Class I Water Treatment Plant Operator Program Manual

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1.0 INTRODUCTION

1.1 GOALS AND OBJECTIVES

A water treatment plant operator has three main goals:

- Protect the public's health;
- Protect the environment; and
- Protect the public's purse.

The water treatment plant operator's job is one of the most important in the community. Everyone depends on the operator to provide them with safe, clean water in sufficient quantities so they have enough for drinking, cooking and cleaning.

The people trust their water treatment plant operator to make sure that the water is safe to drink and that they will not get sick.

People depend on the operator to make clean, safe water 24 hours a day, 365 days a year and to do all this without spending too much money. When the operator does his job well, no one notices. When the operator does his job poorly, everyone notices.

Operating a water treatment plant is complex and requires knowledge of machinery, electricity, chemistry, math and health sciences.

Do not try to memorize everything that you will hear and read in this course. Instead try to understand how your treatment plant operates and what you are trying to accomplish. Know where to find information when it is needed.

1.2 CONTACTS AND SOURCES OF INFORMATION

The best water plant operators are not people who know everything but know where to look for information and who to ask for help.

You should remember these three things:

- Look it up;
- Write it down; and
- Work in teams.

If you are not sure about something, look it up in your course manual or water treatment plant O&M manual. *Never* guess about how to do something as you or other people can get hurt.

The more you can read or ask questions about how your water treatment plant operates, the better you will be able to do your job. Part of your job is to keep learning as much as you can about water treatment.

Know who to ask for help. You should remember that you are not alone in carrying out your duties. You are part of a team of engineers, scientists, technicians, inspectors and health care professionals who are dedicated to trying to make sure that the people in your community get safe, clean water. Each water treatment plant operator will work with different people depending on where they live and how big their community is. You should know who these people are, how to get in touch with them and what their responsibilities are. Some people who may be part of your team are listed below.

Table 1-1: Contacts and Duties

Person/Department/Agency	Duty
Environmental Health Officer (EHO)	Enforces Public Health Act and Regulations, Checks drinking water quality. Helps with water sampling.
Department of Health & Social Services/ Regional Health Board	Protects public health, water sample analysis, approving modifications and new designs to water supply and treatment systems.
Department of Public Works & Services	Helps with training.
PW&S Area Maintenance Officer	Helps to maintain PW&S owned/operated facility.
Town Engineer	Helps solve operating problems. Helps with training.
MACA Regional Office	Funding for new capital projects and planning of new infrastructure. Helps solve operating problems. Helps with training. Provides policy.
Senior Administrative Officer/ Band Manager	Hires and pays operators. Collects payments for water. Helps with records
Community Residents	Pay taxes, water bills and your salary. Help to protect water supply.
Water Board	Protect environment, issues water licence.
Indian & Northern Affairs Canada	Help community to protect water source from contamination.
INAC Water Resources Officer	Enforces Water Licence.

Make a list for your community and post the list, including phone numbers, in the water treatment plant and municipal offices. Talk with your team members and get to know them and make sure that they know you, your plant and community.

Good water treatment plant operators are hard to find. If you do your best to learn about water treatment and do a good job running your plant, you will most likely have a good job for the rest of your life. Even more important, the people in your community will have a better life because of you and what you do.

1.3 ROLES & RESPONSIBILITIES

The water treatment plant operator and others who are involved in the treatment and distribution of water are responsible for making sure that water delivered is safe to drink.

A certified water treatment operator is a professional. In many cases they are the only ones who know the proper operation of their treatment plant. Therefore, you have a professional responsibility to the public.

You must be aware that if you are negligent in your duties and someone gets sick or dies, you may be charged with a criminal act such as criminal negligence and could go to jail or have to pay a fine. An example of negligence is described as follows:

> Friday afternoon Sam checks his water treatment plant and notice that the chlorine solution tank is getting low and will probably not last until Monday. Since it is Friday afternoon he decides not to make a new **solution** as he doesn't get paid for working late and he wants to go away for the weekend.
>
> On Sunday, the chlorine runs out, unchlorinated water is delivered to house 105 and the Jones' get sick because the water was contaminated.
>
> The Jones' complain to Council and threaten to sue. Sam is required to explain to Council what happened. Sam is told he will be charged with a criminal act.

When an operator knows that his inaction could result in someone getting hurt, he is negligent. If people get sick they can take your employer and you to civil court and sue the people you work for and you and the people you work for, for damages. This is exactly what happened in Sam's case.

If you are not given enough time to do your duties, this is something you have to discuss with your employer. It cannot be used as an excuse why unsafe water was delivered.

1.4 MULTI-BARRIER APPROACH TO SAFEGUARDING RAW WATER

We have already talked about what harm different types of contamination, faecal coliforms for example, could do to the community if they entered the water supply. How do we prevent contamination from occurring? Health Canada has developed a multi barrier approach from source to tap.

The multi-barrier approach is...

… an integrated system of procedures, processes and tools that collectively prevents or reduces the contamination of drinking water from source to tap in order to reduce risks to public health.

Even though no approach will guarantee 100 per cent protection all of the time, it has been demonstrated that the most effective way to manage drinking water systems is to implement a multi-barrier approach. The goal of this approach is to reduce the risk of contamination of the drinking water, and to increase the feasibility and effectiveness of remedial control or preventative options.

As a safeguard, it is important for contingency plans to be in place to respond to incidents as they arise, and for redundancies to be built into the system wherever feasible.

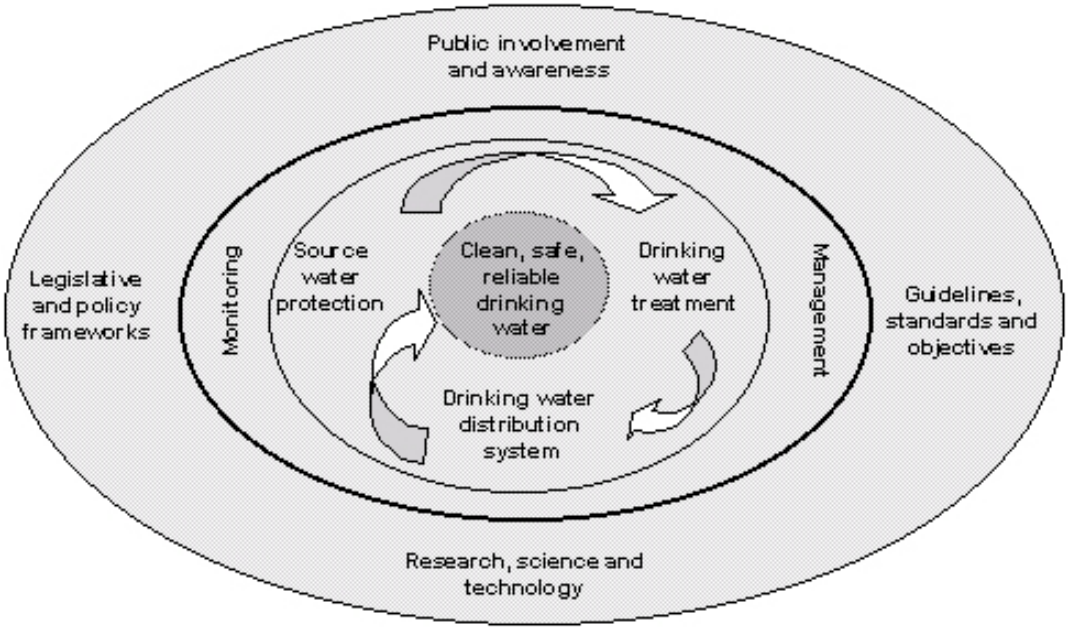
Figure 1-1 depicts a multi-barrier approach to safe drinking water that has three major elements. These elements are source water protection, water treatment, and the drinking water distribution system. These are addressed in an integrated manner by using a system of and tools, such as:

- Water quality monitoring and management of water supplies from source to tap;
- Legislative and policy frameworks;
- Public involvement and awareness;
- Guidelines, standards and objectives;
- Research; and
- The development of science and technology solutions.

More information can be found at:

http://www.hc-sc.gc.ca/hecs-sesc/water/publications/source_to_tap/source_to_tap-toc.htm

Figure 1-1: The Multi-Barrier Approach



1.5 REVIEW

1. What is your role as an operator?

2. What do you do if you do not have sufficient time to complete your duties?

2.0 MICROBIOLOGICAL CHARACTERISTICS

2.1 OBJECTIVES

The trainee will be able to do the following.

1. Understand the need for the production of the highest quality of water.
2. List the sources of **bacteria** in the water.
3. Understand the use of "indicator" bacteria.
4. Understand the use of the Guidelines for Canadian Drinking Water (GCDWQ).
5. Determine the minimum number of water samples required for testing the water supply.
6. Understand the importance of correct sampling procedures.
7. List three important criteria for effective destruction of bacteria.
8. List activities in operators' community that may impact on the water quality.

This section should be read in conjunction with the Canadian Drinking Water Quality Guidelines found in Appendix C.

2.2 BACTERIA

2.2.1 GENERAL

Bacteria are small, one-celled microorganisms, which cannot be seen with the naked eye. Most bacteria are harmless and are even beneficial to humans. Bacteria are found naturally everywhere, the kinds and numbers varying from place to place.

Since bacteria are everywhere there are many sources which can contaminate a water supply, including; sewage, water from washing, animal droppings and dead animals.

The water that is supplied to the community must meet the limits for various bacteriological parameters listed in the *Public Health Act and Regulations*, and in the Guidelines for Canadian Drinking Water Quality, published by Health Canada, shown in Appendix C.

2.2.2 NATURE OF BACTERIA AND ALGAE

2.2.2.1 Size

Bacteria can only be seen with the aid of a microscope, and usually only after some kind of **staining** procedure. A magnification of about one thousand times (1000 x) is required to view them clearly, because their size is about a thousand of a millimetre (1/1000 mm). One one-thousandth of a millimetre is given the name "micron" and the symbol µ which is the Greek u.

Algae, in contrast, can be examined using a magnification of only one to two hundred times and they are green-coloured because they contain chlorophyll. Algae are about 5 microns in size or 5/1000 mm.

2.2.2.2 Shape

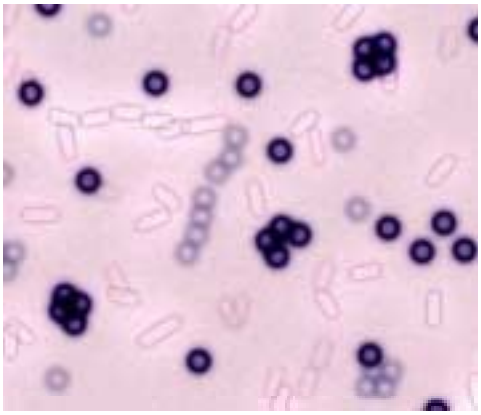
There are two basic shapes of bacterial cells;

1) Spherical forms called *cocci*,

2) Rod-shaped forms called *bacilli*,

There are variations in the two basic shapes, such as bean-shaped *cocci* or spiral forms.

Figure 2-1 A mixed culture of cocci and bacilli



2.2.2.3 Arrangement

Bacterial cells may either be found singly or may be attached to one another to form chains or clumps of cells. These arrangements are very characteristic, and are useful in identifying the various types of bacteria (Figure 2-1). For instance, *streptococci* are spherical bacteria occurring in chains; *staphylococci* are spherical bacteria occurring in irregular clusters.

Some bacteria possess special structures called flagella, which enable them to move.

2.2.3 METABOLISM

The **metabolism** of an organism is the process by which it uses food sources to grow and generate energy.

Many bacteria can metabolize very simple food sources, such as simple sugars and mineral salts. It doesn't take much organic material, such as what may be present in treated drinking water, to support the growth of many species of bacteria. This means that bacteria can live even in drinking water that is very clean. Some types of bacteria, like *Pseudomonas aeruginosa,* can grow even in distilled water.

The way in which certain bacteria use food can be used to identify the presence of those particular bacteria. Coliforms can be identified by fermenting sugar under special conditions. Coliforms will be discussed in much more detail in section 2.7.

2.2.4 REPRODUCTION

Bacteria can multiply, usually very rapidly, by one cell splitting into two. The speed of multiplication depends upon environmental conditions. Most coliform bacteria multiply faster in slightly higher temperatures and where abundant organic matter can be found. That is why water samples should be kept cool, during collection and shipment for test results to be accurate.

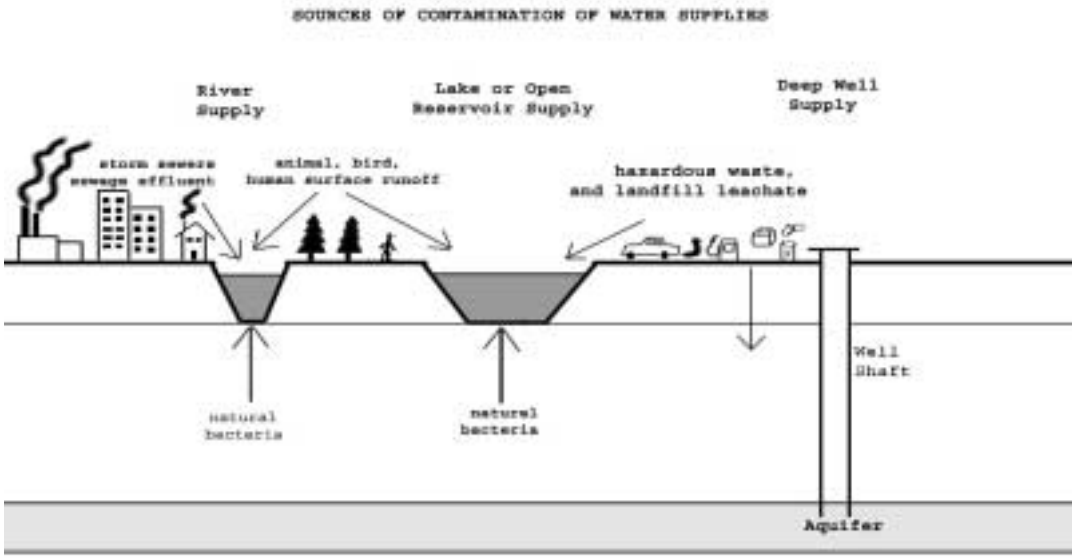
2.2.5 SOURCES OF BACTERIA IN WATER

There are many sources of bacteria present in any body of water as shown in Figure 2.2. The bacteria from these sources contribute to the "normal flora" of the water, having been washed off vegetation, soil, farmlands or from by sewage plant and storm water effluents. In water treatment, the bacteria that are of the most concern grow in, and are excreted from, the intestinal tract of man and animals. Some of these bacteria are of concern as they can be the source of disease and make people sick as discussed before. However there are also many other sources of bacteria as demonstrated in Figure 2.2

2.2.6 BACTERIA AND PATHOGENICITY

In the intestinal contents of man and animals, some bacteria are "normal flora". One group of these is the coliform group, made up of total coliforms and faecal coliforms; other kinds are the faecal streptococci and the *Aeromonas* group. All these kinds of bacteria are normally non-pathogenic, but some of them do have pathogenic qualities and always present in the intestinal contents. If the water is consumed untreated or the water treatment plant is not operated correctly, an epidemic of waterborne disease could result.

Figure 2-2 Sources of Contamination of Water Supplies



2.2.6.1 Heterotrophic plate count

Heterotrophic plate count (HPC) is a method used to indicate the microbial quality of water. HPC is also known as Standard Plate Count.

The types and concentrations of species recovered using a HPC procedure vary depending on many factors, including the physical and chemical characteristics of the water. Recovered microorganisms can include those naturally found in the water environment and others from many different pollutant sources. HPC tests recover a broad range of bacterial species, only some of which may be pathogens.

Unlike other indicators, such as total coliform or *E. coli*, low concentrations of HPC organisms will still be present after treatment. Some water utilities can achieve HPC concentrations of less than 10 cfu/ml in finished water.

HPC are not a health concern in drinking water to the general public.

HPC is an indicator of microbial quality. HPC can change before changes occur in coliform bacteria. Therefore, operators are wise to test routinely for HPC.

Once positive results are seen in the coliform groups, contamination has already occurred. Operators aware of changing HPC concentrations may be able to prevent a microbial intrusion.

Plant operators can use HPC concentrations in water during treatment and immediately upon leaving the treatment plant in conjunction with other routine tests to monitor plant operation.

HPC does not replace these tests. Other tests include those for coliform bacteria, turbidity and chlorine demand.

HPC can also be used as a measure of quality deterioration in wells, distribution lines and reservoirs.

As an operational guideline HPC concentrations should be relatively consistent and NOT exceed 500 cfu/mL.

Should elevated HPC not respond to increased chlorine, operators should immediately contact their EHO.

Chlorine demand and turbidity should be part of diagnostic testing.

2.2.6.2 Coliforms

The type of bacteria that are regulated in water treatment are the coliform bacteria.

Coliform bacteria originate in the intestinal tract of warm-blooded animals and can be found in their wastes. Coliform bacteria can also be found in soil and on vegetation. Coliform bacteria are relatively simple to identify and are present in much larger numbers than more dangerous pathogens. Coliform bacteria react to the natural environment and treatment processes in a manner and degree similar to pathogens.

By monitoring coliform bacteria, the increase or decrease of many pathogenic bacteria can be estimated. It has been proven that when coliforms are detected in water, particularly faecal coliforms, pathogenic organisms are also present. Coliforms themselves are normally non-pathogenic, but some of them do have pathogenic qualities.

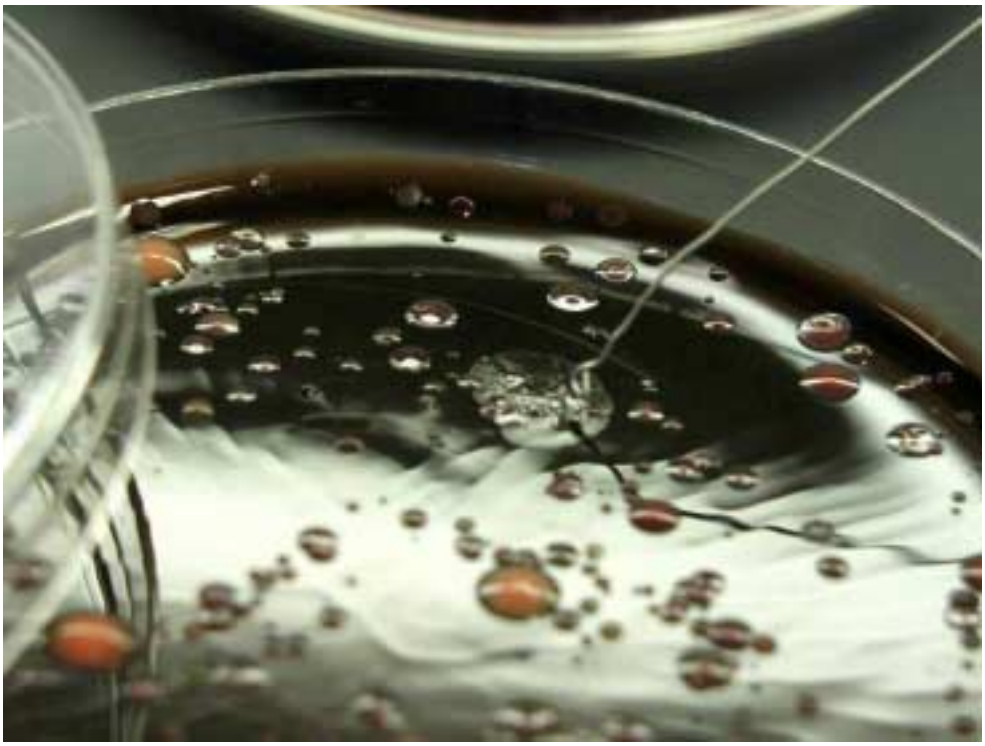
2.2.6.3 Total Coliform

The total coliform test is a measure of all of the coliform bacteria in the water sample. It is used as an indicator of contamination.

If you receive a positive result for total coliform, you must take action immediately to ensure that your chlorination process is working properly.

Then you must sample again to make sure that the first sample was not somehow contaminated by you.

Figure 2-3 A petri dish of coliform bacteria



While you are waiting for those results you should assess your system to see if there are any obvious sources of contamination.

If the test is positive a second time, you must report to your Environmental Health Officer (EHO). Then you must undertake a rigorous sampling program to determine where the total coliforms are coming from and take steps to remove the source of contamination.

The Guidelines for Canadian Drinking Water Quality state that:

1. **There should be no more than 10 coliform organisms in any 100mL test.**
2. **No two, consecutive tests should show the presence of coliform bacteria.**
3. **No more than 10% of the tests should show the presence of coliform bacteria.**

2.2.6.4 Faecal coliform

The faecal coliform test is a measure of faecal coliform bacteria in the water sample. It is another indicator of contamination.

Faecal coliform is a sub-set of the coliform bacteria group. "Faecal" means that the organism is associated with faeces; the excreted waste from animals.

Faecal coliforms are a specific class of bacteria, which only inhabit the intestines of warm-blooded animals and hence, are found in faeces. Again, not all faecal coliforms are pathogenic but the percentage is higher. A test for faecal coliforms can be done in 48 hours.

The Guidelines for Canadian Drinking Water Quality state that no 100mL test should show the presence of faecal coliforms.

If you receive a positive result for faecal coliform, after you immediately check your disinfection system, you must contact the EHO and follow instructions.

Usually, a second test will be taken to confirm the first, and again while you wait for the results, you need to assess your system.

2.2.6.5 Escherichia coli (E. coli)

E. coli is a specific type of faecal coliform that is often used in place of the test for faecal coliforms. *E. coli* tests can be conducted as a standard presence/absence test. It is preferred to the faecal coliform count because it can be done in 24 hours, compared to 48.

It is important to note that not all *E. coli* are harmful. In fact there are over 25,000 strains, but only 150 might make you a bit sick and only one strain, O157:H7, will make you truly ill.

The O157:H7 *E. coli* strain causes what is known as “Hamburger Disease” because it is more often associated with improperly cooked meat.

If you have a positive result for *E. coli*, the actions are the same as for faecal coliform.

2.2.7 PROTOZOA

Protozoa are small microorganisms about 4 to 40 microns is size, that more similar to animals than bacteria. They are larger than bacteria; their eggs have a hard shell, and are resistant to chlorine. Two of the most common protozoa related to health problems from drinking water are *Cryptosporidium* and *Giardia*. When people get ill from these organisms, they do not build immunity as they would from a viral infection. Therefore, they can get ill over and over again.

Giardia (gee-ar-dee-a) comes from warm-blooded mammals such as beaver, muskrat, caribou, dogs, and man. Sometimes called "beaver fever", its symptoms are like the flu.

Figure 2-4 *Giardia lamblia* (scanning electron microscope photo)

Cryptosporidium is more serious than *Giardia*. The diarrhoea caused by this organism can be compared to that caused by cholera and can cause death. Children, Elders, and people with reduced immune systems are most susceptible.

Currently, there are no guidelines related to protozoa in the GCDWQ. However, it does mention the need of “effective disinfection” of protozoa from the drinking water and “suggests” than 99% of the organisms should be removed during disinfection.

2.3 VIRUSES

Viruses are small organisms (from 10 to 25 nanometers in diameter), composed of nucleic acids with a protein coating. The most relevant viruses related to water are the enteric viruses (which live in warm blooded animals intestines). The most serious of these viruses include hepatitis A and the *Norwalk* type virus. Environmental factors such as high levels of suspended solids increase the viability of viruses in the water supply, while high water temperatures and sunlight will kill the viruses. There are no specific guidelines for viruses in the Guidelines for Canadian Drinking Water Quality (GCDWQ). An effective water

treatment system including filtration, disinfection and chlorination should remove viruses in the water supply.

2.3.1 ALGAE

Algae are a group of microorganisms neither related to plants, nor bacteria, but in a kingdom of their own, *Protoctista*. The "green algae" is the most diverse group of algae, with more than 7000 species growing in a variety of habitats. The "green algae" contain two forms of chlorophyll, which they use to capture light energy to fuel the manufacture of sugars, but unlike plants they are primarily aquatic.

Individual algae can be similar in size to bacteria, but can form long, filamentous chains that are visible to the naked eye. Algae, some which are shown in Figure 3-5, in small quantities are relatively harmless and do not cause health problems, however they can, as stated before, cause taste and odour problems as well as clog up pipes.

One variety of algae, the blue-green algae, excretes the toxin microcystin that is a health concern in higher concentration. Blue-green algae are not commonly found in the NWT.

2.4 WATER TREATMENT

Since there are so many different ways that pathogenic organisms can get into our water, water must always be treated to kill the pathogenic organisms before people drink it. Treating water to kill pathogenic organisms is called disinfection.

Treatment of delivered began after it was recognized that disease could be spread through untreated water. Chlorination was introduced in Canada in 1910 and is responsible for saving millions of lives. In order to chlorinate water municipalities need to address other water quality issues, which will be discussed later in the text.

