records. The chart contains % w/v Glucose results for the Medium Check Standard collected over the last 20 runs of Krazy Kola



It is obvious from the control chart that only one measurement (# 20) falls outside the control region and would be rejected. But the control chart tells us much more. Can you see what is happening?

There are a number of situations where the measurement system may not be in control even though all check results lie within the Upper and Lower Control Limits. In these situations the check results show abnormal behaviour indicating that the results for the test samples may not be valid.

Examples of this sort of behaviour include:

- ✓ A run of consecutive values on one side of the mean (values should fall around the mean on a random basis)
- ✓ Sharp drops or increases from one value to the next
- ✓ A run of consecutive values increasing or decreasing.

Guidelines, referred to as Westgard Rules, have been established to assist the operator to determine whether check results are normal or not. The exact set of rules used will vary between applications and institutions.

The control chart just investigated has yielded some valuable information about the glucose analysis. Even though only the last of the twenty values for the Medium Check Standard was outside the range of acceptance, the control chart has highlighted three regions where there were problems.

One way to investigate these problems is to go through an exercise to arrive at the root cause (ie the one underlying factor that caused the variation). There are a number of

avenues to investigate the root causes, looking at the:

- ✓ Past performance of the glucose analyser instrument
- ✓ Maintenance history of the analyser
- ✓ Calibration of the analyser
- ✓ QC program
- ✓ Glucose Reagent used for the test
- ✓ Stability of the Glucose Reagent
- ✓ Operators using the analyser.

Test Method, Sampling and Sample Preparation Procedure

The test method procedures used at Lab shall be those of Australian and International standards and protocols. Client-supplied or specified methods may also be used. Where 'in-house' developed methods are employed, these will be validated based on published methods.

Unless directly requested by a customer, simulab shall apply the most appropriate testing method for the designated testing.

Simulab's test methods (sops) are contained in the Methods Manual kept at locations within the laboratory.

Samples of materials supplied by clients to simulab for testing are assumed to have been sampled according to recognised sampling procedures (eg AS 1199). Testing reports supplied by simulab are for the properties of the material as supplied to us. Unless otherwise specified by the client, simulab assumes materials supplied for testing are uniform for the purposes of the test requested by the client.

Samples are prepared for testing according to standard simulab protocols and sops employed by simulab, unless alternative procedures are requested and specified by the client.

Test results shall be reported to significant figures and in units as specified in simulab protocols and sops, unless requested otherwise by the client.

Equipment Calibration and Maintenance Procedure

All testing equipment shall be calibrated and the record of calibration, routine service and maintenance shall be recorded in the Calibration Log.

Maintenance procedures for testing equipment shall follow equipment manufacturer's recommendations and shall be recorded in the Calibration Log.

Repairs to testing equipment shall be recorded in the Calibration Log.

The Calibration Log shall contain the following details:

- ✓ Equipment number
- ✓ Description of equipment
- ✓ Calibration frequency
- ✓ Calibration status

Details of calibration, maintenance and repairs including:

- ✓ Date
- ✓ By
- ✓ Comments.

To keep track of testing equipment at simulab all items are given a unique Equipment Number and logged in an equipment register (kept in Laboratory Supervisor's office). The equipment register shall contain the following details:

- ✓ Equipment number
- ✓ Name, model number and serial number of equipment
- ✓ Brief description of equipment
- ✓ Any special OHS considerations
- ✓ Purchase date
- ✓ Supplier
- ✓ Warranty details
- ✓ Location of manuals and documentation
- ✓ Service details/Intervals.

Any pieces of equipment that is not to be used for testing purposes (eg requiring service) shall be labelled as such and quarantined from use.

Use appropriate quality improvement techniques to rank the probabilities of possible causes

The use of the glucose analysis scenario in the last step involved significant statistical analysis and some detective work to get to the root causes of the problems that were indicated by the Medium Check Standard values.

Some basic errors were made during these runs and the answers were relatively obvious.

Unfortunately, life is not always so easy. Often the problems associated with variability are subtle and numerous but nonetheless significant. Often they do not necessarily arise from operator error or machine failure (Special Causes) but are part of the overall system (Common Causes). Special Causes and Common Causes are discussed in more detail in Task 3, Step 1.

There are a number of techniques to enable us to identify and rank possible causes in a process. We will look at two of these techniques.

- ✓ Brainstorming
- ✓ Ishikawa Charts (also known as Fishbone Charts, or Cause and Effect Diagrams).

Brainstorming a Solution

Brainstorming is defined as 'a technique used in groups where everyone contributes ideas without any self- or group evaluation of validity'.



Read and print out the following guidelines for brainstorming, as you will need them for the next activity.

- ✓ To begin with, a problem or question must be clearly formulated, for example, 'What is causing browning of the apple pulp during pie production?'
- ✓ Several people must be involved (between six and twelve participants is preferable).
- ✓ Brainstorming should be undertaken in a comfortable and supportive environment.
- ✓ Each person in turn calls out a possible cause or reason.
- ✓ A 'scribe' writes the reason on a whiteboard or a piece of butcher's paper.
- ✓ There is to be ABSOLUTELY NO evaluation of answers or comments on answers - there must be free-flowing thought.
- ✓ The process continues until the answers run out.
- ✓ The reasons are then grouped into similar categories, and duplicates are eliminated.
- ✓ The group then votes in order to rank the reasons from the MOST probable to the LEAST probable.
- ✓ The group then proposes solutions for the three 'most probable' reasons.
- ✓ Management implements the solutions and the success (or otherwise) of the solutions is monitored.
- ✓ The process may be repeated until success is achieved (note that very complex problems may require a number of rounds of this process).

RECOMMEND CORRECTIVE AND/OR OPTIMISATION ACTIONS

You know that variability (inaccuracy, imprecision, mistakes etc) contributes to a reduction of quality in the workplace but who or what is responsible for this variability? Is it the fault of sloppy workers, inflexible management, Acts of God or what?

Analyze causes to predict likely impacts of changes and decide on the appropriate actions

We will start by considering Defective Goods and Poor Service. These are what the customer usually sees when variation is uncontrolled.

Causes of Variability

We discussed previously how errors lead to variability and how errors can be classified into two types ie systematic and random.

Systematic errors remain constant or vary in a specific manner, for example, a particular thermometer may always read 1°C too high or a particular pipette may always deliver 5% below a given volume. Systematic errors arise from a bias somewhere in the measurement system and lead to inaccuracy. Bias can be introduced by operators as well as by equipment. For example, a technician may consistently use a pipette in exactly the same incorrect manner.

Random errors are unpredictable and lead to imprecision.

Variation or variability is the cumulative sum of all the errors (systematic and random) in a process. The Root Causes of variation can be broken down into two types called Common Causes and Special Causes.

Common Causes are part of the system and lead to the normal variation you would expect to see in results. As they are part of the system the technician cannot fix them (without fundamental changes to the system). For example, the owner may decide to use the cheapest pipettes available; despite extreme care in their use, the cheap pipettes are inaccurate and deliver incorrect volumes.

Special Causes are generally one-off causes and are assignable to a particular person or event. Special causes lead to variation in results which are not normal. For example, a momentary power failure causes the QC program on the analyser to reset to last year's parameters. This is not noticed until the end of the week and consequently 300 specimens have to be redone. Special causes can be identified and removed.

Initiating Change

If 85% of variability is due to common causes then 85% of the corrective effort should be directed at the Management System. Is this what usually happens?

NO - in reality we often direct 85% of our effort to solving special causes (sloppiness, mistakes, personality conflicts etc) even though we are doomed to only achieving a maximum of 15% improvement in variability even if we can solve 100% of the special causes (which in itself is an impossibility).

It stands to reason that the major effort should always be directed to changing the SYSTEM (through

continuous improvement etc).

Identify required changes to standards and procedures and training

Good quality management requires the ability to identify the changes required to improve methods, procedures and training.

A lot of the approaches to Quality Management are common sense and it is easy to identify how to do things better. However, other factors, such as costs, may impinge on your ability to identify required changes.

For example, one way of solving the variation associated with the % w/v Glucose analysis is the purchase of a fully automated system that comes with full software integration and single-use aliquoted reagents and controls. But the system costs \$275,896 and simulab only does \$30,000 of soft drink glucose testing per year. Would you change to the new system?

Identifying and making changes is not always as straightforward as deciding when to purchase new equipment. It may involve correction and amendment of current documents, and checks to determine if current documents fulfil current objectives.

Report recommendations to designated personnel

There are four major steps to quality improvement:

1. Identifying the problem(s)
2. Deciding on an appropriate course of action
3. Reporting recommendations to the decision makers in such a way that a decision to change is more likely than less likely
4. Implementation, monitoring outcomes and adjustments.

For very minor matters often all that is needed is a 'word in the boss's ear' to get the OK to move ahead. In other cases, a written submission is required. Written submissions often cause panic amongst those who do not write them often.

In this step we will look at a 'Submission Model' that takes all the worry out of writing a report. Let's look at a couple of recent submissions at simulab. Which recommendation would you support?

PARTICIPATE IN THE IMPLEMENTATION OF RECOMMENDED ACTIONS

In your workplace you will be asked to become involved in workplace change. How you approach these tasks may be vital to your career. In this task, we will investigate some common quality approaches to implementation of change.

Implement approved actions and monitor performance following changes to results

One of the common tools used for the implementation of change is the PDCA or Deming

Circle developed by W Edwards Deming, one of the founders of Total Quality Management (TQM) and the quality movement. The Deming circle represents the problem analysis process and the quality improvement cycle and provides focus on defect correction as well as defect prevention.

- ✓ P PLAN the change
- ✓ D DO implement the change
- ✓ C CHECK that the change is having the desired effects
- ✓ A ACT to follow up and make adjustment based on outcomes to date.

Planning involves:

- ✓ Determining the goals and targets of what needs to be done to make the change happen
- ✓ Determining the methods for reaching goals

Doing involves:

- ✓ Educating, training and informing relevant people of what is going to happen and who is doing what
- ✓ Implementing the changes.

Checking involves:

- ✓ Checking the effects of implementation to see that the change is happening as required.

Acting involves:

- ✓ Taking appropriate action to make amendments, if required, to make the change happen as planned.

Implement changes to systems and procedures to eliminate possible causes

Construct a Cause and Effect Diagram (Ishikawa or Fishbone Chart) relating to a problem from your own experience. In your answer you included:

- ✓ The Cause and Effect Diagram
- ✓ A description (two to three lines) of the problem or variation
- ✓ The top three causes (in your opinion)
- ✓ An explanation of how you would reduce the variation, linked with these causes.

In the following activity you will follow this procedure through to the next step.

Assignment - Cause and Effect Diagram, Implementing Change

In your Cause and Effect Diagram you produced earlier, you identified the top three factors involved that cause variation in your process and outlined how you would rectify them.

In this activity imagine that you have implemented these three changes. What would happen? Who would be affected? Are there laboratory-resource implications (for example,

equipment required)?

Provide clear, concise and detailed answers to these questions (above) and be sure to include the following:

- ✓ The effect of the changes to resources and procedures
- ✓ The effect of the changes on staff (and customers if appropriate)
- ✓ A list of documents that may need to be changed (the names only - do not write them!)
- ✓ A brief 'guesstimate' of any training required
- ✓ A rough estimate of additional costs or savings
- ✓ Any other relevant factors.

Document outcomes of actions and communicate them to relevant personnel

Now need to consider the implications of your three changes in terms of documentation and communication. Click on the link below to do an activity on quality actions and outcomes.

Assignment - Quality Actions and Outcomes

How would you document the changes you decided were needed in the Assignment - Cause and Effect Diagram, Implementing Change and how would you communicate the changes to staff (and customers if appropriate)?

Provide clear, concise and detailed answers to these questions (above) and be sure to include the following:

- ✓ The names of new or altered documents required
- ✓ A full example of one document (choose the shortest one)
- ✓ A list of changes that may need to be made to other documents, for example the creation of a new fire safety SOP may need to be referred to in another SOP
- ✓ How and why you would communicate the changes to staff (and others if appropriate).

PARTICIPATE IN THE DEVELOPMENT OF CONTINUOUS IMPROVEMENT STRATEGIES

To be recognised as competent in this unit you must be assessed in both the knowledge content and the workplace skills. The assessment is in two parts, part one is a knowledge assessment and part two is a practical assessment.

The four tasks you have attempted to date have used continuous assessment throughout. Many of the concepts and activities in this final task build on and extend the work done previously. As such, there will be no separate formal assessment of the whole unit of competency.

Instead your performance in this final task will be your final assessment which consists of a

number of assignments - good luck!

Introduction

Total Quality Management (TQM) is a philosophy for managing the quality of an enterprise at every level and on a continuous basis. Remember, there is no such thing as a perfect process - it can always be improved.

Important aspects of TQM

- ✓ Quality and Competition
- ✓ Continuous Improvement
- ✓ Strong Customer Focus (both internal and external)
- ✓ Variability Reduction
- ✓ Employee Participation in Problem Solving

TQM looks at the three components in the creation of goods or services:

- ✓ Customer
- ✓ Producer
- ✓ Supplier

TQM strives to delight the customer with outstanding service. The customer is defined as anyone that relies on you for information or a product and includes External Customers (people who purchase goods or services from simulab) or Internal Customers (your fellow workmates at simulab).

Colin, the trainee technician, asks you if you will help him set up the QC for the Glucose Analyser. He is now your customer as he is relying on you for help and information. You should provide him with timely and effective service. If you do not then the external customer who is relying on Colin to provide them with the Krazy Kola results will not be given outstanding service and the reputation of simulab (and maybe the bottom line) will suffer.

Continuous Improvement - you will now concentrate on the implementation of continuous improvement procedures but remember that the needs of the customer (both external and internal) and variability reduction are also significant parts of the process and must be considered in your activities.

Terminology

The following Quality Management terms must be understood to fully appreciate the simulab quality system.

Quality

Quality is a term that is often used inaccurately. The term can cause confusion because it has

TWO related but different meanings:

- ✓ High grade, superior excellence
- ✓ A characteristic, property or attribute (The Macquarie Dictionary).

It is the SECOND meaning of quality that is used in the context of business, manufacturing, and commerce, or in this case, laboratory testing. Note that this second meaning does not specify whether the quality is high or low.

Quality Control (QC)

Quality control involves checking the product to ensure that it complies with given parameters. QC can never improve a product - it just removes or repairs defective products before they get to the customer.

Quality Assurance (QA)

This is the task of overseeing the quality function. This includes planned, systematic actions leading to adequate confidence the goods or services will satisfy given requirements. QA improves the product by putting in place systems and procedures that lead to a better product.

Total Quality Management (TQM)

This is an on-going strategy that changes the culture of an organisation. A philosophical approach that concentrates on the needs of the customer and strives to give outstanding customer service, and uses continuous improvement whilst maintaining 'fitness for purpose'.

History

The history of the quality movement is complex and lengthy, stretching as far back as ancient times. The following is a brief summary.

Roman Empire

Bridge engineers were directly responsible for the quality of their work. Poor quality often resulted in death!

Before the Industrial Revolution

Craftsmen dealt directly with purchasers (fitness for purpose was very important).

Industrial Revolution

Foremen assumed responsibility for QC. Craftsmen/workers now not necessarily in contact with the customer.

1925

Bell Telephone Company established modern concepts of QC and QA - used sampling, inspection and testing, and 'do it right first time'.

1940s (World War Two)

USA led a massive quality training effort including the use of statistical research.

1950s - 1970s

The Western world became complacent about Quality; standards remained the same or slipped.

1950s

Deming and Juran went to Japan (post-war reconstruction of Japanese industry) leading to a massive turnaround in quality of products and many innovative approaches to design and manufacture, for example:

- ✓ Quality Control Circles
- ✓ Kanban (Just in Time)
- ✓ Kaizen (Continuous Improvement).

1970s - Present

Others in the Western world caught up with Japan. Strong emphasis on TQM. Development of standards such as the ISO 9000 series and ISO 17025 for Laboratory Operations.

Continuous Improvement

Continuous Improvement is a never-ending process of searching for ways to improve a process or product. Steps may be small, incremental and time-consuming, but the philosophy is for steady improvement to be made. Ideas for improvement are solicited from staff and customers.

Tools of Quality

There are many tools that are used to measure, evaluate and improve quality. Some of these include:

- ✓ PDCA (Plan, Do, Check, Act) - cycle for improvement
- ✓ Ishikawa Charts, Fishbone Charts and Cause and Effect Diagrams - for evaluation of processes
- ✓ Pareto Charts and analysis - to determine how inputs are related to products or results
- ✓ SWOT Analysis (Strengths, Weaknesses, Opportunities, Threats) - used to evaluate a process, product or business in terms of these four interrelated parameters
- ✓ Run Charts, Control Charts, Histograms and Scattergrams - used to represent QC data in a logical and readable form

- ✓ Brainstorming - for continuous improvement purposes and problem solving.

TQM Concepts

Total Quality Management is an all-encompassing philosophy that includes the concepts of QC, QA and Statistical QC, as well as the following concepts:

- ✓ Quality & Competition
- ✓ Continuous Improvement
- ✓ The concept of Internal and External Customers
- ✓ Variability Reduction
- ✓ Employee Participation in problem solving.

Customer Complaints

The handling of customer complaints is an important aspect of the simulab quality system (and it's also a requirement in the laboratory competency standard, ISO 17025).

At simulab all customer complaints are to be:

- ✓ Treated as an opportunity to improve
- ✓ Logged in the Customer Complaint Folder
- ✓ Investigated and acted upon
- ✓ Recorded
- ✓ In all but the most extreme circumstances, resolved to the customer's satisfaction.

Review all relevant features of work practice to identify possible contributing factors leading to sub-optimal performance

W Edwards Deming distilled his decades of quality experience into two sets of helpful hints:

- ✓ Deming's 14 TQM Points
- ✓ Deming's Seven Deadly Diseases

Deming's 14 TQM points

- ✓ Create constancy of purpose towards service improvement.
- ✓ Adopt the new philosophy (TQM).
- ✓ Cease dependence on inspection to achieve quality (QC).
- ✓ End the practice of awarding business solely on the price tag (our suppliers).
- ✓ Constantly improve the process of planning production and service.
- ✓ Institute training on the job.
- ✓ Institute leadership for people and systems improvement.
- ✓ Drive out fear in order to encourage employees to work together.
- ✓ Break down barriers between departments and work areas.
- ✓ Eliminate slogans, exhortations and production targets.
- ✓ Eliminate numerical quotas for management and the workforce.
- ✓ Remove barriers to pride of workmanship (empowerment).

- ✓ Institute a vigorous program of education and self-improvement for everyone in the organisation.
- ✓ Put everyone in the organisation to work accomplishing the transformation (everyone is responsible for quality!)

Deming's Seven Deadly Diseases

- ✓ Lack of constancy of purpose to improve products and services by providing resources for long-range planning, research and training.
- ✓ An emphasis on short-term profits and the quarterly dividend.
- ✓ Individual performance evaluations through merit ratings and annual reviews.
- ✓ Managers who are highly mobile, hopping from company to company.
- ✓ Use by management of numbers and figures that are visible and available, with no thought of what information may be needed but unknown or hidden.
- ✓ Excessive medical costs.
- ✓ Excessive legal liability costs, swollen by lawyers who work on contingency fees.

In previous examples you have concentrated on the processes themselves, the science and human errors. We will now concentrate on the systems, procedures and policies that impact on quality delivery.

Remember that 85% of causes of variation are common causes that are part of the system installed by management. TQM and Continuous Quality Improvement (CQI) are tools for improving the system.

Assignment - Deming and You I

Select one of the examples that you used in an earlier activity and answer the following questions with clear, concise and detailed answers.

- ✓ Which of Deming's 14 TQM Points are NOT followed or are followed infrequently in a workplace you know?
- ✓ Choose one point and briefly explain why it is not followed and how it leads to sub-optimal performance.
- ✓ Which of Deming's Seven Deadly Diseases exist in a workplace you know?
- ✓ For one Deadly Disease, briefly explain why it exists and how it leads to sub-optimal performance.

Note: some of the Deadly Diseases are equal to the omission of a Point (for example, the omission of point number one equates with the first deadly disease). There is no need to talk about the same thing twice.

Identify options for removing or controlling the risk of sub-optimal performance

Whenever an example of a factor contributing to sub-optimal performance is identified

there are a number of factors to consider.

- ✓ The how, why, what, where and when of change
- ✓ Up-front costs and possible long term savings
- ✓ Personnel implications, for example, training, resistance, numbers, changes in management
- ✓ Customer implications, for example, improved service, increased cost, turn around time
- ✓ Supplier implications, for example cost, availability, supplier's quality system
- ✓ Documentation
- ✓ Flow on changes to other aspects of the workplace.

This range of factors will lead to the generation of a number of options including:

- ✓ Do nothing (too expensive, customer does not need it, supplier cannot supply)
- ✓ Do it all at once ('crash through' approach)
- ✓ Do it over time (often easier to gain staff acceptance this way)
- ✓ Remove the risks completely (eg replace machine, replace staff, pull out of this testing)
- ✓ Control the risks (better QA, more sensitive QC).

In the following activity you will identify options to rectify shortcomings in some special testing you are doing for Krazy Kola. Click on the following link to access this activity.

Assignment - Deming and You II

Simulab does a significant amount of work for the Krazy Kola Company. Krazy Kola produces a range of soft drinks as well as fruit juices, however their number one seller is Krazy Kola - the biggest selling soft drink in the country. They have had some unresolved problems with their QC Department (probably related to poor sampling of raw materials) and have asked simulab to 'mirror' their QC processes as an aid to monitoring their own department.

The project is very 'hush hush' as Krazy Kola does not want their QC Department to know that they are being evaluated.

As a result of this a midnight truck arrives at simulab with large volumes of bulk (ie not packaged) Krazy Kola for testing and evaluation. Simulab's testing processes and procedures are coping well with the science side of this arrangement, but there is one problem.

What to do with 500 L of leftover Krazy Kola each week? Krazy Kola are willing to pay for reasonable costs associated with disposal but they cannot take the leftovers back for 'security' reasons!

Try to find a solution to this problem by identifying factors and options (as listed on the task page). Your answers should be clear, concise and detailed and should include the following:

- ✓ Two alternative recommendations
- ✓ Some environmental considerations
- ✓ Any 'win-win' situations that you can think of
- ✓ Any OHS or community health implications
- ✓ Any costs or benefits associated with the proposals ('guesstimates' only).

Assess the adequacy of current controls, quality methods and systems

Philip Crosby is often described as the 'evangelist' of quality management. He wrote a book called 'Quality is Free' which expounds his contention that Quality actually saves money and is therefore free. His view is that the price of getting things wrong (price of non-conformance) always outweighs the cost of getting things right (price of conformance). Thus 'Quality is Free'.

Crosby's view intermeshes with many of Deming's Points.

Crosby's philosophy has three main points:

- ✓ Quality is free: poor quality is expensive
- ✓ Do things right the first time
- ✓ 'Zero defects' is the only legitimate goal of a quality program.

In the following activity you will apply Crosby's broad principles and Deming's Points and Diseases (where appropriate) to assess the Quality System in your own experience.

Assignment - Crosby and You

Keep a copy of your final assignment for your own records, as you will use the details in a further activity.

Choose one complete aspect of a quality system from your work experience. For example, if you work in a winery and choose the production of Pinot Noir wine, then you would need to consider the entire quality processes from the decision to pick the berries to when the bottle of wine is delivered to the wholesaler.

If you are not employed, pick a system or process that you know a lot about and apply the same principles to your evaluation of this system. Scrutinise the quality system using Crosby's three main points and Deming's Points and Deadly Diseases (where relevant) to assess the adequacy of the current controls, quality methods and systems.

You will be using a 'broad brush' approach here. Do not talk about the finer points of berry sugar content, just concentrate on whether the quality system allows the berries to be picked at the optimum time.

Your answers should be clear, concise and detailed and should include the following:

1. Your evaluation of the system against Crosby's three main points

2. Your evaluation against the relevant Deming's Points and Deadly Diseases
3. Your recommendations for change.

Identify opportunities to continuously improve performance

Quality is one aspect of simulab's activities. We have discussed quality at length to define it, manage it and improve it. Another aspect of simulab's activities is performance.

Obviously, performance is related to quality and the two are sometimes discussed as being the same thing. But performance comes out of the quality system and of course quality is related to how we perform.

Sound confusing? Put simply, performance is what we do (for example, doing glucose measurements on 30 samples of Krazy Kola by 3.00 pm today) and quality is how well we do it (for example QC, meet the deadline, minimise wastage, report results correctly with appropriate units).

The US Joint Commission on Accreditation of Healthcare Organisations (JCAHO) has developed nine Dimensions of Performance and these are listed below.

- ✓ Efficacy (ability to produce the desired effect)
- ✓ Appropriateness
- ✓ Availability
- ✓ Timeliness
- ✓ Effectiveness (producing the intended or expected result)
- ✓ Continuity
- ✓ Safety
- ✓ Efficiency (competently)
- ✓ Care and Respect

Note: efficacy, effectiveness and efficiency have different meanings. To illustrate these different meanings, we will consider the scenario concerning the measurement of glucose levels in Krazy Kola:

- ✓ The test procedure is efficacious if it is able to measure the glucose level
- ✓ You are effective if you have the ability to produce accurate glucose levels
- ✓ You are efficient if you can do it by 3.00 pm.

Whilst there has been great debate about whether it is appropriate to measure and improve performance instead of quality, the nine dimensions of performance do provide a useful tool to use to investigate performance.

Assignment - Performance and You

Keep a copy for your own records, as you will use the details in a further activity.

Go back to your experience-based evaluation in the activity - Crosby and You.

This time apply the nine Dimensions of Performance to your situation and answer the following questions:

1. Did this process highlight any new options for improvement?
2. If so, what are they?
3. Did this process help you gain a better insight into your Crosby options?
4. If so, what are they?

Develop recommendations for continual improvements of work practices, methods, procedures and equipment effectiveness

Continual improvements or Continuous Quality Improvement (CQI) sounds very useful in theory but the practice sometimes requires hard work.

The Japanese car industry has an approach to CQI that works well because of the structure of Japanese society.

- ✓ Each and every employee is required to make a certain number of quality improvement suggestions per month (say one per month, twelve per year)
- ✓ Management evaluates all suggestions and puts in place all viable suggestions
- ✓ The worker receives workplace admiration and respect for the great idea and sometimes a monetary reward.

This is a relatively simple process (but a potential personnel relations nightmare - imagine telling Australian workers that it was mandatory to come up with 12 suggestions per year!). The results are evident in the excellent (and relatively cheap) Japanese cars on the market today.

Assignment - CQI and You

Base the following exercise on the activities - Crosby and You, and Performance and You.

Your task is to describe what you would do in order to institute Continuous Quality Improvement (CQI) in your chosen scenario, and how you would do it. Strategies might include suggestion boxes, an open-door policy, surveys, meetings, and advertising.

Your description, or plan, should be clear, concise and detailed and should address the following:

1. Practical aspects (how you would go about instituting CQI)
2. How you would manage the personnel issues (strategies might include encouragement, recognition or reward for great ideas, breaking down cynicism and mistrust)
3. How you would manage work practices, methods, procedures and equipment effectiveness.

Consult with appropriate personnel to refine recommendations before implementation of approved improvement strategies

Quality Improvement in the workplace is fine when outlined on paper. It may take a lot of work but we can collect data, review quality systems, institute automated QC data management, purchase better equipment and even move to a new building BUT we cannot do any of these things without CONSULTATION.

Consultation means:

- ✓ Meeting for deliberation
- ✓ Seeking information or advice from someone who knows more than we do
- ✓ Taking counsel
- ✓ Taking suggestions into consideration.

Whenever you consult always keep these points in mind. You need to:

- ✓ Meet, talk and listen
- ✓ Seek advice
- ✓ Talk to the right people.

Assignment - Consultation and You

You have a problem at simulab. Read the following situation and give a report on how you would consult to refine recommendations outlined below before implementing the improvement strategies.

The owner, Mr Elgar, is always on the lookout to improve his bottom line (profits). He recently attended a high-powered quality management conference in Vienna and has come home brimming with ideas.

Mr Elgar wants to:

- ✓ Expand the car parking area so that all staff and customers can have their own spaces
- ✓ Amalgamate the Analytical and Biological Laboratories and reduce staff by one scientist and one technician
- ✓ Introduce quality training for ALL staff
- ✓ Introduce an incentive scheme for staff - the more specimens put through - the more money earned.

This exercise is specifically related to the art of consultation so do not go into fine detail about methods, sops or testing. Think instead of the 'big picture' human implications in these proposals.

Review the above scenario from three perspectives:

- ✓ Staff
- ✓ Customers

✓ Resources.

Your answer should be clear, concise and detailed and should include the following:

1. A list of the possible implications of each of the proposals.
2. A list of the positives and negatives associated with each proposal.
3. A list of possible objections to each of the proposals.
4. A list of who you would consult with at simulab (and elsewhere?).
5. An indication of which recommendations you would support and why.
6. Choose one of the proposals that you would support - is there any fine-tuning required?

Document outcomes of strategies and communicate them to relevant personnel

You will be aware by now that documentation is vital for all quality operations and for the continued existence of simulab and all businesses. You have also learnt about quality management and practised some of the tools of quality.

This final activity will test your ability to develop a strategy, then document the strategy outcomes and communicate the information to relevant staff.

Click on the following link to do an activity on strategies and communication.

Assignment - Strategies and Communication

Suppose the Specimen and Sample Drop-off area at simulab is no longer functional. When simulab was a smaller, more specialized chemistry laboratory it was logical to locate the Specimen and Sample Drop-off area in a space shared with Reception.

But now simulab receives environmental, biological and human pathology specimens in abundance. This poses an OHS risk to Reception staff, customers and visitors.

Simulab are going to move the Specimen and Sample Drop-off area into an under-used laboratory area and put a new door through to this area from the hallway for ease of courier access.

Your task is to develop a 'Transfer Strategy' that allows transfer of the area's activities from the old location to the new location with a minimum of fuss, customer confusion and loss of time.

Unfortunately for a number of logistical, engineering and electrical reasons the changeover will take three days so it cannot be completed over a weekend.

Develop a strategy to move the Specimen and Sample Drop-off area with minimum disruption. How would you document this strategy and how (and to whom) would you communicate the strategy?

Your answer should be clear, concise and detailed and should include and address the following:

- ✓ An outline of the strategy (a flow chart or diagram would be useful).
- ✓ What major factors did you consider in the development of the strategy?
- ✓ How would you document the strategy?
- ✓ How would you communicate the strategy?
- ✓ To whom and why?

UNIT 10

UNDERTAKE WASTE DISPOSAL IN LABORATORY SETTING

IDENTIFY WASTE PRODUCED IN LAB

This chapter presents methods for the management and ultimate disposal of laboratory waste that may present chemical hazards, as well as those multihazardous wastes that contain some combination of chemical, radioactive, and biological hazards. The best strategy for managing laboratory waste aims to maximize safety and minimize environmental impact, and considers these objectives from the time of purchase. As suggested in previous chapters, there is a strategic hierarchy for managing chemicals and waste to accomplish these objectives.

IDENTIFY WASTE PRODUCED IN LAB

Waste characteristics are identified

Conducting laboratory tests lead to production of waste and can be hazardous and need to be properly disposed. Before beginning a detailed discussion of the handling of waste once it has been generated, it is important to understand the definition of waste, how it is characterized, and the regulations that govern it.

Types of wastes are differentiated by waste stream or waste categories within lab setting. Waste must be categorized as to its identity, constituents, and hazards so that it may be safely handled and managed. Categorization is necessary to determine a waste's regulatory status, hazardous waste ID number, and treatability group, and to determine its proper procedures for managing waste by the Environment Protection Agency of the Maldives.

The great variety of laboratory waste makes waste categorization challenging. Transport and waste regulations are written for commercially available high-volume chemicals, which may make it difficult to categorize some laboratory chemicals, such as experimental or newly synthesized materials. Categorization procedures must account for the common laboratory waste management practices of placing small containers of waste chemicals into a larger overpack drum, and combining of many solvents and solutes into a single drum of flammable liquids.

There are several acceptable information sources for waste characterization, including the identity of the source or raw materials, in-laboratory test procedures (such as those described below), and analysis by an environmental laboratory. *Generator knowledge* can be used for waste characterization, such as the knowledge of waste characteristics and constituents by laboratory personnel who conducted the process, procedure, or experiment.

Characterization for Off-Site Management

When waste is to be shipped off-site for recycling, reclamation, treatment, or disposal, the waste characterization information needed depends on the waste management facility's requirements and its permit. Analytical methods have been established by the U.S. Environmental Protection Agency (EPA), and environmental laboratories that use EPA

methods are often certified or accredited. Most of these methods are for commercially available chemicals, and so approved analytical procedures may not be available for some laboratory chemicals. It is important to work with your waste disposal firm to determine how laboratory waste is to be categorized. To avoid redundant analysis for recurring waste streams (e.g., chlorinated solvents, labpacks of organic solids), waste disposal firms and off-site facilities often establish a waste-stream profile. In some cases, detailed analytical information is not necessary if waste containers fall within the profile's hazard classification.

Identification Responsibilities of All Laboratory Personnel

Because proper management and disposal of laboratory waste requires information about its properties, it is very important that laboratory personnel accurately and completely identify and clearly label all chemical and waste containers in their laboratory, as well as maintain the integrity of source material labels. It is recommended that supplementary information be kept in a separate, readily available record (e.g., laboratory information system, lab notebook), especially for very small containers or collections. In academic laboratories where student turnover is frequent, identification is particularly important for the materials used or generated. This practice is as important for small quantities as it is for large quantities.

The following information is commonly required by treatment and disposal facilities before they agree to handle unknown materials:

- ✓ **Physical description.** Include the state of the material (solid, liquid), the color, and the consistency (for solids) or viscosity (for liquids). For liquid materials, describe the clarity of the solution (transparent, translucent, or opaque). If an unknown material is a bi- or tri-layered liquid, describe each layer separately, giving an approximate percentage of the total for each layer. After taking appropriate safety precautions for handling the unknown, including the use of personal protection devices, remove a small sample for use in the following tests.
- ✓ **Water reactivity.** Carefully add a small quantity of the unknown to a few milliliters of water. Observe any changes, including heat evolution, gas evolution, and flame generation.
- ✓ **Water solubility.** Observe the solubility of the unknown in water. If it is an insoluble liquid, note whether it is less or denser than water (i.e., does it float or sink?). Most nonhalogenated organic liquids are less dense than water.
- ✓ **Ph.** Test the material with multirange pH paper. If the sample is water-soluble, test the pH of a 10% aqueous solution. Carrying out a neutralization titration may also be desirable or even required.
- ✓ **Ignitability (flammability).** Place a small sample of the material (<5 ml) in an aluminum test tray. Apply an ignition source, typically a propane torch, to the test sample for 0.5 second. If the material supports its own combustion, it is a flammable liquid with a flash point of less than 60 °C (140 °F). If the sample does not ignite, apply the ignition source again for 1 second. If the material burns, it is combustible. Combustible materials have a flash point between 60 and 93 °C (140 and 200 °F).
- ✓ **Presence of oxidizer.** Wet commercially available starch-iodide paper with 1 N hydrochloric acid, and place a small portion of the unknown on the wetted paper. A

change in color of the paper to dark purple is a positive test for an oxidizer. The test can also be carried out by adding 0.1 to 0.2 g of sodium or potassium iodide to 1 ml of an acidic 10% solution of the unknown. Development of a yellow-brown color indicates an oxidizer. To test for hydroperoxides in water-insoluble organic solvents, dip the starch-iodine test paper into the solvent, and let it dry. Add a drop of water to the same section of the paper. Development of a dark color indicates the presence of hydroperoxides.

- ✓ **Presence of peroxides.** The following tests detect most (but not all) peroxy compounds, including all hydroperoxides. Please take care.
 - Peroxide test strips, which turn to an indicative color in the presence of peroxides, are available commercially. Note that these strips must be air dried until the solvent evaporates and exposed to moisture for proper operation.
 - Add 1 to 3 ml of the liquid to be tested to an equal volume of acetic acid, add a few drops of 5% aqueous potassium iodide solution, and shake. The appearance of a yellow to brown color indicates the presence of peroxides. Alternatively, addition of 1 ml of a freshly prepared 10% solution of potassium iodide to 10 ml of an organic liquid in a 25-ml glass cylinder produces a yellow color if peroxides are present.
 - Add 0.5 ml of the liquid to be tested to a mixture of 1 ml of 10% aqueous potassium iodide solution and 0.5 ml of dilute hydrochloric acid to which has been added a few drops of starch solution just prior to the test. The appearance of a blue or blue-black color within 1 minute indicates the presence of peroxides.

None of these tests should be applied to materials (such as metallic potassium) that may be contaminated with inorganic peroxides.

- ✓ **Presence of sulfide.** Commercial test strips for the presence of sulfide are available, and their use is recommended. If the test strips are not available in the laboratory, the following test can be performed. **Warning: This test produces hazardous and odiferous vapors. Use only small quantities of solution for the test and use appropriate ventilation.** The test for inorganic sulfides is carried out only when the pH of an aqueous solution of the unknown is greater than 10. Add a few drops of concentrated hydrochloric acid to a sample of the unknown while holding a piece of commercial lead acetate paper, wet with distilled water, over the sample. Development of a brown-black color on the paper indicates generation of hydrogen sulfide.
- ✓ **Presence of cyanide.** Commercial test strips for the presence of cyanide are available, and their use is strongly recommended.
- ✓ **Presence of halogen.** Heat a piece of copper wire until red in a flame. Cool the wire in distilled or deionized water, and dip it into the unknown. Again, heat the wire in the flame. The presence of halogen is indicated by a green color around the wire in the flame.

Hazardous and dangerous waste and non-conforming waste are detailed.

What Is Hazardous Waste?

Hazardous waste is waste that poses a severe threat to human health or the environment if improperly disposed of. According to the EPA, a substance is a hazardous waste if it appears

on specific lists of hazardous waste or exhibits the established characteristics of hazardous waste.

Listed wastes appear on one of four official lists: the F, K, P and U lists.

The F list identifies non-source-specific hazardous wastes from common industrial and manufacturing applications. The K list identifies source-specific wastes from specific areas within industry and manufacturing.

The P and U lists define wastes that consist of pure, commercial-grade formulations of specific unused chemicals. To be classified as a P or U waste, a substance must meet the following three criteria:

7. The waste must contain one of the chemicals on the P or U lists.
8. The chemical in the waste must be unused.
9. The chemical in the waste must be a commercial chemical product. The EPA considers a commercial chemical product to be one that is either a 100 percent pure commercial-grade product or one that is the sole active ingredient in a given chemical formation.

The P list differs from the U list in that it designates acute hazardous wastes — those that are toxic even at low levels.

Characteristic Waste

The EPA considers characteristic waste to be waste that exhibits any of four properties:

1. **Ignitability:** Hazardous wastes that demonstrate the characteristic of ignitability include the following: wastes with flashpoints of less than 60 degrees Celsius, non-liquid materials that cause fires, ignitable compressed gases and oxidizers.
2. **Corrosivity:** Corrosive hazardous wastes include acidic liquid wastes with a pH of two or less and basic liquid wastes that have a pH of 12.5 or more and can corrode steel.
3. **Reactivity:** Reactive hazardous wastes include wastes that are unstable under standard conditions, react with water, give off toxic fumes or have the capability to explode or detonate when they are heated.
4. **Toxicity:** Toxic hazardous wastes include wastes that are harmful to health when swallowed or absorbed. Toxic wastes are of particular concern because they can leach through soil and contaminate groundwater.

Common Examples of Hazardous Waste

Many pesticides, herbicides, paints, industrial solvents, fluorescent light bulbs and mercury-containing batteries are classified as hazardous wastes. So are medical waste products such as cultures, human tissue, contaminated gloves, sharps and so forth. Below are a few lists of common examples of hazardous wastes by list and category.

Common F-List Wastes

The hazardous wastes on the EPA's F list are divided into seven different categories based on the industrial application from which they originated:

1. Spent Solvent Wastes

Some common types of spent solvent wastes include tetrachloroethylene, trichloroethylene, methylene chloride, carbon tetrachloride and chlorinated fluorocarbons, all of which are spent halogenated solvents used in degreasing.

Some common types of spent non-halogenated solvents include xylene, acetone, ethyl acetate, ethylbenzene, ethyl ether, n-butyl alcohol, methanol, nitrobenzene, toluene, methyl ethyl ketone, isobutanol, pyridine, benzene and many more.

All spent solvent solutions that contain 10 percent or more of any of these substances also qualify, as do still bottoms from the recovery of spent solvents and spent solvent mixtures.

2. Electroplating and Other Metal-Finishing Wastes

Electroplating and other metal-finishing wastes include spent cyanide bath plating solutions and any plating bath solutions and residues from operations where cyanides have been used. They additionally include wastewater treatment sludges from the chemical coating of aluminum.

3. Dioxin-Containing Wastes

Dioxin-containing wastes include wastes from the production of tri-, tetra- or pentachlorophenol or their derivatives, which are usually pesticides. Wastes from the production of tetra-, penta- and hexachlorobenzenes also belong to this category.

4. Wastes from the Production of Chlorinated Aliphatic Hydrocarbons

Chlorinated aliphatic hydrocarbons such as perchloroethylene and trichloroethylene are often used as solvents in dry-cleaning and other industries. Their hazardous wastes include distillation residues, heavy ends, tars, clean-out wastes from reactors, condensed light ends, spent filters and filter aids and spent desiccant waste.

5. Wood-Preserving Waste

Wood-preserving waste is classified as hazardous waste if it comes from facilities that use the preservative creosote — a potential carcinogen — or arsenic or chromium preservatives. This waste can include process residuals, preservative drippings and spent formulations.

6. Petroleum Refinery Wastewater Treatment Sludge

Any sludge created by the separation of oil, water and solids or by oily cooling wastewater during petroleum refining is classified as hazardous waste. These sludges are often generated in separators, tanks, impoundments, ditches, sumps, stormwater units that receive dry weather flow, induced air flotation units and dissolved air flotation units.

7. Leachate from Multiple Sources

Leachate is any liquid that has percolated through waste disposed of on land. Leachate that has flowed through more than one type of waste included on the EPA's hazardous waste listings is automatically classified as hazardous as well.

Common Wastes on the K List

The hazardous wastes on the K list, unlike those on the F list, come from specific manufacturing and industrial sectors. Sources for the different types of wastes on the K list fall into one of the following 13 categories:

1. Wood preservation
2. Organic chemicals manufacturing
3. Pesticides manufacturing
4. Petroleum refining
5. Veterinary pharmaceuticals manufacturing
6. Inorganic pigment manufacturing
7. Inorganic chemicals manufacturing
8. Explosives manufacturing
9. Iron and steel production
10. Primary aluminum production
11. Secondary lead processing
12. Ink formulation
13. Coal processing into coke

A few of the common hazardous materials on the K list are the following:

- ✓ **Bottom-sediment sludge** from wood-preserving wastewater whose processes use creosote or pentachlorophenol, a pesticide and disinfectant.
- ✓ **Wastewater treatment sludge** from the production of different-colored pigments.
- ✓ **Distillation bottoms or side cuts** from the transformation of ethylene into acetaldehyde.
- ✓ **Still bottoms** from the distillation of benzyl chloride.
- ✓ **Heavy ends from the fractionation column** in the production of ethyl chloride, often used as a topical anesthetic.
- ✓ **Heavy ends from distillation** in the production of ethylene dichloride or vinyl chloride.
- ✓ **Aqueous spent antimony catalyst waste** from the production of fluoromethane, often used in the production of semiconductor or electronic products.
- ✓ **Distillation bottoms** from the production of nitrobenzene.
- ✓ **Centrifuge and distillation residues** from the production of toluene diisocyanate, often used in foam for furniture, bedding, carpet underlay and in coatings, sealants and adhesives.
- ✓ **Column bottoms or heavy ends** from the combined production of trichloroethylene and perchloroethylene, both industrial solvents.

- ✓ **Byproduct salts** generated in the production of MSMA and cacodylic acid, both arsenic-based herbicides.
- ✓ **Wastewater treatment sludge** from the production of chlordane or creosote, or from toluene reclamation distillation in the production of disulfoton, a pesticide.
- ✓ **Filter cake** from the filtration of diethylphosphorodithioic acid in the production of phorate, commonly used as a pesticide.

Common Wastes on the P List

Hazardous wastes on the P list are classified as acute hazardous waste — they are toxic to humans even at low doses or when properly managed. Some examples of the many acute hazardous wastes on the P list include the following:

- ✓ Acetamide
- ✓ Allyl alcohol
- ✓ Arsenic acid
- ✓ Barium, calcium, copper, hydrogen, potassium, silver, sodium and zinc cyanides
- ✓ Beryllium powder
- ✓ Benzyl chloride
- ✓ Disulfoton
- ✓ Epinephrine
- ✓ Fluorine
- ✓ Nicotine and salts
- ✓ Nitric oxide
- ✓ Nitrogen oxide and dioxide
- ✓ Strychnine and salts
- ✓ Tetraethyl lead
- ✓ Thallic oxide
- ✓ Toxaphene

Common Wastes on the U List

A few of the common hazardous wastes on the U list are the following:

- ✓ Acetone
- ✓ Acrylic acid
- ✓ Benzene
- ✓ Diethylhexyl phthalate
- ✓ Methyl bromide
- ✓ Chlorobenzene
- ✓ Chloroform
- ✓ Methyl chloride
- ✓ Creosote
- ✓ DDT
- ✓ Dichlorodifluoromethane
- ✓ Dimethyl sulfate
- ✓ Ethyl acetate
- ✓ Ethyl ether

- ✓ Formaldehyde
- ✓ Hexachloroethane
- ✓ Hydrogen fluoride
- ✓ Isobutyl alcohol
- ✓ Lead acetate
- ✓ Mercury
- ✓ Methyl alcohol
- ✓ Methyl chloroform
- ✓ Methyl isobutyl ketone
- ✓ Nitrobenzene
- ✓ Pentachlorobenzene
- ✓ Phenol
- ✓ Pyridine
- ✓ Selenium sulfide
- ✓ Tetrachloroethylene
- ✓ Toluene
- ✓ Uracil mustard
- ✓ Xylene

Contaminants present in waste are noted.

Contaminants present in waste are noted based on the hazards or non-hazards nature of the substance

A solid waste, or combination of solid waste, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may (a) cause, or significantly contribute to, an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or (b) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

Proper hazardous waste identification is essential to the success of the hazardous waste

Management program. The regulations require that any person who produces or generates a waste must determine if that waste is hazardous. Following presents the steps in the hazardous waste identification process:

- ✓ Is the waste a "solid waste"?
- ✓ Is the waste a "listed" hazardous waste?
- ✓ Does the waste exhibit a characteristic of hazardous waste?

Is the Waste a Listed Hazardous Waste, Or Does It Exhibit a Characteristic?

The final steps in the hazardous waste identification process determine whether a waste actually poses a sufficient chemical or physical hazard to merit regulation. These steps in the hazardous waste identification process involve evaluating the waste in light of the regulatory definition of hazardous waste. The remainder of this module explains the definition of hazardous waste in detail.

Further information on waste is obtained by questioning appropriate personnel to ensure correct identification.

Environmental hazard identification is the first step in environmental risk assessment, which is the process of assessing the likelihood, or risk, of adverse effects resulting from a given environmental stressor. Hazard identification is the determination of whether, and under what conditions, a given environmental stressor has the potential to cause harm.

In hazard identification, sources of data on the risks associated with prospective hazards are identified. For instance, if a site is known to be contaminated with a variety of industrial pollutants, hazard identification will determine which of these chemicals could result in adverse human health effects, and what effects they could cause. Risk assessors rely on both laboratory (e.g., toxicological) and epidemiological data to make these determinations.

Conceptual model of exposure

Hazards have the potential to cause adverse effects only if they come into contact with populations that may be harmed. For this reason, hazard identification includes the development of a conceptual model of exposure. Conceptual models communicate the pathway connecting sources of a given hazard to the potentially exposed population(s). The Agency for Toxic Substances and Disease Registry establishes five elements that should be included in a conceptual model of exposure:

The source of the hazard in question

- ✓ Environmental fate and transport, or how the hazard moves and changes in the environment after its release
- ✓ Exposure point or area, or the place at which an exposed person comes into contact with the hazard
- ✓ Exposure route, or the manner by which an exposed person comes into contact with the hazard (e.g., orally, dermally, or by inhalation)
- ✓ Potentially exposed populations.

IDENTIFY HAZARDS AND RISK

Other potential hazards and risks present in work environment are listed.

A hazardous waste characteristic is a property that indicates that a waste poses a sufficient threat to deserve regulation as hazardous. EPA tried to identify characteristics which, when present in a Waste, can cause death or illness in humans or ecological damage. EPA also decided that the Presence of any characteristic of hazardous waste should be detectable by using a standardized test Method or by applying general knowledge of the waste's properties. EPA believed that unless Generators were provided with widely available and

uncomplicated test methods for determining Whether their wastes exhibited hazardous characteristics, this system of identifying hazardous Wastes would be unfair and impractical. Given these criteria, EPA only finalized four hazardous Waste characteristics. These characteristics are a necessary supplement to the hazardous waste Listings. They provide a screening mechanism that waste handlers must apply to all wastes from all Industries. In this sense, the characteristics provide a more complete and inclusive means of Identifying hazardous wastes than do the hazardous waste listings. The four characteristics of Hazardous waste are:

- ✓ Ignitability
- ✓ Corrosivity
- ✓ Reactivity
- ✓ Toxicity.

To determine whether a waste displays characteristics, they are not required to do so. In other words, any handler of industrial waste may apply knowledge of the waste's properties to determine if it exhibits a characteristic, instead of sending the waste for expensive laboratory testing. As with listed wastes, characteristic wastes are assigned waste codes. Ignitable, corrosive, and reactive wastes carry the waste codes D001, D002, and D003, respectively.

Ignitability

Ignitable wastes are wastes that can readily catch fire and sustain combustion. Many paints, cleaners, and other industrial wastes pose such a fire hazard. Most ignitable wastes are liquid in Physical form. EPA selected a flash point test as the method for determining whether a liquid Waste is combustible enough to deserve regulation as hazardous. The flash point test determines the lowest temperature at which a chemical ignites when exposed to flame. Many wastes in solid or nonliquid physical form (e.g., wood, paper) can also readily catch fire and sustain combustion, But EPA did not intend to regulate most of these nonliquid materials as ignitable wastes. A Nonliquid waste is only hazardous due to ignitability if it can spontaneously catch fire under normal handling conditions and can burn so vigorously that it creates a hazard. Certain compressed gases and chemicals called oxidizers can also be ignitable. Ignitable wastes carry the waste code D001 and are among the most common hazardous wastes.

Corrosivity

Corrosive wastes are acidic or alkaline (basic) wastes which can readily corrode or dissolve

Flesh, metal, or other materials. They are also among the most common hazardous waste streams. Waste sulfuric acid from automotive batteries is an example of a corrosive waste. EPA uses two Criteria to identify corrosive hazardous wastes. The first is a ph test. Aqueous wastes with a ph greater than or equal to 12.5, or less than or equal to 2 are corrosive under EPA's rules. A waste may also be corrosive if it has the ability to corrode steel in a specific EPA-approved test Protocol. Corrosive wastes carry the waste code D002.

Reactivity

A reactive waste is one that readily explodes or undergoes violent reactions. Common examples are discarded munitions or explosives. In many cases, there is no reliable test method to evaluate a waste's potential to explode or react violently under common handling conditions. Therefore, EPA uses narrative criteria to define most reactive wastes and allows waste handlers to use their best judgment in determining if a waste is sufficiently reactive to be regulated. This is possible because reactive hazardous wastes are relatively uncommon and the dangers they pose are well known to the few waste handlers who deal with them. A waste is reactive if it meets any of the following criteria:

- ✓ It can explode or violently react when exposed to water, when heated, or under normal handling conditions
- ✓ It can create toxic fumes or gases when exposed to water or under normal handling conditions
- ✓ It meets the criteria for classification as an explosive under Department of Transportation rules
- ✓ It generates toxic levels of sulfide or cyanide gas when exposed to a pH range of 2 through 12.5. Wastes exhibiting the characteristic of reactivity are assigned the waste code D003.

Supervisor and team members are informed of job requirements, hazards and risks.

Understand WHS responsibilities

Here is a summary of employees, employers and others' responsibilities.

Employee responsibilities

These responsibilities are for all employees. The main things you must remember after training are to:

- ✓ Work safely – you must follow all training, processes and procedures
- ✓ Not put anyone else in danger and do everything you can to ensure a person's safety, in line with your duty of care requirements
- ✓ Report any hazards or incidents including near misses
- ✓ Follow the instructions you are given
- ✓ Use equipment, including protective equipment, properly – in the way you have been trained and following the manufacturer's instructions
- ✓ Cooperate with your supervisor and employer
- ✓ Understand your rights and responsibilities are equally important.

It is just as important for you to follow the training you are given as it is for you to receive that training from your employer. It is also important for you to share information about any hazards or potential hazards. You must follow your workplace policies and procedures and report any hazards or incidents to the right person. This will usually be the HSR and your

supervisor.

Workers have a duty of care (a legal responsibility) to keep themselves, people they support and others safe, therefore, they need a basic understanding of the risks associated with various hazards. As conditions in a workplace may change, information about WHS policies and procedures should be provided regularly to work teams.

Health and safety representative

Health and safety representatives (hsrs) are a key link between employees and Employers. They tell employers about employees' safety and health concerns. They Also help employers to make sure workplace safety processes and procedures work. To be an HSR the person must:

- ✓ Be employed at the workplace
- ✓ Be elected by members of that work group
- ✓ Once elected, undertake training in work health and safety, approved by the regulator (or have previously undertaken the training)

Health and safety representatives:

- ✓ Inspect workplace areas
- ✓ Immediately investigate accidents or risk of serious injury or harm
- ✓ Must keep up with information provided by the employer on hazards in the workplace, and liaise with government and other bodies
- ✓ Report hazards in the workplace
- ✓ Refer safety and health matters they think appropriate to the safety and health Committee (if the workplace has one)
- ✓ Liaise with employees about safety and health
- ✓ Must be informed by the employer about dangerous situations or accidents, or when an inspector visits the workplace
- ✓ Must be notified of any changes in the workplace that may affect employees' safety and health
- ✓ Can attend any safety and health discussion between an employer and an employee if the employee asks them to be there
- ✓ Can expect space and time to help them carry out their duties; for example, they will need storage space to keep records and information, and time off work on normal pay to attend to the safety and health functions
- ✓ Can expect to be trained according to the regulations – they can get paid leave to attend accredited introductory training on WHS.

WHS committees

Some workplaces might have a health and safety committee (HSC). A committee is a group of people who meet to talk, share information and make decisions about a certain topic. A health and safety committee will be responsible for thinking about WHS issues and how they can be solved. The committee might include:

- ✓ Support workers
- ✓ Maintenance staff
- ✓ Other health professionals
- ✓ Supervisors or managers.

It is a good idea for a committee to have people from all different parts of the organisation. This way, all the different parts of the business can share ideas. For example, if you did not include maintenance staff, you might miss out on important ideas about how to keep equipment operating safely. Everyone on the WHS committee is responsible for thinking of ways to make the workplace as safe as possible. They will then share their ideas with the managers or your employer.

Safe work practices that prevent risk behaviour are outlined to supervisor.

Supervisors are responsible for a great deal of what goes on day to day in the workplace; it's not just a position that solely assigns tasks. Supervisors must ensure a safe and healthful workplace for employees. Employees must be able to report unsafe or unhealthful workplace conditions or hazards to a supervisor without fear of reprisal.

The following is a list of primary responsibilities that supervisors have in the area of occupational safety and health for all employees under their supervision.

Conduct Orientation and Training of Employees:

Train and instruct employees so they can perform their work safely. Know what personal protective equipment is needed for each task and how this equipment must be properly used, stored and maintained. When there are mandated safety training courses, ensure that your employees take them and that they are appropriately documented.

Enforce Safe Work Practices:

It's the supervisors responsibility to enforce safe work practices and procedures; failure to do so is an invitation for accidents to occur. Workers must be encouraged to identify unsafe or unhealthful workplace conditions or hazards and absolutely not be disciplined for doing so!

Correct Unsafe Conditions:

Supervisors' must take immediate steps to correct unsafe or unhealthful workplace conditions or hazards within their authority and ability to do so. When an unsafe or unhealthful workplace condition or hazard cannot be immediately corrected, the supervisor must take temporary precautionary measures. Supervisors must follow-up to ensure that corrective measures are completed in a timely manner to address the hazard.

Prevent Lingering Unsafe or Unhealthful Workplace Conditions or Hazards:

Many near miss incidents are caused by unsafe or unhealthful workplace conditions or hazards. It's the supervisor's responsibility to train and periodically remind employees of what to look for and how to correct or report unsafe conditions or hazards. If a hazard is identified, the supervisor must act.

Investigate Workplace Accidents:

Supervisors are responsible for conducting accident investigations and for ensuring that all occupationally injured employees report to the relevant personnel within the workplaces.

Promote Quick Return to Work:

Employees must be encouraged to return to work as soon as possible. The longer an employee is away from work, the less likely he or she will actually return. When possible, light or limited duties should be identified and considered, to assist in returning the employee to work.

Emergency response procedures are practiced with team members.***Hazardous Materials Leaks/Spills***

- ✓ If there is a spill, leak, or fire involving hazardous material (flammable, toxic, corrosive, oxygen, cryogenic), confine the spill, leak, fumes, or fire by exiting the space and shutting the door. Avoid contact with the material. If time permits, locate the Material Safety Data Sheets (MSDS) for any identifiable materials.
- ✓ Sound the building fire alarm so evacuation can begin.
- ✓ Dial 911, then call the Department of Campus Safety at (626) 815-3898, or use one of the Code Blue call boxes located throughout the campus. Give your name, department, location of the emergency, nature of the incident, and description of the material.
- ✓ Evacuate to the designated evacuation area. DO NOT return to the building until instructed that it is safe to do so.
- ✓ Even SUSPECTED hazardous materials, leaks, or suspicious odors should be reported to Campus Safety so appropriate action can be taken.

Medical Emergencies

- ✓ To determine what is a true medical emergency, check for signs such as chest pain, difficulty breathing, excessive or uncontrollable bleeding, unconsciousness, and life-threatening injuries (severe head injuries, severe burns, etc.)
- ✓ Call relevant hotline, and report the nature of the illness or injury, your name, and the location and telephone number from which you are calling.
- ✓ Administer first aid (if you are trained AND permission is granted by the injured)
- ✓ Direct emergency and medical personnel to the scene.
- ✓ Remain with the victim until emergency personnel arrive.

Power/Utility Outage

- ✓ Students should remain in their living area, and employees should consult with their supervisor before leaving their workstation, whenever possible.
- ✓ If movement between floors is necessary, use stairways, NOT ELEVATORS.
- ✓ DO NOT use candles; use battery-operated lights instead.

- ✓ Turn off electronic equipment, and avoid using the university telephone system if possible, to preserve battery power for official use.
- ✓ Exercise caution with valuables, and follow directions from building coordinators and emergency personnel.

DISPOSE OF WASTE

Appropriate disposal is arranged with regard to waste quality, quantity and EPA and government regulations

Hazardous Material Disposal

Hazardous waste is waste that is dangerous or potentially harmful to our health or the environment. Under the United States Environmental Protection Agency (USEPA), waste can be a listed hazardous waste, or characteristically hazardous. Listed hazardous wastes, by definition, have been determined by USEPA as being hazardous.

Waste that has not been specifically listed can still be characteristically hazardous if it exhibits any one of the following characteristics:

- ✓ Ignitability;
- ✓ Corrosivity;
- ✓ Reactivity; or
- ✓ Toxicity.

Ignitability

- ✓ Flammable Liquids – Flashpoint <140°f (e.g., alcohols, acetone, ethyl acetate, mineral spirits, gasoline)
- ✓ Oxidizers (e.g., nitrates, perchlorates, bromates, permanganates, peroxides, iodates)
- ✓ Organic Peroxides (e.g., benzoyl peroxide, cumene hydroperoxide, methyl ethyl ketone peroxide)

Corrosivity

Aqueous liquids with a ph < 2 or > 12.5 or other liquids capable of corroding steel at a rate of > 6.35 mm (0.250 inches) per year at a test temperature of 55°f.

- ✓ Inorganic Acids (e.g., hydrochloric acid, sulfuric acid, nitric acid, perchloric acid, phosphoric acid)
- ✓ Organic Acids – (e.g., formic acid, lactic acid)

- ✓ Bases – (e.g., hydroxide solutions, amines)

Reactivity

Materials which can react violently or create toxic fumes:

- ✓ Sulfides and cyanides
- ✓ Peroxide formers (e.g., ethers, potassium amide, sodium amide, vinyl acetate, tetrahydrofuran)
- ✓ Water Reactive Materials (e.g., sodium, potassium, lithium, calcium carbide)
- ✓ Multi-nitrated Compounds (e.g., picric acid, nitrosoguanidine, trinitroaniline)
- ✓ Perchlorate crystal formers (e.g., perchloric acids)
- ✓ Compounds that may undergo vigorous polymerization (e.g., acrylic acid, vinyl acetate, methyl acrylate)

Toxicity

A waste which, when using the toxicity characteristic leaching procedure (TCLP), leaches any number of metallic, organic, or pesticide constituents in concentrations greater than specified in the regulation. Examples for these constituents include arsenic, barium, cadmium, chloroform, chromium, m-cresol, mercury, selenium, and silver.

Disposal of hazardous materials into sinks, drains, commodes, or other sewage disposal channels is STRICTLY PROHIBITED.

Storage

All chemical wastes shall be stored using proper chemical segregation practices to avoid intermixing of incompatible materials. (See the Chemical Segregation and Storage Chart for guidance on how to properly store chemical waste containers).

All chemicals shall be stored in a satellite accumulation area near where the waste was generated. Moving/relocating hazardous wastes away from where they were generated is prohibited.

Labeling

All hazardous waste containers shall be properly labeled with the words "Hazardous Waste", a description of the waste contained in the container, the hazards associated with the waste, and the location where the material was generated. If bottles are reused, remove the old chemical name and hazards completely and indicate the type of chemical waste on the container without abbreviations. Hazardous waste containers not labeled in accordance with this policy shall not be removed from the area until such label is affixed to the container (see "Labeling-Hazardous Waste Containers"). If the contents of the container are unknown, please indicate this on the label and in the waste pick up request. Containers of unidentified wastes may need to be evaluated in person by waste vendor before they are removed for disposal.

In an effort to make container labeling easier for users EHS has created multiple labeling options. Please see the links below for links to Adobe forms for printed and handwritten label formats. Additionally, waste labels may also be printed from within the EHS Assistant program once a waste request has been entered.

Packaging

All hazardous waste shall be packaged in accordance with the following instructions:

- ✓ Use a leak-proof container that will safely contain the contents. Open chemical containers, plastic bags or culture dishes will not be accepted.
- ✓ Containers must be closable.
- ✓ The container shall not be overfilled with liquid waste.
- ✓ Empty space of at least five percent of the container volume shall be left to allow for thermal expansion.
- ✓ Be suspicious of any pressure build-up inside the container (e.g. Pirahna waste)
- ✓ If this is a concern when closing the container, use a cap designed to allow venting of over-pressure or do not secure the cap tightly and if appropriate, place the container inside a fume hood or other well-ventilated area until the chemical reaction has reached equilibrium and is removed by the waste collector.
- ✓ Old cans of dry picric acid or other shock sensitive compounds and all known or suspected peroxide forming chemicals (PFC) shall be left in place and not moved until the waste collector has evaluated the condition of the container. (Note: Friction, heat, and exposure to air can cause aging pfc's to explode).

Pfcs that MUST be disposed of within three (3) months of opening:

- ✓ Divinyl acetylene
- ✓ Divinyl ether
- ✓ Isopropyl ether
- ✓ Potassium amide
- ✓ Potassium metal
- ✓ Sodium amide
- ✓ Vinylidene chloride
- ✓ Pfc's that must be monitored for peroxides or discarded 12 months after opening. (This list is not exhaustive. Please check the SDS and dispose of the material per the manufacturer's expiration date.)
- ✓ Acetal (1,1-diethoxyethane)
- ✓ Acetaldehyde
- ✓ Benzyl alcohol
- ✓ 2-Butanol
- ✓ Cumene
- ✓ Cyclohexanol
- ✓ 2-Cyclohexen-1-ol
- ✓ Cyclohexene
- ✓ Decahydronaphthalene
- ✓ Diacetylene
- ✓ Dicyclopentadiene

- ✓ Diethyl ether
- ✓ 4-Heptanol
- ✓ 2-Hexanol
- ✓ Methylacetylene
- ✓ 3-Methyl-1-butanol
- ✓ Methylcyclopentane
- ✓ Methyl isobutyl ketone
- ✓ 4-Methyl-2-pentanol
- ✓ 2-Pentanol
- ✓ 4-Penten-1-ol
- ✓ 1-Phenylethanol
- ✓ 2-Phenylethanol
- ✓ 2-Propanol

Refrigerators and Freezers

Equipment containing refrigerants must be disposed of in a manner which is compliant with the EPA's Clean Air Act. For more information regarding the disposal of refrigerators, freezers or other small appliances containing <5 Gallons of refrigerant please see the Disposal of Refrigerators and Freezers guidance document.