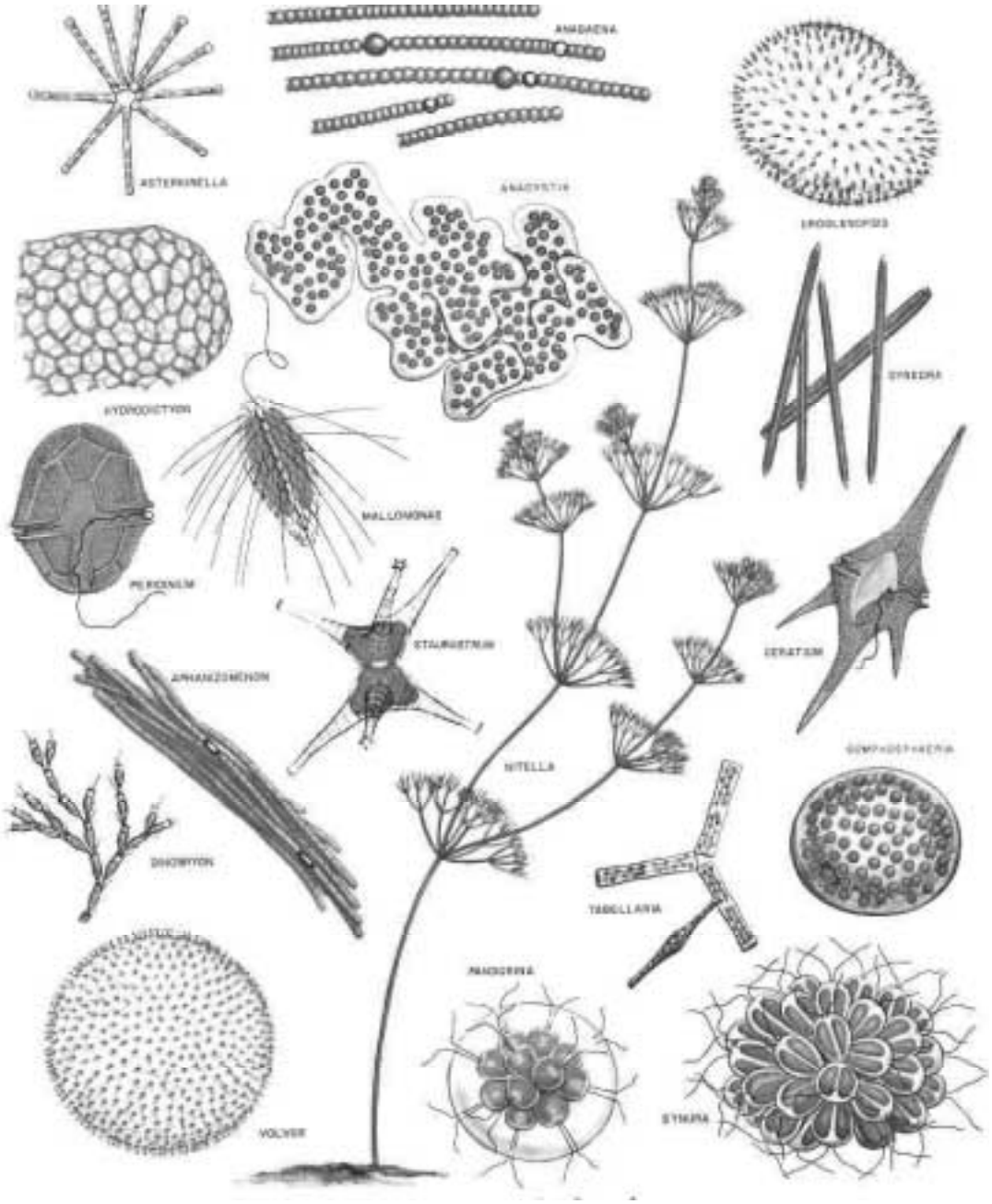
Chlorine is also used in northern communities. It is important to understand suspended solids or **turbidity** in the water can prevent chlorine from killing bacteria. Chlorination will only work when it is added to clear water with low turbidity.

To reduce harmful microorganisms effectively, there are many important factors;

1) The amount of chlorine added,
2) The contact time allowed between the chlorine and the bacteria,
3) The amount of particulate matter or turbidity present in the water,
4) The temperature of the water,
5) The pH of the raw water, and
6) The overall chemical characteristics of the water.

Figure 2-5 Taste and Odour Algae

(from *Standard Methods for the Examination of Water and Wastewater – 17th Edition,* Clesceri et al, American Public Health Association, Washington, 1989)



A number of factors effect the quality of water coming into a treatment plant: Some of them are:

- In the spring, melting snow carries soil from the land into rivers and lakes increases the amount of suspended solids. Increased stream velocities re-suspend materials from the streambed. Thus, turbidity increases.
- During the summer windstorms or rainstorms can increase the amount of suspended solids, and turbidity.

2.5 REVIEW

1. Coliform bacteria have been found in your drinking water sample. Why might this be a problem from a public health point of view?

2. List the three factors that are important in destroying bacteria effectively.

3. What are some possible causes of bacterial contamination in raw water sources?

4. What is the difference between coliform bacteria and faecal coliform bacteria? Why do we not want faecal coliforms in our drinking water supply?

3.0 PHYSICAL AND CHEMICAL CHARACTERISTICS

3.1 OBJECTIVES

The trainee will be able to do the following.

1. Identify four physical characteristics of water.
2. Identify the causes of taste and odours in water.
3. Give the Guidelines for Canadian Drinking Water Quality objectives for acceptable levels of:
    a. Turbidity
    b. Colour
4. Define the terms:
    a. Maximum Acceptable Concentration (MAC)
    b. Interim Maximum Acceptable Concentration (IMAC)
    c. Aesthetic Objective (AO)
5. Define the terms:
    a. Alkalinity
    b. Hardness
    c. pH
6. Identify the problems associated with high levels of the following chemical constituents; chlorides, iron, manganese, nitrates, and sulphates.

This section should be read in conjunction with the Guidelines for Canadian Drinking Water Quality (GCDWQ) found in Appendix C. Parameters not discussed fully in this section are discussed in detail in the above guidelines.

3.2 PHYSICAL CHARACTERISTICS

Physical tests do not measure the safety of a water supply, but they do give an indication of its acceptability to consumers. The physical qualities, which primarily concern waterworks operators, include:

1) Turbidity;

2) Colour;

3) Taste and Odour; and

4) Temperature.

Substances producing turbidity are mostly **inorganic** while those causing taste, odour and colour are generally organic compounds.

Inorganic matter refers to substances, which do not come from plants or animals. Examples of inorganic matter are sand, metals and rocks.

Organic matter refers to substances, which come from plant or animal matter. Examples of organic matter are plant leaves and topsoil.

Turbidity, colour and taste and odour requirements can be attained by properly designed and operated treatment plants and distribution systems. Failure to meet the requirements indicates either inadequate treatment facilities or improper operation of the system.

3.2.1 TURBIDITY

Turbidity in water is caused by the presence of inorganic suspended matter such as clay, silt, **colloidal** (clay size) particles. Turbidity can serve as a source of food for **microorganisms** and interfere with the tests to detect if harmful organisms are present in the water. Suspended particles adsorb heavy metal ions and other contaminants in turbid waters. Turbidity has also been related to trihalomethane formation in chlorinated water.

The most important health effect of turbidity is its interference with disinfection and with the maintenance of chlorine **residual**. High turbidity can shield harmful organisms from chlorine,

which results in an increased chlorine demand to treat the water. Outbreaks of disease from water which is chlorinated have been traced to high turbidity in the water.

A maximum acceptable turbidity level of one turbidity unit (1 **nephelometric turbidity unit** - NTU) or 1 Formazin turbidity unit – FTU) has been established as the highest turbidity that is acceptable in a drinking water supply.

Table 3-1 illustrates the relative times required to settle various types of particles that cause turbidity. Note that the smaller particles like bacteria and colloidal matter cannot be removed by settling in the typical water treatment process due to their excessively high settling times.

Table 3-1 Particle Size and Settling Time for a 30 cm tall tank.

Diameter of Particle (microns)	Order of Size	Approx. Time Require to Settle
100	Fine Sand	12.4 s
10	Silt	10.7 min
1	Bacteria	17.9 hr
0.1	Colloidal Particle	74.7 days

Note: 1000 microns = 1 mm

Figure 3-1 Drinking water with low turbidity and high turbidity

3.2.2 COLOUR

Colour in drinking water may be due to the presence of organic substances as well as certain metallic ions such as those of iron, manganese and copper.

True colour is measured after the water sample has been filtered with a 0.45 micron filter paper. Apparent colour is measured without filtering the water sample. The different type of colour tests can tell us where the colour in the water comes from.

Inorganic materials such as heavy metals that are in particulate form tend to affect apparent colour, but can be removed by **filtration**. Organic materials such as plant matter, may contribute to true colour which is not removed by filtration. Colour becomes noticeable to consumers at levels greater than the aesthetic objective of 5 true colour units (TCU - platinum cobalt scale).

3.2.3 TASTE & ODOUR

Taste and odour are intimately related, and consumers frequently mistake odours for tastes. In general, the sense of taste is most useful in detecting the ionic, inorganic constituents of drinking water, whereas the sense of smell is most useful in detecting covalent, organic constituents.

Taste and odour problems constitute the largest category of consumer complaints. Changes in the taste of drinking water may indicate possible contamination of the raw water supply, poor treatment, or contamination of the distribution system.

A numerical limit for taste has not been specified because there is no objective method for the measurement of taste and because there is considerable variation among consumers as to which tastes are acceptable. Water provided for public consumption should have an inoffensive taste.

Although an odour can be attributed to a specific substance, it is usually impractical and often impossible to isolate and identify the odour-producing chemical. Evaluation of this parameter is therefore dependent on individual senses of smell but because odour cannot be objectively measured, a numerical limit has not been specified. The odour of drinking water should not be inoffensive.

Taste and odours in water supplies may result from any one or a combination of conditions. They are usually caused by the presence of dissolved gases and organic substances. In some cases, inorganic compounds such as those of mineral and metallic salts may impart tastes to the water at very low concentrations. However, organic substances are likely to be responsible for the presence of odours. Sources of material causing taste and odour problems may be one or more of the following.

1) Dissolved gases i.e. hydrogen sulphide, chlorine.

2) Biological growths such as algae, and slimes.

3) By-products of decaying algae and vegetation.

4) Contaminants from sewage effluents and surface runoffs.

5) Contaminants from industrial waste discharges.

6) Growths of nuisance organisms in the distribution system i.e. iron bacteria.

7) Dissolved minerals i.e. chlorides, manganese, sulphates.

The variation in odours caused by algae has a wide range. Examples include the following.

1) Aromatic Odour - these odours are very often described as a particular flower or vegetable. Organisms in small numbers can produce these odours.

2) Fishy Odour - these odours are often produced by the same algae that produce the aromatic odours. The organisms are usually present in much larger numbers.

3) Grassy Odours - this odour is very common when the green algae are present in large numbers.

4) Musty and Earthy Odour - the musty odour in some waters is very often encountered in the presence of certain blue-green algae.

The control and prevention of many tastes and odours caused by algae may be with the use of:

1) Chlorine (Cl_2) and Potassium Permanganate ($KMnO_4$),

2) Powdered Activated Carbon (PAC) and Granular Activated Carbon (GAC), and

3) Microstraining.

3.2.4 TEMPERATURE

It is desirable that the temperature of drinking water be less than 15^{o}C as colder water tastes better.

Low water temperatures offer a number of other benefits. A temperature below 15^{o}C will tend to reduce the growth of nuisance organisms and hence minimize associated taste, colour, odour and corrosion problems. Low temperature also helps maintain a free chlorine residual by reducing the rates of reaction leading to hypochlorous acid removal. Hypochlorous acid is a form of chlorine formed during oxidation in water.

Although low temperatures can decrease the efficiency of the water treatment processes, this effect may be compensated for by increasing the amount of chemicals required for treatment. Although low temperatures inhibit the production of acceptable water quality, it can be easily accounted for by the operator.

Warm water does not taste as good as cold water. Temperatures above 27^{o}C are unsuitable and above 32^{o}C render the water unfit for public use.

3.3 CHEMICAL CHARACTERISTICS

Chemical characteristics of water supply refer to substances such as heavy metals (iron, lead, nickel) and synthetic organics (PCB's, oil and grease).

Normally, laboratory analyses for chemical constituents are only needed twice a year. But if the supply is suspected of containing undesirable materials, periodic determinations for the suspected toxicant or material should be carried out more often (every month for example).

On the other hand, where experience, examination and results indicate that particular substances are consistently absent from a water supply or are below levels of concern, then, with the approval of the Environmental Health Officer, semi-annual examinations for these substances may be omitted.

The various types of limit guidelines concerning the chemical constituents in water are included in the Guidelines for Canadian Drinking Water Quality (GCDWQ) included in Appendix C. The guidelines include both the limits and reasoning for the limits and hence it is essential that operators be well acquainted with this literature.

3.4 REVIEW

1. What is turbidity and why can it cause problems with drinking water?

2. What's the difference between Maximum Acceptable Concentration (MAC), Interim Maximum Acceptable Concentration(IMAC) and Aesthetic Objective(AO)?

3. What is the ideal range of pH for drinking water at the treatment plant and why?

4.0 PRE-TREATMENT

4.1 OBJECTIVES

The trainee will be able to describe:

- pH adjustment;
- Water stabilization;
- Hydrogen sulphide removal; and
- Pre-sedimentation.

4.2 pH ADJUSTMENT

The pH of water may need to be adjusted to:

- Improve coagulation and flocculation; and/or
- Reduce corrosivity.

pH is usually adjusted with lime, or soda ash.

4.3 WATER STABILIZATION

Water stabilization is another term for pH adjustment. When alum is added for example, the pH may drop out of the optimum range. In this case the water is considered to be unstable. Lime or soda ash is added to increase the alkalinity of the water and thus, its "stability".

4.4 HYDROGEN SULPHIDE REMOVAL

Hydrogen sulphide (H_2S) s not a constituent of surface water and is only found in ground water that has not been exposed to the atmosphere. Where H_2S is a problem, it can be removed by:

- Aeration; or
- Oxidation with chlorine, permanganate, or another oxidizing agent.

4.5 PRE-SEDIMENTATION

Pre-sedimentation is a step that is often required before coagulation and flocculation in order to remove large particles from the raw water stream. These larger particles can reduce the efficiency of the coagulation and flocculation process.

Settling of larger-sized particles occurs naturally when surface water is stored for a sufficient period of time in a reservoir or a natural lake. Gravitational forces acting in the lake accomplish the same purpose as sedimentation in the water treatment plants; larger particles such as sand and heavy silts settle to the bottom.

Debris dams, grit basins or sand traps can also be used to remove some of the heavier particles from source water. The facilities may be located upstream from the reservoir, treatment plant intake or diversion facilities, and serve to protect the municipal intake pipeline from siltation.

Grit basins may be located between the intake structure and the coagulation flocculation facilities. Thus, pre-sedimentation facilities such as debris dams, impoundments and grit basins reduce the solids removal load at the water treatment plant. At the same time, they provide an equalizing basin, which evens out fluctuations in the concentration of suspended solids in the source water. Water with more suspended solids is mixed with water with less suspended solids.

Pre-sedimentation facilities are often installed in locations where the source water supply is diverted directly from rivers or streams, which can be contaminated, by overland runoff and point source waste discharges.

Ideally, surface waters should be stored in a reservoir and transported directly to the water treatment plant in a pipeline. In a reservoir the heavier solids can settle out before they reach the plant. However, geographical, physical and economic considerations often make this alternative impractical.

5.0 COAGULATION AND FLOCCULATION

5.1 OBJECTIVES

The trainee will be able to do the following.

1. Describe the need for **coagulation** and **flocculation**.
2. Explain the coagulation and flocculation process.
3. Explain the need for pre-sedimentation in the coagulation and flocculation process
3. Identify the various methods of flash mixing.
4. Identify factors that affect the coagulation-flocculation process.
5. Describe the purpose of performing a jar test.

5.2 GENERAL

Particulate impurities in water result from land erosion, pickup of minerals, and the decay of vegetation. Additional impurities are added by airborne contamination, industrial discharges, and by animal wastes. Thus, **surface water** sources, polluted by man and nature, are likely to contain suspended and dissolved organic and inorganic material, and biological forms such as bacteria and plankton.

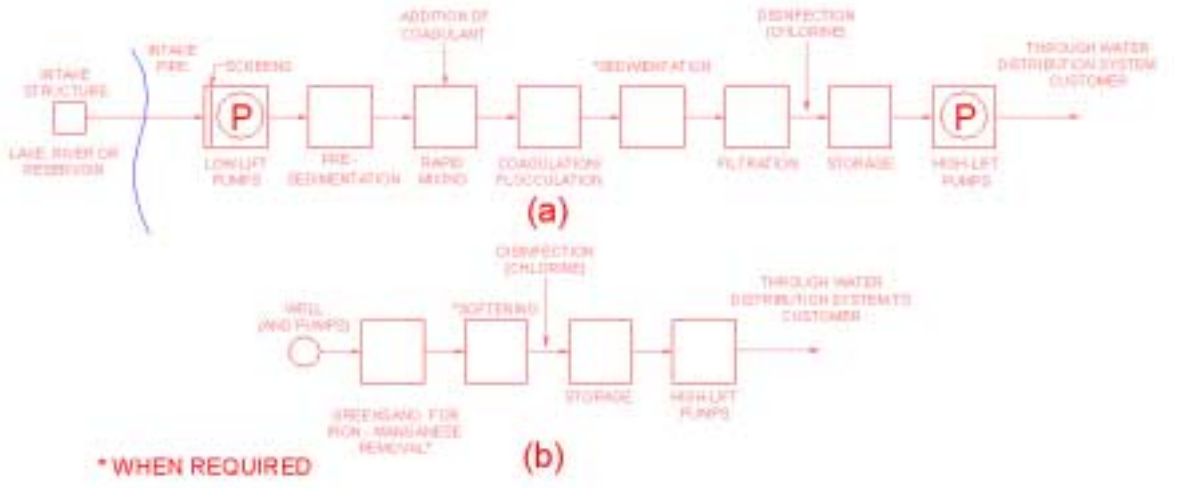
These particulates, commonly called suspended solids, cover a broad range of sizes. Larger sized particles such as sand and heavy silts can be removed from water by slowing down the flow to allow for simple gravity settling. These particles are often called settleable solids. Settling of larger sized particles occurs naturally when surface water is stored for a sufficient period of time in a reservoir or a lake. Smaller sized particles, such as bacteria and fine clays and silts, do not readily settle and treatment is required to produce larger particles that are settleable. These smaller particles are often called non-settleable solids or colloidal matter.

The purpose of coagulation and flocculation is to remove particulate impurities, especially non-settleable solids and colour from the water being treated. Non-settleable particles in water are removed by the use of coagulating chemicals.

In the coagulation process, chemicals are added which will initially cause the particles to become destabilized and clump together. These particles gather together to form larger particles in the flocculation process.

With few exceptions, surface waters require treatment to remove particulate impurities and colour before distribution of water to the consumer.

Figure 5-1 Flow Chart of Coagulation and Sedimentation



(a) Surface water source (b) Groundwater source

5.3 THE COAGULATION/FLOCCULATION PROCESSES

The coagulation and flocculation processes are required to precondition or prepare non-settleable particles present in the raw water for removal by sedimentation and filtration. Small particles, without proper coagulation and flocculation are too light to settle out and will not be large enough to be trapped during filtration. In this regard it is convenient to consider coagulation-flocculation as one treatment process.

Since the purpose of coagulation-flocculation is to promote particulate removal, the effectiveness of the sedimentation and filtration processes, as well as overall plant performance, depend upon successful coagulation-flocculation. Disinfection of the water can also be affected by poor coagulation-flocculation performance. Bacteria and other disease-causing organisms can be bound up in suspended particles and thereby shielded from disinfection if the solids removal processes before final disinfection, especially filtration, are ineffective. Effective coagulation-flocculation promotes the removal of natural organic compounds. Removal of these compounds will reduce the formation of trihalomethanes following the use of chlorine for disinfection.

5.3.1 PROCESS CONTROL

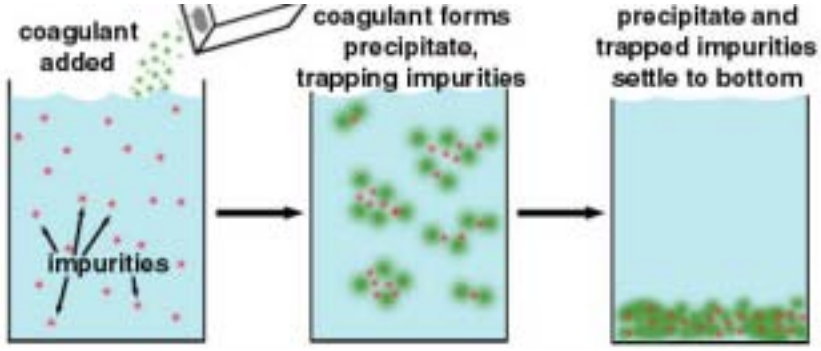
In theory, the chemical reactions and the formation of floc associated with the coagulation-flocculation process are rather complex. Yet from a practical viewpoint the operator of a water treatment plant must be able to measure and control the performance of these processes on a day-to-day basis.

The most important consideration in coagulation-flocculation process control is selection of the proper type and amount of coagulant chemical(s) to be added to the water being treated. This determination is commonly made in the laboratory with the aid of a jar testing apparatus. When selecting a particular type of coagulant chemical, consideration must be given to the quantity and the solids content of the **sludge** created and the means of ultimate disposal. The frequency of jar tests should be determined by the results of daily tests of fluoride, colour, chorine, pH and a variety of other chemical and physical factors.

5.4 COAGULATION

Coagulation is a physical and chemical reaction occurring between the alkalinity of the water and the coagulant added to the water, which results in the formation of **insoluble flocs**. **Polymers** are also generally added with the coagulants to stimulate or improve the formation of insoluble flocs. These polymers are called coagulant aids and will be discussed further in section 5.3.2.

Figure 5-2 Coagulation



The most common coagulant used in water treatment is aluminum sulphate; otherwise know as alum. We will be focusing on this coagulant for the remainder of the manual.

For aluminum sulphate, the **pH** of the water determines which **hydrolysis** chemical compounds predominate. Lower pH values tend to favour positively charged compounds which are desirable for reacting with negatively charged colloids and particulates, forming **insoluble** flocs and removing impurities from the water. Higher pH values favour negatively charged colloids and particulates.

The best pH for coagulation usually falls in the range of pH 5 to 7. The proper pH range must be maintained for the **coagulants** to form flocs. Residual alkalinity in the water serves to buffer a pH change in the system and aids in the complete precipitation of the coagulant chemicals. The amount of alkalinity in the raw water is generally not a problem unless the alkalinity is very low. Alkalinity may be increased by adding lime or soda ash.

Generally, the operator has no control over the pH and alkalinity of the raw water. Hence, evaluation of these water quality indicators help to select the type of chemical coagulants to be

used at a particular water treatment plant or to change the type of coagulant normally used if significant changes in pH and alkalinity occur in the raw water.

Overdosing as well as under dosing of coagulants may lead to reduced solids removal efficiency. This condition can be corrected by carefully performing jar tests and verifying process performance after making any changes in the operation of the coagulation process.

5.4.1 COAGULANTS

In practice, chemical coagulants are referred to either as primary coagulants or as coagulant aids. Primary coagulants are used to cause the particles to become destabilized and begin to clump together, while the purpose of coagulant aids is to add density to slow-settling flocs and add toughness so the floc will not break up in the following processes. In view of this definition, coagulant aids could also be called flocculation or **sedimentation** aids.

Metallic salts are commonly used as coagulants chemicals, such as aluminum sulphate (commonly called alum), ferric sulphate, ferrous sulphate and synthetic organic polymers (cationic, anionic, non-ionic). They are used as coagulation chemicals in water treatment because they are effective, relatively low cost, available, and easy to handle, store and apply. Alum is the most commonly used coagulant in the NWT.

When metallic salts such as aluminum sulphate or ferric sulphate are added to water, a series of reactions occur with the water and with other ions in the water. Sufficient chemical quantities must be added to the water to exceed the solubility limit of the metal hydroxide, resulting in the formation of a precipitate floc. The resulting floc formed will then adsorb on particles of turbidity in the water. In other words, enough metal hydroxide has to be added to the water so that the solution passes the point where it can hold dissolved metal hydroxide and the floc precipitates out.

5.4.2 COAGULANT AIDS

Polymers (also known as polyelectrolytes) are the most commonly used coagulant aids in the NWT. They are synthetic, high molecular weight organic compounds. They are used to make flocs:

- Bigger;
- Stronger; and
- More settable under difficult treatment conditions.

Polymers act similarly coagulants in that they bind to the particles in water through a difference in electrical charge between the particle and the polymer. This is how polymers are classified into three different groups, by their different charges:

- **Anionic**: having a negative charge
- **Cationic**: having a positive charge
- **Nonionic**: having no charge

The only way to determine the best polymer for your water treatment plant is by jar testing. Jar testing will be covered in Chapter 6.

While alum is perhaps the most commonly used coagulant chemical, cationic polymers are used in the water treatment field as both a primary coagulant, in place of metallic salts, and as a coagulant aid used in conjunction with metallic salts. Anionic and nonionic polymers have also proven to be effective in certain applications as coagulant aids and filter aids. A list of coagulants and coagulant aids are shown in Table 5-1.

Table 5-1 List of Coagulants and Coagulant Aids

Chemical Name	Chemical	Primary Coagulant	Coagulant Aid
Aluminum Sulphate	$Al_2(SO_4)_3.14H_2O$	X	
Anionic Polymer	Various		X
Bentonite	Clay		X
Calcium Carbonate	$CaCO_3$		X
Calcium Hydroxide	$Ca(OH)_2$	X*	X
Calcium Oxide	CaO	X*	X
Cationic Polymer	Various	X	X
Ferric Chloride	$FeCl_3.6H_2O$	X	
Ferric Sulphate	$Fe_2(SO_4)_3.9H_2O$	X	
Ferrous Sulphate	$FeSO_4.7H_2O$	X	
Hydoofluorosalicic Acid	H_2SiF_6		
Nonionic Polymer	Various		X
Polyaluminum Chloride	$Al_2ClH_5O_5$ or $Al_2(OH)_5Cl{\cdot}_2H_2O$ or $[Al(OH)_2Cl]_x$ or $Al_6(OH)_{15}Cl_3$; $[Al_2(OH)_5Cl]_x$	X	
Sodium Aluminate	$Na_2Al_2O_4$	X*	X
Sodium Silicate	Na_2SiO_3		X

*Used as primary coagulants only in water-softening processes

For your safety:

Always consult the Material Safety Data Sheet (MSDS) before working with any chemical you are unfamiliar with. Some may have extreme reactions to human health and to other chemicals.

5.4.3 REGULATORY REQUIREMENTS FOR CHEMICALS

All chemicals and materials used in water treatment must be approved by the Department of Health and Social Services. Generally, meeting applicable **NSF**, **UL** or **CSA** Standards is acceptable. Contact your Environmental Health Officer for details.

5.5 FLOCCULATION

Flocculation is the slow stirring process that causes the gathering together of small, coagulated particles into larger, settle able particles. Once gathered together into floc, the floc is easily removed by sedimentation and filtration. The collision between particles, or the gathering of particles, occurs because of gentle stirring by a mechanical or hydraulic means of mixing.

Floc formation is controlled by the rate at which collisions occur between particles and by the effectiveness of these collisions in promoting attachment between particles. The purpose of flocculation is to create a floc of a good size, density, and toughness for later removal in the sedimentation and filtration processes. The best floc size ranges from 0.1 mm to about 3 mm, depending on the type of removal processes used. If algae are present in large numbers in the water, the floc will have a stringy appearance. A picture showing floc formation is shown in Figure 5-3.

Figure 5-3 Close-up of floc formation

Although the floc formed contains most of the suspended matter in the water, it is still made up of approximately 96% water. Because of this, it is very fragile and must be treated gently. This means that high-speed flocculation must be avoided.

An efficient flocculation process involves the selection of the right stirring time (**detention time**), the proper stirring intensity, a properly shaped basin for uniform mixing, and mechanical equipment or other means of creating the stirring action.

Detention time is required for the necessary chemical reactions to take place. Detention time is usually not a critical factor in the coagulation or flash-mixing process, if the chemical coagulants are well dispersed into the water being treated and mixed for at least several seconds.

In the NWT, since we have different types of packaged treatment plants, the retention time varies from one plant to the next. The minimum detention time recommended for flocculation ranges from about 5 to 20 minutes for direct filtration systems and up to 30 minutes for conventional filtration. The size and shape of the flocculation facility also influences the detention time needed for optimum floc development. Some operators have been able to reduce coagulant dosages by increasing the amount of detention time between the point of addition of the coagulant and the flocculation basins.

5.5.1 FLOCCULATORS

Two types of mechanical **flocculator**s are commonly installed:

1. Horizontal paddle wheel types; and

2. Vertical flocculators.

Both types can provide satisfactory performance; however, the vertical flocculators usually require less maintenance, since they eliminate submerged bearings and packings. Vertical flocculators can be of the propeller, paddle, or turbine types.

The best flocculation is usually achieved in more than one compartmentalized basin rather than one equivalent-sized basin. The compartments are separated by baffles to prevent short-circuiting of the water being treated, and to reduce the level of turbulence in each succeeding compartment by reducing the speed of the stirrers, or reducing the area of the paddles. This is called "tapered-energy mixing".

The reason for reducing the speed of the stirrers is to prevent breaking apart the large floc particles that have already been formed. Breaking up the floc will not accomplish anything, reduces the efficiency of the settling, and will overload the filters because not as many flocs will be settled out in sedimentation.

5.5.2 JAR TESTING

The jar test attempts to duplicate in the laboratory what is occurring in the plant in relationship to detention times, mixing and settling conditions. By watching the jar test floc form and settle, the operator can get a good idea of what should happen in the plant for that chemical dose. The jar test should be used as an indication of what to expect in the water treatment plant. By closely watching the floc form in the flocculators and settle out in the sedimentation basin of the plant, the operator can also get a good indication of whether the best coagulant dosage has been chosen. It should be realized that it is almost impossible to duplicate in the jar test exactly the flow conditions that are occurring in the treatment plant.

Also by observing the performance of the filters and by looking at the laboratory test results, the operator will gain additional information that will help make the necessary adjustments to the actual chemical feed rates.

For a step-by-step procedure on how to perform a jar test go to Chapter 6.

5.5.2.1 Jar Test Evaluation

Several factors are important in evaluating jar test results. These include:

1) Rate of floc formation;

2) Type of floc particles;

3) Clarity of water between floc particles;

4) Size of floc;

5) Amount of floc formed;

6) Floc settling rate;

7) Clarity of water above the settled floc, and;

8) Physical water quality factors such as pH, temperature and turbidity.

Visible floc formation should begin shortly after the flash mix portion of the jar test. During flocculation mixing, a number of small particles will gradually clump together to form larger particles. Floc particles that are discrete and fairly dense in appearance are usually better than floc particles that have a light, fluffy appearance. Large floc is impressive but it is neither necessary nor always desirable. Large, light floc does not settle as well as smaller, denser floc and it is more subject to breaking up by paddles and water turbulence.

The quantity of floc formed is not as critical as floc quality or clarity of the settled water produced. The water between the floc particles should be clear and not hazy nor milky in appearance. The best chemical dosage will produce finished water that meets the Guidelines for Canadian Drinking Water Quality at the lowest cost. Another important consideration is the

amount of sludge produced. Smaller amounts of sludge are desirable to reduce sludge handling and disposal requirements. Most of the sludge volume consists of precipitates of the added chemicals rather than suspended solids.

After mixing has stopped, the rate at which the floc settles is another important consideration. The floc should start to settle as soon as the mixer is turned off, and should be almost completely (80 to 90 percent) settled after about 15 minutes.

Floc that remains suspended longer than 15 to 20 minutes in the jar test, is not likely to settle out in the sedimentation basin, and will increase the load on the filter.

If the floc starts to settle before mixing is completed, or more than 80 percent of the floc has settled within one or two minutes after mixing has stopped, the floc is too heavy. In your water treatment plant, this can result in the floc settling out in the flocculation basins rather than in the sedimentation basins. This is a rather rare occurrence and indicates that too much chemical has been added.

There is no substitute for experience in evaluating jar test data. Therefore, it is recommended that jar tests be performed regularly during periods of high raw water turbidity, even if the plant is producing good quality finished water at the time. This will provide a basis for comparing coagulation-flocculation effectiveness under different conditions and allow "fine-tuning" of the chemical treatment to achieve the best efficiency.

Jar tests of flash-mixer water samples should be performed regularly at the start of every shift and more frequently during periods of high turbidity in the raw water. The results of these tests may give an early warning, impending treatment process problems.

Always verify the effectiveness of a change in treatment based upon jar test results. To verify jar test results with treatment plant performance, obtain a water sample just downstream from the flash mixer. Collect the sample after sufficient time has passed for the treatment change to take effect. This sample should haven been mixed by the jar test apparatus under the same conditions that the original raw water sample was mixed. Ideally, the test should mimic the conditions of the plant’s water treatment process as accurately as possible.

Jar tests are an effective tool for predicting the results of chemical treatment alternatives. However, jar test results are useless unless applied and verified in your treatment plant.

5.5.2.2 Applying Jar Test Data

After evaluation of the jar test results, apply the dosage used in the best jar test to your water treatment plant operation. One of the best ways to evaluate the performance of your coagulation-flocculation process is to observe the actual process. When you walk through the treatment plant, take some clear beakers. Dip some water out of each stage of the treatment process. Hold the sample up to a light and look at the clarity of the water between the floc and study the shape and size of the floc. Study the development of the floc from one flocculation chamber to the next and into the sedimentation basin. The following is a short list of what you should look for in your plant.

1) Observe the floc as it enters the flocculation basins. The floc should be small and well-dispersed throughout the flow. If not, the flash mixer may not be providing effective mixing or the chemical dose or feed rate may be too low.

2) Tiny alum floc may be an indication that the chemical coagulant dose is too low. A "popcorn flake" is a desirable floc appearance. If the water has a milky appearance or a bluish tint, the alum dose is probably too high.

3) What does the floc look like as it moves through the flocculation basins? The size of the floc should be increasing. If the floc size increases and then later starts to break up, the mixing intensity of the downstream flocculators may be too high. Try reducing the speed of these flocculators, or increasing the polymer dosage.

4) Does the floc settle out in the sedimentation basin? If a lot of floc is observed flowing over the **weirs**, the floc is too light for the detention time produced by that flow rate. Increasing the chemical coagulant dose or adding a coagulant aid such as a polymer may produce a heavier larger floc. The appearance of fine floc particles washing over the effluent weirs could be an indication of too much alum and the dose should be reduced.

In summary, use the procedures that will be improve quality of the floc by changing only one operational variable at a time and wait to analyse the results before changing another variable. Keep good records. Evaluate the performance of your plant and adjust your procedures as necessary.

5.6 PROCESS TROUBLESHOOTING

Changes in source water turbidity levels, either increases or decreases, generally require that the operator verify the effectiveness of the coagulant chemicals and dosages being applied at the flash mixer. This is best accomplished by performing a series of jar tests as discussed previously. You must realize that decreasing raw water turbidity levels can be just as upsetting to the process as increasing levels.

Visual observations of flash-mixing intensity as well as the condition of the floc in the flocculation basins may also indicate the need for process changes, such as adjustment to mixer speed or coagulant dosage.

Alkalinity, pH and temperature changes in the source water quality may have an impact on the clumping together of floc during the coagulation-flocculation process. In addition, water temperature changes may require an adjustment in the level of mixing intensity in flash mixers or flocculators. Temperature changes are usually gradual over time, thus large process adjustments are seldom necessary.

Sudden increases in filtered water turbidity could be caused by poor filter performance. However, poor coagulation-flocculation performance is usually the culprit, and the operator must take immediate action to correct the problem, remembering that several hours may pass before changes in the operation of the coagulation-flocculation process are seen in the filter

effluent. One quick remedy may be to feed a filter-aid chemical such as a non-ionic polymer directly to the filter **influent**. While this may solve the short-term problem, only changes in the coagulation-flocculation process will enhance long-term plant performance. Again, the results of laboratory jar tests should be used as the basis for making process changes.

5.7 FLASH MIXING

Flash mixing is the first step in coagulation. The coagulant is added to the flash mixer and dispersed throughout the water. It is desirable to complete the coagulation reaction in as short a time as possible. The following is a list of flash mixing examples:

- Hydraulic mixing using flow energy in the system,
- Mechanical mixing,
- Diffusers and grid systems,
- Pumped blenders,
- Static mixer.

Hydraulic mixing with baffles or throttling valves works well in systems, which have sufficient water velocity to cause turbulence in the water being treated. The turbulence in the flowing water mixes the chemicals with the water.

Mechanical mixers (paddles, turbines and propellers) are frequently used in coagulation facilities. Mechanical mixers are versatile and reliable; however, they generally use the greatest amount of electrical energy for mixing the coagulant with the water being treated.

Diffusers and grid systems consisting of perforated tubes or nozzles can be used to disperse the coagulant into the water being treated. These systems can provide uniform distribution of the coagulant over the entire coagulation basin. However, they are generally sensitive to flow changes and may require frequent adjustments to produce the proper amount of mixing.

Pumped blenders have also been used for mixing in coagulation facilities. The coagulant is added directly to the water being treated through a diffuser in a pipe. This can provide rapid dispersion of the coagulant and does not create any significant head loss in the system. Electrical energy consumption is considerably less than that of a comparable mechanical mixer.

5.8 REVIEW

1. What is a floc?

2. Why is alkalinity important in the coagulation/flocculation process?

3. Why is coagulation/flocculation important in the water treatment process?

4. What are some of the chemicals involved in coagulation and flocculation and what is their purpose?

6.0 JAR TESTS

6.1 OBJECTIVES

The trainee will be able to:

- Perform a jar test.

6.2 GENERAL

As stated before, jar tests are used by operators to determine the correct dosage of coagulants and coagulant aids. They are also designed to show the effectiveness of chemical treatment and water stabilization requirements such as pH adjustment in a water treatment facility. Many of the chemicals that are added to water can be evaluated on a small laboratory scale by the use of a jar test. The most important of these chemicals are those used for coagulation such as alum and polymers.

Using the jar test, the operator can approximate the correct coagulant dosage for plant use when varying amounts of turbidity, colour or other factors indicate raw water quality changes. The jar test is also a very useful tool in evaluating new coagulants or polymers being considered for use on a plant scale.

6.3 APPARATUS

1) Stirring machine with variable speeds from 0-100 rpm.

2) An illuminated base (preferred but not necessary).

3) 6, 2L square containers.

4) 1 graduated cylinder 1000 mL.

5) 1 Pipet 10 mL, graduated.

6) 10mL and 1mL syringes.

7) Stock coagulant solution prepared from actual coagulant used in the treatment process.

8) Clock or timer.

6.4 PROCEDURE

1) Collect 8 litres of sample of the water to be tested.

2) Immediately measure six 1500 mL quantities and place into each of six 2000 mL containers.

3) Place all six containers on stirring apparatus.

4) With stirring paddles lowered into the containers, start stirring apparatus and operate it for one minute at a speed of 100 rpm. Speeds and times should be similar to conditions in the plant.

4) With a measuring pipet, add increasing dosages of coagulant solution to the containers as rapidly as possible. Select a series of dosages so that the first beaker will represent an under-dose and the last an over-dose. Do not add chemicals to one beaker and use it as a "control".

5) Reduce the stirring speed for the next 30 minutes to 20 rpm*.

6) Observe and evaluate each container as to that specific dosage's floc quality. Sample the containers for pH turbidity, colour and other parameters as required by treatment goals. Record results.

Figure 6-1 A flocculating and a non-flocculating jar test

7) Stop the stirring apparatus and allow samples in beakers to settle for 30 minutes *. Observe the floc settling characteristics. A hazy sample indicates poor coagulation. Properly coagulated water contains floc particles that are well-formed and dense, with clear liquid between the particles. Describe the results as poor, fair, good or excellent.

The jar test is easy to perform but it is useless unless the operator records the data and observations he has obtained. Figure 9-3 shows a typical data sheet used to record jar test data.

6.5 CHEMICAL SOLUTIONS

Stock solutions of coagulants, coagulant aids and other chemicals should be prepared at concentrations such that quantities suitable for use in coagulation tests can be measured accurately and conveniently.

Figure 6-2 Chemical Doses for Jar Tests

Approx. Dosage Required mg/L	Grams/Litre to Prepare	1 mg/L Added to 1 Litre Sample Equals	Stock Solution Conc., mg/L(%)
1-10 mg/L	1 g/L	1 mg/L	1,000 mg/L (0.1%)
10-100 mg/L	10 g/L	10 mg/L	10,000 mg/L (1.0%)
100-500 mg/L	100 g/L	100 mg/L	100,000 mg/L (10.0%)

6.6 REVIEW

1. Describe briefly how to do a jar test.

2. When is a jar test used?

7.0 SEDIMENTATION

7.1 OBJECTIVES

The trainee will be able to do the following.

1. List the purposes of sedimentation.
2. Describe the various types of sedimentation basins and how they work.
3. Identify factors affecting the sedimentation process.

7.2 PROCESS DESCRIPTION

The purpose of the sedimentation process is to remove suspended solids that are denser than water and to reduce the load on the filters. The suspended solids may be in their natural state, such as bacteria, clays, silts or they may be pre-conditioned by prior treatment in the coagulation-flocculation process to form floc or may be precipitated impurities (hardness and iron precipitates formed by the addition of chemicals).

Sedimentation is accomplished by decreasing the velocity of the water being treated below the point where settleable suspended material can be transported. This allows gravity to remove particles held in suspension. When water is almost still in sedimentation basins, settleable solids will move towards the bottom of the basin.

7.3 FACTORS AFFECTION THE SEDIMENTATION PROCESS

The size, shape and weight of the particles to be settled out, as well as physical and environmental conditions in the sedimentation tank, have a significant impact on the type of pre-treatment needed and the sedimentation process efficiency. Factors affecting particle settling include:

1. Particle size and distribution;
2. Shape of particles;
3. Density of particles;
4. Temperature (viscosity and density) of the water;
5. Electrical charges on particles;
6. Dissolved substances in water;

7. Flocculation characteristics of the suspended material;

8. Environmental conditions (such as wind, if the unit process is outdoors); and

9. Sedimentation basin hydraulic and design characteristics (such as inlet conditions and shape of basin).

7.3.1 PARTICLE SIZE, DISTRIBUTION AND SHAPE

Because of their size and density, sand and silt particles greater than 10 microns in diameter (1 micron = 0.001 mm) can be removed from water by sedimentation. Finer particles do not readily settle and treatment is required to produce larger, denser particles (floc) that are settleable as shown in Table 7-1.

Figure 7-1 Settling of different particles sizes in a typical settling tank

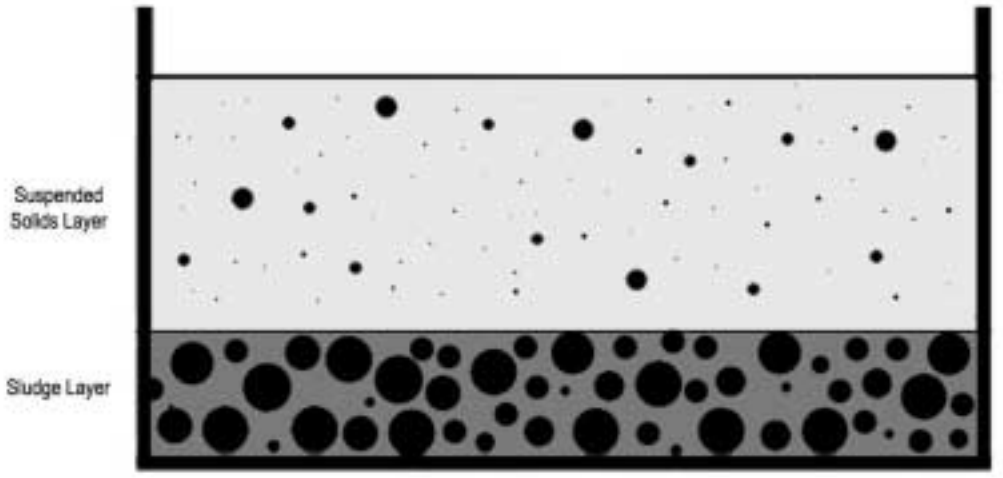


Table 7-1 Typical Sizes of Particles in Surface Water

Source	Diameter (microns)
Coarse Turbidity	11 - 1000
Algae	3 - 1000
Silt	10
Bacteria	0.3-10
Fine Turbidity	0.1 - 1
Viruses	0.02 - 0.26
Colloids	0.001 - 1

The shape of the particles influences particle settling as well. Smooth circular particles will settle quicker than irregular shaped particles with ragged edges.

Most particles have a very slight electrical charge. If all of the particles have a negative charge, they will tend to repel each other and not settle. Since alum consists of aluminum with a positive charge, the negatively charged particles are attracted to the positively charged aluminum ions. This causes the clumping together which helps the particles to settle out.

7.3.2 TEMPERATURE

Another consideration in sedimentation is the effect of water temperature changes. The settling velocity of a particle becomes much slower as the temperature drops. The colder the water temperature becomes, the longer the particles take to settle out. This means that longer time periods are required for effective settling at colder water temperatures, or that chemical dosages must be adjusted for the slower settling velocities.

7.3.3 CURRENTS

Several types of currents are found in the typical sedimentation basin:

1. Surface currents caused by winds;

2. Density currents caused by differences in suspended solids concentrations and temperature differences, and

3. Eddy currents produced by the flow of the water entering and exiting the basin.

Currents in the sedimentation basin are beneficial to the extent that they promote flocculation. Collectively, however, these currents distribute the suspended particles unevenly throughout the basin, thereby reducing the expected performance of the sedimentation basin.

Some of these currents can be substantially reduced in the design of a treatment plant by providing baffled inlets and other hydraulic control features. Wind-induced currents can only be eliminated by providing covers or suitable windbreaks for the sedimentation basins. In most instances, basin covers are not economically feasible nor necessarily desirable from an operations and maintenance standpoint.

7.4 SEDIMENTATION BASIN ZONES

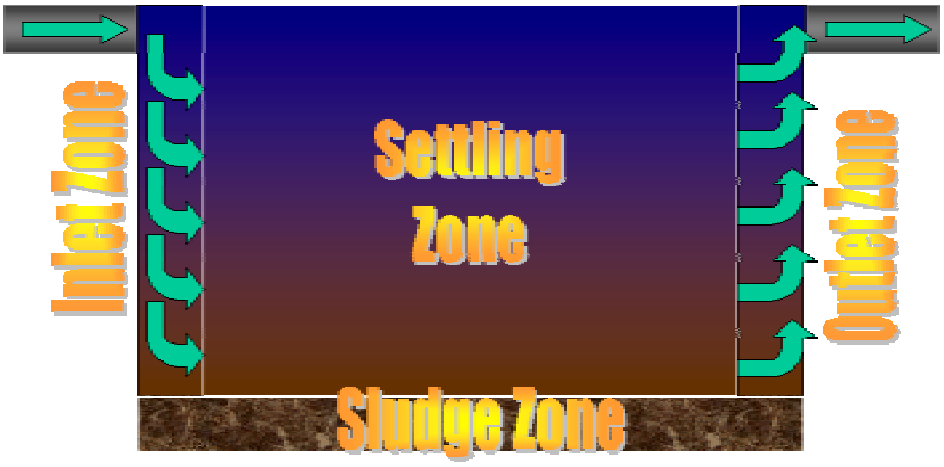
For convenience in discussing sedimentation basins, a typical sedimentation basin can be divided into four zones:

1. Inlet zone;

2. Settling zone;

3. Sludge zone; and

4. Outlet zone.



The inlet to the sedimentation basin should provide a smooth transition from the flocculation basin and should distribute the flocculated water uniformly over the entire cross-section of the basin. A properly designed inlet such as a perforated baffle wall will significantly reduce short circuiting of water in the basin, and will minimize the effects of the water wanting to flow at the inlet velocity straight through the basin.

The settling zone is the largest portion of the sedimentation basin. This zone provides calm, undistributed storage of the flocculated water for a sufficient time period to permit effective settling of the suspended particles in the water being treated.

The sludge zone is located at the bottom of the sedimentation basin and is a temporary storage place for the settled particles. In addition, the sludge zone is used to allow for compression settling of the sludge.

Basin inlet structures should be designed to minimize high flow velocities near the bottom of the sedimentation basin, which could distribute or scour settled particles in the sludge zone, causing them to become resuspended.

Sludge is removed from the sludge zone by scraper and vacuum devices, which move along the bottom of the sedimentation basin as necessary or on a regularly scheduled basis. Some plants require that the basin be drained and flushed to remove the sludge if the removal devices do not operate the entire length of the basin.

The basin outlet should provide a smooth transition from the sedimentation basin to the settled water conduit or channel. The outlet can also control the water level in the basin.

Skimming or effluent troughs commonly referred to as launders are frequently used to uniformly collect the settled or clarified water. Adjustable V-notch weirs are generally attached

to the launders to enable a uniform draw-off of basin water by controlling the flow. If the water leaving a sedimentation basin flows out unevenly over the weirs or at too high a velocity, floc can be carried over to the filters.

Rectangular sedimentation basins are commonly found in many large-scale water treatment plants. Rectangular basins are popular for the following reasons:

1. High tolerance to shock loading (water quality changes);

2. Predictable performance;

3. Cost effectiveness;

4. Low maintenance; and

5. Minimal short-circuiting.

High-rate or tube settlers were developed to increase the settling efficiency of conventional rectangular sedimentation basins. They have also been installed in sedimentation basins with successful results. Water enters the inclined settler tubes and is directed upward through the tubes. Each tube functions as a shallow settling basin. Together they provide a high ratio of effective settling surface area, per unit volume of water. The settled particles can collect on the inside surfaces of the tubes or settle to the bottom of the sedimentation basin.

Parallel plate or tilted plate settlers can also be used to increase the efficiency of rectangular sedimentation basins, and these function in a manner similar to tube settlers.

High-rate settlers are particularly useful for water treatment applications where site area is limited, in packaged-type water treatment units, and to increase the capacity of existing sedimentation basins. In existing rectangular and circular sedimentation basins, high-rate settler modules can be conveniently installed between the launders.

The solids-contact process, also referred to as "up-flow solids-contact clarification" and "up-flow sludge-blanket clarification", was developed to improve the overall solids removal process under certain design conditions. These units combine the coagulation, flocculation and sedimentation processes into a single basin, which may be either rectangular or circular in shape. Flow is generally in an upward direction through a sludge blanket or slurry of flocculated, suspended solids.

Solids-contact units generally have provisions to control removal of solids so that the concentration of solids retained in the basin can be maintained at some desired level.

Solids-contact units are popular for smaller packaged-type water treatment plants and also in cold climates where the units have to be inside a building. However, care must be exercised in the operation of these units to assure that a uniform sludge blanket is formed, and is subsequently maintained throughout the solids removal process. The sludge blanket is sensitive to changes in water temperature. Temperature density currents tend to upset the sludge blanket.

Loss of the sludge blanket will affect the performance of the filters. Other important operational factors include control of chemical dosage, mixing of chemicals and control of the sludge blanket.

Under ideal conditions, solids-contact units provide better performance for both turbidity removal and softening processes requiring the precipitation of hardness. With softening processes, chemical requirements are usually lower also. In the case of turbidity removal, coagulant requirements are often higher. In either case, solids-contact units are very sensitive to changes in influent flow or temperature. In these facilities, changes in the rate of flow should be made infrequently, slowly and with great care.

7.5 SLUDGE HANDLING AND REMOVAL

Water treatment plant sludges are typically alum sludges, with solids concentrations varying from 0.25 to 10 percent when removed from the basin. In gravity flow sludge removal systems, the solids concentration should be limited to about 3 percent. If the sludge is to be pumped, solids concentrations as high as 10 percent can be readily transported.

In horizontal-flow sedimentation basins preceded by coagulation and flocculation, over 50 percent of the flow will settle out in the first third of the basin length. Operationally, this must be considered when establishing the frequency of operation of sludge removal equipment. Also you must consider the volume or amount of sludge to be removed and the sludge storage volume available in the basin.

Sludge, which accumulates on the bottom of sedimentation basins, must be periodically removed for the following reasons:

1) To prevent interference with the settling, process such as resuspension of solids due to scouring;

2) To prevent the sludge from becoming **septic** or providing an environment for the growth or microorganisms that can create taste and odour problems, and

3) To prevent excessive reduction of detention time.

In large-scale plants, sludge is normally removed on an intermittent basis with the aid to mechanical sludge removal equipment. However, in smaller plants with low solids loading, manual sludge removal may prove to be the most cost effective.

In manually cleaned basins, the sludge is allowed to accumulate until it reduces settled water quality. High levels of sludge reduce the detention time and floc carries over the filters. The basin is then dewatered; most of the sludge having been removed by stationary or portable pumps, and the remaining sludge is removed with squeegies and hoses. Basin floors are usually sloped towards a drain to help sludge removal. The frequency of shutdown for cleaning will vary from several months to a year or more, depending on amount of suspended solids in the raw water.

In larger plants, a variety of mechanical devices can be used to remove sludge including:

1) Mechanical rakes;

2) Drag-chain and flights; and

3) Travelling bridges.

Circular or square basins are usually equipped with rotating sludge rakes. Basin floors are sloped towards the center, and the sludge rakes progressively push the sludge towards a center outlet.

In rectangular basins, the simplest sludge removal mechanism is the chain and flight system. An endless chain outfitted with wooden flights pushes the sludge into a sump. The disadvantage of this system and of the rotating rakes previously described is high operation and maintenance costs. Most of the moving parts are submerged so the basin has to be dewatered to perform major maintenance.