Empty Chemical Containers

Chemical containers that have been emptied of their contents by normal methods are not regulated as hazardous waste. The container shall be triple rinsed with water or other suitable solvent and air-dried to ensure that it is free of liquid or another visible chemical residue before disposal.

Empty reagent bottles may be used for the disposal of laboratory chemical wastes. However, it is important to verify that the chemical wastes are compatible with the empty reagent containers.

Note: It is improper to dispose of volatile liquids by evaporating.

Glass Containers

Empty, intact, unbroken glass chemical containers that meet the above requirements for empty containers may be disposed of as regular laboratory waste in the general waste stream. Completely remove or deface chemical labels using a permanent black marker before disposal. Remove any caps from the bottles.

Broken laboratory glassware free from any biohazardous, radioactive, and chemical contamination shall be disposed of by packing in a designated broken glass receptacle, cardboard box, or other rigid container. This includes the disposal of the following uncontaminated items:

- ✓ Broken glass
- ✓ Glass vials

To minimize various potential hazards when discarding broken or un-serviceable glassware, the guidelines below shall be followed:

- ✓ Dispose of broken laboratory glassware in designated broken glass containers only. These shall be puncture proof, double-lined cardboard boxes or other containers specifically designed for the disposal of glassware not weighing more than 20 pounds when full. They can be obtained from various laboratory equipment distributors;

- ✓ When the box is full, securely seal with tape to prevent any leaks;
- ✓ Label the container as "TRASH";
- ✓ Never use broken glassware boxes for the disposal of sharps, medical/biohazardous materials or liquid wastes;

The following items contaminated with medical/biohazardous material shall be placed in a designated sharps container (for more information see the Potentially Infectious Waste Policy):

- ✓ Broken glassware
- ✓ Glassware with sharp edges or point
- ✓ Pasteur pipettes
- ✓ Glass slides

Contact the appropriate Facility Manager to make arrangements for pick-up

All personnel handling broken glass containers should:

- ✓ Check the weight and integrity of the container prior to lifting;
- ✓ Wear safety glasses and work gloves when handling the container;
- ✓ Do not remove the box if you see a red or orange liner;
- ✓ Do not remove the box if open, compromised, wet or suspected of containing chemicals; and
- ✓ Immediately contact your supervisor with any issues.

Metal Containers

Metal containers must be triple-rinsed with water or other suitable solvent and air-dried. If the container is free of hazardous chemical residues, remove or deface any hazard markings or labels, it may then be placed in the regular laboratory trash or recycling receptacles.

Secondary Containers

Containers that were used as overpack for the primary chemical container may be placed in regular trash or recyclable trash. Any packing materials, such as vermiculite, perlite, clay, Styrofoam, etc., may be placed in the regular trash unless it was contaminated with the chemical as a result of container breakage or leak. Packing materials contaminated with hazardous materials shall be disposed of as hazardous waste.

Waste is disposed of in an appropriate way to ensure compliance with workplace and EPA standards

There are several basic steps and regulations that all individuals must follow to properly and safely handle, store and dispose of hazardous materials generated in their work area:

- ✓ First investigate whether or not processes using hazardous materials can be eliminated; or determine if alternative methods exist for processes that do not use hazardous materials.
- ✓ Attempt to reduce the quantity, toxicity or other hazardous characteristic of materials being generated from processes that cannot be eliminated or substituted for by an environmentally safe process.

- ✓ Evaluate hazardous materials characteristics to ensure that incompatible materials are not combined or stored near one another.
- ✓ Do NOT dispose hazardous materials to the sanitary sewer system, atmosphere (i.e., evaporation), or solid trash receptacles.
- ✓ Insure that proper containers are available to accumulate each waste stream in advance of actually conducting research, analyzing samples or starting a chemical process.
- ✓ Properly label containers with words that accurately identify each container's contents.
- ✓ Keep track of accumulations to the container (all constituents and their concentrations). A log book with entries referenced to unique container numbers is helpful.
- ✓ Containers must ALWAYS be kept closed between accumulations.
- ✓ Minimize the accumulation of hazardous materials in your area by submitting materials and full containers promptly to EHS for disposal. Never accumulate more than 55 gallons of hazardous materials or one liter of acute hazardous waste in a given area.
- ✓ Submit all chemicals and hazardous materials to EHS for final characterization, collection and proper disposal.

Any subcontractors are checked to ensure they comply with EPA and government regulation

Consultation is a critical element for success in any WHS process. It is a legal requirement for a person conducting a business or undertaking (PCBU) and workers to engage in open communication about WHS matters. Consultation is also about talking with the work group and encouraging them to raise their concerns and identify any WHS queries or questions they may have.

Consultation usually occurs through either one-to-one or group meetings.

All forms of consultation have both benefits and drawbacks. For one-to-one consultation, the benefit lies in the confidentiality aspect and that the individual may feel they can speak more freely about issues they may have; however, this comes at the expense of having group knowledge available that may be able to resolve any issues immediately. The ideal forum or consultation option in the workplace is therefore a personal preference and may involve a combination of the two options.

Wastage rates are documented or collated for further review

The record-keeping requirements specified are designed to facilitate investigation, should an incident occur. Documentation of hazards, risks, training and incidents provides a history from which an organisation can learn and incorporate continuous improvements. Having thorough and accurately documented WHS records also stands the organisation in good stead, should any incident occur and lead to legal action taken against a person or the organisation.

PREPARE AND FILL DOCUMENTS

Fill in the relevant document related to waste disposal

Various records are required in relation to workplace health regulations, standards and codes of practice depending upon the industry or sector. There may also be further requirements, which must be met by organisations, from industry associations or groups as part of terms of membership. It is important to note that there may be specific lodgment time limits for some forms and notifications. That is, the report, such as a WHS incident report, must be lodged with the appropriate government agency within a certain time period.

WHS legislative reporting requirements relate to:

- ✓ Serious incident and injury reporting
- ✓ Registered plant (equipment)
- ✓ Hazardous substances and dangerous goods
- ✓ Environmental monitoring
- ✓ Health surveillance.

Update document on daily basis.

Regular reviews of the documentation (daily, monthly, bimonthly or quarterly) in regard to WHS can provide an indication of success, or any areas where adherence to WHS practices has been neglected in the preceding period. These should then be discussed at team meetings to ensure all workers know what is and is not being achieved in terms of safety practices.

11. CONTRIBUTE TO CONTINUOUS IMPROVEMENT OF QUALITY SYSTEMS

INTERPRET AND COMMUNICATE QUALITY SYSTEM REQUIREMENTS

Drinking water quality standards describes the quality parameters set for drinking water. Despite the truth that every human on this planet needs drinking water to survive and that water may contain many harmful constituents, there are no universally recognized and accepted international standards for drinking water. Even where standards do exist, and are applied, the permitted concentration of individual constituents may vary by as much as ten times from one set of standards to another.

Countries like Maldives, drinking water quality systems aligned to the standards developed World Health Organization to ensure water produced and supplied are of acceptable and quality for all.

Parameters	Maximum WHO permissible limit
Al	0.2 mg/L
Ca	75 mg/L
Fe	0.3 mg/L
Mg	50 mg/L
NO ₃	50 mg/L
pH	6.5 - 8
TDS	1000 mg/L
E. coli	0

The accreditation requirements for relevant water quality systems are interpreted, understood and communicated to work colleagues.

As the leading body, WHO produces international norms on water quality and human health in the form of guidelines that are used as the basis for regulation and standard setting across the world. However, country specific guidelines also exist across Europe and USA and often implemented through the Environment Protection Agency (EPA) of their respective country.

The Guidelines for drinking-water quality (GDWQ) promote the protection of public health by advocating for the development of locally relevant standards and regulations (health based targets), adoption of preventive risk management approaches covering catchment to consumer (Water Safety Plans) and independent surveillance to ensure that Water Safety Plans are being implemented and effective and that national standards are being met.



Accredited bodies are established to monitor and approve drinking water quality and one such organization is the Water Quality Association of USA, that accredits water quality.

WQA Provides third-party certification - notably it's Gold Seal - for products consumers can buy for water treatment. This program, after decades in existence, is the oldest third-party testing and certification program in the water treatment industry. The Gold Seal is easily recognizable and informs consumers that products are safe and work properly.

The Gold Seal Program is accredited as a reputable certification agency in the United States and Canada by ANSI (American National Standards Institute) and SCC (Standards Council of Canada) to ISO/IEC 17065.



Consumers and industry professionals should remember to always look for the Gold Seal when choosing their water treatment products.

Manufacturers and suppliers can seek Gold Seal Certification for most products that contact household water. Certification covers everything from chemicals to plumbing components to filtration systems and water softeners. Product certification indicates a third-party organization has monitored the manufacturer's operations to ensure they meet guidelines for manufacturing processes and materials used. Products are tested to ensure compliance with industry standards, performance and certification requirements. Standards are detailed and rigorous and specific to the products certified. There are standards to cover many different water treatment technologies; some standards cover UV disinfection while other ensure that reverse osmosis systems perform as claimed. Certification also helps verify that manufacturers have good customer service measures in place and offer adequate product literature or information as well. Once companies go through this demanding process, they must retest their certified products regularly and submit to annual facility inspections to ensure that the products continue to meet or exceed industry standards.

The implications of non-conformance with quality accreditation requirements are identified and communicated

Non-compliance to water quality will jeopardise health of the consumers and could often become public health danger to a community. Being a Lab technician at a water testing facility, it is the responsibility of the lab technicians to report cases of non-compliance and undertake proper communication with respective personnel within or outside the organization.



Standard operating procedures are regularly reviewed to ensure compliance with current quality standards.

If issues are identified through the testing of water parameters, it is important that water treatment procedures are reviewed and actions taken to ensure the produced water quality remain within the set standards.

To effectively maintain safe water limits, it is vital that the laboratory technician affiliated with any such plant regularly review the procedures to ensure water produced remain within the set standards of any particular water plant.

IMPLEMENT QUALITY SYSTEMS

Like other countries, although we follow WHO guidelines on drinking water, responsible organization for the implementation of water quality is developed by the EPA Maldives.

Implement quality systems

In case of Maldives, EPA has developed certain quality parameters that need to be followed to ensure water produced or sold across the Maldives need to follow the EPA standards and guidelines. In particular, review the following parameters to ensure their respective number are compliant to the local standards.

- ✓ Chlorides
- ✓ Nitrates
- ✓ Ammonia
- ✓ Iron
- ✓ Hydrogen Sulphide
- ✓ Total Hardness
- ✓ Suspended solids

Individual roles and responsibilities in quality system implementation are defined.

As a lab technician, you will be involved in a variety of laboratory-based investigations within biological, chemical, physical and life science areas. This can include sampling, testing, measuring, recording and analyzing results as part of a laboratory technician team. It is vital that all are aware of the roles and responsibilities of the quality system being followed to function effectively, while adhering to correct procedures and health and safety guidelines.

Standard operating procedures are implemented to ensure compliance with quality systems.

It is anticipated that the laboratory you are working have developed the relevant standard operating procedures. It is the responsibility of all to follow the standard operating procedures to ensure compliance with quality systems.

Relevant data is recorded for quality system monitoring.

Data related to the tests being performed involve collection of samples and gathering of data and it is vital that proper procedures are always followed for accurate and reliable test results being tested in the laboratory setting.

Observations of non-conformance with quality accreditation requirements are recorded and reported promptly.

A non-conformance indicates a problem that should be addressed with corrective action. It's a sign that something went wrong in your service, process, product, supply side or in the system itself by not meeting the specifications. It can be identified via audits, external audits, customer complaints, incoming material inspection or routine testing. Developed procedure need to include immediate actions to stop further non-conformance. Assess and contain the effects of the problem by taking corrective action or placing defective items in quarantine

and notifying affected customers, if necessary. It is also important to document your non-conformance procedure and keep a record of the problem and action taken.

IDENTIFY AND CORRECT QUALITY SYSTEM IMPLEMENTATION PROBLEMS

Identifying and solving quality management issues keeps your organization on the right side of the EPA and on the trusted water plant operator or supplier among the clients. Excellence in water quality management helps your organization produce the best water on the market.

However, due to systems errors or malpractices of those involved, issues could rise and if not conscious, water produced through the water plant or supplier may become associated with poor quality. Sometimes these issues were caused by scaling too quickly. Other times, it was a breakdown of people, processes, or technology. In every case, quality management shouldn't be viewed as an expense. It's an investment into your company's long-term success.

We need to identify through research and investigation on the cause of these issues and continuously implement rectification process and procedures to ensure the water produced remain of high quality and be always above the basic water quality standards set by the local authorities.

CONTRIBUTE TO IMPROVEMENT OF QUALITY SYSTEM IMPLEMENTATION

Maintaining a quality product is challenging and same applies to drinking water being treated and supplied to the market. It is therefore vital that all contribute positively towards this goal of maintaining quality among the water being produced and treated from the water plants.

Creating a quality management system requires input from employees at all levels of an organisation, starting with top management. Their firm commitment to change and improvement is vital to the success of system implementation. After securing the support of top management, you should follow these key steps to implement a quality management system:

- ✓ Review and analyse product by breaking it down into key stages and processes. These will often be areas that are crucial to your clients' satisfaction. Water plant operators and senior staff should be involved on regular basis and discuss the changing parameters that may affect the water quality being produced or supplied.
- ✓ Review and research your approach by deciding which resources you need and discuss the effectiveness of existing processes with staff. Conduct a gap analysis to determine what the current processes are and how they need to change. Assemble your team and develop an implementation plan.
- ✓ Inform and train team members on the identified gaps and improved and enhance the processes that are identified to be problematic and that are affecting quality.

Decide if new processes are necessary and tell staff about them. Provide training and explain how the new system will benefit both staff and customers.

- ✓ Consider supporting documentation, such as quality policies, procedures, training materials, work instructions, etc. Use version control documents to keep your documentation in order.
- ✓ Deploy the system and check that the processes are working. Give someone the responsibility for the system and ensure that proper procedures are followed. Set targets for how each process contributes to the success of quality goals. Control, measure and monitor your outputs to ensure that they meet the expected quality levels.
- ✓ Review and revise processes where necessary. Schedule routine product or process audits to monitor compliance with policies and procedures, and any certification requirements. Continue to audit and review regularly to ensure continuous improvement.

UNIT 12

PROCESS AND INTERPRET DATA

This unit of competency covers the ability to retrieve data, evaluate formulae and perform scientific calculations, present and interpret information in tables and graphs and keep accurate records

RETRIVE AND CHECK DATA

Store and retrieve data using appropriate files and/or application software

Information management is a system that incorporates all the processes needed for effectively managing data—both incoming and outgoing test information. The information management system may be entirely paper-based, computer-based, or a combination of both. Whatever technology is employed, information management is another of the essentials of a quality system, and is closely related to documents and records

When planning and developing an information management system, whether it is a manual, paper-based system, or an electronic system, there are some important elements to consider:

- ✓ Unique identifiers for samples
- ✓ Standardized test request forms (requisitions)
- ✓ Logs and worksheets
- ✓ Checking processes to assure accuracy of data recording and transmission
- ✓ Protection against loss of data
- ✓ Protection of patient confidentiality and privacy
- ✓ Effective reporting systems
- ✓ Effective and timely communication.

Verify the quality of data using workplace procedures

Quality control in the laboratory is a statistical process used to monitor and evaluate the analytical process that produces patient results.



When a diagnostic test is performed in the medical laboratory, the outcome of the test is a result. The result may be a patient result or it may be a quality control (QC) result. The result may be quantitative (a number) or qualitative (positive or negative) or semi-quantitative (limited to a few different values). QC results are used to validate whether the instrument is operating within pre-defined specifications, inferring that patient test results are reliable. Once the test system is validated, patient results can then be used for diagnosis, prognosis, or treatment planning. For example, when a patient's serum is assayed (tested) for potassium, the test result tells us how much potassium (concentration) is present in the blood. This result is then used by the physician to determine whether the patient has a low, normal or high potassium.

Let's assume the measured value of potassium in a patient's serum is 2.8 mmol/L (a unit of

measure, millimoles per liter). This result is abnormally low and indicates an inappropriate loss of potassium.

But how does the person performing the test know that this result is truly reliable? It could be possible that the instrument is out of calibration and the patient’s true potassium value is 4.2 mmol/L – a normal result. The question of reliability for most testing can be resolved by regular use of quality control materials and statistical process control.

Rectify errors in data using workplace procedures

Comparison of Quality Control Results to Specific Statistical Limits

In Table below, there are two ranges reported. The acceptable range for the Level I (Normal Control) is 3.7 – 4.3 mmol/L. The range for Level II (Abnormal Control) is 6.7 – 7.3 mmol/L. When the daily QC result obtained for the normal control is compared to the range calculated for the normal control, it becomes apparent that each result lies somewhere within the expected range. This indicates that the analytical process is “in control” at the normal level on that day of testing.

When the daily QC result for the abnormal control (high potassium) is compared to the defined range for the abnormal control, the analytical process is shown to be “in control” for each day of testing except for the last day (11/7). On November 1 through November 6, both controls were “in control” and patient values could be reliably reported. However, the laboratory was “out of control” for abnormal high potassiums on November 7 because the value obtained for the QC material (8.0 mmol/L) was outside the acceptable range (6.7 – 7.3 mmol/L).

This means that some error occurred which may have made some patient results unreliable. The laboratory should not report any patient samples with an abnormally high potassium result until the error is resolved and the abnormally high sample(s) are re-tested.⁶

Perhaps it is now apparent that the range defined for each level of control is fundamental to the quality control system. The next section describes how to calculate the basic statistics required to develop an acceptable control range.

Example of a QC Log with Patient Results			
<i>Test: Potassium</i>	<i>Instrument: Instrument No. 1</i>		<i>Unit of Measure: mmol/L</i>
Range	Level I Normal Control 3.7 - 4.3 mmol/L	Level II Abnormal Control 6.7 - 7.3 mmol/L	Patient Results
1 November	4.0	7.0	4.2, 4.0, 3.8, 5.0, 5.8, 4.2
2 November	4.1	7.0	3.8, 4.4, 4.6, 3.9, 4.8, 4.4, 3.9
3 November	4.0	6.9	4.4, 3.9, 3.7, 4.7
4 November	4.2	7.1	4.7, 5.6, 4.2, 3.7, 4.3
5 November	4.1	7.0	4.2, 4.3, 4.1, 4.3
6 November	4.1	7.0	4.6, 4.4, 5.5, 3.8, 3.2
7 November	4.2	8.0	2.8, 4.6, 4.2, 3.2, 3.9, 4.1, 6.0, 4.3

CALCULATE SCIENTIFIC QUANTITIES

Calculate statistical values for given data

Calculating a Mean [x̄]

The mean (or average) is the laboratory's best estimate of the analyte's true value for a specific level of control. To calculate a mean for a specific level of control, first, add all the values collected for that control. Then divide the sum of these values by the total number of values. For instance, to calculate the mean for the normal control (Level I) in Table 1, find the sum of the data {4.0, 4.1, 4.0, 4.2, 4.1, 4.1, 4.2}. The sum [Σ] is 28.7 mmol/L. The number of values is 7 (n = 7). Therefore, the mean for the normal potassium control in Table 1 from November 1–7 is 4.1 mmol/L (or 28.7 mmol/L divided by 7).

Formula 1: Calculating the Mean [x̄]

$$\Sigma x_n / n$$

Where:

Σ = sum

x_n = each value in the data set

n = the number of values in the data set

Calculating the Mean

Calculate the normal and/or abnormal control mean for each of the following sets of control data.

Laboratory A

Level I (Normal Control)

Unassayed Chemistry Control, Lot No. 12345

Test: Creatine Kinase

Instrument: ABC

Units: U/L

Control Values are: {94, 93, 97, 95, 95, 100, 100, 99, 100, 99}

Level II (Abnormal Control)

Unassayed Chemistry Control, Lot No. 12345

Test: Creatine Kinase

Instrument: ABC

Units: U/L

Control Values are: {327, 325, 321, 323, 315, 308, 304, 298, 327, 334}

Laboratory B

Level II (Abnormal Control)

Unassayed Chemistry Control, Lot No. 12345

Test: Aspartate Aminotransferase (AST)

Instrument: ABC

Units: U/L

Control Values are: {183, 185, 182, 181, 182, 180, 182, 181, 179, 181}

Laboratory C

Level I (Normal Control)

Unassayed Chemistry Control, Lot No. 12345

Test: Creatine Kinase

Instrument: XYZ

Units: U/L

Control Values are: {86, 93, 97, 90, 95, 100, 103, 99, 104, 92}

Level II (Abnormal Control)

Unassayed Chemistry Control, Lot No. 12345

Test: Creatine Kinase

Instrument: ABC

Units: U/L

Control Values are: {342, 325, 321, 323, 315, 298, 288, 298, 327, 350}

CALCULATE USING SCIENTIFIC QUANTITIES

Chemical Use calculations

In a typical plant operation, the chemical use (in lb/day or gpd) is recorded each day. Such data

Provide a record of daily use from which the average daily use of the chemical or solution can be

Calculated.

To calculate average use in lb/day, we use.

$$\text{Average use (lb/day)} = \frac{\text{total chemical used (lb)}}{\text{number of days}}$$

To calculate average use in gallons per day (gpd), we use:

$$\text{Average use (gpd)} = \frac{\text{total chemical used (gal)}}{\text{number of days}}$$

To calculate the supply in inventory,

$$\text{Inventory supply (days)} = \frac{\text{total chemical in inventory (lb)}}{\text{average use (lb/day)}}$$

$$\text{Inventory supply (days)} = \frac{\text{total chemical in inventory (gal)}}{\text{average use (gpd)}}$$

Problem

The pounds (lb) of calcium hypochlorite used each day for a week are given below. Based on the

Data, what was the average lb/day hypochlorite chemical use during the week?

Monday,	50	Friday,	56
lb/day		lb/day	
Tuesday,	55	Saturday,	51lb/day
lb/day		lb/day	
Wednesday,	51	Sunday,	48
lb/day		lb/day	
Thursday,	46		
lb/day			

Solution

$$\begin{aligned}\text{Average use (lb/day)} &= \frac{357}{7} \\ &= 51 \text{ lb/day}\end{aligned}$$

Problem

The average calcium hypochlorite use at a plant is 40 lb/day. If the chemical inventory in stock is 1100 lb, how many days of supply is this?

Solution

$$\begin{aligned}\text{Inventory supply (days)} &= \frac{1100 \text{ lb in inventory}}{40 \text{ lb/day average use}} \\ &= 27.5 \text{ days}\end{aligned}$$

Determine chlorine dosage (feed rate)

The units of milligrams per liter (mg/L) and pounds per day (lb/day) are most often used to describe

The amount of chlorine added or required. Equation 19.1 can be used to calculate either mg/L or

Lb/d chlorine dosage:

$$\text{Chlorine feed rate (lb/day)} = \text{chlorine (mg/L)} \times \text{flow (MGD)} \times 8.34 \text{ lb/gal}$$

Problem

Determine the chlorinator setting (lb/day) required to treat a flow of 4 MGD with a chlorine dose of 5 mg/L.

Solution

$$\begin{aligned}\text{Chlorine (lb/day)} &= 5 \text{ mg/L} \times 4 \text{ MGD} \times 8.34 \text{ lb/gal} \\ &= 167 \text{ lb/day}\end{aligned}$$

Problem

A pipeline that is 12 inches in diameter and 1400 ft long is to be treated with a chlorine dose of 48 mg/L. How many lb of chlorine will this require?

Solution

Determine the gallon volume of the pipeline:

$$\begin{aligned}\text{Volume (gal)} &= 0.785 \times D^2 \times \text{length (ft)} \times 7.48 \text{ gal/cu ft} \\ &= 0.785 \times 1 \text{ ft} \times 1 \text{ ft} \times 1400 \text{ ft} \times 7.48 \text{ gal/cu ft} \\ &= 8221 \text{ gal}\end{aligned}$$

$$\begin{aligned}\text{Chlorine (lb)} &= 48 \text{ mg/L} \times 0.008221 \text{ MG} \times 8.34 \text{ lb/gal} \\ &= 3.3 \text{ lb}\end{aligned}$$

Problem

A chlorinator setting is 30 lb per 24 hr. If the flow being chlorinated is 1.25 MGD, what is the

Chlorine dosage (expressed as mg/L)?

Solution

$$30 \text{ lb/day} = x \text{ mg/L} \times 1.25 \text{ (MGD)} \times 8.34 \text{ lb/gal}$$

$$x = \frac{30}{1.25 \times 8.34}$$

$$x = 2.9 \text{ mg/L}$$

Problem

A flow of 1600 gpm is to be chlorinated. At a chlorinator setting of 48 lb per 24 hr, what would

Be the chlorine dosage (in mg/L)?

Solution

Convert the gpm flow rate to MGD flow rate:

$$\begin{aligned}1600 \text{ gpm} \times 1440 \text{ min/day} &= 2,304,000 \text{ gpd} \\ &= 2.304 \text{ MGD}\end{aligned}$$

Now calculate the chlorine dosage in mg/L using Equation 19.1:

$$\text{Chlorine (lb/day)} = x \text{ mg/L} \times 2.304 \text{ MGD} \times 8.34 \text{ lb/gal} = 48 \text{ lb/day}$$

$$x = \frac{48}{2.304 \times 8.34}$$

$$= 2.5 \text{ mg/L}$$

Ensure calculated quantities are consistent with estimations and expectations

In following Table, there are two ranges reported. The acceptable range for the Level I (Normal Control) is 3.7 – 4.3 mmol/L. The range for Level II (Abnormal Control) is 6.7 – 7.3 mmol/L. When the daily QC result obtained for the normal control is compared to the range calculated for the normal control, it becomes apparent that each result lies somewhere within the expected range. This indicates that the analytical process is “in control” at the normal level on that day of testing.

When the daily QC result for the abnormal control (high potassium) is compared to the defined range for the abnormal control, the analytical process is shown to be “in control” for each day of testing except for the last day (11/7). On November 1 through November 6, both controls were “in control” and patient values could be reliably reported. However, the laboratory was “out of control” for abnormal high potassiums on November 7 because the value obtained for the QC material (8.0 mmol/L) was outside the acceptable range (6.7 – 7.3 mmol/L).

This means that some error occurred which may have made some patient results unreliable. The laboratory should not report any patient samples with an abnormally high potassium result until the error is resolved and the abnormally high sample(s) are re-tested.

Perhaps it is now apparent that the range defined for each level of control is fundamental to the quality control system. The next section describes how to calculate the basic statistics required to develop an acceptable control range.

Table : Example of a QC Log with Results			
Test: Potassium	Instrument: Instrument No. 1		Unit of Measure: mmol/L
Range ▶	Level I Normal Control 3.7 – 4.3 mmol/L	Level II Abnormal Control 6.7 – 7.3 mmol/L	Results
1 November	4.0	7.0	4.2, 4.0, 3.8, 5.0, 5.8, 4.2
2 November	4.1	7.0	3.8, 4.4, 4.6, 3.9, 4.8, 4.4, 3.9
3 November	4.0	6.9	4.4, 3.9, 3.7, 4.7
4 November	4.2	7.1	4.7, 5.6, 4.2, 3.7, 4.3
5 November	4.1	7.0	4.2, 4.3, 4.1, 4.3
6 November	4.1	7.0	4.6, 4.4, 5.5, 3.8, 3.2
7 November	4.2	8.0	2.8, 4.6, 4.2, 3.2, 3.9, 4.1, 6.0, 4.3

Report all calculated quantities using the appropriate units and correct number of significant figures

Defining the Terms Used to Discuss Significant Figures

Significant Figures: The number of digits used to express a measured or calculated quantity. By using significant figures, we can show how precise a number is. If we express a number beyond the place to which we have actually measured (and are therefore certain of), we

compromise the integrity of what this number is representing. It is important after learning and understanding significant figures to use them properly throughout your scientific career.

Precision: A measure of how closely individual measurements agree with one another.
Accuracy: Refers to how closely individual measurements agree with the correct or true value.

Digits that are Significant

1. Non-zero digits are always significant.
2. Any zeros between two non-zero digits are significant.
3. A final zero or trailing zeros in the decimal portion **ONLY** are significant.

Examples:

How many significant figures are in:

1. 12.548

There are 5. All numbers are significant.

2. 0.00335

There are 3. The zeros are simply placeholders and locate the decimal. They are not trailing zeros. They are not significant.

3. 504.70

There are 5. The two zeros are not simply placeholders. One is between two significant digits and the other is a final, trailing zero in the decimal portion. Hence, they are both significant.

4. 4000

This is a bit confusing. It is somewhere between 1 and 4. In order to clarify, we need to convert this to scientific notation. If it were 4×10^3 , there is one significant figure. If it were 4.000×10^3 , then there are 4 significant figures.

Rules for Using Significant Figures

- For addition and subtraction, the answer should have the same number of decimal places as the term with the fewest decimal places.
- For multiplication and division, the answer should have the same number of significant figures as the term with the fewest number of significant figures.
- In multi-step calculations, you may round at each step or only at the end.
- Exact numbers, such as integers, are treated as if they have an infinite number of significant figures.
- In calculations, round up if the first digit to be discarded is greater than 5 and round down if it is below 5. If the first discarded digit is 5, then round up if a nonzero digit follows it, round down if it is followed by a zero.

More Examples:

Addition and Subtraction. $12.793 + 4.58 + 3.25794 = 20.63094$

- ✓ With significant figures it is 20.63 since 4.58 has 2 decimal places, which is the least number of decimal places.
- ✓ Multiplication and Division. $56.937/0.46 = 130.29782609$

With significant figures, the final value should be reported as 1.3×10^2 since 0.46 has only 2 significant figures. Notice that 130 would be ambiguous, so scientific notation is necessary in this situation.

Tidiness at the end of a calculation.

So you have carried out a calculation that requires a series of seven or eight mathematical operations and at the end, after punching everything into your calculator, you see the result "14.87569810512...". The question you should ask yourself is how many digits to include when reporting your final answer.

It is at this point that you must refer back to the quality of the data you were given (i.e., how many significant digits are included with the given data). We illustrate this here with one final example.

Three scientists determine the mass of *the same sample* of FeCl_3 . Scientist A works in a field laboratory and carries a portable balance for determining the sample mass, the balance can determine masses to the nearest ± 0.1 g. Scientist B has a better, but still somewhat crude balance, which reports the mass to the nearest ± 0.01 g. Scientist C has a balance, like the analytical balances you will find in chemistry laboratories at WU, that can determine sample masses to the nearest ± 0.0001 g. If each scientist wants to indicate the total number of moles of FeCl_3 in the sample, how will each do this in a way that reflects the precision of the instrumentation they are using? The three scientists all use the atomic masses suggested by IUPAC (International Union of Pure and Applied Chemistry), which are included in the table below.

	Scientist A	Scientist B	Scientist C
Given data	<ul style="list-style-type: none"> • Sample mass: 19.0 g • Fe atomic mass: 55.847 g/mol • Cl atomic mass: 35.4527 g/mol 	<ul style="list-style-type: none"> • Sample mass: 18.99 g • Fe atomic mass: 55.847 g/mol • Cl atomic mass: 35.4527 g/mol 	<ul style="list-style-type: none"> • Sample mass: 18.9925 g • Fe atomic mass: 55.847 g/mol • Cl atomic mass: 35.4527 g/mol
Reported moles FeCl_3	• 0.117 mol FeCl_3	• 0.1171 mol FeCl_3	• 0.11709 mol FeCl_3
Why?	The balance used for the mass determination limits the result to 3 significant digits.	The quality of the instrumentation is better, than that used by Scientist A, but the result is still limited to only 4 significant digits.	Why not 6 significant digits in the reported result? This time the answer is limited by the uncertainty in the atomic mass of Fe, which is known to 5 significant digits!

PRESENT DATA

Present data in clearly labelled tables, charts and graphs

Tables are often used to display data clearly, particularly when it is important that the data are displayed accurately, such as on a food label, or when a lot of data needs to be displayed in a concise form, such as on a bus or train schedule.