In an attempt to reduce operation and maintenance costs and to improve sludge removal equipment maintainability, the travelling bridge was developed. This bridge looks like an old highway bridge except it has no deck for cars. The travelling bridge spans the width of the sedimentation basin and travels along the length of the basin walls. Moveable sludge sweeps, which are hung from the bridge structure, remove the sludge from the basin floor with suction pumps or by siphon action. There are few submerged parts in this system and these can normally be removed for maintenance without dewatering the basin. Traveling bridge sludge removal systems will operate effectively on the simplest of basin designs.

7.6 PROCESS CONTROL

The actual performance of sedimentation basins depends on the settling characteristics of the suspended particles and the flow rate through the sedimentation basins. To control the settling characteristics of the suspended particles, adjust the chemical coagulant dose and the coagulation-flocculation process. The flow rate through the sedimentation basin controls the efficiency of the process in removing suspended particles. The higher the flow rate, the lower the efficiency (the fewer suspended particles are removed). Once the actual flow rate becomes greater than the design flow rate, you can expect an increase in suspended particles flowing over the V-notch weirs.

If adequate detention time and basin surface area are provided in the sedimentation basins, solids removal efficiencies greater than 95 per cent can be achieved. However, high sedimentation basin removal efficiencies may not always to be the most cost-effective way to remove suspended solids.

In low turbidity source waters (less than 10 NTU), effective coagulation, flocculation and filtration may produce satisfactory filtered water without the need for sedimentation. In this case, the coagulation-flocculation process is operated to produce a highly filterable pinpoint

floc, which does not readily settle due to its small size. Instead, the pin-point floc is removed by the filters.

However, there is a practical limitation in applying this concept to higher turbidity conditions. If the filters become overloaded with suspended solids, they will quickly clog and need frequent backwashing. This can limit plant production and cause a degradation in filtered water quality.

From a practical standpoint, you will want to operate sedimentation basins near design flows. However, to achieve the intended removal of suspended particles once design flows are exceeded, suspended particles leaving the sedimentation basin may overload the filters with solids and require additional filter backwashing. Study the settling characteristics of the particles by using laboratory jar tests. Then verify your test results and make adjustments based on actual performance of the water treatment plant.

During periods of low flow the use of all sedimentation basins may not be necessary. Since the cost to operate a basin is very low, it is recommended that all basins be kept in service except during periods of draining for maintenance and repairs.

7.7 REVIEW

1. How does particle size affect sedimentation?

2. Why is it important to remove sludge periodically from the sedimentation tank?

3. What is a clarifier?

4. When is sedimentation not required in a water treatment process?

8.0 WATER FILTRATION

8.1 OBJECTIVES

The trainee will be able to:

1. Learn the purpose of filtration;
2. Describe the filtration process;
3. In a rapid sand filter describe the purpose of different "layers";
4. Determine efficiency by monitoring:
    a) Loss of head;
    b) Turbidity; and
    c) Rate of flow;
5. Understand:
    a) Filtration rates;
    b) Backwashing;
    c) Air wash systems; and
    d) Air/water scour;
6. Define and describe the operating problems of a filter; and
7. Describe the differences between:
    a) A pressure filter; and
    b) A rapid sand filter.

8.2 PURPOSE OF FILTRATION

The primary purpose of filtration is to remove suspended materials such as small particles and microorganisms from the raw water stream.

8.3 GENERAL CONSIDERATIONS

A prerequisite to filtration is proper pre-treatment. This may be accomplished by:

1. Treating the "raw" water entering the plant with various chemicals,

2. Mechanically agitating it for proper mixing and coagulation of the suspended matter to produce the desired floc, and

3. Allowing enough retention time in the plant to settle out most of the suspended matter (in most plants).

The next and most important phase through which it passes is - FILTRATION.

Filtration is the process of removing turbidity (suspended particulate matter) from water by passing it through some porous filter media such as sand, anthracite or a combination of both.

8.4 FILTRATION PROCESS

Many years of laboratory research and in-situ operational observations have shown that the filtration process removes up to 95% of turbidity from the water presented to the filter. This is accomplished by:

- Mechanical Straining;
- Impingement;
- Electrolytic Action; and
- Chemical Reactions.

8.4.1 MECHANICAL STRAINING

The largest particles remain on top of the filter because their size will not allow them to pass through the small spaces between the individual grains of media.

8.4.2 IMPINGEMENT

Did you ever wonder why it is that when you drive your car through mud in pouring rain, that the mud is splashed onto your car instead of being washed off with the rain? For the same reason, when turbid water passes down through the sand grains in a filter it sticks to them. This is because a natural attraction causes the particles to move to the surface of the media (your car, sand grains) and stick to it.

8.4.3 ELECTROLYTIC

Both sand and anthracite grains carry an electrical charge as do the particles of turbidity that are suspended in the water. The forces generated by the electrical charges cause the suspended particles to cling together.

8.4.4 CHEMICAL REACTIONS

There are many organisms in the top layer of the filter media. These organisms will promote chemical reactions with incoming turbidity and with other organisms, affecting the filtering action.

8.5 THE SLOW SAND FILTER

Filtration as we know it today began in about 1830 when the first slow sand filter was built in London, England. These units operated at about 4 lpm per sq. m (1/10 gpm per sq. foot). The slow sand filter is fast disappearing mainly because of the high cost of labour and the amount of land required to operate these units.

The slow sand filter consisted of an underground drain system with a gravel bed over it. On top of this was spread the filter sand. The water flowed in, on top of the sand and filtered down through it, depositing the turbidity particles in the upper layers of the sand. During its passage through the sand layer the bacteria already present in the filter attacked and in most cases, destroyed any harmful bacteria present. This was the only method of disinfection practiced at that time. Once the rate of flow through the filter became too slow for any further operation, the water was shut off, the unit drained and the top layer of sand was removed and replaced by hand.

8.6 THE RAPID SAND FILTER

The Rapid Sand Filter evolved from the concept of the slow sand filter. There are two types of rapid sand filters, gravity filter or pressure filter. In either case, water passes through the bed of sand at flow rates from 80 to 610 lpm per sq. m (2 to 15 gpm per sq. foot). The higher rates are generally used in deep bed anthracite filters. The water is usually pre-treated by coagulation and settling to remove the majority of the suspended matter before the actual filtration process. Because very little bacterial purification occurs, chlorination is practiced after filtration to achieve disinfection.

The rapid sand filter can be cleaned of accumulated turbidity by reversing the direction of the flow of water. This process is called backwashing. In backwashing, the flow of water expands the sand, scours the bed and carries the accumulated solids to the sewer or waste treatment facility.

The media used in the rapid filter include sand, crushed anthracite coal and in some cases, a combination of these called, dual media if there are two different types and mixed media if there are more than two types.

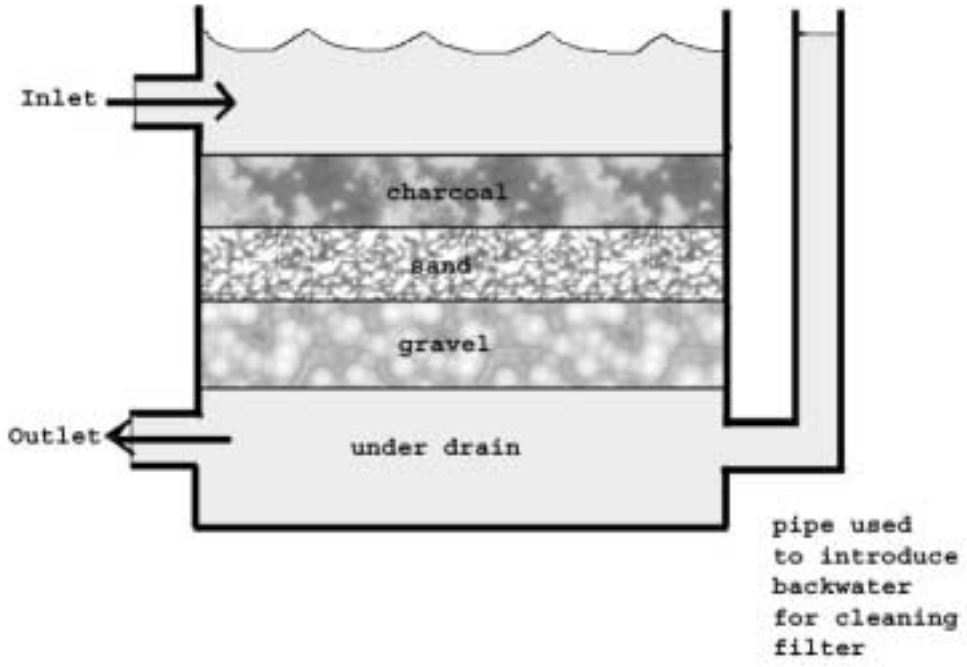
8.7 DIRECT FILTRATION

Although we have been discussing filters that operate in water treatment together with coagulation/flocculation and sedimentation, in some installations sedimentation is neither necessary, nor practical. In many locations, the turbidity of the raw water is low enough that the filters do not require sedimentation of the floc. This method of water treatment is generally limited to raw waters with a maximum turbidity of equal or less than 40 NTU and whose average turbidity are in the range of 5 to 12 NTU.

Direct filtration begins like conventional filtration; alum is applied to the water through a mixer, followed by flocculation. All the turbidity particles and floc are applied directly to the filter.

The filter media used is usually mixed media because if has enough room to store the large amounts of solids applied to the filter and still prevent rapid overloading and frequent backwashing. Either gravity or pressure filters can be used for direct filtration.

Figure 8-1 Typical Sand Filter



8.8 CONSTRUCTION OF A SAND OR ANTHRACITE FILTER

A gravity filter is essentially a metal, fibreglass or concrete box. Its length, width and depth are determined to suit the desired rate of flow. The depth of the box is determined by the amount of head or pressure required and also by the type of underdrain.

The principal parts, which make up a gravity filter are shown in and include:

- The underdrain system;
- The gravel subfill;
- The filter media; and
- The surface washer, wash troughs and air scour system.

8.8.1 UNDERDRAIN SYSTEM

The underdrain system collects the filtered water that passes through the media. The most common type of underdrain is the vitrified clay "LEOPOLD" drain tile. Holes on the upper side of the drain tile are properly sized to handle the water flows required for adequate water distribution during filtration and backwash operation. The backwash flow rate of the average filter is 490 - 610 lpm per sq. m (12 to 15 gpm per sq. ft.) and the operating rate only about 163 lpm per sq. m (4 gpm per sq. ft.) The only head available during the filtration process is the depth of water in the filter. Consequently the holes are sized to handle the filter flow. Adequate distribution of water is ensured at the higher flows encountered in backwashing due to the diffusing effect achieved by the flow and resultant loss of head through the underdrain systems.

8.8.2 GRAVEL SUBFILL

The subfill performs two primary functions:

1. It supports the upper layers of sand and anthracite and separates them from the underdrain system, and
2. It distributes evenly the flow of water through the filter in both directions. (The depth of gravel required in design of filters is directly related to the distance between the holes and their size in the underdrain system).

Different layers, or size, of gravel make up the required depth. Progressively finer grades of gravel are spread on top of the coarse gravel. The minimum depth of a layer is 2". The final layer of gravel, or "torpedo sand" as it is sometimes called, will support the actual filter media.

All our NWT systems use gravel support. Ft. Providence tried to go gravel-less but we couldn’t retrofit the existing Waterboy and the cost is too high.

8.8.3 FILTER MEDIA

The actual filter media is on top of the gravel bed and varies in depth depending on plant design. Typical filter bed depths in the NWT are around 35 – 45cm (4 to 5ft). Today, with the advent of multi-media systems, garnet and other types of sand are used. These materials incorporate in the grain structure such things as carbon, which greatly reduce their weight.

Anthracite, hard coal that has been crushed (screened) for size and graded to have a uniform density is the most widely used filter media. Crushed anthracite coal has a lower specific gravity (1.75) than sand (2.65); consequently, a lower velocity is required when backwashing the filter compared to that required to wash a sand filter of equal depth.

Crushed anthracite coal is lighter in weight – 880 kg per cu. m. (55 lbs. per cu. ft.) than sand – 1600 kg per cu. m (100 lbs. per cu. ft.); therefore, in order to benefit from both of these media, they are generally used together. They can be readily backwashed together and should always remain separated due to the difference in their specific gravities. The coarse anthracite on top gives the filter a larger capacity for turbidity removal, while the finer sand layer is below the anthracite supporter by a gravel support layer. The combination of the two provides a media that will give longer filter runs with a resulting better quality of water. Recent designs utilize entire bed depths of anthracite for removal and storage of suspended matter.

8.8.4 WASH WATER TROUGHS

The wash water troughs are located above the surface wash equipment. They are installed, half the bed depth above the bed to provide a free space between the underside of the trough and the top of the bed. This space is normally provided for when the filter is backwashed to allow for the filter media to expand when cleaning without losing filter media.

The depth of the wash troughs varies with the amount they can hold so the distance from the top of the wash trough to the top of the bed will vary widely.

8.8.5 OTHER NECESSARY ACCESSORIES

Other necessary components include:

- The influent wash water valve;
- The effluent wash water valve;
- A valve to control the flow of water to the surface wash equipment; and
- Pumps.

All of these valves are controlled from a console, usually located in front of and facing the filter. Built into the control console are gauges showing loss of head, rate of flow through the filter, backwash rate of flow, and effluent turbidity.

In some older plants, especially the smaller ones, individual hand valves are still used. The larger, newer plants often have automated systems that backwash the filter and then return to service.

8.9 FILTER INSTRUMENTATION

To operate a filter at its full capacity and highest efficiency, the status of the filter is checked continuously and the turbidity (before and after filtration), loss of head, and the rate of flow, are recorded.

8.10 TURBIDITY

The prime function of a filter is to remove suspended matter and thereby removing pathogenic organisms from the water.

Most of these organisms are bound up in the coagulated floc particles entering the filter. The turbidity remaining in the filter effluent is the best indicator of filter performance. Turbidity can be measured in the laboratory by such instruments as the Hellige or Hach turbidimeter, and can be monitored on the filters with indicating and or recording type instruments such as those producing by Keen and by Hach manufacturers.

Public Health Act and GCDWQ call for maximum turbidity in the effluent of 1.0 NTU.

8.11 LOSS OF HEAD

A filter was earlier described as a box with an underdrain, gravel subfill and filter medium; the box, of course, is filled with water. In most large filters, the distance from the surface of the water to the centre of the underdrain system is approximately 3m (10 ft.) This is the total head or pressure available to push water through the filter. When the filter has just been backwashed, it is in its cleanest state and offers the least resistance to flow through it. This resistance or loss of head is the difference between the total depth and the initial loss, leaving an available head in most filters of about 2.4m (8 ft.).

When in operation, the filter removes the turbidity from the water. As the turbidity accumulates in the bed, the resistance to the flow of water increases; in other words, the available head through the filter decreases. Therefore, the reading of the loss-of-head gauge is an indication of the "cleanliness" or the "dirtiness" of the filter. The loss-of-head gauge indicates when the filter needs backwashing. A simple loss-of-head gauge can be constructed by connecting a clear piece of plastic tubing to the underdrain header and running the tubing up to the side of the filter box so that the open end of the tubing is above the surface of the water in the filter. Mark the level of

the surface water in the filter on the wall next to the tubing. Then, at any time, the distance from this point down to the liquid level in the tube can be measured - this distance is the head loss. This is also a good method of cross checking loss-of-head instruments. Most modern loss of-head instruments operate on this principle and simply transmit the measurement (or distance) to the instrument located on the control panel.

8.12 CONSTANT RATE AND DECLINING RATE FILTRATION

8.12.1 CONSTANT RATE

Constant rate filtration describes flow through a filter, which is maintained by the filter rate control valve independent of head loss. In other words, the operator sets the required flow. The rate control valve then senses a decrease in flow, which results from plugging of the filter bed (and increased head loss) and opens slightly to maintain the desired flow rate.

8.12.2 DECLINING RATE

Declining rate filtration controls the filter operating head by raising or lowering the pressure in the filter discharge header. This action allows a clean filter to operate initially at a higher rate of flow per sq. m and then as head loss increases through the filter, a lower rate of flow is achieved per sq. m of filtering area.

This system has been shown to reduce terminal breakthroughs while increasing production.

No significant difference was found in the quality of water produced by either control method.

8.13 FILTER OPERATION

8.13.1 PRE-TREATMENT

The most important thing to remember about the water arriving at the filter(s) is to condition and pre-treat it thoroughly before it gets there. Without this pre-treatment, or if the pre-treatment is inefficient the operating efficiency of the filter(s) is going to be drastically reduced. Filter runs will be cut short, resulting in a considerable increase in backwashing and the amount of wash water used. Consequently, plant output will be reduced because filters have to be washed with filtered water that could have been delivered to the customer. The filter beds will become overloaded with algae and particulate matter, and mud balls will very likely develop.

As already discussed, the type of conditioning applied to the raw water depends on the quality of the raw water entering the plant. The demand on water treatment plants, however, is continually increasing. If a given chemical treatment produces a good floc, coagulates well, and results in a water passing over the filter with, for example, turbidity of one (1) unit, at a flow rate of 25 MGD, an increase in flow rate to 40 MGD may not produce the same quality water over

the filters even if the chemical dosage is increased in proportion to the increase in flow. This is because increasing the flow rate by 60% will allow less time for the floc to settle out. This results in a greater carry-over to the filters, causing shorter filter runs.

8.13.2 FILTRATION RATES

Until a few years ago, the normal design filter rate for a rapid sand filter producing potable water, was 80 – 160 lpm per sq. m (2 - 4 gpm per sq. ft.) of filter bed-area. Since then investigations of filter aids have been carried out, using dual and multi-media filters. As a result, operating filter rates are notably increased. It is common today to find filters operating at rates of 245 – 325 lpm (6 - 8 gpm per sq. ft.) of filter bed area.

It is sometimes possible to increase the flow rate through the filter. Filters are normally designed for specific rates of flow, and such things as the inlet flumes, the underdrain system, rate of flow controllers, and the discharge piping are all sized for this flow plus a factor of safety. Therefore, to double the rate of flow, the total head available in the filter may be sufficient to maintain this flow rate for short periods of time.

New filters use a media in which the particle size is greatest at the top. By using various types of filter media, the particle size gets progressively finer, down through the bed to the bottom. Since the voids (or spaces) between the particles will be larger where the particle size is greatest, the voids in the upper portion of the bed are largest. These provide a greater storage area for turbidity particles. As the water proceeds through the bed, the size of these voids becomes progressively smaller due to the accumulation of turbidity particles. At the same time, the storage for the turbidity is becoming less, but the degree of filtration is becoming better.

It is common today to have up to five different layers of material in a filter bed. In other types of media, two layers are used, generally sand and crushed anthracite: two-layer filters are commonly known as dual media filters. The type of filter to be used is determined after a thorough study of the treatment process and raw water conditions.

The conventional rapid sand filter uses one grade of sand (0.45 - 0.55 mm and a S.G. of 2.65) approximately 75 cm (30 inches) thick underlaid by graded layers of gravel as supporting media. Normally under these conditions, the actual entrapment of suspended matter is restricted to the top several centimetres of the sand bed. The remaining sand acts as insurance against a serious turbidity breakthrough, which means the turbidity on the filter has increased to the point where it is being carried through by the water being filtered.

The storing capacity for suspended matter in the conventional rapid sand filter is considerably less than in a dual-media filter where the top 45 cm (18 inches) of the sand bed have been replaced with a coarser and lighter media, such as a graded crushed anthracite (0.8 - l.2 mm and a S.G. 1.75). Under ideal conditions, the entire 45 cm depth of anthracite plus 3 - 5 centimetres of sand is available for the storage of suspended matter. This means that the head loss, instead of being concentrated in the top 5 cm in the conventional sand bed, is distributed through a depth of 45 cm to 50 cm (18 - 20 inches) in the dual-media bed. This makes it possible to use higher filter rates for longer filter runs.

8.13.3 BACKWASHING

Backwashing a filter is the exact opposite to filtration. When backwashing, the water rises up through the filter rather than passing down through it. The backwashing process removes the accumulated turbidity from the filter. Municipal filtration plants always utilize treated water for backwashing. The water is delivered to the filter either from an elevated tower or via a backwash pump (from the clearwell). Either method provides the necessary pressure and volume for carrying out the backwash process.

A normal rate of flow during the backwash cycle for conventional filters is 610 lpm per sq. m (15 gpm per sq. ft.) of filter bed area. These figures will vary depending on the temperature of the water used to backwash. As the temperature increases, the backwash rate is increased to give the same amount of expansion to the filter bed. The backwash water enters through the underdrain. Rising up through the gravel bed, it enters the filter media. The gravel bed further distributes the water uniformly throughout the entire filter.

It is extremely important to note that in the operation of any filter, all valves have to be opened or closed slowly. As the backwash valve is opened, the amount of water rising up through the filter media gradually increases and as more and more water is forced up through the sand bed, the pressure on the underside of the individual grains of filter media becomes greater. This pressure eventually overcomes the weight of the particle of filter media and the point at which this occurs is known as the point of fluidity. Once the flow reaches this point, the article will rise and the filter bed will start expanding.

The normal expansion of the filter bed is 30 to 50 per cent during the backwash period. Backwash space must be provided in the filter to permit this expansion during the washing period. This is why the wash trough must be at a fixed height above the filter bed. The particles of media roll around in the bed, continuously rising and falling. In the process, they rub against each other. The combined action of the water moving past the particle of media and the scrubbing action of the particles rubbing against each other removes the accumulated turbidity from the filter media grains.

It was found from experience that this does not always remove all of the turbidity from the filter media, and that over the years turbidity will accumulate on the media grains, limiting their effectiveness as a filter media. Superior backwashing may be achieved in the winter due to the denser water, however, a savings may be realized by reducing the backwash time because the bed is cleared faster.

Adequate backwashing in every filter operation is extremely important. The backwash flow rate should be as high as possible without losing filter media. The backwash should be carried on until the filter media is substantially cleaned. No media will ever be absolutely clean, regardless of the extent of the backwash.

8.13.4 SURFACE WASH SYSTEM

Auxiliary scour better describes the function of this device as it aids in cleaning much more than the filter surface. The purpose of the surface wash is to aid in cleaning the filter surface and prevent mudball formation by applying a jet of water to the encrusted surface before and during wash cycles.

The most common surface washers are rotary surface washers; the washer is mounted just above the filter bed and begins to rotate when water jets out of the nozzles. As the filter bed starts to expand during backwashing the washer not only cleans the top of the filter bed but becomes immersed in the filter media. Fixed jets are sometimes used as well instead of rotating washers.

Initially the filter media is backwashed at about 245 lpm per sq. m (6 gpm/sq. ft.). This is the point at which the particles of media are in effect "weightless" in the filter bed. The agitator is then turned on and allowed to run for a period of 5 to 7 minutes. The force of the jets of water from the agitator cleans the grains of the filter media and moves them so that the entire bed is gradually turned over and exposed to the jet action.

Following this, the backwash rate is gradually increased and the agitator turned off. The filter is backwashed at its normal backwash rate for as long as economically necessary to remove all accumulated turbidity. The water is then slowly turned off and the media allowed to settle before returning the filter back to operation.

8.13.5 AIR SCOUR WASH

Another method used to assist in cleaning the filter is accomplished by introducing compressed air into the backwash stream before it reaches the filter. Underdrain systems used for air scour usually have smaller holes, thereby creating a much diffused air-water mixture. This mixture causes extensive agitation of the media as it passes through the bed. Many feel that the method is more efficient at cleaning the filter bed than is possible by standard backwashing.

Air scour systems blast the filter media with jets of air from the bottom of the filter. The air scour systems are activated prior to backwashing and remains on until the wash water troughs begins to fill with wash water. A common problem with air scour systems is that they inadvertently remove filter media into the wash trough damaging the filter. This can usually be remedied by reducing the backwash velocity, by properly guarding the filter media and by ensuring the air scour is turned off before the backwash reaches the wash water troughs.

8.14 OPERATING PROBLEMS OF A FILTER

The operating problems of a filter can be divided into two categories:

1. Failure of the filter bed due to improper pre-treatment or operating procedures; and

2. Mechanical failure of controls and equipment.

8.14.1 FILTER BED FAILURE

When seeking the causes of filter bed failure, look for the following.

1. Clogging the filter media by turbidity accumulation. This is caused by incomplete removal during the backwash operation or inadequate pre-treatment.

2. "Cracking" or contraction of the bed. This results from too long a filter run or poor backwash techniques.

3. Mudballs. Tiny balls of accumulated turbidity bind together with particles of filter media. As these mud balls increase in size, they become heavier than the filter media and will gradually sink down to collect on the top layer of gravel.

4. The shifting and intermixing, sometimes called mounding, of the gravel layers. This problem occurs primarily in the fine gravels located in the top of the support bed. It is caused by uneven backwashing rapid change in flow rate, a clog or break in the underdrain system.

5. Negative Head and Air Binding. Some filtration plants have only 1.2 – 1.5m (4 to 5 ft.) of water above the media surface and air binding problems may occur occasionally in the filter media. Air dissolves in water at or near the saturation point. When the pressure is reduced to less than atmospheric pressure below the surface of the media, the dissolved air comes out of solution, and air bubbles accumulate within the media. This may result in a marked increase in the headloss. If the operator is not aware of this problem, media may be lost in the early part of the filter backwash due to the violent agitation of the air being released from the filter media. In most plants troubled by air binding, the problem occurs in the spring season when the surface water is in the stage of "warming up" and is supersaturated with air. To prevent loss of media, care should be taken at the beginning of the backwash to partially drain the filter below the overflow troughs prior to starting the backwash water pumps.

Checking the Filter:

1. Filter Peeker. It is possible to look at gravel inside a filter to check for gravel mounding and also to check underdrains and to determine whether or not mudballs are present. This can be achieved with the use of a filter peeker.

   A filter peeker consists of a hollow copper tube with a periscope type hood and handle at one end to look through and a rectangular shaped conical hood at the other end with a glass plate and small lights inside. Flashlight batteries at the end with the handles poweres a light source. This practical gadget can be constructed by most water works operators.

   The filter peeker is inserted into the filter during a backwash and moved by hand.

2. The maintenance of the filter bed itself involves a periodic probe check of the media to determine the contours of the pea gravel layer. This should be done twice a year.