The table shown below is from the Irish Tourism Fact Card for 2003. There's a lot of information here to sort out, but imagine how confusing it would be if it was a list!

Employment in the Irish Tourist Industry (Numbers Employed by Sector)

Sector/Year	1999	2001	2002	2003	% +/- ('01-'03)
Hotels	53,906	54,275	54,656	54,164	-0.2%
Guesthouses	3,115	2,943	2,914	2,879	-2.2%
Self-catering accommodation	4,580	3,830	N/a	3,878	1.3%
Restaurants	40,283	41,827	41,409	41,085	-1.8%
Non-licensed restaurants	15,221	13,849	N/a	15,642	12.9%
Licensed premises	78,300	78,225	80,121	79,319	1.4%
Tourism services and attractions	33,910	34,568	34,852	34,749	0.5%
Total	229,315	229,517		231,716	0.96%

So how do we start to understand what is shown in a table?

The first thing to do is to look at **the title**. This should explain clearly what the table contains. This table contains the number of people employed in the Irish tourist industry, divided into sectors.

[“Fáilte”, pronounced fall-sha, is an Irish word meaning “welcome”.] Next, check **the source of the data**. Have the data been collected by a reputable organization? Can you check how the data have been collected? This is an important step: if, for example, the data are only based on a few results or have not been collected properly, then you may not wish to rely on the values given in the table. The source of these data is given below the table, a survey conducted in 2004 by Fáilte Ireland, the Tourist Board for Ireland. This is an official organization, so the data are likely to be reliable.

The next step is to examine **the column and row headings**. What information is being given? Raw numbers, or percentages? What units are being used? Do you understand any abbreviations used and how the table is constructed?

The column headings are the years 1999, 2001, 2002, and 2003. Note that the year 2000 is missing; this could affect your interpretation of the figures.

The final column has a confusing heading. Can you work out what it means? Look carefully at the symbols used. It is the percentage change between 2001 and 2003, given as either a positive or a negative number. Between 2001 and 2003, for instance, the number of people employed in hotels in Ireland fell by 0.2%.

The rows give types of tourist facilities, such as hotels and restaurants, with the total for all types given in the bottom row.

Finally, you can look at **the main body of the table** to find the information you need. For example, to find the number of people employed in restaurants in 2001, move along the row labeled restaurants, and down the column labeled 2001. Where this row and column meet, the value is 41,827. This means that, in 2001, 41,827 people were employed in restaurants.

Reading a Table

Before you go on to use the information in the table, here is a summary of the steps in reading a table.

Read the title.

- ✓ Check the source of the data.
- ✓ Examine the column and row headings, particularly the units used.
- ✓ Check that you understand the meaning of any symbols or abbreviations.
- ✓ Extract the information you need from the main body of the table.

Graphs and Charts

Although tables are useful for summarizing a lot of data concisely, clearly, and accurately, sometimes you want to get an overall message across quickly. You can do this using a graph or a chart. Graphs can also be used to explore relationships between sets of data, such as the way in which a sunflower grows over a season.

Activity: Graphs and Charts

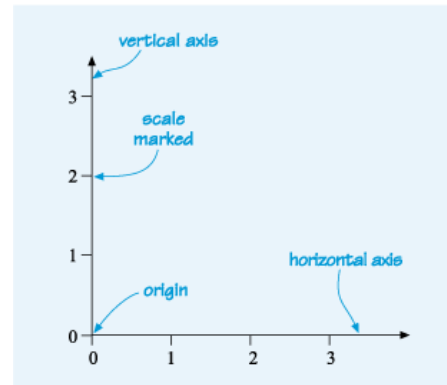
You have probably seen different types of graphs and charts in your day to day life, when watching the TV, reading a newspaper or on the Internet. Spend a few moments now writing down all the different types that you have seen—don't worry if you don't know the math language for these at the moment!

Graph data using appropriate scales to span the range of data or display trends

Plotting Points

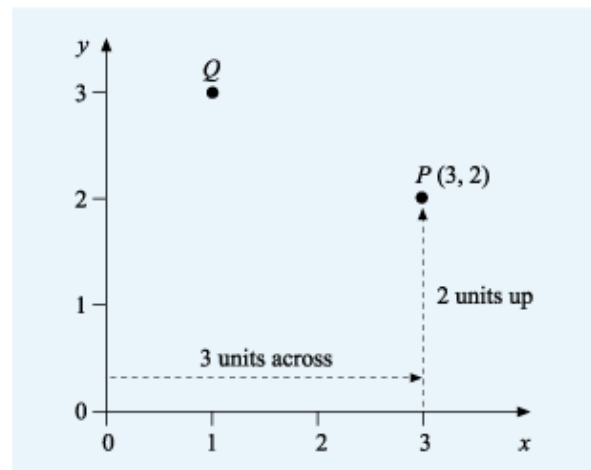
Many graphs and charts are constructed by plotting points on a grid.

The graph below shows two perpendicular lines: the horizontal axis and the vertical axis, which set up a grid. Each axis is marked with a scale, in this case from 0 to 3. The point where the two axes meet and where the value on both scales is zero is known as the origin. (Axes is the plural form of axis.)



Long description

We can describe the location of any point on the grid by its horizontal and vertical distance from the origin. In the graph below, the horizontal axis has been labeled with an “x” and the vertical axis with a “y.” This is because the horizontal axis is usually known as the x-axis and the vertical axis as the y-axis.



Long description

Look at the point P in the above graph. To get to the point P from the origin, move 3 units across and 2 units up. (Alternatively, the point P is opposite 3 on the x-axis and 2 on the y-axis.) We say that P has the coordinates (3, 2).

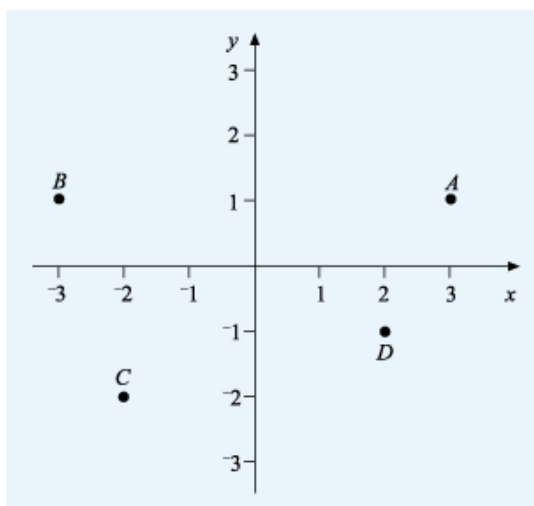
The horizontal distance of P from the origin is known as the x-coordinate of P and the vertical distance from the origin is known as the y-coordinate of P. So for point P, 3 is the x-coordinate and 2 is the y-coordinate.

Notice that the x-coordinate is the first coordinate in the pair and the y-coordinate is the second coordinate in the pair. So the general form for the coordinates of a point is (x, y). This is important to remember to avoid plotting points the wrong way round!

In the same way, Q is 1 unit across and 3 units up, so Q has coordinates (1, 3).

Negative Coordinates

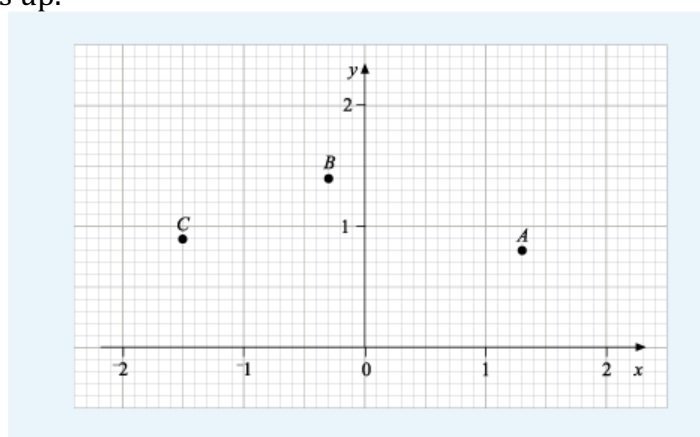
The axes can be extended downward and to the left to include negative values as shown here. In the graph below, B is 3 units to the left of the origin so its x-coordinate is -3 . It is 1 unit up, so its y-coordinate is 1. So B has coordinates $(-3, 1)$.



Decimal Coordinates

In the examples so far, all the coordinates were whole numbers and the scales were also marked at whole unit intervals. It is possible to plot points that have decimal coordinates such as $(1.8, -2.1)$.

In the graph below, each unit along the axes has been divided into ten, so each gray line represents a tenth of a whole unit, or 0.1, just like on the number lines we saw in Unit 2. The point A has coordinates $(1.3, 0.8)$ and is plotted 1.3 units across to the right of the origin and 0.8 units up.



Displaying Data on a Graph or Chart

You have seen that, provided you have both an x- and a y-coordinate, you can plot a point on a chart. So if a set of data consists of pairs of data values, then the data can be plotted on a graph.

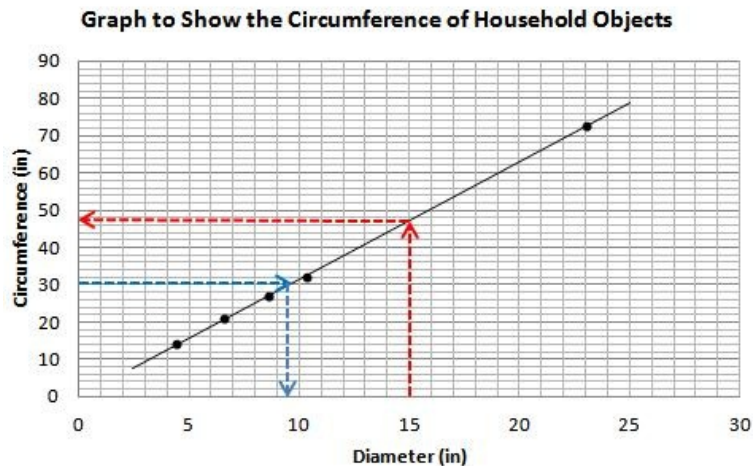
Drawing a Graph

The following data values were collected on the circumferences and diameters of various circular objects. All of the measurements are in inches.

Diameter (in.)	Circumference (in.)
4.4	14.1
6.6	20.9
8.6	27
10.3	32.3
23.0	72.8

(a) On some graph paper or in your notebook, plot these points on a graph with the diameter on the horizontal (x) axis and the circumference on the vertical (y) axis. Draw a straight line through the points.

Note the title and labeling of the axes. You may have used a different scale from us if you had different graph paper. This is fine as long as it makes best use of the paper and is easy to read from.



(b) Use your graph from part (a) to estimate the circumference of a circle of diameter 15 inches.

Answer: To find the circumference of a circle of diameter 15 inches, find 15 on the horizontal axis. From this point, draw a vertical line to meet the graph. Then draw a horizontal line across to the vertical axis and read off the value. The circumference of a circle of diameter 15 in. is about 47 inches.

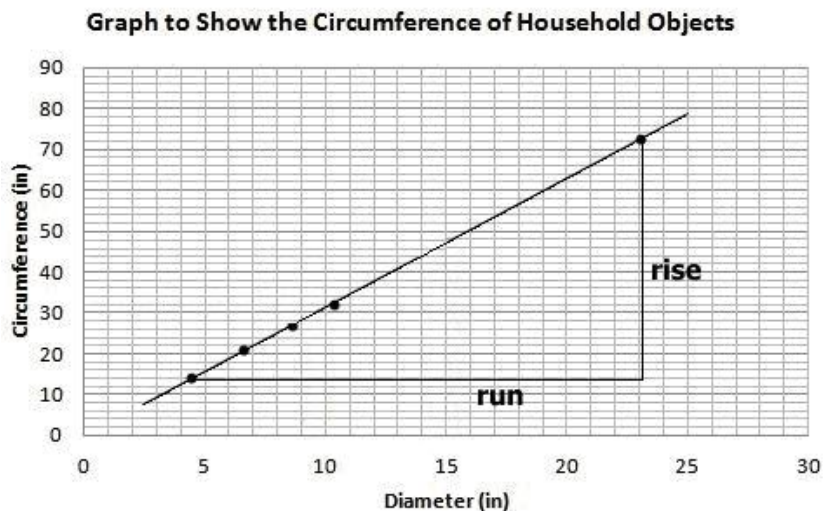
(c) Use your graph from part (a) to estimate the radius of a circle of circumference 30 inches.

Answer: The circumference is 30 in., so find 30 on the vertical axis. From this point, draw a line horizontally across to the graph, then vertically down to the horizontal axis. The point where this line crosses the horizontal axis gives the diameter of a circle whose circumference is 30 inches. It is about 9.5 inches, so the radius of the circle will be half of this, about 4.7 to 4.8 inches.

Optional Brain Stretcher

This is an interesting graph as you can make an estimate for π (π) from it. π is the ratio of the circumference to the diameter of any circle and is a constant.

By measuring the slope (gradient) of the graph that you have drawn you will obtain an estimate for π . This is calculated by dividing the rise of the line by corresponding run of the line as shown below.



Have a go and see if you get a value close to 3.141.

Gradient = rise = 72.8 in – 14.1 in = 58.7 in = 3.156 (to 3 d.p.)

Run 23.0 in – 4.4 in 18.6 in

This is not a bad estimate for π !

Report all data using the appropriate units and number of significant figures

Defining the Terms Used to Discuss Significant Figures

Significant Figures: The number of digits used to express a measured or calculated quantity. By using significant figures, we can show how precise a number is. If we express a number beyond the place to which we have actually measured (and are therefore certain of), we compromise the integrity of what this number is representing. It is important after learning and understanding significant figures to use them properly throughout your scientific career.

Precision: A measure of how closely individual measurements agree with one another.

Accuracy: Refers to how closely individual measurements agree with the correct or true value.

Digits that are Significant

1. Non-zero digits are always significant.
2. Any zeros between two non-zero digits are significant.
3. A final zero or trailing zeros in the decimal portion **ONLY** are significant.

Examples:

How many significant figures are in:

1. 12.548

There are 5. All numbers are significant.

2. 0.00335

There are 3. The zeros are simply placeholders and locate the decimal. They are not trailing zeros. They are not significant.

3. 504.70

There are 5. The two zeros are not simply placeholders. One is between two significant digits and the other is a final, trailing zero in the decimal portion. Hence, they are both significant.

4. 4000

This is a bit confusing. It is somewhere between 1 and 4. In order to clarify, we need to convert this to scientific notation. If it were 4×10^3 , there is one significant figure. If it were 4.000×10^3 , then there are 4 significant figures.

Rules for Using Significant Figures

- ✓ For addition and subtraction, the answer should have the same number of decimal places as the term with the fewest decimal places.
- ✓ For multiplication and division, the answer should have the same number of significant figures as the term with the fewest number of significant figures.
- ✓ In multi-step calculations, you may round at each step or only at the end.
- ✓ Exact numbers, such as integers, are treated as if they have an infinite number of significant figures.
- ✓ In calculations, round up if the first digit to be discarded is greater than 5 and round down if it is below 5. If the first discarded digit is 5, then round up if a nonzero digit follows it, round down if it is followed by a zero.

More Examples:

Addition and Subtraction. $12.793 + 4.58 + 3.25794 = 20.63094$

- ✓ With significant figures it is **20.63** since **4.58** has 2 decimal places, which is the least number of decimal places.

Multiplication and Division. $56.937/0.46 = 130.29782609$

- ✓ With significant figures, the final value should be reported as 1.3×10^2 since **0.46** has only 2 significant figures. Notice that **130** would be ambiguous, so scientific notation is necessary in this situation.

Tidiness at the end of a calculation.

So you have carried out a calculation that requires a series of seven or eight mathematical operations and at the end, after punching everything into your calculator, you see the result "14.87569810512...". The question you should ask yourself is how many digits to include when reporting your final answer.

It is at this point that you must refer back to the quality of the data you were given (i.e., how many significant digits are included with the given data). We illustrate this here with one final example.

Three scientists determine the mass of *the same sample* of FeCl_3 . Scientist A works in a field laboratory and carries a portable balance for determining the sample mass, the balance can determine masses to the nearest ± 0.1 g. Scientist B has a better, but still somewhat crude balance, which reports the mass to the nearest ± 0.01 g. Scientist C has a balance, like the analytical balances you will find in chemistry laboratories at WU, that can determine sample masses to the nearest ± 0.0001 g. If each scientist wants to indicate the total number of moles of FeCl_3 in the sample, how will each do this in a way that reflects the precision of the instrumentation they are using? The three scientists all use the atomic masses suggested by IUPAC (International Union of Pure and Applied Chemistry), which are included in the table below.

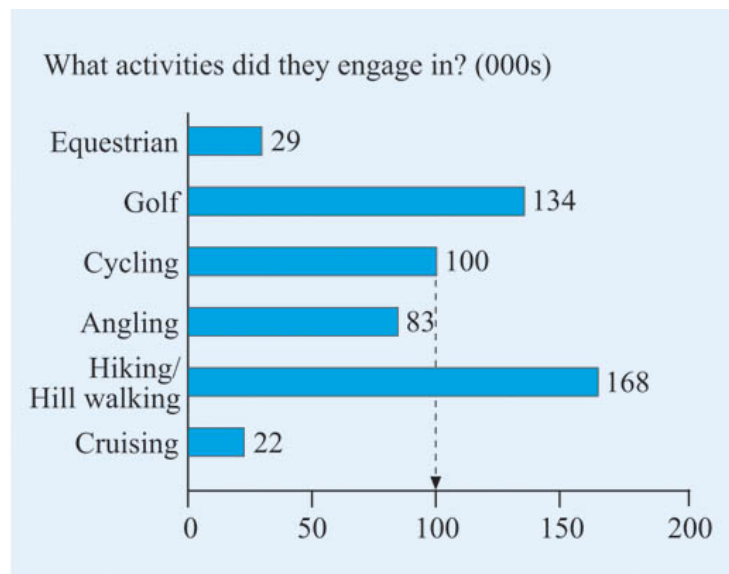
	Scientist A	Scientist B	Scientist C
Given data	<ul style="list-style-type: none"> • Sample mass: 19.0 g • Fe atomic mass: 55.847 g/mol • Cl atomic mass: 35.4527 g/mol 	<ul style="list-style-type: none"> • Sample mass: 18.99 g • Fe atomic mass: 55.847 g/mol • Cl atomic mass: 35.4527 g/mol 	<ul style="list-style-type: none"> • Sample mass: 18.9925 g • Fe atomic mass: 55.847 g/mol • Cl atomic mass: 35.4527 g/mol
Reported moles FeCl_3	<ul style="list-style-type: none"> • 0.117 mol FeCl_3 	<ul style="list-style-type: none"> • 0.1171 mol FeCl_3 	<ul style="list-style-type: none"> • 0.11709 mol FeCl_3
Why?	The balance used for the mass determination limits the result to 3 significant digits.	The quality of the instrumentation is better, than that used by Scientist A, but the result is still limited to only 4 significant digits.	Why not 6 significant digits in the reported result? This time the answer is limited by the uncertainty in the atomic mass of Fe, which is known to 5 significant digits!

INTERPRET DATA

Interpret significant features of tables, charts and graphs, including gradients, intercepts, maximum and minimum values, and limit lines

Bar Charts

Earlier, you saw data from the Irish Tourism Fact Card presented in tables. Information can also be illustrated in bar charts. The chart below is also from the Tourism Fact Card and shows the numbers of visitors participating in different activities. The data were based on estimates from the Irish Central Statistical Office "Purpose of Visit" survey.



In a bar chart, the length of each bar represents the number in that category. On this chart, you can see that the longest bar is for hiking/hill walking, so this was the most popular activity. The shortest bar is for cruising, indicating that this was the least popular activity of those listed.

From the title, we know that the numbers of visitors are measured in thousands. On this bar chart, the values represented by the bars have been marked directly on the chart. For example, the number of visitors who played golf was 134,000 and the number of visitors who went hiking/hill walking was 168,000.

From the title, we know that the numbers of visitors are measured in thousands.

On this bar chart, the values represented by the bars have been marked directly on the chart. For example, the number of visitors who played golf was 134,000 and the number of visitors who went hiking/hill walking was 168,000.

If the values had not been marked on the bars, they could have been estimated by drawing a line from the end of the bar and seeing where it intersected the horizontal axis. For example, the end of the cycling bar is level with the 100 marked on the horizontal scale (as shown by the dashed line), so approximately 100,000 visitors went cycling.

Because the bars on this chart are horizontal, the chart is known as a horizontal bar chart. Bar charts can also be drawn with the bars vertical. Note that in a bar chart, each bar has the same width, and since the bars represent different and unrelated categories, the bars do not touch each other and are separated by gaps.

Can you see anything that is missing from this bar chart?

There is no label on the horizontal axis, which you would normally expect to complete a bar chart.

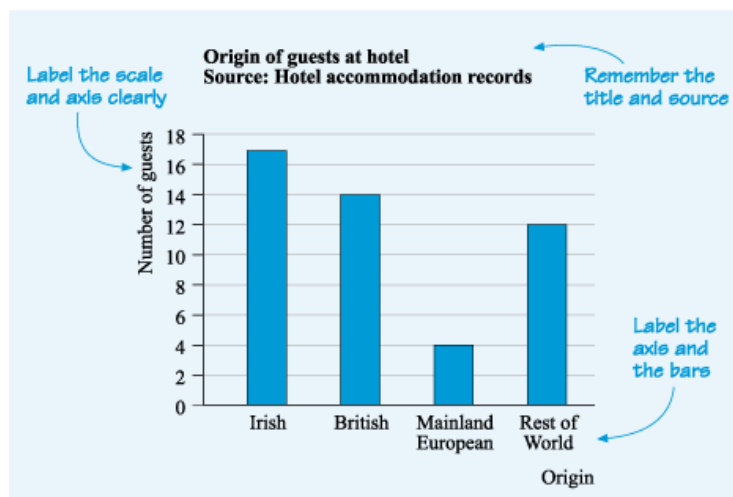
Drawing a Bar Chart

The same basic guidelines apply to drawing a bar chart as they do to drawing a graph, so bear these in mind when completing this activity.

In an earlier activity, you created the following table showing information about hotel guests. Use the table to draw a vertical bar chart to show the total number of guests in each of the nationality categories. Mark the nationality categories on the horizontal axis and the number of guests on the vertical axis.

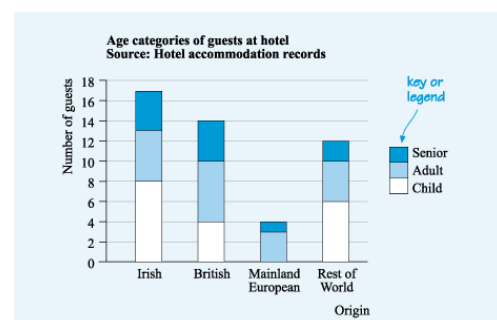
Origin and Age Categories of Hotel Guests

	Child	Adult	Senior	Total
Irish	8	5	4	17
British	4	6	4	14
Mainland European	0	3	1	4
Rest of the world	6	4	2	12
Total	18	18	11	47



Component Bar Charts

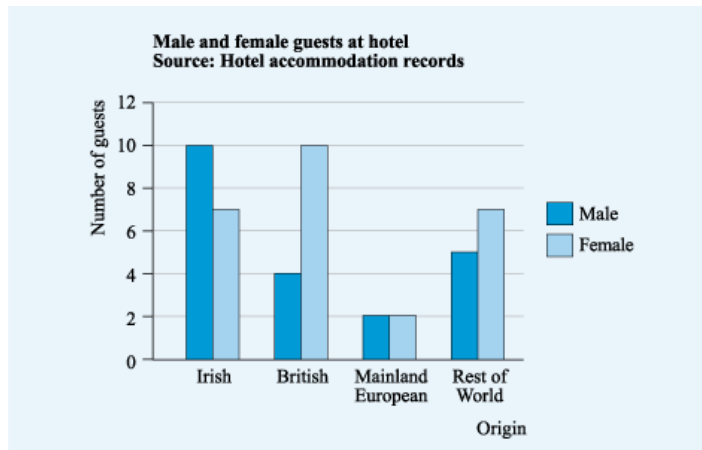
If you wished to show how the totals were broken down into the different age groups, you could split each bar into three different sections where the length of each section represented the number of guests in that age group. The resulting component bar chart is shown below. Notice that a key or legend has been added to the graph to explain the shading for the different categories.



When you read a component bar chart, you need to find the height of the relevant section. For instance, the top of the section representing British adults is opposite the 10 on the vertical scale. The bottom of that section is opposite the 4. So the number of British adults is $10 - 4 = 6$.

Comparative Bar Charts

Another way of displaying the totals would be to split each bar into two, one representing the number of males and the other the number of females in each category. To enable these numbers to be compared directly, the bars representing males and females can be placed next to each other as shown below. This is an example of a **comparative bar chart**.



Using the bar chart above, answer the following questions.

(a) How many female guests from Britain were there?

Answer: There were ten female guests from Britain.

(b) How many male guests in total stayed at the hotel?

Answer: The total number of male guests was 11.

Notice how all these charts followed the same format with the title and source clearly labeled and the axes and scales clearly marked, but they emphasized different aspects of the data. When you are displaying data in a graphical form, it is important to choose a chart or graph that stresses the main points as simply as possible, so that your reader can understand your chart quickly and easily.

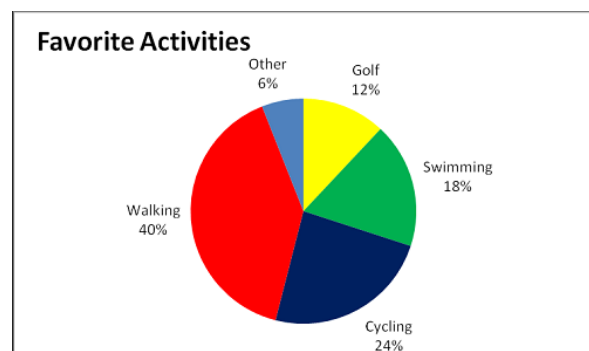
The tourist market bar charts display how many items (in this case, guests) there are in each category. How many times an item occurs is known as the **frequency**. Charts that display frequencies are also known as **frequency diagrams**.

For more practice interpreting bar charts, try the following lesson:

Pie Charts

Although bar charts are useful to display numbers and percentages, sometimes you may wish to stress how different components contribute to the whole. Pie charts are often used where you want to compare different proportions in the data set. The area of each slice (or sector) of the pie represents the proportion in that particular category.

For example, the pie chart below illustrates the favorite type of exercise for a group of people.



This pie chart shows the percentages for each category, so you can read these off directly. The most popular activity was walking (40%), followed by cycling (24%) and swimming (18%).

Notice, however, that the source of the data has not been stated, so you do not know where it came from or how many people were interviewed. It is important to consider both these points. If, for example, it was a small sample, you may not wish to rely on the results to generalize to a larger group.

Sometimes the percentages are not marked on the chart. So, the proportions can then be roughly estimated by eye. For example, the pie chart below illustrates how employees in a particular company travel to work

Activity: How Employees Travel to Work

Use the pie chart above to answer the following questions.

- (a) Do more people travel to work by bus or by train?

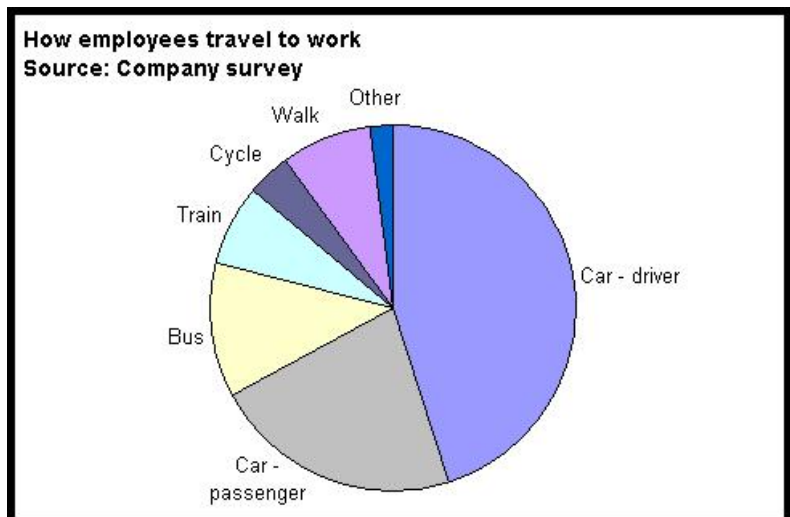
Answer: The slice of the pie representing bus travel is larger than the slice representing train travel, so yes, more people travel by bus than by train.

- (b) Would it be correct to say that the number of employees who travel to work as car drivers is about twice the number who travel as car passengers?

Answer: The slice of the pie representing car drivers is about twice the size of the slice representing car passengers, so it is correct to say that the number of employees who travel to work as car drivers is about twice the number who travel as car passengers.

- (c) Estimate the proportion of employees who travel to work by car, either as the driver or as a passenger.

Answer: The two slices for car drivers and passengers cover about two-thirds of the circle, so about two-thirds of employees travel to work by car, either as the driver or as a passenger.



It is important to remember that pie charts are useful only for comparing proportions, looking at parts of a whole. If you are interested in other aspects such as trends or frequencies, then other graphs or charts may be more appropriate.

If necessary—provided the pie chart has been drawn accurately—you can also work out the percentages by measuring the angle at the center of the pie for each sector, using a protractor. For example, the angle at the center of the circle for the “Car Passenger” category is about 80°.

Because a complete circle measures 360°, the fraction that this sector represents is $\frac{80}{360}$, or 22%. So about 22% of the employees travel to work as car passengers.

Pie charts are often used to give an overall impression rather than detailed information, so on many occasions a rough estimate will suffice.

Reading a Chart or Graph

- ✓ Read the title of the chart and check the source of the data.
- ✓ Check the axes. What is being measured? What units have been used?
- ✓ Examine the scales. How should these be interpreted? What does each interval represent?
- ✓ Check the key or legend. What does the shading or line represent?
- ✓ Finally, examine the chart or graph itself, reading off the information that you need.
Are you looking for a specific value or a trend or some other information?

You have also created graphs by hand. You may prefer to use a computer to draw your graphs and charts. There are many exciting ways to present data, but the important points listed below still apply whether you are drawing graphs by hand or by using software.

Drawing Graphs and Charts

- ✓ Include a clear title—so that your reader can see at a glance whether this chart is the one they are interested in.
- ✓ Include the source of the data—so that your reader can make further checks on how the data was collected if they wish.
- ✓ Choose the simplest graph or chart that illustrates the point you wish to emphasize.
- ✓ Label axes with both words and units.
- ✓ Mark scales clearly, choosing a scale that is easy to interpret.
- ✓ Include a legend if you have used more than one type of shading or line.

Look out for real-life graphs and charts in newspapers, magazines, on television, or on the Internet. Do these graphs follow the guidelines? Can you understand what the graphs are illustrating?

KEEP ACCURATE RECORDS AND MAINTAIN CONFIDENTIALITY

Transcribe information accurately

There are a range of different levels of accuracy and different ways of rating it. However, the vast majority of transcription companies and services indicate accuracy levels of about 95-99%.

But how accurate are the accuracy levels, and is it really possible for transcription businesses to be claiming that they can provide 99% accuracy?

The first issue is how you measure accuracy.

Quite a lot of transcription is of single or dual speakers either dictating/speaking or alternatively one person asking questions and the other person answering. If a transcription is being undertaken with strict rules of notating everything to do with the recording (strict verbatim) then 100% or even 95% accuracy is impossible unless the transcription company subjectively decides that their version of the transcription is completely correct. This is because a lot of the strict verbatim or strict transcription is dependent on the subjective decision of the transcriber on what they notate and where. For example, a pause in the recording can be notated in different ways, or similarly the number of 'ums' and 'ahs' can

vary according to how many the transcriber has picked up as they have gone through the work.

Accuracy levels are much easier when the transcriber is undertaking intelligent verbatim or standard transcription, which is where the transcriber makes an informed judgement on what is and what isn't needed. The transcriber is in fact quite restricted in terms of what they can leave out because the wording of the typed version of the recording is going to be dependent exactly on what has been said. Usually the only errors that human transcribers pick up are grammatical, with the use of 'their' and 'there', or the mispronunciation of names (e.g. Not catching a brand name and being able to decipher it), or to miss a localism or dialect and mis-transcribe it (e.g. Ey up me duck).

Ensuring 95% accuracy on these types of transcription is fairly straightforward to measure and the usual way of doing it is for the transcription company to take a paragraph of work every now and then as a sample and to compare that to the original recording to see how many errors there have been before using this to assert their accuracy levels and those of their transcribers.