   To do a probe check, sketch an outline of the filter area. Drain the water from the filter to be checked. Walk along with wash troughs and thrust a 2-metre length of steel rod down through the filter media until you feel the bottom of the rod come into contact with the pea gravel. Check a marker near the top of the rod against the lip of the wash trough to determine the depth of the gravel at that point. Enter the reading obtained by the probe at the appropriate point on the sketch of the filter area. Repeat over the whole bed to obtain an accurate picture of the gravel contour. If undue humping of gravel is found in any part of the filter, the sand anthracite must be removed from the area and the pea gravel re-graded and levelled.

3. Bacterial Growth within the Filter Bed - If prechlorination is not practiced, trouble may be experienced with filter clogging due to bacteria growth within the bed. One effective method of cleaning up such a bed is by heavy chlorination, using one of the following methods:

   a) Dosing the filter bed directly with a 12% hypochlorite solution;

   b) Hooking up the plant chlorination facility to the backwash pump; and

   c) Hooking up a hypochlorinator to the backwash pump.

8.14.2 MECHANICAL FAILURE OF FILTER CONTROLS AND EQUIPMENT

A good preventive maintenance program is essential to prevent mechanical failure of filter controls and equipment. This includes hydraulically or pneumatically operated gate valves, butterfly valves, sluice gates, rate of flow controllers, surface wash equipment, instruments for filter operation such as loss of head and rate of flow gauges, as well as the gauges used for indicating and recording the wash rates.

If you have a full and complete record of past troubles and breakdowns, including the required repairs, a periodic review of such records will alert you to possible future trouble spots. Also, keep enough spare parts on hand to limit any downtime resulting from a breakdown of equipment and have the proper facilities and tools for repairs.

The filter console gauges for loss of head and rate of flow will provide continuous accurate readings only if they are given periodic calibration checks and maintained in good condition. No matter how sophisticated the instrumentation, the following checks should be made to determine their accuracy.

8.15 INSTRUMENT CHECKING AND MAINTENANCE

1. To check the actual loss of head through any filter, obtain a length of polyethylene tubing, l/4" or 3/8" diameter, pass one end down to the pipe gallery floor from the filter

console above, connect the tubing to a centre tap on the filter effluent line and open the top allowing water to rise in tubing. The distance from the level of the water in the filter to the level of the water in the tube is the actual loss of head across the filter at that particular moment. If the indication on the filter gauge console does not agree with this valve (plus or minus the allowable tolerance) the gauge reading is incorrect. Maintenance is required to correct the situation.

2. To check the actual rate of flow through the filter, use a "Hook Gauge". It is very accurate. A "Hook Gauge" consists mainly of a supporting member (l/8" x l" scrap iron or similar) about 48" long to which are fastened two small brackets. On each bracket is positioned a l/4" x l-l/2" brass machine screw which has been ground to a needlepoint at one end. The pointed ends of the brass screws are held in the vertical position by the small brackets and lock nuts. These two "points" on the hook gauge can be positioned so that the distance between points is exactly 15 cm or 30cm (six inches or l foot), whichever is preferred.

   A stopwatch is used with the hook gauge. In use, the top end of the scrap iron is bent at right angles and the gauge is lowered into the filter, between any two wash troughs. To check the actual filter rate, close the filter influent valve leaving the effluent valve open. Watch the water dropping in the filter and when the water just "breaks" the top point of your gauge, start the stopwatch.

   Stop the watch exactly at the point where the dropping water just "breaks" the bottom "point" of the gauge. The time taken for the filter to pass either 15 cm or 30cm of water in a given period is determined accurately. Knowing the filter area, the rate can be calculated in millions of litres per day (MLD), which is indicated on the console instrument. A very accurate check is obtained on another aspect of the filter, because a given volume of water passing through the filter in a given time is measured and determined. Allowances must be made for the space occupied within the filter by such accessories as wash water troughs and gully walls, and whether the time is checked with the water level above the troughs or below them.

3. The operating cylinders on the various valves (influent, effluent, wash and waste) need periodic checking to replace the gland packing and occasionally to replace the cup leathers on the piston.

4. The surface wash equipment requires little maintenance except for occasional cleaning of the jets on the agitator arms. If the filter media is anthracite some fine grains may become lodged in the jets but it is a simple matter to unscrew these for cleaning. Even though this is a minor maintenance chore, it should be done periodically, because the agitator arms will not perform effectively if a number of jets become clogged. The ball bearings on which the agitator arm rotates give very little trouble, but should be part of the regular P.M. programs.

8.16 PRESSURE FILTERS

There is relatively little difference in the design of gravity and pressure filters as far as the internal components are concerned. There *is* one very large difference in its *operation*. A gravity filter only has a pressure of approximately 2.4m (8 feet) of water on it; the pressure across the bed of a normal pressure filter can be as high as 415– 480 kpa (60-70 psi.) It is therefore possible to drive or push the water through these filters.

Since it is generally not feasible to provide large vessels equivalent to the capacity of the flocculation and sedimentation chambers of a conventional plant, it therefore becomes quite difficult to provide both adequate settling and transfer of water from the effluent of the settling basin to the filters. This transfer, in the case of a pressure filter, requires more vigorous pumping rates at a higher pressure than on a rapid sand filter.

The pumping process would cause a break up of the floc particles resulting in a much deeper penetration of the filter and less filter efficiency. The in-line application of coagulant such as alum is generally not satisfactory, and lends itself to only a very limited number of water sources to be treated. Coagulant aids (polyelectrolytes) are a great help when applied to pressure filters, as they can be used for in-line application. Application is achieved by use of an in-line flash mixing device and a subsequent rapid floc formation results.

Since the sand bed cannot be seen during the backwash period (and this is one of the main disadvantages of such a unit from the operator's viewpoint) the best procedure is to provide a sample stream which can be examined continuously during the backwash and ensure that the rate of flow will not backwash the filter media out of the unit.

From time to time, however, it is necessary to increase the backwash rate to a point where a small amount of media is being lost. This determines that the unit is being backwashed at the maximum possible rate. All these difficulties can be overcome through the installation of proper controls, so pressure filters of either the vertical or the horizontal type can be used to good advantage in small installations where gravity filters are too costly.

8.17 REVIEW

1. List some of the types of common filters with a brief description of each.

2. What is meant by backwashing and why is it done?

3. Describe the effect of temperature on the filtration process?

4. How can you as an operator determine the head loss across a filter?

5. Why and when would a facility use pre-treatment before the filtration process?

9.0 IRON AND MANGANESE CONTROL

9.1 OBJECTIVES

The trainee will be able to:

1. Know why it is important to control iron and manganese;
2. Know three ways to control iron and manganese;
3. Understand how a manganese **greensand** filter works; and
4. Understand how to operate a manganese greensand filter.

9.2 THE NEED TO CONTROL IRON AND MANGANESE

Ground water, such as that found in Wha Ti, Fort Liard and Nahanni Butte, often contains iron and manganese. Although usually referenced together, they can be found separately. Typical concentrations for iron and manganese are 10 ppm and 2 ppm, respectively.

Neither element has any direct adverse health effects for humans. Both are found in multivitamins; however, iron and manganese in normal drinking water have no **nutrient** value. For the water to contain beneficial amounts, the taste of the water would be rather unpleasant.

Clothes laundered in water containing iron or manganese above certain concentrations often come out stained. They can also lead to stains on plumbing fixtures such as sinks and toilets.

The biggest problem, however, is that they promote the growth of a group of organisms called **autotrophic bacteria**. These bacteria use non-carbon sources such as iron and manganese for their food. They form thick slime layers inside pipes and storage tanks. These slime layers can cause their own problems when they become loose and create dirty water and customer complaints. But the slime layers also consume chlorine and can harbour pathogenic organisms.

9.3 REGULATORY REQUIREMENT

There is no regulatory requirement for iron and manganese. The Guidelines state an aesthetic objective of 0.3 mg/l for iron, and 0.05 mg/l for manganese.

9.4 TREATMENT METHODS

9.4.1 OXIDATION BY AERATION

Metallic iron, found in water, can be oxidized by **aeration** to form insoluble ferric hydroxide. The reaction rate depends on the pH of water. The higher the pH, the shorter the treatment time. Often, small quantities of lime, sodium carbonate or sodium hydroxide are added to increase the pH.

There are several methods to provide aeration. Either the water being treated is dispersed into the air, or the air is bubbled through the water. Most commonly, aeration is achieved by using compressed air, which passes through diffusers in the water creating small bubbles capable of oxidizing the iron in the water. There are also waterfall or cascade aerators that are a series of small waterfalls that provide an opportunity for air to contact the water. Spray aerators are also used, which uses jets of fine spray that provide contact between the air and water.

Following aeration, the water is passed to a reaction basin. The basin is a usually cylindrical shaped basin similar to a clarifier. It is present to allow sufficient time for the oxidization process to occur. Usually, reactions take around 30 to 60 minutes. The basin must be cleaned regularly to avoid sludge build up that could clog the filters. The basins must be covered at all times and all vents must be properly screened. An **air gap** must be present to avoid contamination resulting from **backflow**.

After the ferric hydroxide forms in the settling tank, it is removed either by sedimentation or filtration, where the rest of the water continues throughout the water treatment process.

ADVANTAGES

- No chemicals are usually required, unless pH adjustment is required.

DISADVANTAGES

- Small changes in surface water pH will have a drastic effect on iron removal efficiency;
- Manganese oxidization efficiency is very low and hence, this treatment method is not valid where manganese concentrations are high;
- Humidity issues may occur is open aeration is used; and
- Higher costs.

9.4.2 CHLORINATION

Chlorine will oxidize both iron and manganese to their insoluble forms. The higher the chlorine residual in the water, the faster the reaction is. For typical iron and manganese removal needs, water is often treated to an initial chlorine residual of 5 to 10 mg/L, then the insoluble iron and manganese formed is filtered and then finally the water is dechlorinated to an acceptable residual for domestic use.

Doses beyond 10 mg/L can causes excess concentrations of total trihalomethanes (TTHMs), which can cause adverse health conditions.

Filtration of the insoluble iron and manganese can be done in the same method as outlined in the "oxidization by aeration" treatment method. The dechlorination uses a **reducing agent** such as sodium bisulphate to remove the excess chlorine.

Usually a reaction basin is added after the dechlorination process in a similar matter done by the "oxidization by aeration" treatment process to allow for sufficient time for the oxidization to occur.

ADVANTAGES

- Removes both iron and manganese from the water.

Disadvantages

- Requires additional chemicals with exact dosages; and
- Requires an additional dechlorination step to the water treatment process.

9.4.3 MANGANESE GREENSAND FILTER

A manganese greensand filter is capable of removing both iron and manganese from the water. A greensand filter is very similar to a regular sand filter except that the granular material has been treated with potassium permanganate.

The filter can be operated in three modes:

1. Continuous Regeneration,
2. Intermittent Regeneration, and
3. Catalytic Regeneration.

9.4.3.1 Continuous Regeneration

In the continuous regeneration process, chlorine is first added, oxidizing most of the metallic iron and manganese present in the raw water. Then a slight excess of potassium permanganate is added to remove the rest of iron and manganese. Finally, the water is

passed through the Greensand filter where two things occur: (1) the insoluble iron and manganese oxides are filtered and (2) the excess permanganate is reduced to manganese oxides, regenerating the greensand. Once the head loss is too high through the filter, the filter is then backwashed.

ADVANTAGES

- Can remove moderate concentrations of manganese and iron in the water.

DISADVANTAGES

- Requires the addition of chlorine and if required, a dechlorination step; and
- Manganese oxidization efficiency is very low and hence, this treatment method is not valid where manganese concentrations are high.

9.4.3.2 Intermittent Regeneration (IR)

The intermittent regeneration process is suitable where mostly manganese is present, having very little iron in the raw water. Oxidation occurs directly on the greensand as raw water flows over it. In this process small amounts of iron are also removed. Lastly, the filter is backwashed when the head loss becomes too large.

ADVANTAGES

- Suitable for situations where manganese removal is the main treatment requirement; and
- Does not require chlorine or dechlorination.

DISADVANTAGES

- Cannot effectively treat water with significant iron concentrations; and
- Filter must be backwashed frequently.

9.4.3.3 Catalytic Regeneration

Catalytic Regeneration is suitable where iron and manganese concentrations are small, less than 1.0mg/L and where the pH is greater than 7.0. Sufficient chlorine is added to the raw water before the filter to maintain a chlorine residual of 0.5 to 1.0 mg/L. As the water passes though a special grade of greensand, the chlorine regenerates the greensand and the manganese is oxidized right on the filter.

ADVANTAGES

- Suitable for situations where iron and manganese concentrations are relatively low and the pH is above 7.0;
- Longer filter run lengths are observed in comparison with the previous two methods;
- Low chemical operating costs; and
- Low suspended solids in backwash wastes.

DISADVANTAGES

- Cannot treat water with high iron and manganese concentration; and
- Requires a specially refined greensand, often Pyrolox.

9.5 OPERATION OF A MANGANESE GREENSAND FILTER

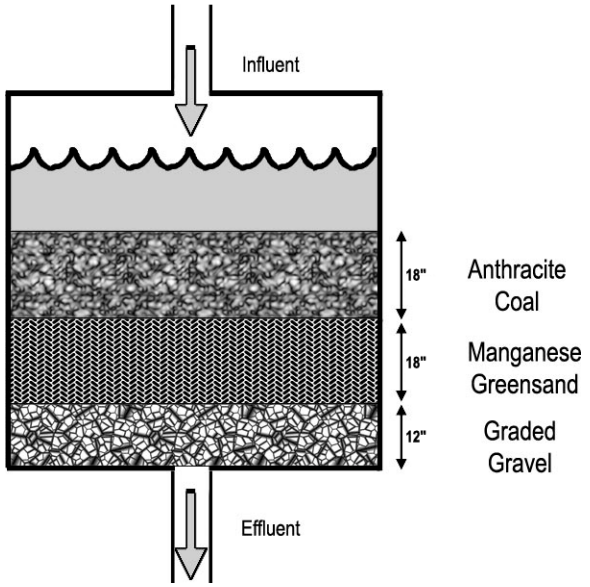
Most plants use a continuous regeneration greensand filter for iron and manganese removal. This section will look into the operation of this specific type of greensand filter. Since iron and manganese removal can often be a fairly expensive process, it is important for the operator to understand the treatment process as well as how to identify when something goes wrong or when concentrations are exceeded.

9.5.1 EQUIPMENT

The filter usually consists of 3 different types of layers. One layer on top consists of 45 cm (18 inches) of anthracite coal, followed by 45 cm of manganese greensand, with 30 cm (12 inches) of graded gravel on the bottom. The greensand filter is different from a conventional sand filter as the greensand contains much finer sand, having a slower filtering and backwash rate.

The greensand filters can remove 95% of the iron and manganese in the water if iron concentrations are below 10 mg/L and manganese concentrations are below 5 mg/L. However, when these concentrations are exceeded, the efficiency of filtration is reduced and the frequency of backwashing is increased resulting in an overall decrease in plant efficiency. In these situations, pre-treatment is often required.

Figure 9-1 Greensand gravity-feed filter diagram



9.5.2 PROCESS CONTROL

Raw water enters the system and is neutralized, if required, so that the pH remains between 6.2 and 6.8 by adding sodium carbonate or sodium hydroxide to the water. Next the water is injected with chlorine, flash mixed and flocculated for a period of ten minutes in order to oxidize most of the iron. The amount of chlorine required can be determined by:

$$Cl_2 \text{ Required, mg/L} = 1 \times [Fe] \text{ Conc., mg/L}$$

After chlorination, potassium permanganate ($KMnO_4$) is added to complete the oxidation of any remaining iron and soluble manganese.

$$KMnO_4 \text{ Required, mg/L} = (0.2 \times [Fe] \text{ Conc., mg/L}) + (2 \times [Mn] \text{ Conc., mg/L})$$

If the influent flow to the greensand filter was properly treated, the influent should have a slight pink colour. As the pretreated water flows through the greensand filter, the permanganate will be reduced to manganese oxide and regenerate the filter while removing most of the remaining iron and manganese in the water.

9.5.2.1 pH Control For Manganese

Manganese is often more difficult to remove when compared to iron and H_2S. During commissioning of the Nahanni plant a bench study showed that raw water pH had to be increased from about 8 to over pH 9 to see some reduction of manganese.

For your safety

Do not allow Potassium Permanganate to come with alcohols, powdered metals or sulphuric powders. Keep away from open flames and areas of high heat. Wear gloves, goggles and a surgical mask when working with the chemical.

9.5.2.2 Backwashing

Backwashing should occur when the head loss reaches about 69 kpa (10 psi.) and the duration of the backwash should be around 10 to 15 minutes allowing the system to unclog the settled insoluble iron and manganese oxides trapped in the filter. Filter cracking can occur which will affect apparent head loss. Filters should be backwashed everyday, but no less than every 2 days to prevent cracking.

It is very important not to underfeed the amount of permanganate added to the pre-treatment process or else the greensand filter will lose its oxidative properties. However, if the potassium permanganate charge is somehow lost in the filter, the operator can regenerate the greensand manually. The filter must be first shut down. Then, a saturated solution of potassium permanganate (around 5%) is poured into the filters and left to sit for 24 hours.

After 24 hours, the system is backwashed and restarted. Another way the system can be recharged without shutting down is by increasing the potassium permanganate dosage until pink water flows out of the bottom of the greensand filter. When the pink water flows out of the filter, the filter is recharged and regular doses of potassium permanganate can continue.

The operator should perform iron, manganese, pH and chlorine residual tests on a daily basis in order to determine if there are any problems in the system.

Remember, the above is only meant as a guide. Specific backwash requirement are site and equipment specific. Refer to manufacturer specification and procedures as they relate to your plant.

For your safety

When mixing chemicals, always add chemicals to water

Never add water to chemicals.

9.6 REVIEW QUESTIONS

1. What is the purpose of a reaction basin following the aeration process?

2. After chlorine has been added to treat for iron and manganese, how is the water dechlorinated?

3. How can an operator tell whether enough potassium permanganate is being fed in a CR greensand filtration process?

4. How can an operator regenerate the potassium permanganate in the greensand filter that has lost its oxidizing ability?

10.0 CHLORINATION

10.1 OBJECTIVES

The trainee will be able to:

1. Identify the purposes and properties of chlorination;
2. Describe chlorine reactions;
3. Calculate the chlorine dose based on demand, residual and break point.
4. Describe other uses for chlorine.

For more information on the basics of chlorination, refer to your Small Systems manual.

10.2 PURPOSE OF CHLORINATION

As stated in Chapter 2, bacteria are found in all raw water sources. Therefore, disinfection is required to destroy some of the harmful bacteria than can work its way into community water supplied. The most common and widespread method of disinfection is the addition chlorine in the treatment process.

The amount of chlorine necessary to obtain a satisfactory reduction of bacteria will vary greatly with the composition of the raw water and/or the degree of treatment the plant provides. The selection of the appropriate disinfection procedures is based on the results of bacteriological tests and other evaluations of the total system.

10.3 SOURCES OF CHLORINE

There are three common sources of chlorine:

- Calcium Hypochlorite;
- Sodium Hypochlorite, also known as liquid bleach; and
- Chlorine gas.

10.4 PROPERTIES OF CHLORINE

Table 10-1 Properties of the 3 types of chlorine used in water treatment

	Calcium Hypchlorite (Powdered HTH)	Sodium Hypochlorite (Liquid Bleach)	Chlorine Gas
Properties	HTH is a white powder that is reactive with powdered metals, acids, organics (such as skin), nitrogenous substances, alcohols and other reducing agents. HTH is not combustible on its own, but can readily cause fires and explosions as a result of chemical mixing. Corrosive when exposed to moisture.	Sodium hypochlorite or liquid bleach is a clear or yellow liquid that usually comes in 4.5% (Javex) and 12.5% concentrations. Reactive with powdered metals, acids, organics, nitrogenous substances, alcohols and soaps. Corrosive, especially the 12.5% bleach. Degrades when exposed to temperatures above 21^{o}C. Non-combustible on its own.	Chlorine gas is greenish-yellow gas with a sickening odour. Stored as a compressed gas, it is extremely toxic and corrosive when in contact with moisture. Highly reactive with powdered metals, acids, hydrocarbons and nitrogenous substances. Non-combustible on its own.
Method of injection	Added to water to form a disinfecting solution that is added to the treatment stream.	Added directly to treatment stream.	Injected as a gas and dissolved into the treatment stream.
General Safety	Wear gloves, goggles, apron and particulate mask. Always add powder to water and never water to the powder.	Wear gloves, goggles, apron and mask.	Full self-contained NIOSH approved breathing apparatus, gloves, goggles and apron required. Never change gas tanks when you are alone. Never operate a gas chlorination system unless properly trained.
Shelf Life	1 year	3 months	Indefinite

10.4.1 CALCIUM HYPOCHLORITE

Calcium Hypochlorite is also known as HTH (High Test Hypochlorite). It is manufactured in a tablet, liquid, powder or granular form. Over time, HTH will lose its strength. It can lose up to 10% of its strength in a year.

Should it get wet, it will lose its strength much more rapidly. As it deteriorates it gives off heat. If it comes in contact with an oily rag or cardboard, a fire could result. HTH must be kept dry and separate from other materials.

FOR YOUR OWN SAFETY

Water should be first placed in the mixing barrel and then the HTH should be added. HTH should never be placed in the mixing barrel first and the water added, to avoid dangerous spraying or spilling of chemicals.

FOR YOUR OWN SAFETY

You must avoid contact with the HTH dust because it turns into an acid when it gets wet and it will burn your skin and your eyes. If you breathe it in, it will burn your nasal passages and your lungs. You must wear rubber gloves, a rubber apron, and nose and eye protection when you are working with the dry chemical or the mixed solution. There must also be a proper eyewash facility nearby.

To mix the dry powder for a 1% solution, it is placed into a separate mixing barrel.

The solution should be allowed to sit in the mixing barrel until a white coloured layer forms on the bottom of the barrel. This is a binding agent used to hold the chlorine in the powder form. Once the chlorine is in solution, the liquid above the sediment layer is slowly siphoned into the feed barrel. The sediment left in the mixing barrel should be thrown out because it will clog the chemical feed pump and the small tubing.

10.4.2 SODIUM HYPOCHLORITE

Sodium Hypochlorite is also known as liquid bleach. Two types are available: a high strength 12%; or regular strength 4.5% bleach (Javex or Purex are two trade names) available in any grocery store. Unlike HTH, bleach can be mixed directly into the mixing barrel without fear of clogging the pump or the tubing. Sodium hypochlorite deteriorates very rapidly (60 to 90 days), especially when exposed to light, and so it should be stored in a cool, dry, dark area.

FOR YOUR OWN SAFETY

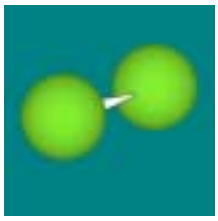
You must wear rubber gloves, a rubber apron, and nose and eye protection when you are working with sodium hypochlorite.

10.4.3 CHLORINE GAS

Chlorine gas a greenish-yellow with a penetrating and characteristic odour. It is 2½ times heavier than air. One volume of liquid chlorine, which has an amber colour, equals 450 volumes of chlorine gas. At -35°C it has zero vapour pressure. However, as the temperature rises so does the vapour pressure and at 20°C it is 565 kpa (82 psi) gauge pressure. This characteristic has to be considered when:

- Feeding chlorine gas from a cylinder, or
- Dealing with a leaking cylinder.

Chlorine gas molecule



Chlorine has a high coefficient of expansion. For example, a temperature rise of 25°C (from -5°C to 20°C) will increase the volume by approximately 85 per cent. Such an expansion could easily rupture a cylinder or line if it is full of liquid chlorine. This is the reason for the regulation that all chlorine containers must not be filled to more than 85% of their volume.

Chlorine by itself is non-flammable and non-explosive, but it will support combustion.

Figure 10-1 Properties of Chlorine

Greenish Yellow Colour
Heavier than Air
High Rate of Expansion
Moderately Soluble in Water
Non-Flammable and Non-Explosive
Supports Combustion at High Temperature

10.4.4 MIXING A 1% SOLUTION OF HYPOCHLORITE

A 1% chlorine solution is made by mixing hypochlorite with water as follows:

Hypochlorite Stock	Available Chlorine	Amount Stock + water
Bleach (Javex)	4.5%	25 litres + 100 litres
Sodium Hypochlorite	12%	10 litres + 120 litres
Calcium Hypochlorite	74%	2 litres + 130 litres (or 8 cups in 30 gallons)

Now assuming the demand plus the residual equals 2.0 mg/l, the 1% hypochlorite solution is injected into the water as the truck is being loaded at the rate of 900 ml per 4540 litres and then either increased or decreased to produce the correct residual

Why do you want to use a 1% solution for injection? There are four reasons:

1. You do not want water moving too slowly through the tubing or else the tubing will become clogged and you will have to do additional maintenance;

2. If the hypochlorite solution is too strong, you may have difficulty in controlling the residual as a very small amount of solution can make a big change in the residual;

3. You want to operate the pump within its operating range; if the hypochlorite solution is too weak, you will have to pump a lot of solution; this means that you may not be able to put enough in the truck during the fill cycle to get the residual you want; and

4. You will have to make up solution much more often, which will take you away from other duties.

From experience, a 1% solution seems to solve all these problems most of the time.

What if you have to add the hypochlorite directly from the bottle to the truck?

If hypochlorite is added directly from the bottle to each truck (make sure you add the hypochlorite before the truck is filled to ensure good mixing) and further assuming that the chlorine demand is 1.5 mg/l and you hope to achieve a 0.5 mg/l chlorine residual:

then either increase or decrease amount to produce the correct residual.

10.4.5 CALCULATING THE CHLORINE DOSE

Here is the mathematical equation so you can calculate the chlorine dose yourself. This general equation is the fundamental relationship of the conservation of mass, which means mass cannot be made or destroyed.

$$V_1 \times C_1 = V_2 \times C_2$$

Where: V_1 is the volume of liquid chlorine (litres)

C_1 is the chlorine concentration of the hypochlorite solution (*mg/L*)

V_2 is the volume of the final solution (for example 4500 litres)

C_2 is the chlorine concentration of the final solution (*mg/L*)

Example 1:

How much HTH powder do you have add to the mixing barrel to make a 1% stock solution?

Answer:

V_1 is what amount of HTH you are trying to determine.

C_1 is the concentration HTH - 74%.

V_2 is the volume of the mixing barrel - 130 litres

C_2 is the chlorine concentration of the final solution - 1%

Now you have a value for all but one of the factors in the equation.