What is often a better measure of accuracy levels is to look for a transcription company who don't necessarily indicate a percentage of accuracy, but instead promise to adjust and amend the transcription until the customer is completely satisfied with it. In reality most transcriptions of recordings are going to contain errors because of the nature of the work. The transcription of a 60 minute recording can involve thousands of words, and even the best transcribers with many years' experience are not going to get 100% accuracy when notating these. Usually this does not matter too much, unless the transcription is Jefferson levels (i.e. Full notation) or the context of an answer or statement is lost because the transcriber has used the wrong words in the wrong order.

However one would expect on every occasion that transcription work is undertaken the level of accuracy from a fully competent native language speaking transcriber with more than 2 years' experience to be at least 92% if not 95%. We think it is rare that anyone would ever hit 100% success and that they would do this with any regularity, because it is virtually impossible without considerable effort, which almost certainly falls outside the scope of usual transcription company prices.

Verify the accuracy of records following workplace procedures

Assessing qualitative accuracy typically requires input from SMES. SMES have specific knowledge to check that the content of documents is up to par.

As a document controller, your role is to make sure the right people are involved for Quality Control (QC) checks on the documents. It can be challenging to book time with in-demand resources to perform these QC checks. The best strategies to ensure you have access to these Subject-Matter-Experts (SME) include:

1. Make them aware of how important their contribution is, and how you can't do it without them
2. Formalize the QC process into a regular task and bring senior management into the conversation to:
 - ✓ Demonstrate support for your ask – remember, top-down support is by far the most effective!
 - ✓ Allocate the SME's time specifically for this task

You or the SME might be required to make sure an individual form is complete. Typically, spot checks are enough in this regard. What you're verifying here is qualitative accuracy and completeness of the documents.

But, if you're dealing with more than one document, then qualitative QA checks are not the whole story!

Quantitative Completeness

Has your project manager ever asked, "Did we get everything from the consultant?" Sometimes, this can be hard to evaluate. Sure, you got a lot of stuff, but how do you know there isn't one document missing?

As a document controller, you're likely also responsible for identifying the completeness of a document set.

Assessing this completeness of an entire document set is a measure of quality called quantitative verification. Here, you are focusing on completeness in terms of document quantity. So, how do you go about this?

The biggest challenge in quantitative document verification is knowing how many documents you are expecting to receive. There are a few approaches to this:

- ✓ Verify against assigned document numbers. For engineering drawings for example, it is common to define drawing numbers in advance. Consultants may generate their own document numbers, or they may request them from your organization. In either case, there should be a list of document / drawing numbers which have been created. This is the first place you can do a cross-reference check to see if you got everything. But sometimes, there's an even better way to do this.
- ✓ Verify against an asset. Technical records, which are often the most important documents you deal with, are typically related to an asset. As "asset" could be: A facility, or area of a facility; A piece of equipment; A vehicle; An energy transportation vessel, like a power line, or pipeline.

File all reference documents logically and keep them up-to-date and secured

Forms and logs

Developing an appropriate record-keeping system is an important step for inventory management. Good tools for managing the stock include:

- ✓ Standardized forms

- ✓ Card systems
- ✓ Log books.

For any system that is used, the following information should be recorded:

- ✓ Date reagent or set of supplies are received;
- ✓ Lot numbers for all supplies, reagents and kits;
- ✓ Pass or fail acceptance criteria;
- ✓ Date the lot number or box of supplies was put into service or, if not usable, the date and method of disposition.

Logbook

The stock logbook or card system will provide a way to keep track of all supplies and reagents that are on hand at any given time. In addition to information mentioned above, it is a good idea to record:

- ✓ Name and signature of the person receiving the materials
- ✓ Date of receipt
- ✓ Expiration date
- ✓ Quantity of the material received
- ✓ Minimum stock that should be on hand
- ✓ Current stock balance.

Additional information to record could include:

- ✓ Shelf number or name
- ✓ Destination (e.g. To -20°C freezer to media room).
- ✓ It is a good idea to keep the stock logbook in the storage area.

Observe workplace confidentiality standards

Confidentiality is the protection of personal information. Confidentiality means keeping a client's information between you and the client, and not telling others including co-workers, friends, family, etc.

Examples of maintaining confidentiality include:

- ✓ Individual files are locked and secured
- ✓ Support workers do not tell other people what is in a client's file unless they have permission from the client
- ✓ Information about clients is not told to people who do not need to know
- ✓ Clients' medical details are not discussed without their consent
- ✓ Adult clients have the right to keep any information about themselves confidential, which includes that information being kept from family and friends.

The types of information that is considered confidential can include:

- ✓ Name, date of birth, age, sex and address
- ✓ Current contact details of family, guardian etc
- ✓ Bank details
- ✓ Medical history or records
- ✓ Personal care issues
- ✓ Service records and file progress notes

- ✓ Individual personal plans
- ✓ Assessments or reports
- ✓ Guardianship orders
- ✓ Incoming or outgoing personal correspondence.

Other information relating to ethnic or racial origin, political opinions, religious or philosophical beliefs, health or sexual lifestyle should also be considered confidential.

Adult clients have the right to determine what information they consider personal and confidential.

There is, however, no such thing as absolute confidentiality in the community services industry. Workers are required to keep notes on all interactions with clients and often to keep statistics about who is seen and what issues are addressed. As a worker, there will be times when you could be faced with some personal difficulties regarding confidentiality. You need to give your client an assurance that what is said will be in confidence (that it will stay secret between you and the client) because, unless you are able to do that, the client is unlikely to be open with you. However, you also need to be aware of the limits to the confidentiality that you are offering. There are several instances where total confidentiality is either impossible, undesirable or illegal. These include:

- ✓ Cases where the law requires disclosure of information which will be
- ✓ If the health and/or welfare of a child or young person is at risk. You are required to contact Department of Community Services and notify them of your concerns.
- ✓ If your client tells you he/she has committed a serious crime. You are required to notify your supervisor or the police directly.
- ✓ If a worker is subpoenaed to present information in a court of law
- ✓ When the client needs to be protected from harming themselves (eg if suicidal)
- ✓ Where others may need to be protected (if the client has threatened to harm others or will do so inadvertently)
- ✓ The need to keep records
- ✓ When working in conjunction with other professionals in caring for a client
- ✓ The requirements of professional supervision, training, workshops or seminars.
- ✓ For more details, go to the sections on *Legislation governing confidentiality* and *Exceptions to the general rule of confidentiality*.

It is always good practice to tell clients at the beginning of your contact with them that whatever they tell you is confidential except in the above circumstances.

When writing up case notes you need to be careful about what you include and how you write this information up. Always remember that clients have the right to see files and read anything that has been written about them.

When working with other professionals it is good practice to obtain the written consent of the client before exchanging information.

If you are going to be discussing a client and their situation in supervision, in a training session or at a workshop, you can always change the name and any information that may identify the client. Other workers in these situations are also bound by the same ethical and legal requirements relating to confidentiality that you are.

Confidentiality also extends to things like:

- ✓ Names and addresses of clients
- ✓ Phone numbers and addresses of staff and volunteers
- ✓ Names and personal details of people who donate money or time
- ✓ Details of funding agreements

- ✓ Information about strategic planning.

Importance of confidentiality

Confidentiality is important for several reasons. One of the most important elements of confidentiality is that it helps to build and develop trust. It potentially allows for the free flow of information between the client and worker and acknowledges that a client's personal life and all the issues and problems that they have belong to them.

One of the major purposes for obtaining a client's consent before speaking to a third party (such as another agency or a family member/carer) is to protect the confidentiality and privacy of the client. Informed consent (obtaining personal information with the formal permission of the client or a person who has the legal authority to provide permission on behalf of the client) is considered essential in maintaining the privacy of the client.

It is important to keep your clients' business as just that – their business. You should only discuss matters relating to your clients' business with co-workers, and then only what needs to be discussed. Discussions should take place in the workplace and not be audible to other members of staff or the general public. You should never discuss clients' business with family or friends.

Respect for client confidentiality and staff personal information should be a high priority for all community services to comply with legislation that governs disclosure of information. In this regard all organisations need to have policies and procedures that provide guidelines for workers. Appropriate worker behaviour can also be incorporated in a code of conduct.

To ensure confidentiality, workers should only access confidential information for work that is covered by their job description and the policies and procedures of the organisation. They should only disclose information to other parties where a client (or co-worker in relation to their personal information) has consented to the release of the information or where disclosure is required or mandated by legislation due to indications of risk of harm. Further workers need to ensure that any information that is collected is securely stored and disposed of.

UNIT 13

PERFORM LABORATORY TESTING

This unit of competency covers the ability to prepare samples and perform tests and measurements using standard methods with access to readily available advice from supervisors

INTERPRET TEST REQUIREMENTS

Review test request to identify samples to be tested, test method and equipment involved

All laboratory testing depends upon proper sampling technique. Sampling must be designed to obtain accurate data for identifying treatment process changes and varying water qualities. The objective is to remove a small portion that is representative of the entire flow and adequately reflects actual conditions in the water.

Sample Location

The test requirements usually determine sample location. Obtain the sample where mixing is best and the water is of uniform quality. The sampling location must be accessible. Avoid slippery surfaces. Do not climb on or under guardrails.

Composite Samples

This type of sample is taken to determine average conditions in a large volume of water whose chemical properties vary significantly over the course of a day. Small aliquots are taken at regular intervals and pooled into one large sample over a 24-h period. If composite samples are to be taken manually, the frequency of sampling should depend on the number of changes in water quality. Most often, grabs are taken hourly, and the volume of each is flow proportioned. Samples are then combined into a composite for testing.

Identify hazards and workplace controls associated with the sample, preparation methods, reagents and/or equipment

Grab Samples

A grab sample is taken all at once, at a specific time and place. Insert container upside down into the water. Rotate open end toward direction of flow and allow to fill under the surface. Sample about 12 in. Underwater, or at center of the channel, about medium depth from the bottom. Avoid surface scum and bottom sediment. Be careful not to collect deposits from tank sidewalls. Eliminate any large, uncharacteristic particles that enter the sample. Fill sample bottle completely to exclude air space if sample is to be analyzed for DO, ph, chlorine residual, alkalinity, or vocs.

If preservative or dechlorinating agent has been added to empty sample bottle, adjust sampling technique so that the bottle does not overflow, or the chemical will be washed out. Be careful to handle sterile bottles for bacteriological testing aseptically. Collect enough sample to allow duplicate and spiked analysis. If both influent and effluent

samples are desired from a process unit with a detention time of 2 h, consider the timing. Take the influent sample now, and the effluent sample in 2 h. There will be a good chance of getting the same water.

The Sample Bottle

For chemical testing, the sample bottle must be clean. For bacteriological testing, the sample bottle must be clean and sterile. Bottles may be glass or plastic for most analyses; labels must be firmly attached to the sample bottle, not to the lid. Use labels that will not come off when damp. Use a water-insoluble ink pen. The label on a sample bottle should include sample ID number, date and time of collection, type of sample, location, adverse weather conditions, collector's initials, analysis to be performed, and sample preservation, if any.

Preservation and Transport

Dissolved oxygen, ph, and temperature should be analyzed on site, at the sampling location. Bacteriological tests must be performed within 24 h of sampling. All samples should be analyzed as soon as possible after collection.

Preservation of Samples

Test Preservation	Max.	Time
Acidity	Refrigerate	24 h
Alkalinity	Refrigerate	24 h
Chloride	None required	No max.
Chlorine Residual	Analyze immediately	15 min
Color	Refrigerate	48 h
Specific Conductance	Refrigerate	28 days
Fluoride	None required	28 days
Hardness	Add HNO ₃ to ph2	6 months
Metals	Add HNO ₃ to ph2	No max.
Ammonia	Add H ₂ SO ₄ to ph2	7 days
Nitrate	Refrigerate	48 h
Nitrite	Refrigerate	Do immediately
Organic Nitrogen	Refrigerate, add H ₂ SO ₄ to ph2	7 days
Odor	Refrigerate	6 h
Dissolved Oxygen	Analyze immediately	8 h
Ph	Analyze immediately	15 min
Phosphate	Refrigerate	48 h
Total Phosphorus	Add H ₂ SO ₄ to ph2, refrigerate	28 days
Solids	Refrigerate	7 days
Sulfate	Refrigerate	28 days
Temperature	Analyze immediately	15 min
Turbidity	Refrigerate	24 h

PREPARE SAMPLES

Record sample description, compare with specification, record and report discrepancies

Chain of Custody

This is a legal requirement that refers to the recorded handling of a sample from collection to analysis. It allows for tracing individual samples in case of a problem.

The sample is in custody if it is in hand or in sight, if it is locked away, or if it is placed in a secure area nobody can enter without the possessor's knowledge. When the sample changes hands, a change of possession form is signed by both parties; the date and time are recorded.

The chain of custody records include:

- ✓ Sample labels — For sample identification
- ✓ Sample seals — For shipped samples, to ensure no tampering
- ✓ Field logbook — Includes all information on label, container type, sample size, field analysis, number of samples taken
- ✓ Chain of custody record — Includes label information and change of possession forms

Online Sampling and Analysis

There is increasing, and for some parameters mandatory, use of automatic online sampling and monitoring. It has the advantage of yielding constant and immediate results. Time is saved, and problems due to carriage to laboratory are eliminated. Meters are installed directly into the process flow, and the water is monitored as it flows by. Typical tests that are performed this way are pH, DO, temperature, turbidity, and chlorine residual. The signal may be read on site, or transmitted to the lab or control room for remote readout. Frequent cleaning and calibration of the monitoring instruments are essential.

Laboratory Records

Process control and regulatory compliance depend upon the proper recording of laboratory analysis data. Analysis reports (bench sheets) should include:

- ✓ Name, time, and date of analysis
- ✓ Analyst name
- ✓ Sample preparation
- ✓ Analysis method
- ✓ Test conditions (standards, reagents, instrument settings, temperature, and reaction time)
- ✓ Results of analysis
- ✓ Observations — comments

Prepare sample in accordance with appropriate standard methods

The most important aspect in collecting water samples is to develop a sampling plan, consistently implement the plan and describe why that sampling plan was selected. In addition, documenting what happened when you implemented the plan and how replacement samples or surveys were made if households could not be contacted will assist in understanding the sample selection

First, you will need to determine how many households or water locations to sample. The Sample size that you select will depend on:

- ✓ Your resources for water quality testing and analyzing data
- ✓ The total number of sampling points involved
- ✓ The logistics in reaching the sampling points, especially those in rural, remote areas
- ✓ How much data is needed to make a good decision
- ✓ Your best judgment

Statistical calculations of sample size for more rigorous research are outside the scope of this

Manual. However, CAWST can provide you with additional resources for calculating sample size.

Sample Size for Small Projects (<100 households or locations)

If resources are available, it would be good to test 100% of the households or locations in a small project. As a minimum, 30% of households or locations should be used as the sample size.

Sample Size for Large Projects (>100 households or locations)

It is recommended to use the sample size that corresponds to the project size in the following table. It shows that smaller project needs to select relatively a relatively large number of samples. For example, a project with 1,000 households, should test between 43 and 91 of the households to get an adequate representation of the water quality.

Project and Sample Sizes

Project Size	Sample Size
500	41-83
1,000	43-91
2,000	43-95
3,000	44-97
4,000-6,000	44-98
7,000-15,000	44-99
>20,000	44-100

Geographical location and socioeconomic status can also be considered during the sample selection. Before determining the sample size, the project can be divided into different geographical areas, such as high land, low land, or coastal areas, to get an accurate representation. Households can also be classified based on socioeconomic status such as high, medium, and low income. Then, 10-20% of the households can be taken as a sample from each geographical area and each socioeconomic group.

Deciding What Locations to Sample

There are different methods to choose who or where you are going to sample. It is best to use a random sample (without a particular pattern) so that there is no bias in your results, but this might not always be possible.

Simple Random Sampling

In this method, every household who took part in the project has an equal chance of being selected in the sample. You can use different methods to randomly select the households, such as drawing names or numbers from a hat, or using an online random number generator

Systematic Random Sampling

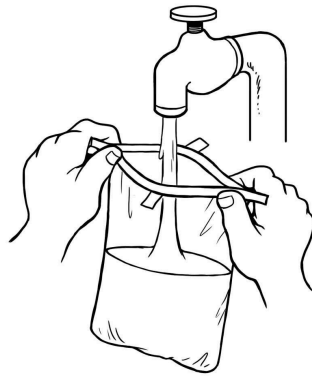
In this method, households are selected at particular intervals. The interval can be calculated by dividing the total number of households who took part in the project by the number of households to be selected (sample size).

Cluster Random Sampling

In this method, the population is divided into clusters or groups, and some of these are then chosen by simple random sampling. It is a good method to use for large projects. Samples taken from households of the same street or households within the same tribe are an example of cluster sampling.

Convenience Sampling

Convenience sampling does not give you a random sample of the population because households are only selected if they can be accessed easily and conveniently. Many projects often use convenience sampling instead of random sampling due to limited time and resources.



Cleaning and Sterilizing Sample Containers

You can reuse glass or heat resistant plastic sample containers. To prepare the containers, they should be washed with soap and rinsed at least three times (five is better) with distilled water to remove any residue. If distilled water is not available, clean chlorine-free water may be used (e.g., filtered and then boiled).

After washing, sample containers for microbiological testing need to be sterilized. Sample containers for physical and chemical tests need to be clean, but not sterilized. However, often the same water sample is used for physical, chemical and microbiological testing, so then the container must be sterilized using one of the following methods:

- ✓ Conventional oven: Heat at 180°C for 30 minutes
- ✓ Boiling: Boil for 10 minutes
- ✓ Autoclave: Heat at 121°C for 20 minutes
- ✓ Pressure cooker: Heat for at least 30 minutes

Never use bleach, chlorine or disinfectants that may leave a residue without properly rinsing (with distilled water) or boiling the containers afterwards. The residue may affect your results by inhibiting or killing the bacteria you are trying to test for.

Using Additives or Preservatives

Whenever chlorine is used for disinfection, chlorine residual may be present in the water after sampling and will continue to act on any microorganisms in the sample. Therefore, the results of any microbiological test may not show the true contamination of the water. If you suspect or know that the water sample has been chlorinated, then you need to add sodium thiosulphate to the sample. The sodium thiosulphate immediately inactivates any residual chlorine but does not affect the microorganisms that may be present. Sodium thiosulphate should be added to the sample container, after it has been sterilized. For 200 ml samples.

Preservatives may also be required for testing other chemicals, such as ammonia or cyanide. The manufacturer of portable test kits or a commercial laboratory will usually include the preservative along with instructions on how to use it properly.

Sampling Surface Water

Lakes and reservoirs can be subject to several influences that cause water quality to vary from place to place and from time to time. Where feeder streams or effluents enter lakes

or reservoirs, there may be local areas where the incoming water is concentrated, because it has not yet mixed with the main water body. Isolated bays and narrow inlets of lakes are frequently poorly mixed and may contain water of a different quality from that of the rest of the lake (UNEP/WHO, 1996).

For rivers or other moving water, you should try to obtain samples from a point where the water is well mixed and representative of the drinking water supply. Do not take samples that are too near the bank, too far from the point of where the drinking water is taken, or at a depth above/below the point of where the drinking water is taken.

Surface water quality can also change depending on the time of day or season. It is important to sample at the same time of the day and record the weather conditions when you are taking your sample.

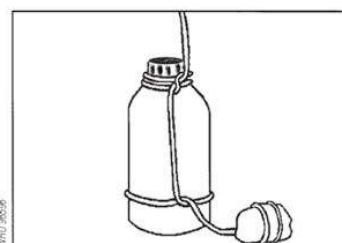
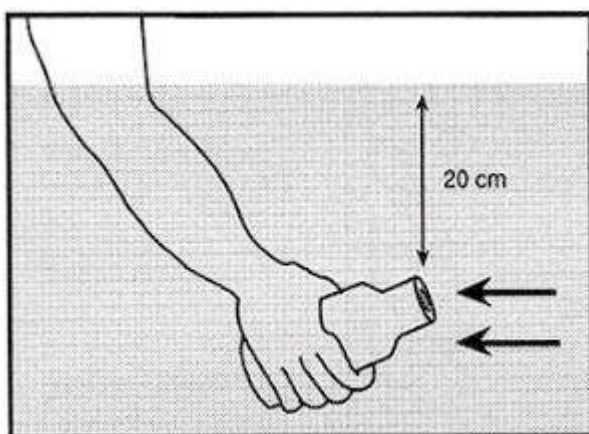
It may be possible to take the sample by hand if it is easy to get to the water. In many cases it may be inconvenient or dangerous to enter the water. In these cases, you may need to tie your container to a piece of wire or rope and throw it into the water. A bridge is an excellent place at which to take a sample, but only if it is close to where people get their drinking water.

Sampling Surface Water

It may be possible to take the sample by hand if it is easy to get to the water. In many cases it may be inconvenient or dangerous to enter the water. In these cases, you may need to tie your container to a piece of wire or rope and throw it into the water. A bridge is an excellent place at which to take a sample, but only if it is close to where people get their drinking water.

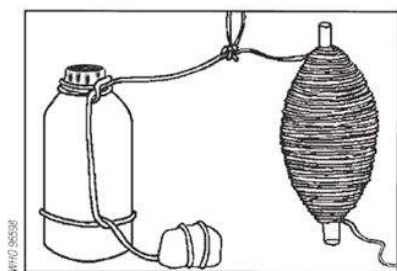
To sample a surface water source:

1. Carefully remove the cap from the container and put it facing up in a clean place or ask somebody to hold it. Take care to prevent dust from entering the container or anything else that may contaminate the sample.
2. Hold the sample container firmly and dip the open mouth of the container into the water.
3. Lower the container about 20 cm below the surface of the water and scoop up the water sample. This scooping action ensures that no external contamination enters the sample container. In areas where the water is moving (e.g., rivers), the sample should be taken against the direction of the flow of water.
4. Lift the sample container carefully and place on a clean surface where it cannot be knocked over. If the container is completely full, pour out a little water to leave an air space in the container. This allows space for mixing the water sample before analysis. Put the cap back on the container.



Sampling an Open Well or Tank

1. Prepare the sample container. Use string, rope or cable to attach a weight (e.g., small rock) to the container.

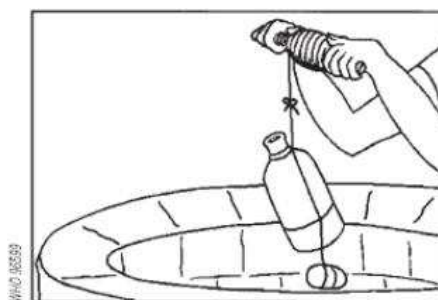


2. Take a 20 m length of string, rolled around a stick, and tie it to the container. Open the container as described above.

3. Carefully remove the cap from the container and put it facing up in a clean place or ask somebody to hold it. Take care to prevent dust from entering the container or

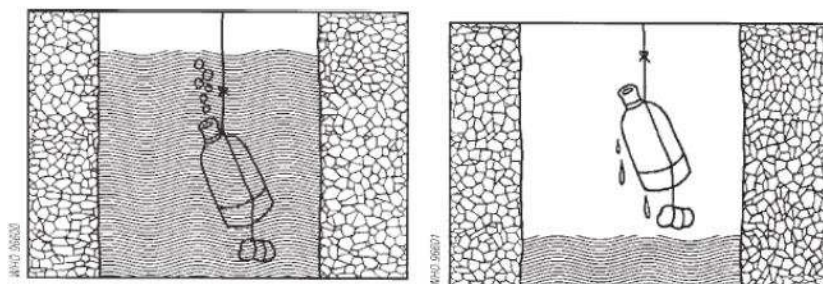
anything else that may contaminate the sample.

4. Lower the weighted sample container into the well or tank, unwinding the string slowly. Do not allow the container to touch the sides of the well or tank because it may pick up dirt and contaminate the sample.



5. Immerse the container completely in the water and continue to lower it below the surface of the water (about 20 cm although this can be difficult to judge). Do not allow the container to touch the bottom of the well or disturb any sediment.

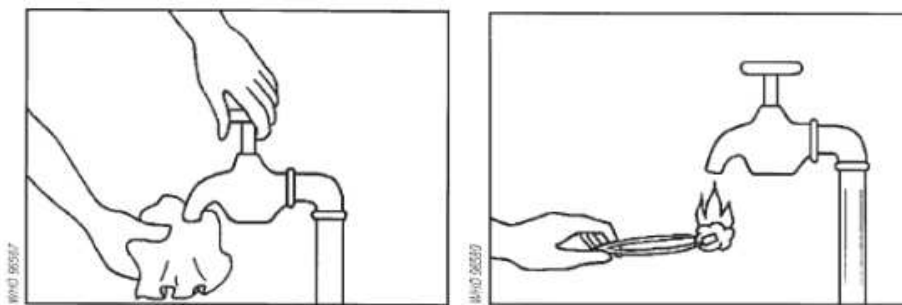
6. Once the container is full, bring it up by rewinding the string around the stick. Lift the container carefully and place on a clean surface where it cannot be knocked over. If the container is completely full, pour out a little water to leave an air space in the container. This allows space for mixing the water sample before analysis. Put the cap back on the container.



Sampling a Tap

1. Remove any attachments (e.g., nozzles, pipes, screens) from the tap. These attachments are a frequent source of contamination.

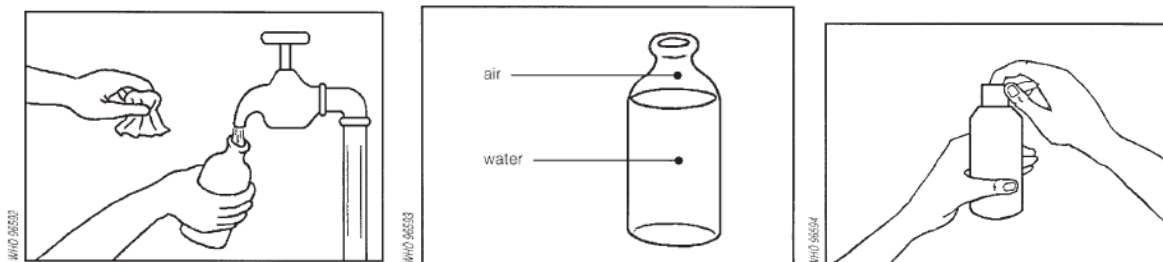
2. Optional - Use a clean cloth to wipe the tap and to remove any dirt. Sterilize the inside and outside of the tap for 1 minute. Pour alcohol on the outlet and flame it with a lighter or use tweezers to hold an alcohol-soaked cotton swab that is lit on fire. If the tap is made of plastic, then use an alcohol-soaked cotton swab that is NOT lit on fire, or else the plastic will melt! Sterilizing the tap will tell you the actual water quality. Not sterilizing the tap will tell you the water quality that people are drinking.



3. Open the tap before sampling. Carefully turn on the tap and allow water to flow at a moderate rate for 2-3 minutes to clear out any deposits in the pipes.



4. Carefully remove the cap from the container and put it facing up in a clean place or ask somebody to hold it. Take care to prevent dust from entering the container or anything else that may contaminate the sample. Hold the sample container under the water flow to fill it. Leave an air space in the container. This allows space for mixing the water sample before analysis. Put the cap back on the container.



CHECK EQUIPMENT BEFORE USE

Set up test equipment in accordance with test method

Laboratory Test Methods

The following methods, in order of complexity, are generally used to test chemical contaminants in the laboratory. A full review of laboratory methods for measuring the various parameters important to drinking water quality is beyond the scope of this

Manual. The WHO Guidelines for Drinking Water Quality provides a comprehensive list of laboratory methods for specific Chemicals that have guideline values (WHO, 2011).

Colorimetric Method

Chemical reagents are added to the water sample which react with the particular chemical parameter of interest. The product that is formed absorbs light at a particular wavelength. The water sample is then analyzed in a colorimeter or spectrophotometer and compared to known standards.

Electrode methods

Ion-selective electrodes can measure the concentration of certain ions in the water sample. Ph Is easily measured with an electrode and meter.

Chromatography

Samples are passed through a column containing a specific packing or coating that selectively Retains certain types of chemicals. Different compounds pass through the column at different Speeds, depending on their affinity to the packing or coating. A detector at the exit of the column Quantifies the concentration of the chemical. There are many types of chromatography: ion Chromatography, liquid chromatography and gas chromatography.

Atomic Absorption Spectrometer (AAS)

AAS is used to analyze the presence of metals. Samples are heated either in a flame or electrically in a graphite furnace, and the concentration is determined by the metal atom's absorption of light at a particular wavelength.

Inductively Coupled Plasma (ICP)

ICP is also used to analyze the presence of metals. Samples are broken down to the atomic level and metals are detected either through atomic emission spectroscopy or mass spectroscopy.

Colorimetric and electrode methods can be implemented in basic laboratories with relative ease. Chromatography and AAS are considerably more expensive and complex, and are more Appropriate for central or reference laboratories. ICP methods are very costly and difficult, and are uncommon in developing countries (UNICEF, 2008).

Portable Test Methods

Many types of portable test kits are available to measure various chemical parameters in drinking water. These are generally used for checking compliance as well as for operational monitoring of drinking water quality.

Although portable test kits have the advantage of being simple to use in non-laboratory environments and are often available at relatively low prices, their analytical accuracy is generally less than that of the laboratory methods listed above. However, when properly used, portable test kits provide valuable tools for rapidly assessing numerous chemical

parameters when commercial laboratories are not available or are too expensive (WHO, 2011).

The most popular portable test methods are test strips, colour comparators, colorimeters and Photometers and digital meters. It is necessary to check the validity of the test method before Using it.

Test (Reagent) Strips

There are many different types of test strips available to measure different chemical Contaminants. They are generally convenient and easy to use, provide quick results, and are the cheapest way to do field testing. Test strips are also available in individual packaging. This can be useful as the strips can deteriorate with humidity, heat, dust and light. The main limitation of test strips is that they are less accurate since they require a visual interpretation of the results.

Test strips typically have a plastic handle with a reagent area at one end. Typically, you dip the reagent area into a water sample, remove it and compare the colour of the reagent area with a colour chart. Some test strips work by presence/absence of a colour change at a maximum concentration.

It is important to use the required activation method for the test strip you are using. Different products require different activation methods, such as:

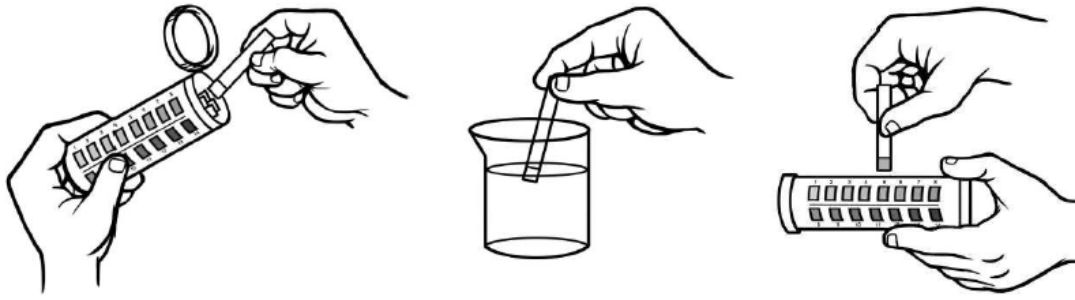
- ✓ Dipping the strip in the sample
- ✓ Swishing the strip back and forth in the sample
- ✓ Holding the reagent area in a stream of the sample

Also, different test strips require different times that you must wait before you compare the strip to the colour chart. Using the wrong activation method or reading your results too early or late for that test strip may lead to incorrect results.

Selecting Equipment and Products

There are several different types of equipment and products available in the commercial market for water quality testing. All have their own advantages and limitations. Some are easy to operate, but may lack in precision. Others are accurate, but may be difficult to read. Similarly, some are unable to measure a small quantity of your water sample. Therefore, selecting the appropriate equipment and products is important to meet your testing objectives.

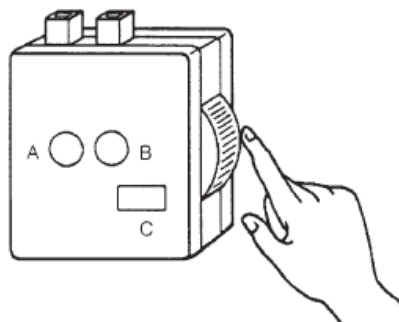
Test strips are available to measure pH and a variety of chemicals, such as chlorine and Manganese.