Substituting in the general equation we get:

$$V_1 \times 74\% = 130 \text{ litres} \times 1\%$$

Note that your units are correct on both sides of the equation.

$$V_1 = \frac{130 L x 1\%}{74\%}$$

V_1 = 1.75 litres, say 2 litres for ease of measurement

Therefore, mix 2 litres of HTH powder in 130 litres of water to make a 1% chlorine solution.

10.4.6 CALCULATING THE CHLORINE DEMAND

Is it important to know the chlorine demand of your water? Yes. A high chlorine demand, say greater than 5 *mg/L* is an indication there may be some additional chlorine consuming material in the water which may lead to either a taste or some other problem. If this is the case, the Regional Environmental Health Officer should be notified.

The chlorine demand can be determined from the conservation of mass equation.

$V_1 \times C_1 = V_2 \times C_2$

Example: We add 250 millilitres of 4.5% bleach to each 4500 litre water truck. The chlorine residual is 0.5 *mg/L*. What is the chlorine demand?

Answer:

V_1 is 250 ml which is 0.25 litres

C_1 is the 4.5% bleach - recall this is 45,000 *mg/L*

V_2 is the volume of the truck - 4500 litres

C_2 is the chlorine demand plus the chlorine residual.

Therefore, C_2 is ? *mg/L* + 0.5 *mg/L*

Let's put brackets around this value so we don't confuse the + sign with an x sign.

(? *mg/L* + 0.5 *mg/L*)

Now substituting in the equation we get:

0.25 litres x 45,000 *mg/L* = 4500 litres x (? *mg/L* + 0.5 *mg/L*)

All the units are correct so we can rearrange the equation to solve for?

$$(?\,mg/L + 0.5mg/L) = \frac{0.25L \times 45{,}000mg/L}{4500L}$$

$$?\,mg/L = \frac{0.25L \times 45{,}000mg/L}{4500L}$$

? mg / L = 2.0 mg / L

Therefore, the chlorine demand for our example water is 2.0 *mg/L*.

10.5 REACTION OF CHLORINE

Chlorine is a compound that will react with many other compounds to produce many different products. These products complicate the process of chlorination because they use up some of the chlorine and thus reduce the chlorine available for the disinfection process.

Because the number and amount of compounds that complicate the disinfection process varies from place to place and from time to time, the amount of chlorine that must to be added is always changing. In addition, it takes a certain amount of time for a complete reaction of the chlorine with these compounds. The reactions generally proceed as follows:

1. *Chlorine first reacts with compounds such as hydrogen sulphide and iron. No disinfection occurs. This is the Chemical Demand on the figure;*

2. *As more chlorine enters the solution, it reacts with organic compounds to form chloro-organic compounds, which have a slight disinfecting action*;

Chlorine used in this way, in steps 1) and 2), is called the **chlorine demand**.

3. *Adding more chlorine will react with ammonia and other compounds containing nitrogen to produce chloramine, which have a disinfecting action which is slow and requires a long contact time*;

Chlorine used by this step, 3), is known as the combined **chlorine residual**.

4. *Adding chlorine, to a certain amount, will destroy the chloramine*.

This is called **break-point chlorination**.

Any excess chlorine added after that is known as *free residual chlorine*. A graph of these reactions is shown in Figure 10-2. Chlorine is measured as milligrams per litre (*mg/L*). To determine the needed dose of chlorine, the chlorine residual needs to be tested.

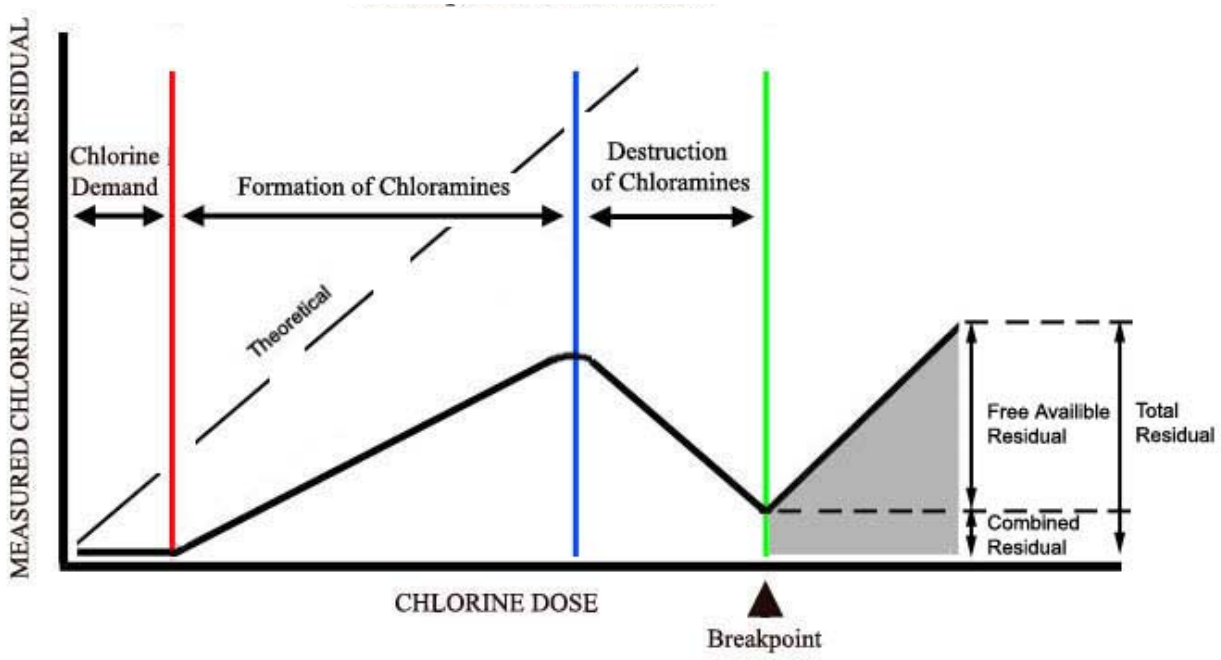
To treat water from a source that has been proven to be free of pathogenic organisms, the minimum free available residual is 0.2 mg/L. It is recommended as a best practice that the treated water be tested after a contact time of at least 2 hours (although 20 minutes is the legal requirement.)

For water supplies where it is uncertain whether pathogenic organisms are present of not, the minimum free available residual should be 0.5 mg/litre following a contact time of at least 20 minutes, however a contact time of a least 2 hours is again suggested as a best practice.

Chlorine residuals in excess of 0.5 mg/L do little to improve disinfection and can cause unpleasant taste and odour to the water.

In the N.W.T. we use residual chlorine to determine disinfection.

Figure 10-2 Breakpoint Chlorination



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Total Residual Chlorine = Combined Residual + Free Available Residual.

Chlorine Dose = Chlorine Demand + Total Residual Chlorine.

10.6 OTHER USES OF CHLORINE

While the principal purpose for chlorinating water supplies is disinfection, it serves other purposes:

- Control of taste and odour problems when free or combined residual chlorination is practiced. If too little chlorine is added, the taste and odour problems may become severe; and
- Oxidation of manganese, iron, nitrites, and ammonia; the destruction of phenols; and the removal of algae and slime growth.

Nitrogen containing organic impurities normally found in swimming pools, body oils, suntan lotions, perspiration, etc is removed by the oxidative properties chlorine. Paradoxically, it is this very action that has given rise to a misconception that has caused many people to believe that the use of chlorine to sanitize swimming pools and drinking water invariably results in a strong "chlorine" odour. When such odours are present, they believe "too much" chlorine has been used.

In fact, the odour is not inevitable and its presence indicates that too little chlorine has been used rather than too much. This is because the odour is actually due to the incomplete oxidation of the nitrogen containing impurities. All of these substances contain proteins that combine to form chlororganics and chloramines. It is these compounds that cause objectionable odours and, in the case of swimming pools, eye irritation. Remaining chlororganics can be removed by adding chlorine past the breakpoint.

10.7 REVIEW

1. What is a free residual?

2. What is meant by breakpoint chlorination?

3. Besides disinfection, what are some of the other roles of chlorination?

4. What are some of the concerns of adding too much chlorine?

11.0 SAMPLING

11.1 OBJECTIVES

The trainee will be able to:

1. Know how to do bacteriological sampling;
2. Know how to do chemical sampling; and
3. Know why sampling is important.

11.2 TYPES OF SAMPLES – REPRESENTATIVE SAMPLES

Errors in sampling can lead to costly and potentially dangerous decisions. Sample volumes are minute in comparison to the volume of water they are taken to represent. The goal of representative sampling is to have the one litre sample removed from the 1,000,000 litre sample site be identical to the 999,999 litres that remain. In practice, the sample may not be a perfect representation, but its results can be used to make competent, cost effective decisions.

There are two types of samples:

- Grab samples – discrete, depth integrated; and
- Composite samples – time dependent, flow proportional.

There are several factors to consider when taking a representative sample:

- Is the water at the site homogeneous?
- How fast do the conditions change?
- Are there daily or seasonal fluctuations?

Many sites can be sampled according to the following categories:

Table 11-1 Representative Samples

Sample Site	Representative Sample	Frequency
Deep well	Discrete grab	Once a year
Shallow well	Discrete grab	Summer, winter, spring – more frequently if influenced by surface water,
Deep lake	Depth integrated grab	Summer, winter, spring
Shallow lake	Discrete grab	Summer, winter, spring
Flowing river	Discrete grab	Monthly, more frequently during freshet
Treated Drinking Water for Compliance	Discrete grab	As required by the EHO
Treated Drinking Water for Due Diligence	Discrete grab	As required by conditions and your confidence in and knowledge of the system.

11.3 BACTERIOLOGICAL SAMPLING

Bacteriological Sampling is done to make sure drinking water is free of harmful bacteria. If the water is contaminated the Environmental Health Officer (EHO) will issue a “Boil Water” order to all community residents.

The Environmental Health Officer will help to make sure that your community water supply is safe. You should discuss your water supply system and sampling program with this key member of your team as often as you can. He or she sets the number of times that the water samples must be collected. For most small communities in the Northwest Territories, the water supply is sampled and analysed every week. There is also a sampling program for chemical parameters.

You are responsible as a professional for making sure the sampling is done at your plant. You may be able to ask someone else, such as the public health nurse to take the water samples but it is you who is responsible.

For communities with less than 5,000 people water samples should be collected as least once a week at the following locations:

Trucked System

- Raw water supply
- Treated water at plant
- Water truck
- Individual holding tank

Piped System

- Raw water supply
- Treated water at plant
- Distribution system as specified by the Environmental Health Officer

In order to get reliable results when taking water samples you must use proper techniques and be very careful. You do not want the sample to include something other than the water itself. If it does, it's possible that the tests will show the water as contaminated, thus you must wash and dry your hands before touching the bottle. Even though you have washed your hands, there still may be bacteria present. Once you have removed the bottle cap do not touch the mouth or inside edges of the bottle and do not let the surface of the bottle cap touch anything. If it touches something, this small amount of contamination could cause an error in the test.

If contamination is found in the water you should contact the Environmental Health Officer, (even if error is suspected). The Environmental Health Officer will issue a "Boil Water Order" until new samples can be taken to prove the water is safe. A Boil Water Order is a very serious event that can cause a lot of embarrassment for the community if issued as a result of an error.

There are seven important parts to the process of sampling.

1. Wash your hands. You could, without even knowing, contaminate the water sample.
2. Put on a new pair of disposable latex surgical gloves. Make sure they are the powderless kind.
3. Take the sample at the time called for. For example, chlorine residual must be taken after at least 20 minutes has passed to ensure a minimum contact time. If you take the sample too soon, you will get an incorrect result, and you could end up putting too much chlorine into the water.
4. Use the correct sample bottle. The bottles must be sterile. The bottle you should use should contain a solution of sodium thiosulphate which will neutralize the effects of

the chlorine. If chlorine remains in the solution, it will continue to kill bacteria and the sample will give a false reading. **DO NOT rinse** the bottle.

5. If the samples are from a tap, the tap should be run for at least two minutes before the sample is taken to flush water that may have been standing for a long time from the pipes. The bottle cap is removed just before the sample is taken and replaced immediately after. The bottle is held under the tap and slowly filled until the level almost reaches the top. Do not over fill the bottle; maintain a small air space.

   A sample can be taken from one of two different sources and the sampling procedure is different for each one: if the sample is from a lake, a river, or a reservoir, the bottle is held below the surface until it is almost full. The cap is replaced to leave a small air space. Do not hold the bottle under the water with your hand. The bottle should be attached to a stiff copper wire. When taking bacteriological samples the wire can be heated with a flame to ensure that it is sterile.

6. Complete a sampling record form for each sample bottle and make sure that the bottle and the form are cross-referenced or even tied together. It is important to know where each and every sample came from.

Contact your Environmental Health Officer for details on sample points and sampling information for your community.

7. Ship the sample to the laboratory in the approved container with ice packs to ensure a constant, cool temperature. It must arrive at the lab and the test started within 24 hours for the results to be meaningful. Sometimes samples are simply returned to the nursing station. Each community is different so make sure you know what to do with the sample before it is collected.

Specific procedures for sampling should be confirmed with your local Environmental Health Officer. The above procedures are meant as a guide and are not meant to supersede any present or future changes in sampling procedures.

For your safety

Wash your hands before and after doing any bacteriological testing. Gloves should be worn at all times with doing the test. Ensure that you don't touch any part of your face while doing the tests.

11.4 CHEMICAL SAMPLING

Chemical samples are supposed to be taken annually until there are three consistent years of data with no exceedances, at which point sampling can be done once every two years and confirmed with your EHO. Water samples are normally taken of the untreated water, and the treated water.

The treated water is taken because the chemicals used in the treatment process can form with compounds in the water to make undesirable chemicals. Or, water treatment chemicals can leave residuals (such as too much aluminum) in the finished water above desirable levels.

Samples are taken in much the same way as for bacteriological samples except the 24 hour limit is not required for most parameters. Because this type of sampling is not done routinely, detailed sampling instructions usually come with the sample bottles. Do not take any samples until you have read the instructions.

11.4.1 LABORATORY REQUIREMENTS

Not all laboratories use identical analytical methods. Therefore, each laboratory will issue instructions on how which type of sample bottle to use, how to preserve the sample if required, and how to store and ship the sample. Before taking any sample, call the lab you intend to use for instructions.

Many samples must be kept cold. The laboratory should provide ice packs with their coolers.

11.5 REVIEW

1. Why do you wash your hands before taking a water sample?

2. What differences are there between sampling from a tap and sampling from a river?

12.0 RECORDS

12.1 OBJECTIVES

The trainee will be able to recall the following.

1. The main reasons for maintaining plant records.
2. The required entries that should be recorded on the daily operating sheets.
3. The information recorded in the maintenance log book.
4. Information, which can be obtained by an analysis of:
    a) Daily operating sheets; and
    b) Maintenance Log Book.

12.2 PURPOSE

Obtaining and recording information is not an end in itself. Process control test results, together with such data as flow rates, power consumption, quantity of chemicals used, hours of pump operation, recorded in an understandable (and easy to use) form must be analysed so that the present and future operating requirements can be met.

Records provide the means of ensuring proper maintenance schedules are adhered to. They provide a basis for justifying plant expansions and provide the information by which design changes can be instituted.

Notwithstanding the overall importance of records, only those that can be useful should be maintained. Records for records sake means a waste of time and labour to the detriment of some more important task.

The main purposes for the establishment and maintenance of a system of records are as follows.

1. Assist the operator in solving plant problems.
2. Provide evidence that the plant is meeting the water quality objectives (due diligence).
3. Provide the basis for handling complaints.
4. Determine equipment, plant and unit process performance standards.
5. Plan equipment replacement schedules, design changes and plant expansions.
6. Establish a cost base.

12.3 RECORD SYSTEMS

Record systems must be set up with two objectives in mind. Firstly, it must be as simple as possible, the form and extent of records being carefully planned. Secondly, a procedure must be established to ensure continuity of the desired records.

Records should be permanent, with entries made in ink or indelible pencil. Ordinary lead pencil notations smudge easily or can be altered. Once a record has been made, it should be filed in such a manner that it can be easily retrieved.

12.3.1 PLANT OPERATIONAL RECORDS

The data which is recorded at an installation will be determined by the type of treatment plant, the volume of water treated and the kind of installations tied in with the treatment plant.

Appropriate record sheets can often be found in O&M Manuals and GNWT's Maintenance Management Operation System that should be provided at your plant.

Records of treatment plant operation may include information on:

- Filter runs;
- Wash water used;
- Pumps in operation;
- Chemical dosage including chlorination rates;
- Condition of raw and treated water;
- Flows;
- Power consumption;
- Results of laboratory tests; and
- Amount of chemicals used.

12.3.2 SOURCE RECORDS

Records should also be maintained for the water source(s). If it is a surface source, information on the following items should be maintained:

- Raw water temperature;
- Raw water quality (turbidity, colour, taste & odour);

- Raw water quantity used; and
- Level of water in river, stream or lake.

If the source is groundwater, information recorded should include:

- Raw water temperature;
- Raw water quality;
- Well logs;
- Pumping intervals;
- Static levels;
- Drawdown levels;
- Rate of replenishment; and
- Quantity of water used.

12.3.3 ACCOUNTING RECORDS

All accounting records may not come under the jurisdiction of the plant operator, but information that includes inventory control, costs of maintenance and time or payroll data does. The payroll records are highly important to the operator. If they are not accurate, and are not submitted to central accounting on time, he will receive complaints.

With the development of computer accounting, many of the major accounting records are maintained electronically. Later, they can be used for billing procedures and collection data.

12.4 MAINTENANCE LOG BOOK

Records should be kept in a ring binder logbook. Each piece of equipment has a separate page in this book, with the following information recorded.

1. Work done.
2. Time spent.
3. Costs for any piece of equipment.

The accuracy, usefulness and reliability of the maintenance system depend upon the conscientious completion of this log book.

Information which can be obtained by analyses of records in a log book:

- Comparison of existing equipment;
- Major equipment faults and problems;
- Evaluation of the maintenance system;
- Evaluation of maintenance and reliability of equipment as a basis for selection of future equipment;
- Evaluation and comparison of maintenance costs for equipment;
- Measures of performance and effectiveness of equipment and maintenance; and
- Information for discussions with suppliers and the provision of "feedback".

Any preventive maintenance system is only a part of the overall maintenance function; its application must be reviewed with this in mind. An evaluation of the success or deficiencies of the preventive maintenance scheme can be obtained only if total maintenance data is recorded.

The costs of preventive maintenance and breakdown maintenance must somehow be minimized. To achieve this, complete maintenance data must be available.

There is no magical mathematical formula to establish how much maintenance should be done. Whenever treatment is incomplete, the question to be asked is "has enough maintenance been done to prevent equipment failure?"

Not only does poor service annoy the consumer, but all water treatment operators and maintenance personnel have a moral responsibility to ensure that the total environment, water quality and service are not impaired.

12.5 DAILY LOG BOOK

Another useful record is the diary or daily log book. Many miscellaneous incidents in plant operation do not fit into the regular records, but they should be kept in some type of permanent form and might include:

- Numerical data and measurements;
- Maintenance items, replacement and repairs;
- Start-ups;
- Trouble, and various methods tried for correction, in start-ups or treatment;
- Complaints from customers;
- Visits by officials and their comments;

- Reports from other agencies (such as the Department of Health and Social Services) on inspections and tests; and

- Similar facts that an operator always appreciates having on hand.

This information may be quickly referred to if the daily summary sheet of operation contains a cross-reference. Knowledge of the date of an occurrence, even without further detail, is often helpful.

The records you keep will depend on the type of plant you operate, the amount and category of information you need to answer enquiries, and any information that will help you to operate the plant efficiently and economically.

Remember that the most important concepts in record keeping are accuracy and continuity. Plant records and log books are your proof of the work that you do. The more accurate information you record in them, the better you will be able to diagnose and deal with problems arising at your plant. Not only that, but your records and logs are legal documents and are your proof that you are doing your job properly.

The following three examples (Figures 12-1, 12-2 and 12-3) are of typical log sheets that where extracted from a typical plant O&M manual. The first example is a typical log sheet for use in chemical mixing and dosing. The second example is a chemical quality sample log sheet used to monitor product water quality. Your logs sheets will most likely be similar, but different nonetheless.

12.6 REVIEW

1. What are the main reasons for maintaining plant records?

2. What are the required entries on daily operating sheets?

3. What information is recorded in a maintenance log book?

13.0 SAFETY

13.1 OBJECTIVES

The trainee will be able to:

1. Name three personal hazards common to treatment plants;
2. Recall the safety measures to follow when working in or around:
    a) Wet Wells;
    b) Chlorine Buildings;
    c) The Laboratory; and
    d) Plant and equipment during servicing.

13.2 INTRODUCTION

The dangers associated with plant operations emphasize the need for safety practices. Physical injuries and body infections are a continuous threat and occur with regularity. Explosions and asphyxiation from gases or oxygen deficiency do occur. Although rare in the North, country-wide such accidents happen daily.

Water treatment plant occupational hazards may be largely avoided by following safe practices and the use of safety equipment. The dangers are many and carelessness happens all too frequently until an accident happens. Then it is too late.

It is the responsibility of supervisors to get to know the hazards associated with plant maintenance and operation and to take steps to avoid them. Accident prevention is the result of thoughtfulness and the application of a few basic principles and knowledge of the hazards involved.

It has been said that the ABC of accident prevention is "Always Be Careful". One must learn how to be careful and what to avoid.

13.3 WORKERS COMPENSATION BOARD

With safety, the ultimate requirements and regulations come from the Workers Compensation Board (WCB) of the Northwest Territories and Nunavut. Know the regulations as applicable to your job and employ them in your everyday work. The WCB maintains a vast library of Operational Health and Safety manuals, which are at your disposal. The information on how to retrieve these manuals can be found on their website which is included in Addendum F.

13.4 CONFINED SPACES

A space is strictly defined by the NWT's *Safety Act* as a "bin, pipeline, pit, sewer, silo, tank, tunnel, utilities vault, vat, vessel or other enclosed or partially enclosed space having restricted access and egress and which, owing to its design, construction, location, atmosphere, the materials or substances in it or other conditions, is or may become immediately dangerous to the life of health of a worker required to enter it".

Confined spaces can be very dangerous areas in which to work and therefore, special training and certification is required that is separate to this course. You cannot work in a confined space unless the oxygen content is more than 18% under normal atmospheric pressure and the area is free of respiratory contaminants, unless some sort of WCB approved respiratory device is provided. Atmospheric tests must be done in advance to entering the space. In addition, proper rescuer equipment must be available as well as another person in order to assist you if required.

For more information on working in confined spaces as applicable to water treatment, consult with the WCB and the NWT's *Safety Act.*

You <u>cannot</u> work in a confined space unless you are properly trained to do so and have assured the necessary safety measures to work safety.

13.5 HAZARDS

The overall dangers of accidents are much the same whether in manholes, pumping stations or treatment plants. These result from:

1. Body infections;

2. Physical injuries; and

3. Dangerous noxious gases or vapours, oxygen deficiencies and hazardous chemicals.

13.6 BODY INFECTION

Workers in treatment plants are exposed to the hazards of water-borne diseases, including typhoid fever, amoebic dysentery, infectious jaundice and other intestinal infections. Tetanus and skin infections must also be guarded against. Typhoid and tetanus inoculations are recommended. These may be obtained free of charge from local Health Officers.

A majority of infections reach the body by way of the mouth, nose, eyes and ears. Therefore, washing your hands is a must before eating or smoking. Wear protection gloves where possible.

This hazard to plant personnel, although very real and ever present can be largely reduced by the operator himself by following a few basic rules of personal hygiene. A few of these self applied rules are as follows.

1. Never eat your lunch or put anything into your mouth without first washing your hands.

2. Refrain from smoking while working in open tanks, on pumps, or cleaning out grit channels, etc. Remember you inhale or ingest the filth that collects on the cigarette from dirty hands. Save your smoking time for lunch hours or at home.

3. A good policy is "never put your hands above your collar when working on plant equipment".

4. Rubber or rubberized cotton gloves, rubber boots and coveralls are designed for body protection against dampness and contact with dirt. Wear them at all times when working in tanks, etc.

5. Rubberized or rain suits can be worn in very wet or dirty places and can be washed off with a hose and brush, the same as rubber boots.

6. Always wear your rubber boots when working in tanks, washing down etc., don't wear your street shoes.

7. Don't wear your rubber boots or coveralls in your car or at home. You could bring more home with you than you think.

8. Always wear rubber or plastic coated gloves when cleaning out pumps, handling hoses, etc.

9. Don't just wash your hands before going home, wash your face too, there is as much of your face to carry germs as there is of your hands. Soaps that don't need to be rinsed off are also available, if you find they are more convenient.

10. Wear a hat when working around sludge tanks, cleaning out grit and other channels, don't go home with your head resembling a mop that just wiped up the floor around a cleaned out pump.

11. Keep your fingernails cut short and clean, they are excellent carrying places for dirt and germs.

13.7 PHYSICAL INJURIES – FIRST AID

Except for minor injuries, wounds should be treated by a doctor and reported for possible Workers' Compensation. Service trucks and plants must have first aid kits. It is recommended that all plant personnel should receive accredited first aid instruction.

It is a WCB regulation that any plant having five (5) or more people working as a group on any shift, one of them is required to be certified in first aid. Remember, no cut or scratch is too minor to receive attention.

13.8 THE PLANT SAFETY PROGRAM

Before starting a safety program, the full co-operation and active support of management is needed. One person in the utility organization must be responsible for the program. In a small water works system, that person may be the superintendent, while in a larger organization, another person who can devote part or full time to the job can be appointed.

The next step in setting up the program is to provide for:

1. Keeping injury records;
2. Identification and location of the hazards;
3. Making equipment, plant arrangements and working methods safe;
4. Getting employees interested in safety; and
5. Controlling work habits

13.8.1 INJURY RECORDS

The keeping of injury records is basic to a safety program. With complete records, the program is given direction and is sure of success. The records should be kept brief but must contain all pertinent data. The forms should cover such items as:

- Accident report;
- Description of accident;
- Physician's statement;
- Corrective action taken;
- Accident analysis chart; and
- The names of all the people involved in the accident and who performed first aid.

13.8.2 LOCATING THE HAZARDS

The person responsible for the safety program should be constantly on the alert for hazards which may cause an injury to an employee. One of the best methods of attacking this problem is

to search the records for the conditions and situations that have produced injuries. Records like this show the need for a corrective program.

Many other sources of information on hazardous conditions are available. These include safety manuals, insurance company brochures, etc. They should be used freely and frequently.

13.8.3 EQUIPMENT, PLANT ARRANGEMENTS, WORKING METHODS

Nothing prevents an accident as effectively as the elimination of the cause. To preach safety while permitting unsafe conditions will discourage the cooperation required from employees. Only when safety is integrated with the job are workers convinced accidents will be prevented.

13.8.4 PROTECTIVE SAFETY EQUIPMENT

The need for protective safety equipment in an accident prevention program has proven its value many times; the program cannot be successful if any phase of accident prevention is overlooked.

Use safety equipment as was it meant to be used. This should be compulsory during the performance of hazardous jobs.

Protect eyes and face when there is any possibility of injuries from hand tools, power tools, welding equipment, etc.

Protect feet with safety shoes to safeguard against injuries while breaking pavements, tamping trenches, handling materials, etc.

Protect head (with hard hats) to prevent serious injuries in construction, excavation or electrical work.

Protect hands (with gloves) to prevent injuries from occurring when handling materials, sharp objects, chemicals or electrical equipment.

Use air packs when hazards such as chlorine, painting or dusty areas exist.

Prevent accidents due to falls by using safety belts, scaffolds, etc.

Be aware of and follow the WCB Safety Regulations as they apply to protective equipment.

13.9 GENERAL PLANT SAFETY

When working at the plant, observe the following common sense rules.

- Keep walkways clear of loose objects such as pails, shovels, loose rope, etc.
- Wipe up grease and oil immediately; salt or sand icy walks.

- Pick up all tools, clean them and return them to their storage area.
- When it is necessary to use tools in an empty tank or manhole, etc., lower them in a pail on a rope and remove them in the same way brooms and shovels can also be transported by rope. Do not attempt to climb up and down ladders with your hands full of tools. Regulations for confined spaces should be followed as applicable.
- Do not overload yourself when using stairways. Keep your load small enough to be able to see over it. Always keep one hand free to use the hand-rail.
- Do not try to climb up or down a ladder or over a railing when handling a hose under pressure.
- Always wear hip wader rubber boots with good treaded soles when washing down the floor of any tank. Do not wear rubber boots with worn soles and heels. Again, regulations for confined spaces should be followed as applicable.
- Always wear the rubber clothing provided when working in a narrow or confined passage where grit or sludge accumulates.
- Always wear rubber or plastic coated, waterproof gloves when cleaning pumps, handling hoses, removing grit or sludge, etc.
- When it is necessary to use an extension ladder to enter any empty tank, use the collector arms in the clarifiers to backstop the ladder legs. In an aeration tank, lash the ladder. Enter the tank from a walkway (not from a narrow dividing wall) and always lash the ladder to a hand-rail.
- Always wear hard hats when working below ground level (in tanks, manholes, etc.) or under scaffolding. Again, regulations for confined spaces should be followed as applicable.
- Maintain signs identifying particularly hazardous areas and the location of first aid supplies.
- Do not hang clothes on electrical disconnect handles, light switches or control panel knobs.
- Replace all manhole covers and trap doors to wells. Close after using. If it is necessary to leave them open, protect them with guard-rails.
- Use the proper tool when removing or replacing manhole covers. Do not attempt to move or close a manhole cover with your hands.
- Do not pull up grit-filled pails by hands only when removing from tanks or wet wells. Use rope with an "A" frame and pulley or some other type of support with a pulley. Be sure the support and pulley are fastened firmly to prevent them from toppling over during use.

- Always wear a safety belt with a short rope and a safety snap when leaning out through the railings over any tank (or cleaning out spray nozzles, etc.)
- Be very careful during repair work on fuel systems of gasoline engines. Close the shutoff valve from the tank and be sure there is adequate ventilation while draining the fuel system.
- Check the ventilation of any enclosed or underground areas when gasoline operated pumps are to be used.
- Do not refill a gas engine when in operation or while still hot. Lock out engine before cleaning out pump unit.

13.9.1 BUILDING MAINTENANCE

Periodic inspections are necessary to eliminate hazards (fire safeguards, etc.). Suggested repairs for safety should receive immediate attention. Floors, hallways, and stairways should always be well lit, clean, orderly and free from oil, dirt and debris. Immediate repairs of hazardous electrical outlets and fixtures should be routine. Adequate sanitary facilities for employees must be provided. Hand-rails on steps and stairways should always be provided and used. Good housekeeping must be maintained.

13.9.2 HAND TOOLS

Hand tools are the cause of many accidents and injuries when improperly used and in unsafe condition. Therefore, use the right tool for the right job in the right way.

Use protective safety equipment where there is a job hazard. Keep the work area clear of hazards, with plenty of working space for solid footing. Tools should be in good condition and used for the purpose for which they were intended.

13.9.3 PORTABLE AND POWER TOOLS

All equipment should be grounded. Check wiring and equipment regularly for defects. Be very careful when using equipment in wet areas. Use protective safety equipment when operating grinders, buffers, or other tools when there is danger of flying material.

13.9.4 TOOLS AND MACHINES

Use protective equipment when operating power equipment if there is any chance of flying objects or other injuries. Inspect all tools and equipment for safe operation. Necessary repairs or replacements should be made immediately. Repair power tools and machinery only when the equipment is turned off.

13.9.5 WELDING

Use the proper protective equipment at all times. Check for fire hazards before cutting or welding in areas of inflammable or explosive mixtures. Only authorized personnel should operate welding equipment. Occupational Health & Safety regulations require a 2 3/4 lb. fire extinguisher be fastened to the welding truck.

13.9.6 INSPECTIONS OF TOOLS AND EQUIPMENT

Periodic inspections should be made of tools and equipment so that those that are broken or worn out may be replaced. Report worn or broken equipment and be sure they are replaced or repaired as soon as possible.

13.9.7 LADDERS

Ladders should be inspected periodically and maintained in good order. Use safety belts when awkward positions are necessary for the work. Do not use metal ladders for electrical work.

13.9.8 LIFTING

Always lift with the leg muscles instead of the back and be sure your footing is secure. Bend your knees and keep your back straight. Don't turn or twist your body when lifting. Get help if load is too heavy or awkward to handle. Use a mechanical device for lifting wherever possible.

13.9.9 SANITATION

Washrooms, toilets, locker rooms, drinking fountains and showers that are clean, ventilated and adequately built are good for employee morale. Clean drinking water and paper cups should be available at each plant, especially if the employees are exposed to skin irritant materials.

13.9.10 STOREROOMS

Good housekeeping must be maintained at all times. Space should be well arranged to permit proper storage, handling and movement of materials. Inspections should be made regularly for fire hazards. Fire extinguishers should be in good order and easily accessible.

13.9.11 WORKING AREA

A safe working area must be provided for efficient work. In the field, traffic should be controlled by the use of traffic cones, barricades, flags, etc., to protect the workmen as well as the public. In the material yard and storerooms, good housekeeping and properly planned storage and work areas must be provided for safe working practices. Shops, plants and offices should be planned for the most efficient production.

13.9.12 TRUCKS AND EQUIPMENT

Routine inspections of trucks and equipment should be made. Any need for repairs should be reported and acted on as soon as possible. Only qualified and licensed operators should be permitted to use and operate vehicles and equipment. Never permit riders on trucks or other mobile equipment. Check electrical and any other hazards constantly when moving heavy equipment. All trucks should be equipped with first aid kits, fire extinguishers, and flares.

13.9.13 BARRICADES AND TRAFFIC CONTROL

An adequate and safe work area must be protected. Sufficient traffic cones and barricades should always be carried by crews assigned to construction or maintenance work in streets. Paint barricades bright, visible colours and keep them in good condition. Be sure warning signs, flags, flares are adequate and in positions where they can be easily seen.

13.10 EQUIPMENT SERVICING

When servicing plant and equipment:

1. **DO NOT** grease or oil or attempt to service any machinery while it is in operation. Pumps on automatic control must be locked out and key carried by the operator during servicing.

2. **DO NOT** make any adjustments to operating machinery while alone. If it is necessary to run the unit to adjust it, a second person must be present and be beside the stop and go switch.

3. **DO NOT** work around electrical panels, disconnects or switches alone.

4. **DO NOT** enter any crawl space under flooring for any purpose until the area has been ventilated. A second person should be present. Regulations for confined spaces apply here.

5. **DO NOT** service pumps and shafts in the dry wells of pumping stations, and in plants where the pumps and shafts are less than three feet apart, without shutting off all pumps and locking them out.

6. **DO NOT** under any circumstances, attempt to grease or service pump shafting while standing on beams, piping, loose planks, guard rails, or by leaning out; over or through guard rails. If a ladder must be used, then a second person must be present to hold the ladder steady and to provide any other assistance.

13.11 PRECAUTIONS FOR ELECTRICAL MAINTENANCE

1. Plan safety into each job. Orderliness and good housekeeping are essential for your safety and the safety of others.

2. Each employee shall be qualified both in experience and general knowledge to perform the particular electrical work, which he is assigned. Outside contractor may have to be called in if not qualified.

3. Study the job carefully to determine all of the hazards present and to see that all necessary safeguards and safety devices are provided for safe working conditions.

4. Examine all safety devices before they are used to ensure that they are in good condition.

5. In all cases where work is being performed on or close to live conductors or equipment, at least two men shall work together. When it is necessary for one to leave, the other workman shall not continue the work until the first man returns.

6. Consider the results of each action. There is no reason for you to take chances that will endanger yourself and others.

7. Satisfy yourself that you are working under safe conditions. The care exercised by others can not be relied upon.

8. Wear close fitting clothing, keep sleeves rolled down, avoid wearing unnecessary articles while working on or close to live circuits or apparatus.

9. Use only approved types of rubber or leather gloves.

10. Protect yourself by placing an insulated medium between you and ground or grounded apparatus to keep any part of your body from providing a path for electrical current when working on conductors or apparatus that may be energized.

11. Use rubber mats when working on any electrical control panel or switch and disconnect boxes.

12. Open and close switches completely with a firm positive motion. Switches in a partly open position may arc or cause a flash-over with damaging results to the switch and possible injuries to the operator.

13. Open switches fully before removing fuses. To remove a fuse from a circuit carrying a current without opening the switch is particularly hazardous. Use an approved low-voltage fuse puller to remove fuses on a circuit of less than 500 volts (where no switch is provided) whether a disconnect is provided or not. Remove fuses by breaking contact with the hot side of the circuit first. Use the reverse procedure when replacing fuses. Insert the fuse in the cold terminal first.

14. Do not stand directly in front of panel to remove fuses or shut off disconnects.

15. Shut off the power when examining or making repairs or alterations on light and power circuits. When this is impractical Head Office must be contacted for further instructions before proceeding with the work.

16. Consider all electrical circuits to be dangerous. Treat dead circuits as though they were alive. This may prevent an accident as the circuit may be closed through an error of some other person.

17. Exercise extreme care when required to locate troubles on a series lamp circuit, before repairs are made make sure the power is cut off.

18. Lock or block open the control devices, open disconnect switches or remove fuses before examining, repairing or working on power circuits. After these precautions have been taken, attach tie-up tags worded "WORKERS ARE WORKING ON LINE." The tag shall bear the name of the workman. Tie-up tags shall remain on the opened devices until removed by the workman whose name appears on the tag. If the workman leaves without removing his tag, it may be removed only on authorization of Head Office.

19. Before working on line circuits at a point remote from the control switch, which has been tagged, it is recommended that the conductors be grounded at a point on the line between the switch and the work station.

20. Make a complete check of the circuit before applying power for the first time. This is to be done by a qualified man in charge of the-repairs, all other workmen to stand off at a safe distance.

13.12 FIRE PROTECTION

Good housekeeping is the basis for fire prevention. Inspections should be made periodically and correction of fire hazards should be made as soon as possible. Consult local fire departments for recommendations. Operators should know the fire suppression methods needed to treat the three types of fires.

Each operator should have first hand knowledge of fire extinguisher, its ABC rating point of contact and time of operation.

A CO_2 fire extinguisher can only be used in an open area where the chance of using up the local oxygen is minimal. Never grab the horn of the extinguisher to direct the CO_2. The gas being expelled will freeze your hand to the horn causing serious injury. There is a handle provided.

Do not direct the CO_2 at anyone. To fight the fire you must approach the fire from upwind, pull the pin and aim directly on the burning area.

Table 13-1 Types of Fires and Method of Extinguishment

Type of fire	Symbol	Types of extinguishers to use
Class A: Ordinary combustible materials, such as wood, cloth, paper, etc.		• ABC Fire Extinguisher • Water
Class B: Flammable liquids, such as oil, gasoline, kerosene, etc.		• ABC Fire Extinguisher • BC dry chemical • Carbon dioxide
Class C: Presence of energized electrical circuits (e.g., electronic motors, electrical wiring, etc.)		• ABC Fire Extinguisher • BC dry chemical • Carbon dioxide
Class D: Fires resulting from combustible metals such as magnesium, sodium and potassium.		• Special Class D fire extinguisher containing sodium chloride or copper, also referred to as a Metal-X extinguisher. **Note**: Never use a Class D fire extinguisher of an A, B or C fire.

Table 13-2 Application Times for CO_2 Fire Extinguishers

Type	Application Time	Max Area (ft^2)	Type of Fire
2½ lb.	10s ± 2s	2	B, C
5 lb.	14s ± 2s	4	B, C
10 lb.	14s ± 3s	6	B, C
15 lb.	25s ± 4s	8	B, C
20 lb.	30s ± 4s	8	B, C

Note: B, C indicates electrical, gas, oil type fires. Weight indicated refers to contents only.

A Dry Chemical extinguisher can be used in any area. Approach from upwind and pull the pin, you do not have to stand as close to the fire as with CO_2. Dry Chemical will put a blanket of chemical over the fire, smothering it.

Note:

1. All extinguishers must be refilled after using no matter what amount has been used.

2. All extinguishers must be hydrostatically tested every five years.

13.13 CHEMICAL HANDLING AND STORAGE

The Occupational Health and Safety Act states that the employer is responsible for providing the necessary protective equipment and clothing for handling dangerous materials. It is the responsibility of the employee, both to his employer and to himself, to use and maintain them.

Eyewash fountains and deluge showers must be located within 4.6m (15ft) of the entrance to any chemical handling area. Plenty of water should be available for washing up after handling chemicals. Protective clothing should be washed after use.

All areas where solvents or other compounds are used and stored must be well ventilated. The working area must be designed and constructed for the safety and convenience of the worker and for his efficient production. The ventilation should be by mechanical means with the air intake drawing air from the outside. In rooms where lime and other dry types of chemicals are used, install dust accumulators in the air discharge pipe.

Operate exhaust fans when handling any chemical whether liquid or dry.

Wear rubber boots, apron, gloves and eye shield or goggles when handling liquids. Wear nose and mouth filter masks and goggles when handling dry chemicals.

13.14 LABORATORY

1. A thorough knowledge of first aid for dealing with lab accidents is essential. Know the relevant sections of the antidote chart.

2. Wear protective clothing.

3. Practice good housekeeping. Keep all unnecessary equipment out of working areas. Use a separate marked container for broken glass.

4. Areas around sinks and taps should be kept clear so that chemicals spilled on one's hands or person can be washed off quickly.

5. Wipe up all spills immediately.

6. All reagent bottles must be clearly labelled so they can be identified. The date when the reagent was made up, or received, should be on the label since some chemicals, particularly nitrogen compounds, become unstable with age.

7. When diluting concentrated acids or bases, always add slowly to the water allowing time to cool. Use only heat resistant (Pyrex) glassware. When diluting sulphuric acid or when making up a solution of sodium hydroxide, cool the solution in a water bath.

8. Chromic acid cleaning solution is a mixture of sodium or potassium dichromate in concentrated sulphuric acid. It dehydrates and oxidizes most organic matter, including clothing. TREAT IT WITH CARE!

9. Use water as a lubricant when making glass to hose connections. For vinyl tubing, hot water can be used to make the plastic more pliable. Gloves should be worn when making hose connections to glass tubing.

10. Suction bulbs should be used on all pipettes. A valved type sold as a "PROPIPET" will save fumbling. NEVER USE YOUR MOUTH TO PIPETTE!

11. Combining chemicals found in the laboratory without knowing how they will react can produce unexpected and unpleasant results.

12. When disposing of any chemical in the sink, dilute with plenty of water.

13. Bottles of hazardous liquids should be stored near floor level in ventilated cupboards.

14. HASTE MAKES WASTE and accidents. Planning can save far more time than hurrying and produces fewer mistakes.

13.15 SAFETY PRACTICES IN WORK AREAS

The following paragraphs list some of the specific safety measures an operator should observe when carrying out his responsibilities in a plant.

13.15.1 NO SMOKING AREAS

1. Chemical storage areas

2. Fuel and lubrication storage areas

3. Wet and dry wells of plant pumping stations

4. Pump rooms

5. Tunnels having pipe galleries

6. Chlorine building

7. Manholes, tanks, reservoirs, excavations, trenches

13.15.2 CHLORINE BUILDINGS

1. The following signs must be posted outside the room door:

   a) Turn on Vent Fan

   b) Danger Chlorine Storage

2. A "Fresh Air" air pack must be located within 4.6 m (15 ft) of room door.

3. An eye wash bath must be located within 4.6 m (15 ft) of room door.

4. Mechanical ventilation of the chlorine room shall be sufficient to produce 30 air changes an hour taking suction from within 45cm (18 in.) of the floor.

5. Operator must wear safety goggles and a pair of rubberized gloves.

6. Two operators shall be present for cylinder changing.

7. Fresh strong ammonia must be used for leak detection.

8. The chlorine room must NOT be used as a plant storage area.

13.15.3 WET WELLS

A wet well is classified as a confined space and therefore confined space regulations apply. Before entering the operator must:

1. Test for oxygen content using an oxygen meter. DO NOT ENTER unless the oxygen content in the atmosphere registers between 18 and 23%;

2. Test the noxious gases and vapours using a combustible gas analyser; and

3. Test for hydrogen sulphide using the colorimetric test. Tests for other gases may also be necessary.

The operator must also take the following precaution on entry:

1. If any atmospheric contamination is suspected, a fixed or portable vent fan of at least 700 cfm capacity must be used before and during entry. If no vent fan is available, a portable air pack must be worn;

2. Explosion and waterproof lighting must be used;

3. An operator with a man hoist must be located at all times at the entrance to the wet well to monitor the meters and observe the operator inside;

4. If a man hoist is not available two operators must be at the entrance;

5. A parachute type harness and lifeline and hard hat must be worn; and

6. A step-through parting is required at the ladder entrance.

13.15.4 DRY WELLS

A dry well is classified as a confined space and therefore confined space regulations apply. Before entering the operator must:

1. Vent fan shall be started before entering the pumping station and left operating continuously while the operator is in the station;

2. "DANGER PUMPS ON AUTOMATIC CONTROLLER" signs should be posted at the control panel floor level, and the pump floor level;

3. "NO SMOKING" signs should be posted at the pump floor level; and

4. Lock out switches at control panel when working on any pump at any floor level.

13.15.5 PUMP ROOMS

1. "Caution Pumps on Automatic" signs must be posted.

2. Vent fans must be on.

13.16 HANDLING CHEMICALS

In handling chemicals in the water treatment process, the general safety requirements outlined earlier should be met. Operators should be aware of the hazards associated with chemicals used in a water treatment.

Chemicals should be properly sealed, kept away from heat sources and preferably stored in locked lockers, when not in use.

13.16.1 ALUM

Wear protective dust-proof equipment (goggles and nose mask) and proper clothing when handling and storing alum. If skin or nose irritations occur, wash thoroughly with plenty of water.

13.16.2 HYDROFLUOSILIC ACID

The vapour or liquid chemical is very dangerous when it comes into contact with the eyes, skin or any part of the body, or if taken internally.

Operator must wear protective clothing and equipment consisting of long gauntlet type rubber gloves, high rubber boots or waders, short type rubber raincoat and chemical safety goggles with a plastic face shield.

13.16.3 FLUORIDE POWDERS

Do not let dust touch skin or inhale fumes.

Air ventilation must be at least ten (10) air changes per hour.

Operator must wear good quality coveralls, rubber boots (knee length), rubber gloves or plastic coated cotton gloves with cuffs of half a forearm length; dust proof cap and rubber apron, plastic goggles, nose mask with replaceable filters approved by National Institute for Occupational Safety and Health (NIOSH) for fluorides. The filter in the nose mask should be replaced each day or more frequently if required.

Showers must be available. All rubberised clothing should be hosed down at the end of a shift.

Empty chemical bags must be deposited in a securely tied plastic bag at a sanitary landfill. DO NOT BURN THESE BAGS.

13.16.4 CALCIUM HYPOCHLORITE (HTH)

This chemical is highly explosive if it is in contact with organic matter. Store it in a clean, cool, dry area. Keep it away from open flame or heat. A "Metal X", Class D fire extinguisher is the only type that will extinguish this material when on fire.

13.16.5 SODIUM HYPCHLORITE (LIQUID BLEACH)

Strong Sodium Hypochlorite solutions are powerful oxidizing agents that rapidly produce burns when in contact with the skin. Do not handle directly or allow the solution to splash or spill on any part of the body. Avoid accidental mixing with acids, as this will liberate chlorine gas. With ammonia or ammonium compounds, explosive products may be formed.

13.16.6 CHLORINE GAS

Chlorine gas is an extremely dangerous chemical to work with and proper training is essentially in operating a plant using chlorine gas as a method of disinfection. Proper eyewear, gloves, self-contained breathing apparatus and aprons are required when handling the gas. A ventilation hood is preferable for the area immediately surrounding the gas

cylinders. Keep far away from ammonia, acetylene, fine metal and any combustible material.

13.16.7 AMMONIA

Store cylinders in a cool, dry, ventilated place. Handle with care. An air pack should be available. In case of cylinder leaks, only trained personnel should make repairs. You must know your first aid if you handle and use this material.

13.16.8 ACTIVATED CARBON

Store in a dry, fire-proof space. Wear protective, dust-proof equipment (goggles and nose mask) when handling activated carbon. Do not smoke while working with or near stored material. Use plenty of water when washing and bathing.

13.16.9 LIME

Use protective, dust-proof equipment (goggles and nose mask) while handling lime and use a dust collecting system, if possible. Store in a ventilated, dry area. If skin or nose irritations occur, wash thoroughly with plenty of water. Consult a physician if irritation becomes severe.

13.16.10 SODA ASH

Handle soda ash as described for lime. See above.

13.16.11 CAUSTIC SODA

Caustic soda used in water treatment is often used in liquid form. Proper gloves, apron and eyewear are essential. Keep caustic soda away from Alum powder, acids, aluminum, tin and zinc products. Always add soda to water and never water to soda. When soda is added to water, it will release substantial heat, so keep oxidizable materials away from where you are mix. If skin comes into contact with soda, flush with clean running water.

13.16.12 SOLVENTS

Be careful when using solvents in confined areas. The area should be well ventilated. Clean solvents from skin to prevent irritations.

13.17 REVIEW

4. What is meant by a confined space? What are the general procedures when working in one of these?

5. List the safety equipment that should be found in a water treatment plant.

6. List 6 general safety rules around the water treatment plant.

7. What two vaccinations are urged for operators working in a water treatment plant?

14.0 EMERGENCY PREPAREDNESS

14.1 OBJECTIVES

In this section you will learn about:

- The need to be prepared for emergencies;
- Assessing the system; and
- Protection of the system.

14.2 INTRODUCTION

All of us who live in communities depend on the community's **infrastructure** to some degree. We would at best be inconvenienced and at worst harmed or killed if the infrastructure does not provide a reliable, safe service. As an example, if the power supply goes out for twenty minutes it would be a minor inconvenience for most of us. If it were out for two weeks in the winter it would be a serious inconvenience and people and property might be harmed.

What would you do if this happened? Do you have a plan that you would follow?

This section will review some of what you need to know about emergency preparedness. The emphasis is on planning for emergencies. You won't find the answers about what to do in this section; you have to do your own planning because every facility is different.

14.3 NEED FOR EMERGENCY PREPAREDNESS

In recent times more attention has been drawn to infrastructure security issues than has been common in the past. The infrastructure components we have to concern ourselves with are the water supply, treatment and distribution systems.

There have been cases where entire community water systems have been compromised and some people have become ill or even died from contamination of water systems. Most of these have been inadvertent, but they illustrate the vulnerability of some systems.

Even if no one is physically harmed by contamination of the water system, think of the cost of having to arrange for alternate water supplies for a community if the present system is compromised. These include:

Physical intrusion

- Vandals;
- Children; or
- Unlawful Entry.

Contaminants intrusion

- Pathogens;
- Fuels and other substances; or
- Deliberate/accidental.

Service interruption

- Facility breakdown; or
- External interruption (e.g., power failure) .

14.4 ASSESSING THE SYSTEM

The system operator will likely be the most knowledgeable about the system, its strengths and weaknesses. He or she is probably the best one to work on a plan to identify all the things that could go wrong with the system. The system operator also needs to be involved in planning what to do when things do go wrong.

If you know what can go wrong, if you have a plan for when things do go wrong, and if you implement the plan, you might be able to prevent a mishap from becoming a catastrophe.

14.4.1 WHAT CAN GO WRONG?

The first thing you need to do is try to think of anything and everything that could possibly go wrong. Make a list of everything you can think of. These could be accidents, natural disasters or deliberate vandalism or sabotage. Don't include failures due to poor operations and maintenance of the system. You are trained and knowledgeable to do a proper job, and you are responsible to do it.

These are just a few examples of the problems that could occur. You will have to develop your own list.

14.4.1.1 Accidents

- Vehicle accidents/spills

Could the fuel truck overturn and spill fuel into the reservoir? Are there any other hazardous materials that could spill into the system? What about the sewage truck?

- Vehicle accidents/damage to facilities

  Could an out-of-control vehicle destroy a critical part of the system?

- Fuel spills

  What would happen if the fuel delivery driver fell asleep while filling the plant tank? Where would the fuel end up? Would it affect the water supply?

- Other hazardous material spills

  Is there anything stored near the facility that could contaminate the water supply if spilled?

- Fire/Explosion

  How would you supply water to the community if a fire or explosion destroyed the system?

- Other accidents

  Are there any other accidents that could prevent you from providing potable water to the community?

14.4.1.2 Natural disasters

- Blizzards

  While blizzards are a normal occurrence in many places in the North and most people have adapted to them, have you considered how a severe one could affect the water supply? Could someone get to the facility to replenish consumables such as chlorine? What if maintenance is required on a pump? Is there a backup?