Using a test strip by dipping it into a water sample and checking the colour against a scale to measure the value

Color Disc Comparator

There are different types of colour disc comparators that are available. The comparator is used with a range of interchangeable colour discs. These colour discs compare the colour produced for the test against the standard test colours provided on the disc. Colour discs are available for a range of chemical parameters such as chlorine, fluoride, nitrate, iron and manganese. Colour comparators can sometimes be more accurate than test strips and they are easy to use, but they are more expensive, require more materials and still require a visual determination of the chemical concentration.



Colour disc comparator

Colorimeter and Photometer

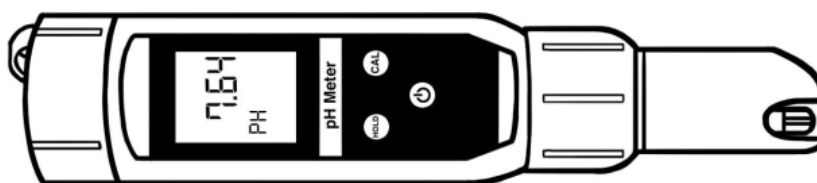
Colorimeters and photometers are digital instruments that use a light source to measure the Chemical concentration in a water sample. Compared to test strips, they offer more accurate And repeatable results since the concentration is given as a digital reading. As well, colorimeters And photometers can read a large variety of chemicals in a water sample, as well as a wider Numerical range within each parameter. However, they are more expensive, need a power Source and require training to ensure they are being used properly.



Photometer used to measure chemicals in water

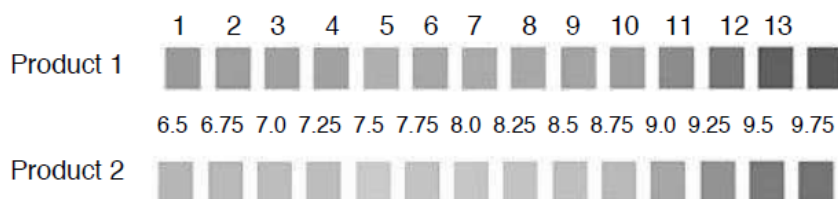
Digital Meters

Some portable test kits include various digital meters to measure parameters like ph and electrical conductivity (EC). They are relatively easy to use and can provide more accurate measurements than other methods, such as test strips. The main disadvantages are the need to calibrate the meters and replace batteries as required, and the general fragility of electronic equipment.



Digital ph meter

Example: A company produces test strips for measuring pH. Two products are available. One with a range between pH 1 to pH 14 and another with a range of pH 6.5 to pH 10.0. As drinking water usually lies between pH 6.5 and pH 8.5, the second test strip is more suited to our work and provides better precision and accuracy.



3.2 Perform pre-use and safety checks in accordance with workplace procedures and manufacturer instructions

Ph meters are calibrated (set to a correct reading) with purchased solutions that have

specific pH values. They are called buffers, and are composed of phosphates, acetates, etc., depending upon the pH of the buffer. These are the standards with which the meter is set to work correctly. The pH is listed on each buffer bottle, and it is dependable, but shelf life is limited. Buffers can also be purchased in dry capsule form (long shelf life) and prepared as solutions when needed. Follow the Instructions carefully on the meter for calibration. Instructions are somewhat different for each meter. Use the buffers indicated for calibration with that meter.

Always calibrate a pH meter with two buffers. A pH meter, near the end of calibration, will usually give a reading of "slope." This has to do with the efficiency of the electrode. It is the change in millivolts per decade of concentration. In pH terms, a decade of concentration is the difference between pH units, since the concentration multiplies by 10 from 1 pH unit to another. The instrument divides this change in mv/decade concentration by the ideal change in mv/decade concentration and obtains a percentage (of probe efficiency). The reading should be over 90% slope; some meters will adjust for the slight amount off 100% accuracy. If the slope reading is under 90%, repeat the calibration. If it is still off, recondition or change the electrode.

If you are using an older meter and there are no directions for calibration, choose two buffers that straddle the expected pH of the sample. Immerse the electrode in one of them and set the calibration knob to read that pH. Do the same with the other buffer, then set the meter to "read pH" and read the sample.

The buffer solution is really a "buffer." It neutralizes any possible acid or alkaline influences present in the water in which it is dissolved, and the pH should reside very stably at its designated value. When the pH electrode is immersed in the buffer, the reading should not drift. If it does, recondition or change the probe. A pH meter operates in millivolts, and it will give millivolt readings all the way through calibration, making the conversion to pH units at the end.

Identify faulty or unsafe equipment and report to appropriate personnel

Ph Troubleshooting Tips

1. Open air port when using. Close when done.
2. Rinse between samples with distilled water.
3. Do not be concerned with odd readings obtained while the electrode is rinsing in distilled water. Although distilled water should have a pH of 7 at 25°C, the electrode has difficulty reading anything at all in distilled water, which does not conduct electricity.
4. Handle the pH electrode carefully. Glass membranes break easily.
5. Wait for the sample reading to settle down before recording it. Wait 5 to 6 min before taking a reading with any electrode method (cleaner waters often have low ionic strength and a slow response time).
6. If an automatic temperature adjustment probe is included with the meter, this must be immersed in the solution with the pH electrode in order to sense the temperature and read the correct pH.

7. Needle drift is frequently caused by the sample changing. Check for drift when immersed in pH 7 buffer. If there is drift when in the buffer, change the filling solution. Recondition or replace the electrode.
8. Don't stir the solution with the pH electrode. It may cause the needle to swing. However, if the sample is not stirred at all, a polarity may build up around the electrode. It is best to stir the sample very slowly with a stir bar.
9. Don't immerse the electrode in very high or low pH solutions. This shocks the electrode and it may have difficulty recovering.
10. Don't immerse the electrode in sample deeper than level of the electrolyte. Sample will flow in rather than electrolyte flowing out.
11. Electrode contamination from electrolyte crystallization can be rinsed off with distilled water. See conditioning instructions in manufacturer's pamphlet.
12. If readings are poor, it is more likely the electrode than the meter that is at fault.
13. Troubleshoot the obvious first:
 - ✓ Is it plugged in?
 - ✓ Is there electrolyte in the electrode?
 - ✓ Is the meter switched to "pH"?
 - ✓ Is the glass membrane broken?
 - ✓ Is the sleeve on the filling port open?
14. After use, store electrode immersed in pH 7 buffer. Never let a pH electrode dry out.
15. Keep electrode clean between uses. pH 7 buffer is phosphate and it stimulates algae and bacterial growth. Change it frequently.

Check calibration status of equipment and report any out-of-calibration items to appropriate personnel

It is important to calibrate equipment according to the manufacturer's specifications to get results. Most electronic equipment will require some sort of calibration. Commonly used water Quality testing equipment that requires calibration include incubators, pH meters, turbidimeters, Colorimeters and photometers. Manufacturers should give the instructions for calibration when You buy a piece of equipment.

PERFORM TESTS ON SAMPLES

Identify, prepare and weigh or measure sample and standards to be tested

Priority Chemical Parameters

Unlike microbiological contamination, most chemicals in drinking water pose a health concern Only after years of exposure. Often chemical contamination goes unnoticed until disease occurs Due to chronic exposure. The severity of health effects depends upon the chemical and its Concentration, as well as the length of exposure. There are only a few chemicals that can lead To health problems after short-term exposure, such as nitrate, unless there is a massive Contamination of a drinking water supply (WHO, 2011).

It is not possible to test water for all of the chemicals that could cause health problems, nor is it Necessary. Most chemicals occur rarely, and many result from human contamination of a small Area, affecting only a few water sources.

However, three chemicals have the potential to cause serious health problems and occur over Widespread areas. These are arsenic and fluoride, which can occur naturally, and nitrate, which Is commonly used in fertilizer for agriculture. These three contaminants are more often found in Groundwater, though surface water can also be impacted. When planning new water supply Projects, especially using groundwater resources, these three contaminants should be Prioritized for testing (UNICEF, 2008).

A second priority for water quality testing should be for chemical parameters that commonly Cause water to be rejected for aesthetic purposes, such as metals (mainly iron and manganese) And total dissolved solids (salinity) (UNICEF, 2008).

When water is disinfected with chlorine, it is also important to monitor the drinking water quality For ph and free residual chlorine (FRC) as indicators of appropriate and effective treatment. As Well, it may be important to test for chemicals that are known to be present locally, such as Mercury or lead from industrial pollution.

Conduct tests in accordance with workplace procedures

There are several factors to be taken into consideration when choosing an appropriate Microbiological test method, including:

- ✓ Available resources
- ✓ Required level of accuracy and precision
- ✓ Technical skills of staff
- ✓ Geographical location
- ✓ Objective of the results

There are three main test methods to determine the presence of indicator bacteria in drinking Water:

- ✓ Presence/absence (P-A)
- ✓ Most probable number (MPN)
- ✓ Membrane filtration

Traditionally, membrane filtration using international standard methods was recommended to test for indicator bacteria in drinking water. This method requires trained technicians, equipment and other supporting materials that were historically only available in a conventional laboratory.

The relatively high cost of membrane filtration made it difficult, impractical or impossible to perform these tests in many parts of the world.

These constraints highlighted the great need for rapid, simple and inexpensive test methods.

This need is especially great for small community and household water supplies that lack access to and cannot afford conventional laboratory testing. On-site testing using portable test kits and the development of alternative and simplified testing methods,

such as P-A or MPN tests, have contributed to overcoming these constraints (WHO, 2002).

Different equipment and products for these test methods are now widespread and commercially available. The following sections discuss the different test methods, how they are conducted, and their advantages and limitations.

Presumptive Test Method

Presumptive tests are the traditional method that was used for identifying indicator bacteria in drinking water. As coliform bacteria grow, they ferment lactose and produce gas, changing the colour of the culture media and making bubbles. Since some noncoliform bacteria can also ferment lactose, this first test is called a “presumptive” test. Bacteria from a positive test can then be grown with a culture media that tests more specifically for coliforms, leading to “confirmed” results. Finally, the test can be completed by taking positive samples from the confirmed test through additional identification steps. Each of the three steps (presumptive, confirmed and completed) needs 1-2 days of incubation. Typically, only the first two steps are performed in coliform and thermotolerant coliform tests, while all three phases are done for periodic quality control or for positive identification of *E. Coli*.

Enzyme Substrate Test Methods

In recent years, tests have been developed that chemically identify specific enzymes produced by particular indicator bacteria. These enzymes react with specific substrates in the culture media and generally produce a strong colour change that is easy to identify. These tests are more rapid than the presumptive test method: some can produce results in 24 hours or less.

Furthermore, they are more specific than presumptive tests; so confirmatory tests are generally not necessary. The main disadvantage is the higher cost to purchase enzyme substrate tests. As well, the culture media doesn't exist in powder form. It is most often in liquid or agar form which needs to be refrigerated. Two of the most relevant enzyme tests for drinking water are described briefly below.

Beta-galactosidase (Beta-gal): Coliform bacteria produce the beta-gal enzyme. A number of specific substrates have been developed which react with this enzyme to produce a strong colour, usually yellow or deep red.

Beta-glucuronidase (Beta-gluc): Over 95% of *E. Coli* produce the beta-gluc enzyme. This enzyme reacts with the substrate 4-methylumbelliferyl-beta-D-glucoside (MUG) to produce a chemical that glows blue when exposed to ultraviolet light. Other substrates can produce a visible colour, typically blue (e.g., 4-chloro-3-indolyl-beta-D-glucuronide, also known as X-gluc).

Many commercially available P-A, MPN and membrane filtration tests use enzyme substrate methods. These tests are recommended by CAWST for their simplicity and specificity and are the basis of the discussion for culture media in this Manual. See Appendix 5 for a summary of different culture media for membrane filtration.

Presence-Absence

Presence-absence (P-A) is a qualitative test that depends on a colour change to indicate the presence of contamination. If the test turns out to be positive, meaning that the indicator bacteria is present, the water sample will change to a specific colour. P-A tests will not tell you the quantity of indicator bacteria in the water sample.

P-A tests are generally only appropriate in circumstances where thermotolerant coliforms are rarely found and when contamination occurs only at low levels (e.g., in deep wells). Quantitative test methods, like MPN and membrane filtration, are preferred where there is known or likely fecal contamination in the drinking water. For example, quantitative test methods are better when testing a surface water source or unprotected well. If positive results are found using P-A testing, the water sample should be re-tested using either MPN or membrane filtration to confirm the level of contamination.

P-A testing is not appropriate for testing the treatment effectiveness of household water treatment (HWT) technologies. We already know that many of these technologies may not be 100% effective for bacteria removal, so there is a chance that P-A tests will turn positive when testing the treated water. The P-A test will not indicate the level of contamination, despite the fact that the treated water quality is improved compared to the original water source, or help to determine the removal effectiveness of HWT technologies.

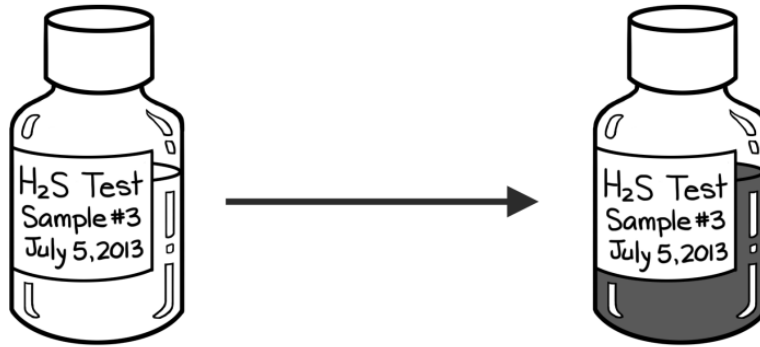
The advantages of P-A tests are that they are relatively inexpensive, quick and easy to use. The main limitation is that it will only measure positive or negative; the results do not tell you the actual number of indicator bacteria in the sample. There are a number of commercially available P-A tests which use enzyme substrate methods.

Different P-A products can test for three types of indicator bacteria:

1. H₂S producing bacteria
2. Total coliform bacteria
3. Total coliform bacteria and *E. Coli*

There are different P-A tests using H₂S bacteria that are produced by different manufacturers.

For example, in the P-A test manufactured by ENPHO in Nepal, a strip of test paper is added to a water sample. If the test paper turns black within 24 hours, it means that H₂S was produced, which means that bacteria coming from feces are likely present in the water sample.



Black water indicates a positive result for H₂S bacteria and likely fecal contamination

There are also different P-A tests that use total coliform and/or *E. Coli* as the indicators. The general process for these tests is:

1. A powdered reagent is added to the water sample
2. The sample is incubated for 24-48 hours at 35°C
3. The results are read: Colourless = negative, Colour = total coliforms present, Fluorescent = *E. Coli* present (seen using a UV lamp)



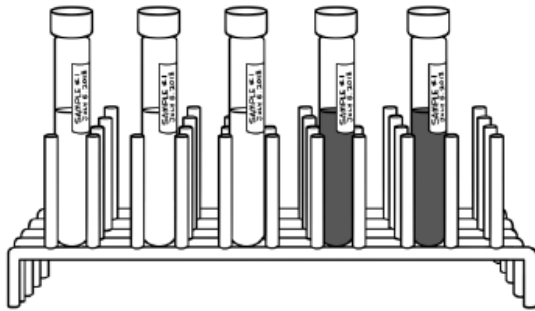
Clear water indicates a negative result for total coliforms, coloured water indicates total coliforms are present,

*Fluorescent water indicates *E. Coli* is present (seen using a UV lamp)*

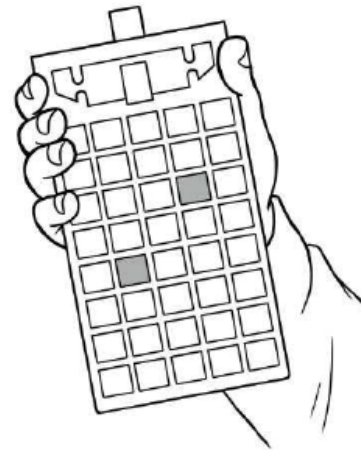
Most Probable Number

The most probable number (MPN) test method estimates the number of indicator bacteria that is most likely to be present in the water sample.

Multiple samples (1-10 ml) of the same water to be tested are added to a culture media in sterile tubes and incubated at a particular temperature for a fixed time (usually 24 hours). Three or five tubes are commonly used, though ten tubes may be used for greater sensitivity. It is becoming more popular to use a disposable tray with multiple small wells instead of multiple tubes since it simplifies the procedure. By counting the number of tubes or wells showing a positive result and comparing with a standard table, a statistical estimate of the most probable number of bacteria can be made. The results are reported as MPN per 100 ml (UNICEF, 2008).



Multiple tubes (10 mL each)



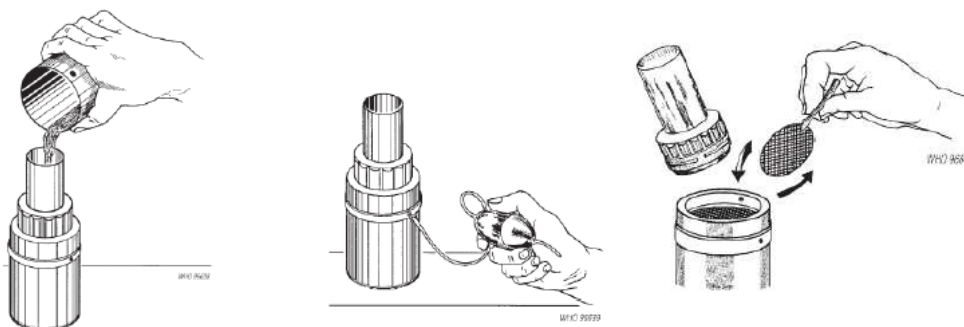
Multiple wells in a disposable tray

Membrane Filtration

Membrane filtration (MF) is the most accurate method to determine the number of indicator bacteria in a water sample and is internationally recognized as a standard method for water quality testing.

Membrane filtration can be done in a laboratory or by using a portable test kit. In general, a 100 ml water sample is vacuumed through filter paper using a small hand pump. After filtration, the bacteria remain on the filter paper which is then placed in a Petri dish with a nutrient solution (also known as culture media). The Petri dishes are placed in an incubator at a specific temperature and time which can vary according the type of indicator bacteria and culture media.

After incubation, the bacteria colonies can be seen with the naked eye or using a magnifying glass. The size and colour of the colonies depends on the type of bacteria and culture media used. The bacteria colonies are counted to determine the number of colony forming units (CFU) per 100 ml.



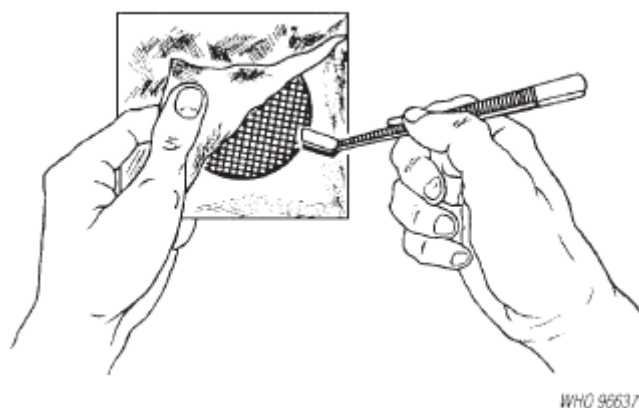
1- Pouring the water sample into a portable membrane filter setup, 2- vacuuming the water through filter paper using a small hand pump, 3- removing the filter paper with the bacteria from the water sample (Credit: WHO, 1997)

Membrane filtration is highly reproducible and can be used to test relatively large volumes of water samples. However, it also has limitations, particularly when testing waters with high turbidity or large numbers of noncoliform (background) bacteria. Turbidity caused by the presence of algae or suspended particles can clog the membrane

or prevent the growth of indicator bacteria on the filter paper. Low coliform estimates may be caused by the presence of high numbers of noncoliform bacteria, toxic metals or toxic organic chemicals (e.g., phenols).

Filter Paper

Filter paper, also called a membrane filter, is used to trap the bacteria from the water sample. A pore size of 0.45 μm is most commonly used since it filters out all coliform bacteria. The filter paper usually has a grid printed on it so that you can more easily count the bacteria colonies. There are various types of filter papers with different grid colours available from manufacturers.



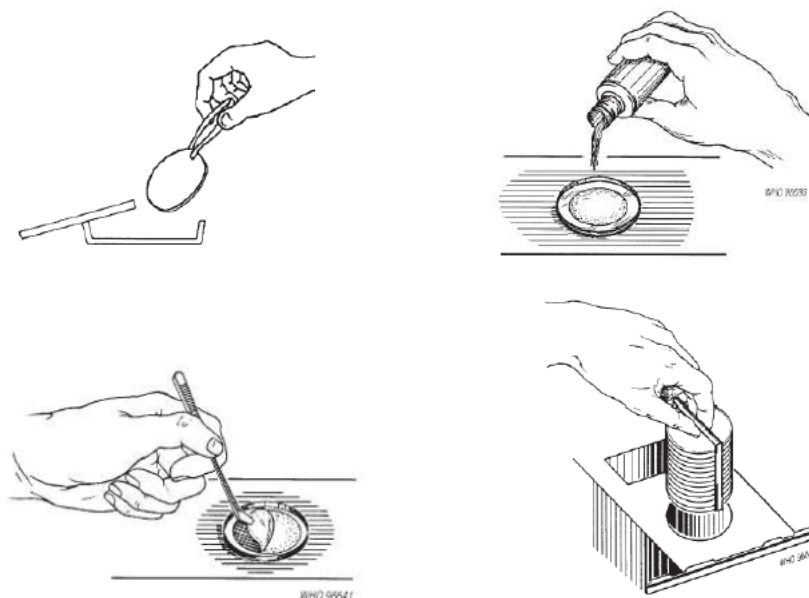
Removing a filter paper from its sterile package

Culture Media

Bacteria cannot be seen with the human eye. In order to observe them, they are grown under Controlled conditions to a size that we can actually see and count them. Culture media are substances which contain nutrients to help the bacteria grow. Culture media in liquid form is Called a broth and the semi-solid form (gel) is called an agar. Different culture media are used to Grow different indicator bacteria.

In most cases, the culture media is poured onto an absorbent pad in a Petri dish. The filter paper with the bacteria is then put on top and soaks up the culture media. The Petri dish with The culture media and filter paper is incubated so that the bacteria will replicate hundreds of Thousands of times and eventually appear on the Petri dish as small dots called colonies. The Number of colonies formed on the media is reported as colony forming units (CFU) per unit of Volume of the water sample (i.e., 100 ml), hence CFU/100 ml.

Different culture media products have different storage requirements and expiration dates. Once opened the media is exposed to contamination and should be stored securely. Be sure to follow the manufacturer's instructions on how to properly use and store the culture media.



1- An absorbent pad is put into the Petri dish, 2- the culture media is poured on top, 3- the filter paper with the bacteria is added, and 4- the Petri dish is put into the incubator (Credit: WHO, 1997)

Resuscitation

Bacteria are alive and are stressed after the filtration process. Stressed bacteria do not grow well and may die if they are further stressed by heat. Therefore, you should wait 1-4 hours at room temperature before incubating samples to allow bacteria time to recover and ensure that they survive and grow.

Incubator

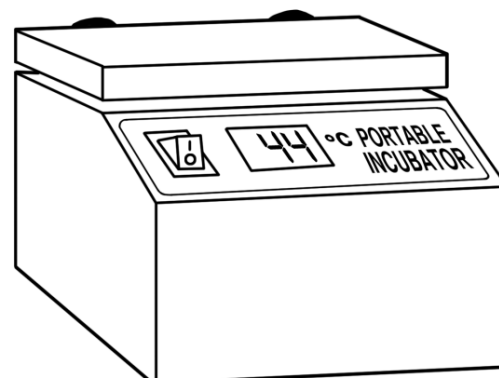
The incubator is another important piece of equipment needed for membrane filtration, and sometimes for P-A and MPN tests. There are different types of incubators made by different manufacturers. Some incubators are portable and use a battery for power supply, while others need to stay in one location and use the main power supply.

The incubation temperature is critical to ensure that microbiological test results are accurate. Different culture media require different temperatures to grow the specific indicator bacteria. For example, thermotolerant coliforms grow at 44°C. The manufacturer of the culture media will give instructions on the temperature needed for incubation.

Incubators need to be calibrated on a regular basis to make sure that the temperature is accurate. Manufacturers will give instruction on how often to calibrate the incubator and the process to do so.

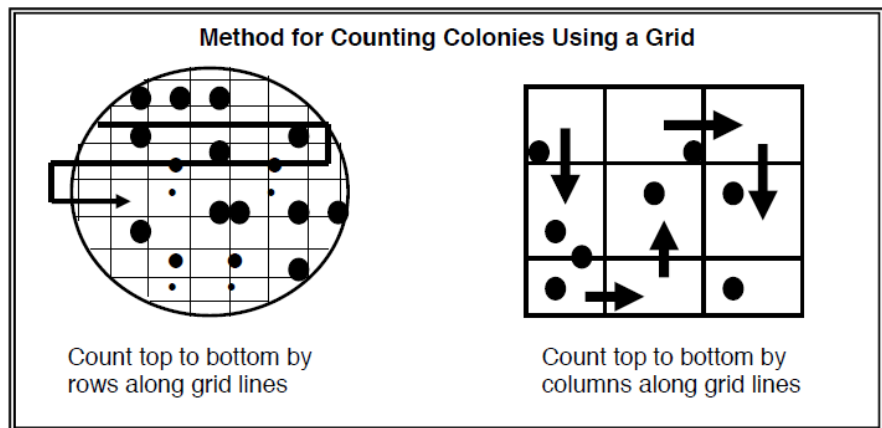
Colony Counting Techniques

After incubation, you remove the Petri dishes and count the bacteria colonies. You will count all



colonies of a certain colour, depending on the indicator bacteria and the culture media used.

Colonies may vary considerably in size. Generally, where there are a large number of colonies, they are smaller in diameter. Where colonies are fewer, they tend to be larger. This is because the colonies compete for nutrients in the culture media and will



grow larger when there is no competition. Use the grid lines on the filter paper to help count large numbers of colonies. Examine and count all colonies with the particular colour you are looking for. Colonies shown in every grid square are counted. Go from top to bottom and left to right until all grid squares are covered.

You will report the number of colony forming units (CFU) per 100 ml of water sample. It is difficult to count more than 100 colonies. Petri dishes with more than 200 colonies can be reported as “too numerous to count” (TNTC). Some colonies may overlap which can cause counting errors. Dilutions can be made to reduce the number of colonies and make it easier to count. See Section 4: Water Sampling and Quality Control for instructions on how to dilute your water sample. Most culture media manufacturers provide an information sheet or troubleshooting guide which can help you to identify and count the colonies.

Record data in accordance with workplace procedures

The analysis of a given sample will provide several results. The form drawn up for recording these results, although it should not be complicated, must be completed. The completed form should contain the data on the sampling, which will also serve to identify the samples, those entered on the sample dispatch form, and data on the bacteriological analysis itself. A suggested comprehensive form is shown in Fig. Once the analysis is completed, the laboratory carrying out the work should record the results obtained in a standardized form (protocol); this should follow the recommendations. The protocol can be a very simple report, which records the sample identification information together with the result of the analysis and the appropriate classification of the water.

WATER-QUALITY CONTROL PROGRAMME

BACTERIOLOGICAL WATER ANALYSIS

[.....] Authority

COMMUNITY:

SAMPLE SITE:

PLACE:

SOURCE:

SENDER:

DATE OF SAMPLING: / /

DATE OF ANALYSIS: / /

TIME:

TIME:

RESIDUAL FREE CHLORINE mg/litre

RESULTS

TOTAL COLIFORMS /100 ml

FAECAL COLIFORMS /100 ml

WATER BACTERIOLOGICALLY

GOOD - BAD

..... Laboratory Technician

..... Chief (Signed)

MAINTAIN A SAFE WORK ENVIRONMENT

Use established safe work practices and personal protective equipment (PPE) to ensure personal safety and that of other laboratory personnel

Personal Protective Equipment (PPE) is widely recognised as a means of protection for individuals working in an environment where all other methods of hazard control are in place and there is still a risk of injury. You must remember that PPE is the last barrier or line of defence between you and the hazardous material you are working with.

The minimum PPE you are required to wear when working in University Laboratories are:

- ✓ Enclosed Shoes (no bare feet, thongs, or sandals and
- ✓ Lab Coat (must be individually issued, worn at all times when working in the lab, removed before

Leaving the lab and laundered regularly and when contamination is suspected). AQIS Note: If you have been working with Quarantine materials, your lab coat must be autoclaved prior to being removed from the lab and laundered

The following additional PPE is provided and should be used where required / instructed / determined by a risk assessment:

- ✓ Safety Glasses / Goggles
- ✓ Gloves
- ✓ Dust Mask / Respirator
- ✓ Face Shield
- ✓ PVC Apron
- ✓ Hearing protection

Eye Protection

The type of eye protection required for a worker or student at the University will depend on the hazards that they work with or which they encounter in the specific work activity, and should be determined by undertaking a risk assessment. The risk assessment should take account of the hazards that are present in the laboratory for most of the time, and consider the work of the group as a whole, not just that of an individual.

Safety Glasses must be worn when:

- ✓ There is a risk of objects striking or causing damage to your eyes.
- ✓ When instructed to do so by your Supervisor or the Lab Manager.
- ✓ If required by the Risk Assessments or Chemical MSDS.

** Safety Glasses may limit, but will not prevent chemicals from splashing into your eyes. Safety Glasses are only suitable when the chemicals you are working with would not harm your eyes in the event of an accident.

Safety Goggles must be worn:

- ✓ When working with hazardous chemical solutions where there is a risk of splash to your eyes.

Face Shield must be worn when:

- ✓ Working with volatile hazardous chemical solutions (eg. Concentrated acids).
- ✓ Working with dangerous substances that could strike/splash the face/eyes.
- ✓ There is a risk of solution explosion or instability causing a splash to the face/eyes.
- ✓ There is a risk of dangerous objects striking the face/eyes, such as particles, glass or metal shards.

Standard Prescription Glasses are not sufficient as protective eyewear if:

- ✓ You are working with hazardous chemical solutions and there is a risk of splash to the eye.
- ✓ You are working with toxic, corrosive, pathogenic or radioactive substances.
- ✓ You are undertaking activities where there is a risk of objects striking the eye, such as particles,
- ✓ Glass or metal shards.

** In these instances, ordinary prescription glasses will not provide adequate protection from injury to the eyes and could even be hazardous to the wearer.

Please see the Laboratory Manager if you require Prescription Safety Glasses.

Gloves

Different gloves are available for different tasks. Please ensure that you are using the right type of glove for the task you are undertaking. For chemicals, this information can be found in the MSDS.

Gloves available in this laboratory include:

- ✓ Latex disposable examination gloves – powder free
 - Protects your cultures / samples from you.
 - Helps stop the spread of some contaminants around the laboratory.
 - Not to be used with hazardous chemicals.
 - ✓ Nitrile disposable gloves (blue)
 - Resistant to many solvents and chemicals.
 - Abrasion and puncture resistance.
 - Helps protect you from exposure to some hazardous chemicals.
 - ✓ Rubber gloves
 - Good resistance to detergents and diluted chemicals.
 - ✓ Cotton gloves
 - For use under other gloves – absorbs perspiration and helps with heat resistance (for eg, against hot dishwashing water).
 - ✓ Leather gloves
 - Some protection when handling broken glass – extreme care must still be taken.
- Heat resistant gloves

- Enables you to handle hot items – extreme care must still be taken.
- Used to remove items from the Drying Ovens and/or Autoclave.

Minimise generation of waste and environmental impacts

Engage and motivate your co-workers to buy green products and help reduce waste. Learn more about how your office can go green.

- ✓ Instead of printing hard copies of your documents, save them to your hard drive or email them to yourself to save paper.
- ✓ Make your printer environmentally friendly. Change your printer settings to make double-sided pages. Use small point fonts when possible and use the “fast draft” setting when possible to save ink.
- ✓ Pay your bills via e-billing programs when possible to save paper.
- ✓ Use paperclips (over staples) when possible.
- ✓ Reuse envelopes with metal clasps and reuse file folders by sticking a new label over the previous one.

Green Purchasing at Work

- ✓ Purchase recycled paper and keep a recycling bin nearby your desk.
- ✓ For information on how to buy more recycled-content products for your office, see EPA’s Comprehensive Procurement Guidelines.
- ✓ Buy energy efficient items with the ENERGY STAR ® logo or items that are EPEAT registered for the office.

The safety of staff undertaking analytical procedures, both in the field and in the laboratory, is of the greatest importance. All staff should be trained in safety procedures relevant to their work. In the laboratory, individual staff members should be authorized to undertake procedures involving risk of any type only after appropriate training; unauthorized staff should not be allowed to undertake analyses.

All laboratories should formulate and implement a safety policy that should cover cleaning, disinfection, and the containment of hazardous substances. Safety equipment such as fire extinguishers, safety glasses, and first-aid kits should be suitably located, and readily available; they should be routinely checked and all staff should be trained in their use.

Ensure safe disposal of laboratory and hazardous wastes

It is the clear responsibility of all research workers to ensure the safe and correct disposal of all wastes produced in the course of their work. Improper and irresponsible disposal of chemical wastes down drains, to the Local Authority, refuse collection, or into the atmosphere is forbidden by law. The Aldrich Handbook provides a useful summary of the correct disposal procedure for most chemicals. Due to new legislation, increasingly strict environmental controls and the escalating costs of disposal, it is essential that the appropriate disposal procedures given below are strictly adhered to:

Wash down drains with excess water

Concentrated and dilute acids and alkalis:

- ✓ Harmless soluble inorganic salts (including all drying agents such as CaCl_2 , MgSO_4 , Na_2SO_4 , P_2O_5)
- ✓ Alcohols containing salts (e.g. From destroying sodium)
- ✓ Hypochlorite solutions from destroying cyanides, phosphines, etc.
- ✓ Fine (tlc grade) silica and alumina

It should be noted in particular that no material on the "Red List" should ever be washed down a drain. This list is as follows:

Compounds of the following elements: - antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, tellurium, thallium, tin, titanium, uranium, vanadium and zinc.

- ✓ Organohalogen, organophosphorus or organonitrogen pesticides, triazine herbicides, any other biocides.
- ✓ Cyanides
- ✓ Mineral oils and hydrocarbons
- ✓ Poisonous organosilicon compounds, metal phosphides and phosphorus element
- ✓ Fluorides and nitrites

5.4 Clean, care for and store equipment and reagents as required Incineration (Solvent Waste collection)

- ✓ All organic solvents including water-miscible ones
- ✓ Soluble organic waste including most organic solids
- ✓ Paraffin and mineral oil (from oil baths and pumps)

Laboratory waste bins and controlled waste

All waste suitable for the Local Authority refuse collection, except recyclable paper and glass, is termed 'controlled waste'. Items in this category which includes dirty paper, plastic, rubber and wood, should generally be placed in the waste bins available in each laboratory and will be collected by the cleaners. However, each laboratory must also have a container for certain items which are not allowed to be put in the normal waste bins. In this special controlled waste container should be put:- all broken laboratory glassware, any sharp objects of metal or glass, all fine powders (preferably inside a bottle or jar) and dirty sample tubes or other items lightly contaminated with chemicals (but not any syringes or needles). Laboratory controlled waste containers must be emptied regularly and never allowed to overflow. Under no circumstances must any item of glass, sharp metal or fine powder ever be put in a normal laboratory waste bin. The tops must be removed from all bottles put out for disposal and there should be no detectable smell of chemicals from any bottle put for disposal.

Waste for special disposal

This is a troublesome and expensive method of disposal and the quantity of special waste must be kept to an absolute minimum. Only the following items should be disposed of in this way:

1. Schedule 1 poisons (but not cyanides) and other highly toxic chemicals
2. Materials heavily contaminated with substances in (i)
3. Materials contaminated with mercury
4. Carcinogenic solids including asbestos.

Special waste must be collected in a separate labelled bottle or jar for disposal. On no account must different types of waste be mixed. Advice should be sought from the School Safety Co-ordinator before beginning any work which will produce waste requiring special disposal in order to ensure that:

- ✓ The waste can be disposed of
- ✓ It is collected in the most suitable form so as to minimise the cost involved and
- ✓ It will be stored under suitable conditions.

The importance of handling waste for special disposal to the School Safety Co-ordinator immediately the container is full or the work is finished is emphasised. The hoarding up of hazardous waste in laboratories is strictly forbidden.

Environmental Health and Safety Services should be notified of all 'Special Waste' on the appropriate form.

Glass recycling

For environmental reasons the recycling of glass is encouraged, but only certain items of waste glass produced within laboratories are acceptable for recycling. Each laboratory should have a bin for recyclable glass. Only clean glass bottles such as those in which chemicals are received, and broken or waste plate glass are allowed. All broken laboratory glassware, items significantly contaminated by chemicals, sample tubes, droppers and glass wool must be disposed of as controlled waste. The recycling service will refuse to empty a recycling container if any of these prohibited items are discovered in it.

Bottles for bulk solvents

The importance of returning the specially labelled winchesters for solvents which are bought in bulk to the Store ready for direct refilling is emphasized. They must not be contaminated in any way and should not normally be washed out. Bottles containing sodium must not, under any circumstances, be returned directly to the Store. When sodium is first added to a bottle of solvent a label indicating this (available from the Store) should be attached. When the bottle is empty the sodium must be safely destroyed by adding ethanol or methylated spirit and the label removed. The bottle must then be washed out, dried and returned to the store ready for direct refilling.

Biohazard/Sharps Disposal - Syringes and Needles

"Sharps" contaminated with biologically hazardous materials must be collected in special containers to be sent for incineration. It is also required, at the request of Fife Council, that

all syringes and needles of any type should be disposed of by the same route. No syringes or needles must ever be put in a laboratory waste bin or controlled waste container.

UNIT 14

CONTROL STOCK

This unit of competency covers the ability to order, maintain and control the use of laboratory materials and/or equipment in the work area. For any laboratory to be properly operated, it is vital that stock is always managed and appropriately controlled to ensure supplies of testing chemicals and other consumables are always available

MAINTAIN AND CONTROL STOCKS OF MATERIALS OR EQUIPMENT

Introduction

As a Laboratory Technician, it is important that you maintain laboratory equipment and chemicals correctly according to the laws, regulations and codes of practice that govern this area.

The steps to undertake in this task are as follows.

- ✓ Label, document and store stocks
- ✓ Follow stock rotation procedures
- ✓ Identify stock discrepancies
- ✓ Identify and replace damaged or worn equipment
- ✓ Initiate QC sampling and testing procedures
- ✓ Report stock control problems.

1.1 Label, document and store stocks in accordance with relevant standards and specific safety requirements

At Lab the main storage area for chemicals and small equipment (or consumables) is in the Chemical Store. Lab has a Standard Operating Procedure that explains the correct way to store chemicals and you should read this before you proceed any further. Go to the Laboratory Supervisor's office and check on the OHS Manual see the table of contents. Obtain the OHS 02 SOP: Storage of Chemicals by clicking on it.

You should familiarise yourself with the **Chemical Store** before you carry out any tasks associated with the area. Before you go to the Chemical Store print out the following activity to take with you.



Assignment: Visit the Chemical Store

When you go to the **Chemical Store** have a look around the room. Some cupboards can be opened by clicking on them and other items will have names that appear when you move the mouse over them.

Reminder: The **Chemical Store** opens off the Analytical **Laboratory**.

Print this page to obtain the list of questions to answer as you look around. **Then send the completed sheet to your tutor.**

1. Name the Class 3 chemical found in the storage area for flammable liquids.

.....

2. Name the Class 8 chemical found in the storage area for corrosives.

.....

3. Name the Class 5 chemical found in the storage area for oxidising substances.

.....

4. Name the Class 6 chemical found in the storage area for poisons.

.....

5. Name the Class 4 chemical found in the storage area for flammable solids.

.....

6. How is the Chemical Store ventilated?

.....

7. Where are the Fire extinguishers located?

..... And

8. Where are the Spill kits located?

..... And

9. What Personal Protective equipment is available?

.....

Go to the **Analytical Laboratory** and click the door marked **Chemical Store**. Have a look around the room (some cupboards can be opened by clicking on them) and many items will have names that appear when you move the mouse over them.

Chemicals kept in the store are recorded in the Lab Database of Chemicals. View the Lab Database below to view the information that appears when the chemical diethyl ether is requested.

The way chemicals are stored in laboratories is set out by guidelines in the Occupational Health and Safety Act, and the Standards Australia documents. Find out more about the Laws, Regulations and Codes of Practice that cover the storage of chemicals by going to the workcover and Victorian Law Today websites. Go to the World Wide Web Catalogue and choose **Victoria workcover Authority** from the list given to locate the Code of Practice - Dangerous Goods Storage and Handling and also **Victorian Law Today** to see the

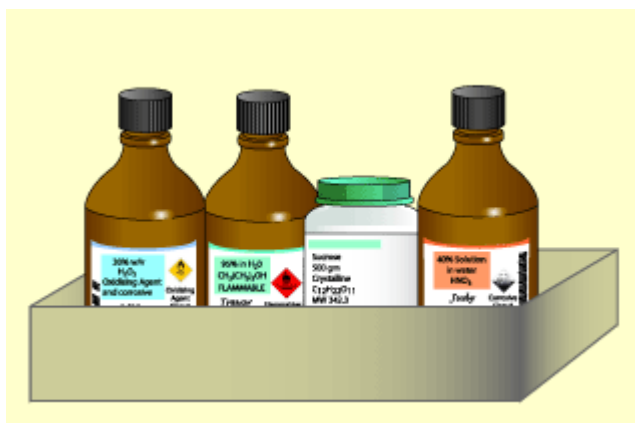
Dangerous Goods Act 1985.

Undertake the following assignment using the Codes of Practice, Dangerous Goods Act and the Australian Standard as your reference material.

Assignment: Storage of Chemicals

Answer the following using the Codes of Practice, Dangerous Goods Act and the Australian Standard as your reference material.

1. Which dangerous goods classes must be segregated from which other classes in the chemical store?
2. What safety equipment must be available in the chemical store?
3. What regulations are there regarding the height of stored chemicals?
4. What requirements are there specific to toxic substances?
5. What requirements are there specific to corrosives?
6. What ventilation requirements must be in place?



SOP: Labelling of Reagents

Purpose of labelling

Workplace reagent labelling primarily serves two purposes, to:

- ✓ Identify the contents of the container
- ✓ Warn of hazards.

Reagent labelling is a complement to other sources of information such as the MSDS and other labelling requirements. It aims to assist with the safer use of a substance by identifying hazards likely to be associated with the use of the substance.

Responsibility

Chemical suppliers and employers have the primary responsibility to ensure that in the workplace, hazardous substances are correctly labelled.

Employers must ensure that:

- ✓ Chemicals are appropriately and correctly labelled
- ✓ Labelling is not removed or modified
- ✓ Decanted substances are labelled
- ✓ There are prescribed measures for lost labels and unknown substances.

Workplace labels

Hazardous substances must be labelled to show:

- ✓ Contents
- ✓ Significant hazards
- ✓ Complementing other information (including MSDS information such as directions for use, first aid and emergency procedures)
- ✓ Date opened.

Scope

Workplace labels are required for containers containing:

- ✓ Hazardous substances
- ✓ Drugs and poisons

And labelling is also required for:

- ✓ Decanted hazardous substances, not for immediate use
- ✓ Items (and substances) that can produce hazardous substances in use
- ✓ Containers not cleaned.

Lost Labels

If the label is lost and the contents are unknown, the container should be:

- ✓ Marked CAUTION DO NOT USE: UNKNOWN SUBSTANCE
- ✓ Stored in isolation until the contents can be identified
- ✓ If contents cannot be identified, the contents should be suitably disposed of (with advice from relevant authorities).

Replacement of labels

A new label must be issued and placed on the container when:

- ✓ The substance changes (including new ingredients)
- ✓ New information becomes available that affects the information provided on the label (often instigated through a change of MSDS)
- ✓ A new expiry date (if used) is required.

Label Requirements - General

The requirements for all workplace labels are:

Physical -

- On outside face of container
- Firmly secured
- ✓ Colouring to contrast with background colour.
- ✓ English language
- ✓ Durable print

- ✓ Legible, through size and style.
- ✓ Variations through removal, defacing, modifications or other alterations are not permitted.

Study Notes: Labelling of Chemicals

Labels indicating a hazardous substance are required for their containers if the containers:

- ✓ Hold hazardous substances
- ✓ Hold decanted hazardous substances that are not consumed immediately (though the label need only have the product name and risk and safety information)
- ✓ Hold items (and substances) which can produce hazardous substances
- ✓ Are not cleaned (until they no longer contain a hazardous substance).

Below is a summary of the classes of hazardous chemicals commonly found in a laboratory:

Class 1	Explosives
Class 2	Gases
Class 3	Flammable liquids
Class 4	4.1 Flammable solids
	4.2 Substances liable to spontaneously ignite spontaneously combustible materials
	4.3 Substances that form flammable gases in contact with water
Class 5	5.1 Oxidising agents
	5.2 Organic peroxides
Class 6	Poisons and infectious substances
Class 7	Radioactive materials
Class 8	Corrosives
Class 9	Miscellaneous dangerous substances

Labelling of chemicals and solutions

Mark bottles and jars clearly with the:

- ✓ Product name
- ✓ Prescribed risk and safety information
- ✓ First aid details, emergency procedures
- ✓ Reference to the MSDS

Name of the owner (initials) and date.

Follow stock rotation procedures to maximise use of stocks within permitted shelf life

Part of your job at simulab is to regularly review the chemicals held in the Chemical Store and correctly dispose of any that are out of date or no longer required for use. The stockpiling of chemicals creates risks. Large quantities of chemicals are a hazard and some chemicals have a limited shelf life.

Today the Senior Technician Max gives you a list of chemicals and he asks you to check if the stocks in the Chemical Store are over the recommended shelf life. Today's date is April 9th 2003.

Below is the list of chemicals that you need to print and take with you when you check the shelf life of the chemicals.

List of Chemicals

Instructions: Print this list for use in the Activity: Check Shelf Life of Chemicals.

Today's date is 9/4/03

Chemicals	Dangerous Goods Class	Shelf Life	Stock amount required for 6 months
Acetone	Class 3	Indefinite	2.5 L
Trypsin	Not classed	3 months	10 g
Chromium nitrate	Class 5	1 year	250 ml
Iodine	Class 8	1 year	100 ml
Magnesium nitrate	Class 5	3 years	100 ml
Casein	Not classed	3 years	250 ml
Phenolphthalein	Not classed	3 years	50 ml
Sodium oxalate	Class 6	1 year	100 ml

The chemicals that are for disposal should be disposed according to the Regulations and Codes of Practice in your State or Territory. In most cases the services of a licensed contractor will be required to comply with the Regulations.

To find out more about the disposal of chemicals visit the University of Queensland and Eco-recycle Victoria websites. Go to the World Wide Web Catalogue and the choose **University of Queensland** and **Ecorecycle Victoria** from the list given.

Identify stock discrepancies and replace redundant or outdated stocks to maintain stocks at prescribed level

Identify stock discrepancies

The amount of chemicals stored in the laboratory should be limited to those required for

about 6 months of work. In the list that Max gave to you, did you note that the last column contained a suggested amount for 6 months use?

You will need to check the amount of stock left in the store for each of these chemicals and report to Max with the amounts you need to order, to maintain stocks at the required levels.

Activity: Check Chemical Stocks

Using the data in the table below identify the amount of chemical you will need to order to fulfil the stock requirements for the next 6 months.

Chemicals	Shelf Life	Amount in Store	Amount required for 6 months	Amount to order
Acetone	Indefinite	2.5 L	2.5 L	
Chromium nitrate	1 year	50 ml	250 ml	
Iodine	1 year	10 ml	100 ml	
Magnesium nitrate	3 years	50 ml	100 ml	
Casein	3 years	50 ml	250 ml	
Phenolphthalein	3 years	50 ml	50 ml	
Sodium oxalate	1 year	10 ml	100 ml	

Choose the correct alternative in the drop-down boxes below to make correct statements.

1. The amount of acetone to be ordered is -----
2. The amount of chromium nitrate to be ordered is -----
3. The amount of iodine to be ordered is -----
4. The amount magnesium nitrate to be ordered is -----
5. The amount of casein to be ordered is -----
6. The amount of phenolphthalein to be ordered is -----

Max suggests that it might be a good idea to make up a chart for the management of stocks. It could be an annual calendar with reminder dates for when stocks will need to be disposed of if not used up in the recommended storage period.

Assignment: Stock Rotation Chart

Make up a chart/calendar with the chemicals below to show how you would manage the rotation of these stocks over 3 years.

Chemicals	Shelf Life	Date of arrival
Acetone	Indefinite	12/99

Trypsin	3 months	2/03
Chromium nitrate	1 year	8/02
Iodine	1 year	6/01
Magnesium nitrate	3 years	4/01
Casein	3 years	11/99
Phenolphthalein	3 years	3/02
Sodium oxalate	1 year	7/02

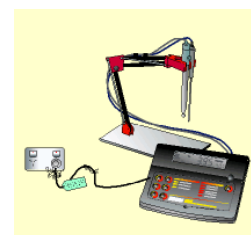
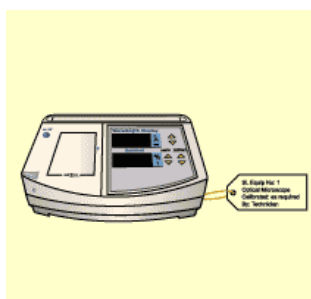
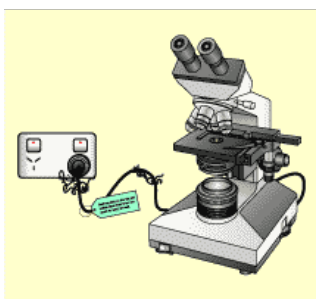
Identify and replace damaged/worn equipment or arrange for repairs or disposal as appropriate

The chemical store is used for some consumable equipment items as well as chemicals. These items are stored in the Not Classed areas and away from hazardous chemicals. It is not recommended to use chemical storage areas as general storage as mixing combustibles with flammables and oxidising substances is risky.

Simulab stores glassware and consumables such as paper towel, tissues, plastic disposable pipettes in the high cupboards with glass doors.

From time to time other equipment is stored temporarily in the Chemical Store eg microscopes, ph meters, and spectrophotometers. You are asked to check the equipment in the Chemical store and organise the repair or replacement of any damaged or worn equipment.

Check the equipment tag and Service Log by clicking on the tag attached to each piece of equipment below. Answer the question and print each screen for the activity that follows.



Initiate quality control sampling and testing procedures when appropriate

An enzyme has been stored on the shelf in the Chemical Store. The storage requirements are not being properly met. Find out what the storage requirements for enzymes are and what quality control checks you can perform to find out if the enzyme is still active and able to be used.

Study Notes: Enzyme Storage Conditions

General Characteristics

Enzymes are large proteins that act as catalysts to speed up reactions without themselves being changed or consumed. They are produced by plants, animals and microorganisms but are not living organisms themselves, but chemical compounds. Enzymes are highly active so that only small quantities are required and highly specific so that a single enzyme usually catalyses only a single reaction. Each enzyme has its own pH and temperature range, and the process of its reaction depends on those conditions along with time and concentration.

Activity

Enzyme activity is measured using assay procedures that are specific for each particular enzyme.

Storage

Shelf life and storage conditions for enzymes depend on their physical form. Liquids usually have the shortest shelf life and should be stored under refrigeration. Powders and tablets are usually stable for short periods (3 months) at room temperature, however should be stored under refrigeration for longer periods. Some enzymes should be stored at -20°C or -80°C for any period, as they are very unstable. Enzymes can normally survive three freeze and thaw cycles. All enzymes should be stored away from direct sunlight.

Safety

Because enzymes are proteins, avoid skin contact and inhalation of dust or aerosols that can cause allergic reactions.

Now do the following activity using the information provided in the Study Notes above.

Activity: Enzyme Storage Conditions

Shelf life and storage conditions for enzymes depend on:

- a) The date of delivery.
- b) Their physical form.
- c) The quantity of enzyme.

Which physical form of enzyme has the shortest shelf life?

- a) Powders and tablets
- b) Frozen
- c) Liquid

Liquid enzymes should be stored:

- a) In the refrigerator.
- b) At room temperature.
- c) By being frozen.

How would you store an enzyme in the form of tablets for less than 3 months?

- a) In the refrigerator.
- b) At room temperature.
- c) By being frozen.

How many freeze and thaw cycles can enzymes normally survive?

- a) 1
- b) 3
- c) 5

Report stock problems outside own knowledge and authority limitations to relevant personnel

There are many factors that can affect chemical stocks and stock control. The factors range from dangerous incompatibilities, short use-by-dates, inaccurate recording of supply or usage to problems with supply or deletion of specialty chemicals from a laboratory suppliers product range!

What stock control problems could you encounter in a Chemical Store?

Assignment: List Stock Control Problems

List the stock control problems you could encounter in a Chemical Store? Indicate which stock control problems you would bring to a more senior staff person's attention.

Max asks you to check if there were any water testing kits in the Chemical Store. What should you do if you find there are none in stock?

ORDER AND RECIEIVE MATERIALS AND EQUIPMENT

Introduction

Keeping an adequate supply of all chemicals and equipment necessary to operate a laboratory takes constant attention and an organised approach. Set procedures should be followed when ordering and receiving stock, and responsibility for maintaining adequate laboratory supplies needs to be assigned.

The steps to undertake in this task are as follows.

- ✓ Inventory control
- ✓ Determine requirements of customers and suppliers
- ✓ Determine demand for stock
- ✓ Place orders using enterprise systems and procedures
- ✓ Follow up orders using enterprise systems and procedures
- ✓ Check condition of received goods.

Inventory control requires finding the right balance between ensuring that there are adequate supplies on hand, keeping the quantity of hazardous substances to a minimum and ensuring chemicals are used before their expiry date.

The stock level at which a replenishment order should be placed is based on experience, including knowledge gained about the usual use of the reagent, the lag time between placing an order and its delivery, and the expiration of the reagent. In general it is a good idea to keep a minimum of one month's supplies of reagents on hand, and to place an order when the stock reaches that level. On the other hand, you should not order so much that the stock is likely to expire before it is used up. Experience shows what the balance between running out of and wasting the reagent will be. Keeping records of the actual use, and of the ordering and receiving of supplies, improves the chances of striking the right balance.

Read the following study notes before attempting the activity.

Study Notes: Inventory Control

Inventory control is based on the following factors.

- ✓ Stock usage - based on historical data and experience.
- ✓ Stock control - including security of stocks against pilfering, leakage etc.
- ✓ Record keeping - computer-based with timely data input.
- ✓ Shelf Life - needs to be managed to avoid wastage.
- ✓ Stock on hand - rule of thumb for how much stock to have on hand at any time (often one month's supply).
- ✓ Hazardous chemicals - keeping these to a minimum consistent with effective running of assays.
- ✓ Ordering system - must be simple to use and manage, and relies on the laboratory staff informing. Someone of stocks running low or placing the order themselves.
- ✓ Supplier capability - long or short are the delivery times.

A number of these factors may be contradictory. For instance, consider the following.

- ✓ Ten litres of concentrated sulfuric acid is a large amount of a hazardous chemical but if this amount were used every fortnight then the 'stock on hand rule of thumb' would require 20 litres to be stored!
- ✓ An enzyme may have a shelf life of two weeks from receipt. Keeping one month's supply would not make sense in such a situation.
- ✓ Erratic demand such as 90% of hay fever testing being conducted in Spring may mean that a higher stock level is kept on hand in September - November than in the rest of the year.

Regular stock checks should be performed to monitor stock losses, to check that there is sufficient stock available and to ensure that all stock is stored in a safe and efficient manner. These stock checks will ensure that the laboratory will never run out of chemicals or materials. If you do run low on a particular item, it should be brought to the attention of the Laboratory Supervisor so that the chemical is reordered.

Safety is a part of inventory control and bulk chemicals should never be stored in a laboratory. A separate chemical store is used for this purpose and should include or contain the following features.

- ✓ A secure lock to prevent unauthorised entry - for safety and to reduce pilfering.
- ✓ Dry and well ventilated.
- ✓ Fume hood - if applicable.
- ✓ Lockable poison cupboard.
- ✓ Fireproof cupboard for volatile, flammable liquids.
- ✓ Gas cylinder store.

Undertake the following activity to ensure that you have a good understanding of inventory control.

Activity: Inventory Control

Based on the Study Notes: Inventory Control, choose the correct response to the following.

Stock usage information is based on:

- a) A 'gut feel' and experience.
- b) Historical data and experience.
- c) Shelf life and supplier capability.

One common factor that leads to inventory wastage is:

- a) Minimal stock levels.
- b) Forgetting to order.
- c) Shelf life.

Hazardous chemicals should be:

- a) Bulk ordered when cheap.
- b) Stored together.
- c) Kept to a minimum.

Factors that relate to ordering patterns include:

- a) Shelf life, expected usage and supplier capability.
- b) Shelf life, supplier capability and a securely locked chemical store.
- c) Expected usage, a fume hood and supplier capability.

If a radioactive reagent has a shelf life of 15 days from receipt and your monthly usage is 25 units, the minimum monthly stock level should be:

- a) 25 units.
- b) 50 units.
- c) None of the above.

Regular stock checks are a good way to monitor:

- a) Stock levels and safe storage.
- b) Stock losses.
- c) All of the above.

One months supply is a good rule of thumb for:

- a) Stock on hand.
- b) Shelf life.
- c) Record keeping.

Determine requirements of customers and suppliers using appropriate communication and interpersonal skills

Although many suppliers can respond to emergency orders, they are costly to the customer and the supplier and are disruptive to the laboratory's functioning. Imagine the disruption to the efficient running of simulab if an essential reagent runs out and a high throughput assay is delayed by two days.

Possible consequences are the following.

- ✓ Delayed turnaround time (TAT) and angry customers
- ✓ Patient health and treatment compromised
- ✓ Loss of reputation for simulab
- ✓ Loss of customers
- ✓ Laboratory staff under utilised
- ✓ Loss of morale in the laboratory and friction between staff
- ✓ Finger pointing and 'blame' for the 'culprit' who failed to order the reagent
- ✓ Loss of profits
- In extreme cases loss of jobs and possible close down of the laboratory!

Reagent, equipment and consumable inventory management is a balancing game between when you need it and when the supplier can deliver it.



For this process to occur smoothly you need to know your average use of the reagent, equipment or consumable and the supplier's ability to deliver. For instance, if the supplier only delivers on a Thursday of the week following order, then you need to ensure that your order is in well ahead of requirements.

You should always allow adequate time to fill and deliver the order – usually 7 to 10 days is the minimum time needed. This means that you need to have enough supplies on hand to cover at least 7 to 10 days ahead. A good rule of thumb is to have one month's supply on hand at all times but this may be dependent on the shelf life of the material.

Read the following study notes before attempting the activity.

Requirements of Customers and Suppliers

For an inventory system to operate effectively the requirements of customers and suppliers must be taken into account. **Customers** are anyone who relies on the inventory system and include **internal customers** (laboratory and other simulab staff) and **external customers** (doctors, patients and other customers, for example).

Customers require the following from the simulab inventory system:

Internal Customers	External Customers
An inventory that never runs out.	Accurate and precise results.
A system that takes account of shelf life.	Timely results within specified tats.
A user friendly and automated system.	An economical service.
A system that saves time and money.	Ability to have priority testing done faster.
A system that reduces wastage.	Belief in the reputation and reliability of simulab.
A system that minimises storage of hazardous chemicals.	Never having results delayed because of inventory shortages.
A system that alerts future stock shortages.	Ability to specify methods and reagents for specific testing.

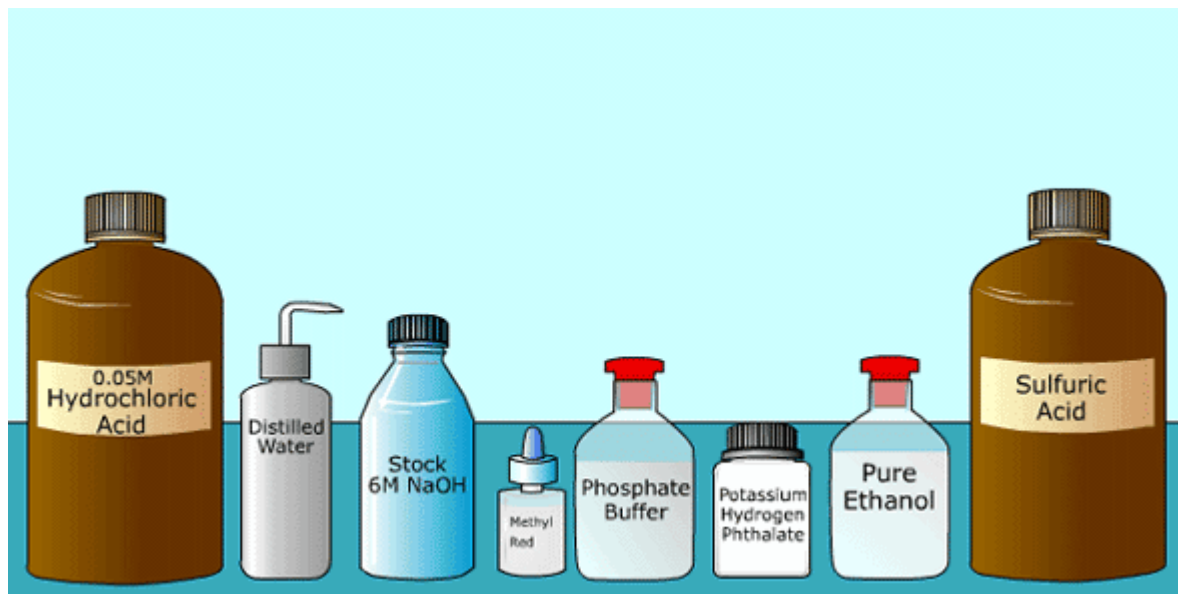
Suppliers are anyone who supplies inventory to the laboratory and again there may be **internal suppliers** (laboratory technicians who make up reagents for other laboratory users are an example) and **external suppliers** (commercial chemical, equipment and consumable suppliers).

Suppliers also have a number of requirements that need to be fulfilled by the simulab inventory system:

Internal Suppliers	External Suppliers
Clear and concise sops.	Orders filled out in an appropriate manner with all details including catalogue numbers.
Access to reagents of suitable grade and quality.	Timely filing of orders and reduction of 'urgent' or 'rush' orders to a minimum.
Required reagents never run out.	Standing orders wherever possible.
Accurate details of requirements (eg 5 L of 0.90M nacl every Monday morning).	Recipient to check all receipts and advise of discrepancies ASAP.
A system that reduces wastage.	Payment of delivery fees.
Access to appropriate containers, labels and processing equipment.	One person to be responsible for all enquiries regarding orders.
Proper training for the preparation of reagents.	All regulatory paperwork, permits etc. To accompany orders (eg drugs of addiction, radioactive substances).
A system that is flexible enough to account for variations in requirements.	Simulab to pay its account promptly according to the terms of supply.

Determine demand for stock, taking into account peak and seasonal variations in stock usage and production conditions

One aspect of inventory control is the ability to predict the average usage patterns of each reagent, equipment or consumable and to order to this pattern. You should also be able to predict when the demand is unusual.



Example of unusual patterns of usage/demand include the following.

- ✓ Holiday periods - for example, if the supplier closes down over Christmas/New Year then you may need to have enough stocks on hand to cover analyses until say 15 January.
- ✓ Periods of increased demand - for example, if simulab provides blood alcohol testing for motorists then we need to be aware of police blitz times such as Easter and the summer holiday season.
- ✓ Fast turnaround time (TAT) for results - for example, simulab may be contracted to provide testing for a new clinical trial that requires very rapid tats.

Undertake the following activity to ensure that you have a good understanding of inventory control.

Place and/or follow up approved orders using workplace systems and procedures

Procedures for ordering chemicals and equipment:

- ✓ Selecting Reagents and Materials
- ✓ Purchasing and Ordering Reagents and Materials
- ✓ Assessment of Suppliers
- ✓ Checking of Deliveries.

LAB PURCHASE ORDER FORM

**Purchase
SLPL019873**

Number:

TO:

Date

Quotation from

Contact Number

On

/ /

Please supply the following goods or services:

Cat#	Goods- Description	Unit size	How many units	@\$	Total (inc GST) \$
	Delivery Charge				
				Total	

Expected Delivery Date:

Requisitioned by:

(add your name here)

Authorised by: Laboratory Supervisor

Follow up orders using enterprise systems and procedures

An effective and efficient ordering system does not stop once the order has been placed. There are a number of follow up actions that must be undertaken.

- ✓ Ensure that the ordered goods arrive
- ✓ Ensure that the ordered goods arrive on time
- ✓ Ensure that all of the ordered goods arrive
- ✓ Ensure that the correct amounts of ordered goods arrive
- ✓ Ensure that unordered goods are rejected
- ✓ Ensure that the correct prices are charged
- ✓ Follow up on back ordered stock.

Following Up Orders

There are a number of situations when follow up activity is required on an order. There are many ways for mistakes and confusion to arise during the ordering process. Many of these will require follow up activity.

The table below lists a number of common order-related situations and the follow up activity required. Note that this list is not exhaustive and lists only the common problems. The follow up activities relate only to the simulab enterprise and should never be used elsewhere.

Common Order-Related Situations	Follow Up Activity Required
Order late in arriving	Check with the supplier, may need to advise laboratory staff.
Order missing items with no indication of back order	Check with the supplier, may need to advise office and laboratory staff.
Order missing items with indication of back order	Check with the supplier and determine delivery date, may need to advise office and laboratory staff.
Incorrect or missing paperwork	Check with the supplier, may need to advise office staff.
Incorrect pack sizes	Check with the supplier, may need to advise office and laboratory staff.
Incorrect number	Check with the supplier, may need to advise office and laboratory staff.
Incorrect grade	Check with the supplier to arrange return, may need to advise office and laboratory staff.
Goods damaged, faulty or unsuitable	Check with the supplier to arrange return, may need to advise office and laboratory staff.
Goods leaking	Check with the supplier to arrange return, may need to advise office and

	laboratory staff.
Individual pack damaged or open	Check with the supplier to arrange return, may need to advise office and laboratory staff.
Goods not transported at the correct temperature	Check with the supplier to arrange return, may need to advise office and laboratory staff.
Wrong catalogue number listed	Check with the supplier, may need to advise office and laboratory staff.
Items ordered completely missing from delivery docket	Check with the supplier to determine delivery date, may need to advise office and laboratory staff.
Order delivered to wrong location	Check with the supplier and advise the correct location, may need to advise office staff of the correct location.
Order delivered to wrong enterprise	You will not know about this unless they contact you. This would appear to you as a late delivery.
Abusive delivery person	Note details, contact the supplier and advise your manager of the situation.

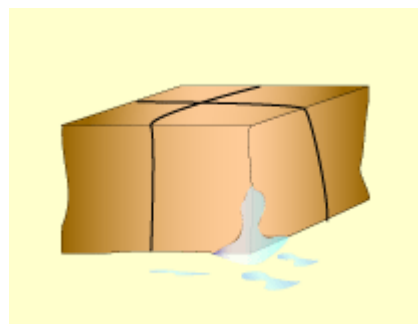
2.4 Check condition of received goods and take appropriate action

In addition to the follow up actions covered in the previous step we must also consider how to check the condition of the received goods.

Condition of Received Goods

The quality of received goods can be compromised in many ways. In this Study Notes we will look specifically at the condition of the goods received because this reflects directly on the ability of the goods to perform the tasks required of them in the laboratory in an accurate and precise manner.

There are many factors that relate to the quality of goods received and some of them are listed below. All of these factors should be checked as soon as possible after arrival of the goods. The supplier should be contacted if there are any deficiencies in the quality of the goods received and the laboratory staff and office staff may also need to be advised.



- **Outer Packaging:**
 - ✓ Intact and undamaged
 - ✓ No evidence of stains
 - ✓ Seals intact
 - ✓ Not leaking
 - ✓ No evidence of tampering
 - ✓ No evidence of contamination.

- **Individual Containers:**
 - ✓ Intact and undamaged
 - ✓ Glassware intact
 - ✓ No evidence of stains
 - ✓ Seals intact
 - ✓ Not leaking
 - ✓ No evidence of tampering
 - ✓ No evidence of contamination
 - ✓ Labels intact.

- **Transport:**
 - ✓ Correct temperature
 - ✓ Correct time
 - ✓ Correct pressure (if appropriate)
 - ✓ Correct transport containers, especially protective measures
 - ✓ Correct paperwork.

- **Equipment:**
 - ✓ Intact and undamaged
 - ✓ No evidence of tampering
 - ✓ No evidence of contamination
 - ✓ All parts present
 - ✓ All documentation present
 - ✓ Operational.

- **Follow Up Actions:**
 - ✓ Put a received date on each container
 - ✓ Process paperwork according to enterprise requirements
 - ✓ Advise appropriate office and laboratory staff of arrival of goods
 - ✓ Store goods in the appropriate manner (temperature, location etc).

MAINTAIN STOCK RECORDS

Record all relevant details accurately using the specified forms/computer system

Introduction

Laboratories need to have all necessary equipment and materials available for their required testing procedures. Most laboratories have a wide range of equipment and material requirements, so managing the stock needs to be done carefully and methodically. Record keeping is an integral part of stock control.

The steps to undertake in this task are as follows.

1. Safety requirements
2. Stock control requirements
3. Record keeping systems
4. Integrity of laboratory records

Safety requirements

Areas where chemicals are stored are regulated because of the hazard represented by the chemicals.



Regulations and standards relevant to the storage of chemicals include the following:

- ✓ Dangerous Goods Regulations which apply at the State level
- ✓ Dangerous Goods Code
- ✓ Standards including:
 - Safe storage and handling information cards
 - Storage and handling of flammable and combustible liquids
 - Storage and handling of corrosive substances
 - Storage and handling of toxic substances
 - Storage and handling of gases in cylinders
 - Safety in laboratories

Ensure that written information is legible and indelible

Detailed stock information needs to be recorded and kept on file in the designated place in the laboratory.

This information is required for a range of reasons including:

- ✓ To ensure inventory levels stay within required storage limits
- ✓ To allow a current chemical manifest, showing inventory levels and storage locations, to be produced for the emergency services. In case of fire the manifest will assist fire

fighters in choosing appropriate fire-fighting methods. Depending on the size of the organisation it may also be a legal requirement to maintain an up-to-date manifest

- ✓ To ensure that msdss for every chemical in the laboratory are readily accessible
- ✓ To ensure the availability of supplier details to facilitate the ordering process
- ✓ To ensure orders are placed when stock levels fall below a 'trigger point'
- ✓ To ensure that chemicals are used, or otherwise disposed of, on or before their expiry date.

Records kept in the laboratory include information on:

- ✓ Stock usage
- ✓ Orders and the progress of orders
- ✓ Equipment servicing and repairs
- ✓ Current inventories
- ✓ QC sampling, testing and stock rotation.

Requirements for Chemical Record Keeping

Record keeping of chemical stocks in a laboratory is done for the following reasons.

- ✓ Safety - to have a database of msdss for all chemicals in stock.
- ✓ Safety - to ensure that stocks of particularly hazardous chemicals are kept to a minimum.
- ✓ Efficiency - to ensure that chemicals do not run out.
- ✓ Efficiency - to take advantage of economies of scale when purchasing bulk supplies.
- ✓ Efficiency - to make it simple to purchase more stock.
- ✓ Efficiency - to make stocktaking of chemicals as simple as possible.
- ✓ Efficiency - to reduce the amount of old stock discarded.
- ✓ Quality - to ensure rotation of stocks.
- ✓ Quality - to manage expiry dates and discard old stock.
- ✓ Quality - often required by quality accreditation bodies.
- ✓ Legislation - to comply with government legislation, eg for drugs of addiction.

Some points of interest regarding chemical stocks

- ✓ A detailed record (or manifest) of chemical stocks is also useful in an emergency as it can be passed on to the emergency services.
- ✓ A detailed record will be useful for the accountant at tax time.
- ✓ The records can be used to highlight wastage in the laboratory.
- ✓ The records should include catalogue numbers of ease of ordering next time.
- ✓ The records should be automated enough to highlight potential out-of-stock situations before they occur. Of course the actual levels at which this occur will be vastly different. For instance, nacl may need to be ordered when the laboratory supply dips below 5 kg whilst a restriction enzyme may need to be re-ordered when there is 20 μ L left.
- ✓ The records should allow checking of goods inward records against orders and invoices to avoid being charged for something that did not arrive.

- ✓ The records must be user friendly enough to allow use by all members of staff including scientists (the end users of the chemicals) and the office staff (for ordering and accounts).
- ✓ The record must be user friendly enough to be able to contain very long and complex chemical names, chemical formulae, different laboratory grades and a wide range of units and pack sizes.

Remember, that the system will only work if it is simple and easy to use, and the staff input the correct data in a timely manner.

Integrity of laboratory records

Laboratory records are vital to the smooth operation of the laboratory, and as such their integrity needs to be assured. All written information must be legible and indelible, and computer records must be secure.

Assignment: Integrity of Laboratory Records

Write a short answer to the following questions. Dot points may be used where appropriate.

1. List the written information that is relied upon for maintaining chemical stocks and chemical safety in the laboratory.
2. For each type of information listed above describe what would happen if the information were erased, illegible or not recorded in the first place. Note that some information is of lesser importance and some is of great importance.
3. What steps need to be taken to ensure that all written information in the laboratory is recorded, legible and indelible?

File all records in the designated place

Make sure all the records are duly filed and the filing system need to be kept in the appropriate place with labels. Information in the form of documents can be categorized as records and no records. Records are official documents valuable enough to be retained and stored in a format for future use. Non-records are of temporary use and eventually disposed of.

Classifying Records

Records are either active or inactive and classified according to use. Active records are accessed and utilized in the current administration of business functions. Inactive records are no longer referred to on a regular basis but still of limited importance.

Importance of Records

Records are classified as vital, important, useful, or nonessential. Vital records are irreplaceable such as accounting, insurance policies, legal documents, etc. Important records can be replaced or duplicated if lost or destroyed. Useful records can be easily replaced and nonessential records are not necessary for the restoration of the company and have no predictable value.

The Records Cycle

A record's life cycle extends from the moment the record is created until its final disposition. Records retention schedules are developed and the value of specific records is determined. A schedule specifies the period of time a record should be stored.

Appraisal of Records

To help establish a records retention schedule, records are evaluated in terms of their primary and secondary value. The value of each record depends on the utilization of those records in ongoing operations.

- ✓ Primary value
 - Administrative value
 - Legal value
 - Fiscal value
 - Research value
- ✓ Secondary value
 - Information value
 - Evidence value

RECORDS CREATION, DESIGN, AND CONTROL

Control in the creation and design phase results in increased quality, improved productivity, reduced costs, and more effective storage and retrieval. Records are created in both conventional and unconventional formats.

Conventional Formats

Conventional formats are records that result in hard copies (printed) or soft copies (electronic).

- ✓ Correspondence
- ✓ Business forms
 - Constant information
 - Variable information
 - Optical-character recognition (OCR)
 - Design must contain a sequence of information
- ✓ Business reports (A business report conveys information to top-level management for decision making purposes or to external sources who need the information to further their own work).
 - Card systems
 - Relative index uses a numeric or alphanumeric system
 - Index records contain reference information and the location of the original file or document
 - Posted records (also called secondary record) update the card system with new information

1.

Nonconventional Formats

Note that the word disks, with a k, typically refers to magnetic disks, whereas the word discs, with a c, refers to compact discs, optical discs, and videodiscs.

- ✓ Microforms
 - Microfilm
 - Fiche
 - Microfiche
 - Ultrafiche
- ✓ Microform packaging
 - Cartridge
 - Cassette
 - Jacket
- ✓ Audiovisual media
- ✓ Electronic media
- ✓ Video tapes
- ✓ Compact discs
- ✓ Digital video
- ✓ Information processing media
- ✓ Database creation

The authenticity of information recorded on magnetic disks, magnetic tapes, or compact discs must be able to be certified to maintain the integrity of the information.

Record Management Equipment System

Records storage equipment and supplies guarantee safety during their useful life. The cost is approximately 20 percent of the overall cost of maintaining the storage and retrieval system.

Filing Equipment for Paper Storage

Conventional storage is used where paper is the primary medium.

- ✓ Vertical file cabinets
- ✓ Lateral file cabinets
- ✓ Stationary shelving units
- ✓ High density mobile storage
 - Powered systems
 - Mechanically assisted or manual
 - Lateral mobile storage
 - Open faced shelving
- ✓ Rotary (carousel) file
- ✓ Automated filing system

Equipment for Microforms Preparation and Storage

Special equipment is needed to prepare microforms for a micrographics system and to view the microforms once they have been developed. Microform technology enables retrieved documents to be viewed if a reader-printer is available.

- ✓ Microform cameras
- ✓ Processors
- ✓ Reader-printer
- ✓ Microfilm reader

Equipment for Optical Disc Preparation and Storage

Special equipment is needed to transfer images and computer-generated information to optical disc storage. The entire text of the document is available and indexed by key content words.

- ✓ Optical character recognition (OCR scanners)
- ✓ Discs
- ✓ Storage equipment called “jukeboxes”
- ✓ Computer
 - Intelligent retrieval is content words (descriptors) used to build the index so that more efficient searching is possible.

Equipment for Digital Storage

- ✓ Computers
- ✓ Office systems software
- ✓ Optical character recognition (OCR)
- ✓ Optical disc technology

Non-computer Assisted Storage/Retrieval Systems and Computer Assisted Storage Retrieval Systems

Records available in paper form are advantageous to business operations because of the file integrity. A computer-assisted storage and retrieval system requires precautionary measures such as imaging of signatures and photographs included with a stored document.

Utilizing filing classification system

Classification systems are established so that records will be filed or stored according to a document set of rules. Records need to be retrievable when needed. Determining the type of filing arrangement appropriate for an organization depends on how records will be utilized.

- ✓ Needs analysis: a needs analysis should be conducted to help determine an appropriate classification system.
- ✓ Types of filing arrangements: the type of filing arrangement depends on the needs of the organization.
 - Alphabetic
 - Numeric
 - Alphanumeric
 - Subject
 - Geographic

- ✓ Standardization: a consistent system is key to an effective records management program.
- ✓ Identification aids and supplies: these consist of folders, folder tabs, file guides, and color coding. Miscellaneous folders house the group of records that have not been assigned individual file folders.

Electronic record system

Computer-based records management systems are an important component of information processing systems. A database is a collection of data files, all relating to the same type of information available. Basic considerations in developing a computer database consisting of a number of data files include data entry and the volume of information. Once data entry is entered correctly, it will not have to be entered again and is ready for user access. Records management technology is an integral part of computer-assisted retrieval systems in which documents are stored on microforms and accessible through the computer system.

A thorough needs assessment will determine the overall volume and procedures being considered.

Basic considerations include:

- ✓ Ease of learning
- ✓ Vendor reputation
- ✓ Other installations in the area
- ✓ Simple, easy to understand manuals
- ✓ Training
- ✓ Security
- ✓ Cost
- ✓ Maintenance

Integration with other systems: optical disc technology and micrographics technology provide integration of business information systems. In computer-assisted retrieval systems (CARS), documents are stored on microforms and are accessible through the computer system.

MAINTAIN SAFE WORKING ENVIRONMENT

Use appropriate personal protective equipment (PPE) to ensure personal safety when sampling, processing, transferring or disposing of samples

Personal Protective Equipment (PPE) is widely recognized as a means of protection for individuals working in an environment where all other methods of hazard control are in place and there is still a risk of injury. You must remember that PPE is the last barrier or line of defense between you and the hazardous material you are working with.

The minimum PPE you are required to wear when working in University Laboratories are:

- ✓ Enclosed Shoes (no bare feet, thongs, or sandals and

- ✓ Lab Coat (must be individually issued, worn at all times when working in the lab, removed before leaving the lab and laundered regularly and when contamination is suspected). AQIS Note: If you have been working with Quarantine materials, your lab coat must be autoclaved prior to being removed from the lab and laundered

The following additional PPE is provided and should be used where required / instructed / determined by a risk assessment:

- ✓ Safety Glasses / Goggles
- ✓ Gloves
- ✓ Dust Mask / Respirator
- ✓ Face Shield
- ✓ PVC Apron
- ✓ Hearing protection

Eye Protection

The type of eye protection required for a worker or student at the University will depend on the hazards that they work with or which they encounter in the specific work activity, and should be determined by undertaking a risk assessment. The risk assessment should take account of the hazards that are present in the laboratory for most of the time, and consider the work of the group as a whole, not just that of an individual.

Safety Glasses must be worn when:

- ✓ There is a risk of objects striking or causing damage to your eyes.
- ✓ When instructed to do so by your Supervisor or the Lab Manager.
- ✓ If required by the Risk Assessments or Chemical MSDS.

** Safety Glasses may limit, but will not prevent chemicals from splashing into your eyes. Safety Glasses are only suitable when the chemicals you are working with would not harm your eyes in the event of an accident.

Safety Goggles must be worn:

- ✓ When working with hazardous chemical solutions where there is a risk of splash to your eyes.

Face Shield must be worn when:

- ✓ Working with volatile hazardous chemical solutions (eg. Concentrated acids).
- ✓ Working with dangerous substances that could strike/splash the face/eyes.
- ✓ There is a risk of solution explosion or instability causing a splash to the face/eyes.
- ✓ There is a risk of dangerous objects striking the face/eyes, such as particles, glass or metal shards.

Standard Prescription Glasses are not sufficient as protective eyewear if:

- ✓ You are working with hazardous chemical solutions and there is a risk of splash to the eye.
- ✓ You are working with toxic, corrosive, pathogenic or radioactive substances.

- ✓ You are undertaking activities where there is a risk of objects striking the eye, such as particles,
- ✓ Glass or metal shards.

** In these instances, ordinary prescription glasses will not provide adequate protection from injury to the eyes and could even be hazardous to the wearer.

Please see the Laboratory Manager if you require Prescription Safety Glasses.

Gloves

Different gloves are available for different tasks. Please ensure that you are using the right type of glove for the task you are undertaking. For chemicals, this information can be found in the MSDS.

Gloves available in this laboratory include:

- ✓ Latex disposable examination gloves – powder free
 - Protects your cultures / samples from you.
 - Helps stop the spread of some contaminants around the laboratory.
 - Not to be used with hazardous chemicals.
- ✓ Nitrile disposable gloves (blue)
 - Resistant to many solvents and chemicals.
 - Abrasion and puncture resistance.
 - Helps protect you from exposure to some hazardous chemicals.
- ✓ Rubber gloves
 - Good resistance to detergents and diluted chemicals.
- ✓ Cotton gloves
 - For use under other gloves – absorbs perspiration and helps with heat resistance (for eg, against hot dishwashing water).
- ✓ Leather gloves
 - Some protection when handling broken glass – extreme care must still be taken.
- Heat resistant gloves
 - Enables you to handle hot items – extreme care must still be taken.
 - Used to remove items from the Drying Ovens and/or Autoclave.

4.2 Minimise generation of waste and environmental impacts

Engage and motivate your co-workers to buy green products and help reduce waste. Learn more about how your office can go green.

- ✓ Instead of printing hard copies of your documents, save them to your hard drive or email them to yourself to save paper.
- ✓ Make your printer environmentally friendly. Change your printer settings to make double-sided pages. Use small point fonts when possible and use the “fast draft” setting when possible to save ink.
- ✓ Pay your bills via e-billing programs when possible to save paper.

- ✓ Use paperclips (over staples) when possible.
- ✓ Reuse envelopes with metal clasps and reuse file folders by sticking a new label over the previous one.

Green Purchasing at Work

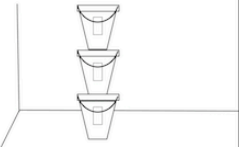
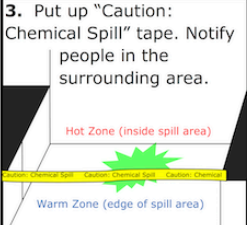
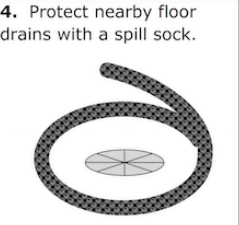
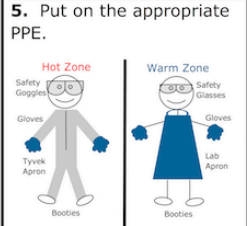
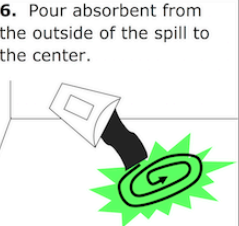
- ✓ Purchase recycled paper and keep a recycling bin nearby your desk.
- ✓ For information on how to buy more recycled-content products for your office, see EPA's Comprehensive Procurement Guidelines.
- ✓ Buy energy efficient items with the ENERGY STAR ® logo or items that are EPEAT registered for the office.


Clean up spills using appropriate techniques

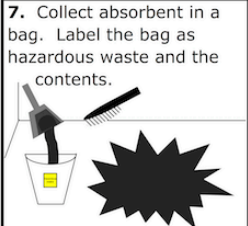
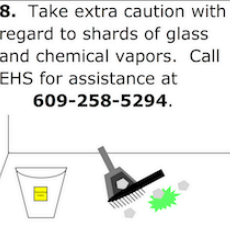
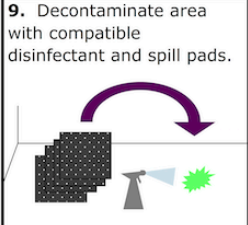
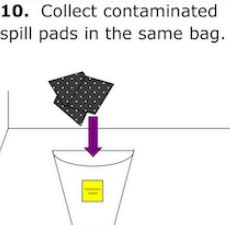
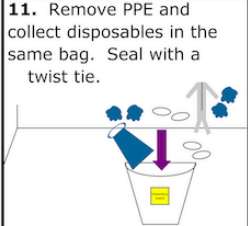
In the event of a chemical spill, the individual(s) who caused the spill is responsible for prompt and proper clean-up. It is also their responsibility to have spill control and personal protective equipment appropriate for the chemicals being handled readily available.

Cleaning up Chemical Spills

EHS: 609-258-5294 PUBLIC SAFETY: 609-258-3333

<p>1. Call Public Safety at 609-258-3333 if...</p> <ul style="list-style-type: none"> • anyone is hurt, • the spill is greater than one gallon • there is a release to the environment • there is a violent reaction or fire 	<p>2. For spills less than one gallon, use this spill kit.</p> 
<p>3. Put up "Caution: Chemical Spill" tape. Notify people in the surrounding area.</p> 	<p>4. Protect nearby floor drains with a spill sock.</p> 
<p>5. Put on the appropriate PPE.</p> 	<p>6. Pour absorbent from the outside of the spill to the center.</p> 



<p>7. Collect absorbent in a bag. Label the bag as hazardous waste and the contents.</p> 	<p>8. Take extra caution with regard to shards of glass and chemical vapors. Call EHS for assistance at 609-258-5294.</p> 
<p>9. Decontaminate area with compatible disinfectant and spill pads.</p> 	<p>10. Collect contaminated spill pads in the same bag.</p> 
<p>11. Remove PPE and collect disposables in the same bag. Seal with a twist tie.</p> 	<p>12. Contact EHS at 609-258-5294 or ehs@princeton.edu to refill the spill kit. Report spills to your supervisor.</p>

The following are general guidelines to be followed for a chemical spill.

Emergency Actions

- ✓ Immediately alert area occupants and supervisor, and evacuate the area, if necessary.
- ✓ If there is a fire or medical attention is needed, contact Public Safety.

- ✓ Attend to any people who may be contaminated. Contaminated clothing must be removed immediately and the skin flushed with water for no less than fifteen minutes. Clothing must be laundered before reuse. See First Aid for Chemical Exposures for more information.
- ✓ If a volatile, flammable material is spilled, immediately warn everyone, control sources of ignition and ventilate the area.

Immediate Spill Response

- ✓ Personal protective equipment, as appropriate to the hazards. Refer to the Material Safety Data Sheet or other references for information.
- ✓ Consider the need for respiratory protection.(link is external) The use of a respirator or self-contained breathing apparatus requires specialized training and medical surveillance. Never enter a contaminated atmosphere without protection or use a respirator without training. If respiratory protection is needed and no trained personnel are available, Public Safety at 911. If respiratory protection is used, be sure there is another person outside the spill area in communication, in case of an emergency. If no one is available, contact Public Safety.
- ✓ Using the chart below, determine the extent and type of spill. If the spill is large, if there has been a release to the environment or if there is no one knowledgeable about spill clean-up available Public Safety.

Category	Size	Response	Treatment Materials
Small	up to 300mL	chemical treatment or absorption	neutralization or absorption spill kit
Medium	300mL to 5L	absorption	absorption spill kit
Large	more than 5L	call Public Safety (609-258-3333)	outside help

- ✓ Protect floor drains or other means for environmental release. Spill socks and absorbents may be placed around drains, as needed.
- ✓ Contain and clean-up the spill according to the table above.
- ✓ Loose spill control materials should be distributed over the entire spill area, working from the outside, circling to the inside. This reduces the chance of splash or spread of the spilled chemical. Bulk absorbents and many spill pillows do not work with hydrofluoric acid. POWERSORB® (by 3M) products and their equivalent will handle hydrofluoric acid. Specialized hydrofluoric acid kits also are available for purchase from lab safety suppliers. Many neutralizers for acids or bases have a color change indicator to show when the spill is neutralized.
- ✓ When spilled materials have been absorbed, use brush and scoop to place materials in an appropriate container. Polyethylene bags may be used for small spills. Five gallon

pails or 20 gallon drums with polyethylene liners may be appropriate for larger quantities.

- ✓ Complete a hazardous waste sticker, identifying the material as Spill Debris involving XYZ Chemical, and affix onto the container. Spill control materials will probably need to be disposed of as hazardous waste. Contact EHS for advice on storage and packaging for disposal.
- ✓ Decontaminate the surface where the spill occurred using a mild detergent and water, when appropriate.
- ✓ Report all spills to your supervisor.

Ensure the safe collection of laboratory and hazardous waste for subsequent disposal

It is the clear responsibility of all research workers to ensure the safe and correct disposal of all wastes produced in the course of their work. Improper and irresponsible disposal of chemical wastes down drains, to the Local Authority, refuse collection, or into the atmosphere is forbidden by law. The Aldrich Handbook provides a useful summary of the correct disposal procedure for most chemicals. Due to new legislation, increasingly strict environmental controls and the escalating costs of disposal, it is essential that the appropriate disposal procedures given below are strictly adhered to:

Wash down drains with excess water

- ✓ Concentrated and dilute acids and alkalis
- ✓ Harmless soluble inorganic salts (including all drying agents such as CaCl_2 , MgSO_4 , Na_2SO_4 , P_2O_5)
- ✓ Alcohols containing salts (e.g. From destroying sodium)
- ✓ Hypochlorite solutions from destroying cyanides, phosphines, etc.
- ✓ Fine (tlc grade) silica and alumina
- ✓
- ✓ It should be noted in particular that no material on the "Red List" should ever be washed down a drain. This list is as follows:
- ✓ Compounds of the following elements:- antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, tellurium, thallium, tin, titanium, uranium, vanadium and zinc.
- ✓ Organohalogen, organophosphorus or organonitrogen pesticides, triazine herbicides, any other biocides.
- ✓ Cyanides
- ✓ Mineral oils and hydrocarbons
- ✓ Poisonous organosilicon compounds, metal phosphides and phosphorus element
- ✓ Fluorides and nitrites
- ✓

Incineration (Solvent Waste collection)

- ✓ All organic solvents including water-miscible ones
- ✓ Soluble organic waste including most organic solids

- ✓ Paraffin and mineral oil (from oil baths and pumps)

Laboratory waste bins and controlled waste

All waste suitable for the Local Authority refuses collection, except recyclable paper and glass, is termed 'controlled waste'. Items in this category which includes dirty paper, plastic, rubber and wood, should generally be placed in the waste bins available in each laboratory and will be collected by the cleaners. However, each laboratory must also have a container for certain items which are not allowed to be put in the normal waste bins. In this special controlled waste container should be put:- all broken laboratory glassware, any sharp objects of metal or glass, all fine powders (preferably inside a bottle or jar) and dirty sample tubes or other items lightly contaminated with chemicals (but not any syringes or needles). Laboratory controlled waste containers must be emptied regularly and never allowed to overflow. Under no circumstances must any item of glass, sharp metal or fine powder ever be put in a normal laboratory waste bin. The tops must be removed from all bottles put out for disposal and there should be no detectable smell of chemicals from any bottle put for disposal.

Waste for special disposal

This is a troublesome and expensive method of disposal and the quantity of special waste must be kept to an absolute minimum. Only the following items should be disposed of in this way:

1. Schedule 1 poisons (but not cyanides) and other highly toxic chemicals
2. Materials heavily contaminated with substances in (i)
3. Materials contaminated with mercury
4. Carcinogenic solids including asbestos.

Special waste must be collected in a separate labelled bottle or jar for disposal. On no account must different types of waste be mixed. Advice should be sought from the School Safety Co-ordinator before beginning any work which will produce waste requiring special disposal in order to ensure that:

- ✓ The waste can be disposed of
- ✓ It is collected in the most suitable form so as to minimise the cost involved and
- ✓ It will be stored under suitable conditions.

The importance of handling waste for special disposal to the School Safety Co-ordinator immediately the container is full or the work is finished is emphasised. The hoarding up of hazardous waste in laboratories is strictly forbidden.

Environmental Health and Safety Services should be notified of all 'Special Waste' on the appropriate form.

Glass recycling

For environmental reasons the recycling of glass is encouraged, but only certain items of waste glass produced within laboratories are acceptable for recycling. Each laboratory should have a bin for recyclable glass. Only clean glass bottles such as those in which chemicals are received, and broken or waste plate glass are allowed. All broken laboratory glassware, items significantly contaminated by chemicals, sample tubes, droppers and glass wool must be disposed of as controlled waste. The recycling service will refuse to empty a recycling container if any of these prohibited items are discovered in it.

Bottles for bulk solvents

The importance of returning the specially labelled winchesters for solvents which are bought in bulk to the Store ready for direct refilling is emphasised. They must not be contaminated in any way and should not normally be washed out. Bottles containing sodium must not, under any circumstances, be returned directly to the Store. When sodium is first added to a bottle of solvent a label indicating this (available from the Store) should be attached. When the bottle is empty the sodium must be safely destroyed by adding ethanol or methylated spirit and the label removed. The bottle must then be washed out, dried and returned to the Store ready for direct refilling.

Empty winchester bottles may be re-used e.g. For the disposal of waste solvents. They must first be washed out with water if they have contained a corrosive or harmful chemical e.g. Concentrated acid or ammonia.

Biohazard/Sharps Disposal - Syringes and Needles

"Sharps" contaminated with biologically hazardous materials must be collected in special containers to be sent for incineration. It is also required, at the request of Fife Council, that all syringes and needles of any type should be disposed of by the same route. No syringes or needles must ever be put in a laboratory waste bin or controlled waste container.

15. REFERENCES

References

- ✓ National Water & Sewerage Policy, Ministry of Environment and Energy, 2017.
- ✓ https://www.who.int/water_sanitation_health/dwq/gdwq0506.pdf
- ✓ Laboratory Quality Management System, Handbook, World Health Organization 2011.
- ✓ <https://ehs.princeton.edu/environmental-programs/waste/biohazard-waste-disposal>
- ✓ Guidelines for Drinking-water Quality “World Health Organization. Guidelines for drinking-water quality”
- ✓ TECHNICAL REPORT: GUIDANCE TO OPERATION OF WATER QUALITY LABORATORIES, UN/ECE Task Force on Laboratory Quality Management & Accreditation, 2002
- ✓ <https://ehs.princeton.edu/environmental-programs/waste/biohazard-waste-disposal>
- ✓ Jordan, James K, “Maintenance management for water utilities” American Water Works Association, 2010.
- ✓ Hauser, Barbara A. Drinking water chemistry: a laboratory manual CRC Press, 2017.
- ✓ Guidelines for drinking-water quality, 2nd Edition, Volume 3, Surveillance and control of community supplies, World Health Organization, Geneva.
- ✓ James E. Smith, Robert C. Renner and Bob A. Hegg, NOYES DATA CORPORATION, 1991.
- ✓ Dr. Charles C. Patton - Applied Water Technology-Campbell Petroleum (1991)
- ✓ <https://www.open.edu/openlearncreate/mod/oucontent/view.php?id=569&printable=1>
- ✓ “Supply water quality standard” **ENVIRONMENTAL PROTECTION AGENCY REGULATIONS**
- ✓ Simplified Procedures for Water Examination by American Water Works Association, AWWA MANUAL M12, Fifth Edition.
- ✓ Rodger B. Baird, Eugene W. Rice, and Steven Posavec, “Standard Methods For The Examination Of Water And Wastewater” 23rd Edition, 2017