- Fire

  Is there enough clear space between any bush and your plant to save it from a forest fire?

- Flood

  Is any part of the system vulnerable to a flood? What can you do about it if the system is threatened?

- Drought

  Would you have enough water in an unusually dry year? Do you have a plan to conserve water?

- Other disasters

  Are there any other natural disasters that could prevent you from providing potable water to the community?

14.4.1.3 Man/made problems

- Vandalism

  Are good sturdy locks on all entrances? Are there intrusion alarms? Are there fences with locked gates?

- Sabotage

  Are good sturdy locks on all entrances? Are there intrusion alarms?

14.4.2 WHAT PROTECTIONS ARE BUILT-IN?

14.4.2.1 Accidents

- Vehicle accidents/spills

  Are there safeguards in place to prevent vehicle accidents from compromising the system? What are they?

- Vehicle accidents/damage to facilities

  Are there safeguards in place to prevent vehicle accidents from compromising the system? What are they?

- Fuel spills

  Is there proper spill containment in place to prevent fuel spills from compromising the water system? Is it properly maintained?

- Other hazardous material spills

  Is there proper spill containment in place to prevent fuel spills from compromising the water system? Is it properly maintained?

- Fire

  Do you have enough of the proper type of fire extinguishers in place? Are they accessible? Does the fire department know what chemicals you store and handle? Are they prepared to deal with chemical fires?

14.5 PROTECTING THE SYSTEM

14.5.1 RESPONSE PLANS

Now that you have an assessment of the system, a good idea of many of the things that can go wrong and some of the tools you have built in to the system to prevent or minimize damage, you should develop a plan to deal with emergencies. It is usually a lot easier trying to follow a plan that has been carefully thought out, than it is to make it up as you go when there is a lot of pressure on you.

Decide what you would do if any, or several, of the emergencies happened. Write the plans down. Things you need to have in the response plan include:

Who do you need to notify?

This could vary, depending on the nature of the emergency. It is likely to always include the senior administrative officer. It may include the Environmental Health Officer. It may include the fire department and police. Remember when you contact them that you need to be able to provide clear, concise and correct information. Don't guess about things you are not sure about.

What do you need to do?

Write down the steps that you would follow to rectify the problems. Write down any steps you would follow to provide temporary service.

What resources do you need?

List the support agencies, people, supplies and equipment you will need to rectify the problem. Write them down with contact numbers. List backups in case your primary resources are not available.

Your SAO has to be involved in preparation of response plans. You will probably require information from others as you develop plans. It has to be a team effort if it is likely to be successful.

Put all this information in a binder so you can update it. There should be a copy in your facility and in the community office. You should probably keep one at home. The fire department should have one. Other copies may be required.

Review the plan at least once a year. Update it if new potential problems arise. Keep the contact information up-to-date.

Remember, the points in this section are intended as examples only. You will need to develop your own security plans, with help from others.

ADDENDUM A

GLOSSARY

GLOSSARY

Adsorption -

The taking up of one substance into the body of another.

ABS -

Abbreviation for Sodium alkyl benzene sulfonate.

Adsorbing -

(1) The adherence of a gas, liquid or dissolved solid onto the surface of a solid.
(2) A change in concentration of a gas or solute at the interface of a two-phase system.

Aeration -

The bringing about of intimate contact between air and a liquid by one or more of the following methods:

a) spraying of liquids into the air,
b) bubbling air through the liquid,
c) agitating the liquid to promote surface adsorption of air.

Air gap -

the distance between the lowest opening of a pipe supplying water to a tank and the upper rim of the tank.

Algae -

Tiny plants, usually living in water and often green in colour.

Algicide -

Anything applied to kill or control algae.

Alkalinity –

Substance that has a pH of greater than 7.

Anionic -

Relating to negatively charged ions.

Aquifer -

Porous, water-bearing formation of rock, sand, or gravel.

Artesian aquifer -

An aquifer where the water is under pressure and will rise to a higher elevation if afforded an opportunity to do so.

Backflow -

The backing up of water through a conduit or channel in the direction that is opposite to normal flow.

Bacteria -
Single-celled microscopic plants living in soil, water, organic matter or the bodies of plants or animals.

Backwash -
The method used to clean filter media by reversing the water flow.

Breakpoint chlorination – Addition of chlorine to water until the chlorine demand has been satisfied. At this point, further additions of chlorine will result in a free residual chlorine that is directly proportional to the amount of chlorine added beyond the breakpoint.

Chelation –
A chemical forming of metallic cations with certain organic compounds such EDTA (ethylene diamine tetracetic acid)

Chlorine demand -
The difference between the amount of chlorine added to a water and the amount of chlorine residual left after a certain length of time.

Chlorine residual -
The amount of chlorine still left available after a certain length of contact time.

Clear well -
Reservoir for storing filtered water.

Coagulants -
In water and wastewater, chemicals used to thicken finely divided suspended solids into groups for easy removal.

Coagulation -
In water treatment, the destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical or by biological processes.

Coliform -
A group of bacteria normally living in the intestines of man and animals and are also found elsewhere in nature. They are pollution indicators in water supplies.

Colloidal -
Too finely divided to settle; requiring coagulation, biochemical action, or membrane filtration for removal.

CSA –
Canadian Standards Association, a group that published safety standards for Canada

Detention Time –

The length of time a drop of water or a suspended particle remains in a tank or chamber.

Filtration –

The removal of solid particles from water by passing the water through a filtering medium such as sand.

Floc -

Small jelly-like masses formed in a liquid by adding a coagulant.

Flocculation -

The collection of coagulated suspended solids into a mass by gentle stirring.

Flocculation aids -

Materials added to liquid to form flocs.

Flocculator -

Mechanical equipment used to encourage the formation of floc in liquid.

Free Available Chlorine –

Chlorine in excess of that required to destroy the chloramines, which is free to form hypochlorite ions.

Greensand –

A granular material that is a natural ion exchange material, which is capable of softening water. Greensand which has been treated with potassium permanganate is called manganese greensand this product is used to remove iron, manganese and hydrogen sulphide from ground waters

Hydrologic cycle -

The movement of water from the atmosphere to the earth and back to the atmosphere through precipitation, infiltration, storage, transpiration, evaporation etc.

Hydrolysis -

A chemical process of decomposition using the addition of water. Also, the process solid matter goes through to become liquid.

Hypochlorination –

Is the application of hypochlorite (a compound of chlorine and another chemical), usually in the form of solution, for disinfection purposes.

Indicator bacteria -

Coliforms that point to the presence of intestinal pathogens.

Influent -
Water flowing into a treatment plant or any of its units.

Injection wells -
Wells created to recharge groundwater.

Inorganic -
Made of matter that is not plant or animal.

Insoluble –
Something that cannot be dissolved

Ion exchange -
A chemical process in which ions from two different molecules are exchanged.

Ionizing -
Creating ions by adding electrons to, or removing them from, atoms or molecules.

Leaching –
Percolating liquid through soil or other solids to remove the soluble ingredients.

Metabolism -
The process in which food is used and wastes are formed by living matter.

MF -
Membrane filter (used in bacteriological lab test)

Microbes -
Microscopic organisms, especially pathogenic bacterium.

Micro-organisms -
Minute organisms, either plant or animal, invisible or barely visible to the naked eye.

MPN -
Most PROBABLE Number (used in bacteriological lab test).

Nutrient -
Food for the growth of organisms.

Nephelometric Turbidity Units (NTU) –
The units we use when we measure *Turbidity.* To estimate how light is scattered by suspended particulate material in the water.

NSF –
An international non-governmental, not-for-profit group that issues standards specializing in food, air, water and the environement.

Organic -
Made of matter that is plant or animal.

Ozonization -
The act or process of charging or treating with ozone. Also, the conversion of oxygen into ozone. Used for disinfection purposes.

Pathogenic -
Disease-producing bacteria.

Permeable -
Having pores or openings that permit liquids or gases to pass through.

pH -
The measure of the acid/alkaline balance, expressed on a scale of 0 to 14, with 7 being neutral; 7 to 0 increasing acidity, and 7 to 14 increasing alkalinity.

Pressure head -
A measure of the pressure exerted by a fluid.

Pseudomonad -
Short rod-shaped bacteria, some of which live on dead or decaying organic matter, or cause disease

Pumping level -
The height where water stands in a well during pumping.

Reducing agent -
A substance that causes the loss of an electron retention time Detention time; the length of time that water or wastewater is held in a unit for any treatment.

Sedimentation –
The process through which solid materials separate out from a liquid. Settling takes place when the velocity of liquid is below the point at which it can transport suspended material.

Septic -
Anaerobic (decomposition without oxygen).

Sludge –
The heavier solids that separate from water and sink to the bottom. Solids accumulate and must be periodically removed by pumping.

Solution –

Consists of two components, a solvent which is the dissolving medium and a solute which is the substance dissolved.

Spores -

Walled, single to many-celled reproductive bodies of microorganisms, able to produce new organisms directly or indirectly.

Staining -

Colouring specimens for microscopic study. Also, colouring or discolouring anything.

Static level -

The height of a water surface when groundwater is not being removed.

Supernatant -

The liquid standing above a sediment. In sludge digestion, the liquid standing between the sludge at the bottom and the scum at the top.

Surface water -

All water found on the surface of the earth.

Suspended solids -

(1) Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering.

(2) The quantity of material removed from water or wastewater in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Wastewater" and referred to as non-filterable residue.

Titration -

The method finding how much of something is in a solution by measuring how much of something else is needed to cause a chemical change.

Total solids -

The sum of dissolved and undissolved constituents in water or wastewater, usually stated in milligrams per litre.

Transpiration -

The process by which plants return water to the atmosphere.

Turbidity -

A condition in water caused by suspended matter; murkiness.

UL –

Underwriters Laboratories Inc., another group that published standards for safety for consumer related activities.

Volatile solids -

The quantity of solids in water, wastewater, or other liquids, lost on ignition of the dry solids at 55 0°C.

Water hammer -

Loud blows caused by moving water against the sides of its containing pipe.

Watershed –

An area that drains into a particular body of water or watercourse.

Weir –

A dam or enclosure in water or wastewater used to raise the water level or change the direction of its flow; it measures the flow.

Well Head –

The top of the well.

ADDENDUM B

MATH REVIEW & DOSAGE EXAMPLES CHEMISTRY, SOLUTION & PREPARATION

MATH REVIEW & DOSAGE EXAMPLES

INTRODUCTION

The objective of this unit is to introduce the operator to the application of mathematics in solving problems related to the field of water treatment and to prepare him or her for further course work in the water treatment field.

We will discuss the theoretical concepts of mathematics which form the basis for solving problems encountered in the operator's day to day work. Examples were written with the objective of showing by example how a typical problem is solved. To assist the student, a number of practice problems follow each section. For each question on the exercise sheet there is a corresponding example and practice problem for the operator to refer to for assistance in completing each lesson.

For those students who are not comfortable with metric measurements, a brief explanation of the system and a set of conversion tables have been provided.

A short review of basic geometry has also been included.

It should be remembered and emphasized that the intent of this course is to allow the operator the opportunity to apply mathematical computations in solving water treatment problems and to improve his skills in mathematics.

METRICS:

Scientists and many other people throughout the world measure lengths, distance, area, volumes, weight, temperature and other values by a standard method called the metric system. There are two major systems of measurement in use, both related to one another. The English System and the Metric System.

The English system of measurement developed from man's need to measure size and distances and were based on units that were a part of his body. For example, a "cubit" was the length of a man's forearm from his elbow to the tip of his middle finger. The Romans used the uncia for the width of a thumb and the English inch comes from this method. Twelve uncia equaled roughly the length of a man's foot and a man's foot was used to measure distance. The foot at first was the length of any man's foot. In some countries it was the length of the 'kings' foot. Measuring units based on a man's size failed because not all men were the same size, and as a result measurements varied from man to man. However, there was little need for standardization until man began to travel and trade with other men and some form of 'standard units' became necessary. Today one still finds different units in-use from one country to another. An example is the volume of a "gallon" by definition between Canada and the United states: 1.0 Imperial gallons = 1.2 U.S. gallons.

Out of such confusion there developed a need for a simple standard system of measurement. In 1670 a French priest, Gabriel Mouton, developed a system of measurement using the decimal system. In 1790 the French National Assembly appointed a commission to study the measurement situation. This commission of French scientists proposed the metric system and in 1799 France adopted it as the legal system of weights and measures. In 1875 the "Treaty of the Metre" was signed to establish the General Conference on Weights and Measures which meets to determine the official definitions for units used in metric countries. In 1960 the present form was adopted and named the Systeme International d'Units or International System of Units more commonly known as SI. Since the early 1970' s both Canada and the United states have been working towards a changeover to the metric system.

The popularity of the metric system stems from two characteristics, its simplicity and standardization. The metric system did not develop haphazardly nor did it use parts of the human body as units. In the metric system all units have a uniform scale based on the decimal system. The principal unit is the metre which is comparable to the yard as a unit of length. One meter is 39.37 inches or 1.093 yards long.

Before 1960 the standard for the meter was a platinum- iridium meter bar, but the metre is now defined world-wide to be 1,650,763.73 wavelengths of the orange-red light from the spectrum of krypton-86 measured in a vacuum. The reason: the length never varies and this measurement can be duplicated in the laboratory.

There are seven basic units which form the foundation of the metric system. The followlng four are involved with most everday use:

1. length or distance with the base unit belng the metre
2. weight or mass when measured on earth is the kilogram
3. the base unlt of time is the second
4. temperature units are expressed in the Kelvin scale but most people when measuring in metrics use the Celsius scale as 1^{o} Kelvin equals 1^{o} Celsius.

The other three units have more specialized uses by the scientist.

5. the ampere is the base unit for electrical measurements.
6. the mole is the base unit involved in chemical reactions.
7. the candela is the base unit for measuring light.

The scientists who desiqned the metric system developed it to fit their needs and they made it logical and exact. The metric system is simple to use for two reasons. First, it follows the decimal number system, that is, units increase or decrease in size by lO's. Secondly, it is made up of only seven basic units of measurement.

The scale of multiples and subdivisions of the meter is ten and all other units can be represented by the product of ten. An example of the decimal scale using meters:

10 millimetres = 1 centimetre
10 centimetres = 1 decimetre
10 decimetres = 1 metre
10 metres = 1 decametre
10 decametres = 1 hectometre
10 hectometres = 1 kilometre

or

Name or Symbol	Measurement: meters
millimetre (mm)	1/1000 m or 10^{-3}m
centimetre (cm)	1/100 m or 10^{-2}m
decimetre (dm)	1/10 m or 10^{-1}m
metre (m)	1 m or 10^{0}m
decametre (dam)	10 m or 10^{1}m
hectometre (hm)	100 m or 10^{2}m
kilometre (km)	1 000 m or 10^{3}m

This same system applies to the other units, the liter and the gram. Ten litres equals one decaliter and 10 decigrams equals one gram. This uniform system of names is one of the advantages of the metric system. With the chief units of measure being tenths, hundredths and thousandths, the various units of measure get their names by adding Latin and Greek prefixes. For example: by adding Latin prefixes deci means one tenth, centi means one hundredth and milli means one-thousandth: by adding Greek prefixes, deca means tens, hecto means hundreds and kilo means thousands.

CONVERSION TABLE:

when you know	multiply by	to find
inches	25.40	millimetres
feet	30.48	centimetres
yards	0.91	metres
miles	1.61	kilometres
millimetres	0.04	inches
centimeters	0.39	inches
metres	1.09	yards
kilometres	0.62	miles
square inches	6.45	square centimetres
square feet	0.09	square metres
square yards	0.84	square meters
square miles	.59	square kilometres
acres	0.41	hectares
square centimetres	0.16	square inches
square metres	1.20	square yards
square kilometres	0.39	square miles
hectares	2.47	acres
fluid ounces US	29.57	millilitres
fluid ounces Imperial	35.49	millilitres
pints US	0.47	litres
pints Imperial	0.57	litres
quarts US	0.95	litres
quarts Imperlal	1.14	litres
gallons US	3.78	litres
gallons Imperial	4.54	litres
millilitres	0.034	ounces fluld US
millilitres	0.028	ounces fluid Imperial
litres	2.11	pints US
litres	1.76	pints Imperial
litres	1.06	quarts US

litres	0.88	quarts Imperial
litres	0.26	gallons US
litres	0.22	gallons Imperial
ounces (dry)	28.35	grams
pounds	0.45	kilograms
grams	0.035	ounces (dry)
kilograms	2.20	pounds
short tons	0.91	metric tons
metric tons	1.1	short tons
^{0}Fahrenheit	5/9 after subtracting 32	^{o}Celsius
^{o}Celsius	9/5 then add 32	^{o}Fahrenheit

p.s.i. (water)	2.31	pressure head in feet
TDH (feet)	0.43	pressure in p.s.i.

METRIC SUMMARY:

Length: 1 metre = 100 cm = 1000 mm

Area: 1 square metre = 10 000 cm^2 = 1 000 000 mm^2

Volume: 1 m^3 = 1000 L = 1 000 000 mL = 1 000 000 cm^3

Mass: 1 kg = 1000 g = 1 000 000 mg

Pressure: 1 pascal = 1 newton per square metre

Note: i) 1 kilogram of water has a volume of 1 litre

ii) A force of 9.81 newtons is required to hold up 1 kilogram of mass

Length: 1 inch = 2.54 cm

1 foot = 30.48 cm

1 metre = 39.37 inches

Areas: 1 square inch = 6.45 cm^2

1 square foot = 929 cm^2

Volume: 1 cubic foot = 28.32 litres

1 gallon Imperial = 4.54 litres

1 gallon US = 3.785 litres

Mass: 1 pound = 453.6 grams

1 kilogram = 2.2 pounds

Force: 1 pound (lb) = 4.45 newtons (N)

Pressure: 1 psi = 6900 newtons/m^2 (N/m^2)

= 6900 pascals (Pa)

= 6.9 kilopascals (kPa)

= 2.31 feet of head

1 pascal = 1 newton/square metre

1 atmosphere = 14.5 psi = 1 Bar = 100 kPa

Water Pressure: 1 meter of water = 9.8 kilo pascals (kPa)

1 foot of water = 3.0 kPa

EXAMPLE CALCULATIONS FOR WATER TREATMENT OPERATORS

RATE OF FLOW CALCULATIONS

These calculations are important as they provide data that is necessary in determining the cost of treatment and the efficiency of the process control equipment. The accuracy of the flowmeters and pumping capacities can be checked and the measurement of flows, contributed by various sources, such as ground water run-off or industrial wastes, can be estimated with some degree of accuracy. Rates of flow must be determined for proper sizing of clarifiers, aeration tanks, grit chambers, filters etc.

EXAMPLE 1

A channel 2 m wide has a water flowing to a depth of 0.5 m. What is the daily FLOW in the channel if the velocity of the water is 0.75 m/s?

RATE OF FLOW = WIDTH x DEPTH x VELOCITY

= (2 m) (0.5m) (0.75 m/s)

= 0.75 m^3/s

However, we are asked to find the daily flow.

Daily Flow = rate of flow x 60 s/min x 1440 min/d

= (0.75 m^3/s) (60 s/min) (1440 min/d)

= 64 800 m^3/d

EXAMPLE 2

What is the daily FLOW in a 300 mm diameter pipe that is flowing 75% full if the velocity is 40 m/min?

Volume of flow = Cross sectional area x Velocity

= (0.75) (πr^2) (40 m/min)

= (0.75) (3.14) (.15 m) (.15m) (40 m/min)

= 2.1 m^3/min

We need to convert 2.1 m^3/min to a standard expression of flow rate. Either L/s or m^3/d are correct, and we are asked to put the answer in terms of daily flow (m^3/d).

Daily flow = Volume of Flow x 1440 min/d

= (2.1 m^3/min) (1440 min/d)

= 3 024 m^3/d

PERCENT

EXAMPLE 1

A lime solution having a mass of 80 kg contains 85% water and the remainder is lime. What is the mass of the lime?

SOLUTION

The total mass of the solution is 80 kg which represents 100%. If the water represents 85%, then the lime represents:

(Total Mass) - (Mass of Water) = (Mass of Lime)

100% - 85% = 15%

Mass of lime = 15% x 80 kg
= 0.15 x 80 kg
= 12 kg

EXAMPLE 2

An alum solution having a mass of 200 kg contains 176 kg of water and the rest is alum.

a) What percentage of the mixture is water?
b) What percentage of the mixture is Alum?

SOLUTION

a) In the above question we are told the total mass of the mixture is 200 kg or 100%. The mass of the water is 176 kg.

To find the percentage of water:

$$\% \text{ of water} = \frac{176 \text{ kg}}{200 \text{ kg}} \times 100\%$$

% of water = 88%

b) If 88% of the mixture is water then;

Total Mass - Mass of Water = Mass of Alum

100% - 88% = 12%

DETENTION TIME

The concept of detention time is used in conjunction with many treatment plant processes. "DETENTION TIME" refers to the length of time a drop of water or a suspended particle remains in a tank or chamber.

Detention time may also be thought of as the number of minutes or hours required for each tank to fill and overflow. The mental image might be one of the flow from the time water enters the tank until it leaves the tank completely , as shown in the following figure. This process is also known as "plug flow".

EXAMPLE

A sedimentation tank has a capacity of 132 m^3. If the hourly flow to the clarifier is 47 m^3/h, what is the detention time?

Since the flow rate is expressed in hours, the detention time calculated is also in hours:

$$\text{Detention time} = \frac{\text{Volume of tank}}{\text{Flow rate}}$$

$$= \frac{132\ m^3}{47\ m^3/h}$$

$$= 2.8\ h$$

WEIR OVERFLOW RATE

The calculation of WEIR OVERFLOW RATE is important in detecting high velocities near the weir, which adversely affect the efficiency of the sedimentation process. With excessively high velocities, the settling solids are pulled over the weirs and into the effluent troughs.

In calculating the weir overflow rate, you will be concerned with the litres per second flowing over each metre of weir length. The following figures can be associated with weir overflow rate in rectangular and circular sedimentation basins.

Since weir overflow rate is L/s flow over each m of weir length, the corresponding mathematical equation is:

$$\text{Weir overflow rate} = \frac{\text{flow (L/s)}}{\text{weir length (m)}}$$

EXAMPLE 1

If a sedimentation tank has a total of 27 m of weir over which the water flows, what is the weir overflow rate when the flow is 90 L/s?

$$\text{Weir overflow rate} = \text{flow (L/s) weir length (m)} = \underline{90 \text{ L/s}}$$

$$\frac{27 \text{ m}}{} = \frac{3.3 \text{ L/s}}{\text{m}}$$

EXAMPLE 2

A circular clarifier receives a flow of 16 416 m^3/d. If the diameter is 24 m, what is the weir overflow rate?

Before you can calculate the weir overflow rate, you must know the total length of the weir. The relationship of the diameter and circumference of a circle is the key to determining this problem.

Circumference = 3.14 x Diameter

In this problem, the diameter is 24 m. Therefore, the length of weir (circumference) is

Circumference = (p) (Diameter)
= (3.14) (24 m)
= 75.4 m

We now must convert m^3/d to L/s by the following:

$$\frac{m^3}{d} \times \frac{1\,000 \text{ L}}{\text{s/d}} \quad \frac{}{m^3} = \text{L/s}$$

$$\frac{16\,416 \text{ m}^3\text{/d}}{86\,400 \text{ s/d}} \times \frac{1\,000 \text{ L}}{\text{m}^3} = 190 \text{ L/s}$$

Now solve for the weir overflow rate:

Weir overflow rate = flow (L/s)
weir length (m)

= 190 L/s
75.4 m

= 2.5 L/s
m

PUMPING RATES

The rate of flow produced by a pump is expressed as the volume of water pumped during a given period of time. The mathematical equation used in pumping rate problems can usually be determined from the verbal statement of the problem.

VERBAL: What is the pumping rate in m^3 per day?
MATH: pumping rate = m

VERBAL: What is the pumping rate in litres per second?
MATH: pumping rate = L

The volume pumped during a period can be determined either by a flowmeter or by measuring the volume being pumped into or out of a tank.

Most pumping rate problems will ask you to give an answer in one form (L/s) and will give you the information in another form (m/d). At first the conversion between these two expressions looks difficult, but once you become familiar with their relationship to each other, converting is simple. Here is the proof.

$$\frac{m^3/d}{86\,400\ s/d} = \frac{m^3}{s} \times \frac{1\,000\ L}{m^3} = L \text{ or } L/s$$

or conversely

$$L/s \times \frac{1\,000\ L}{m^3} = \frac{m^3}{s} \times \frac{86\,400\ s}{d} = \frac{m^3}{d} \text{ or } m^3/d$$

EXAMPLE

An empty rectangular tank 8 m long and 6 m wide can hold water to a depth of 2 m. If this tank is filled by a pump in 55 min. What is the pumping rate in litres per second?

In this example, the entire tank was filled during the 55 min pumping test. Therefore the total volume pumped is equal to the capacity of the tank in m .

Volume of Tank = Area of Rectangle x Depth
= (8 m) (6 m) (2 m)
= 96 m^3

To find L/s we convert 96 m^3 to litres and 55 min to seconds.

$$96\ m^3 \times \frac{1\,000\ L}{m^3} = 96\,000\ L$$

$$55\ min \times \frac{60\ s}{min} = 3\,300\ s$$

Then we divide:

$$\frac{96\,000\ L}{3\,300\ s} = 29.1\ L/s$$

29.1 L/S is the answer to the first part of the question. To find the answer to the second part, we must convert L/s to m /d.

$$\frac{29.1\ L}{s} \cdot \frac{1\,000\ L}{m^3} \times \frac{86\,400\ s}{d} = 2\,514\ m^3/d$$

2 514 m^3/d is the answer to the second part of the question.

DENSITY

For scientific and technical purposes, the **DENSITY** of a body of material is precisely defined as the mass **PER UNIT OF VOLUME.** The density of dry materials, such as sand, activated carbon, lime and liquids such as water, liquid alum or liquid chlorine can be expressed as g/cm^3. The density of gases, such as air, chlorine, methane or carbon dioxide is normally expressed in g/L.

The density of a substance **CHANGES SLIGHTLY AS THE TEMPERATURE OF THE SUBSTANCE CHANGES**. This happens because substances usually increase in volume as they become warmer, as illustrated in Figure 1. Because of the expansion with warming, the mass is spread over a larger volume, so the density is less when a substance is warm than when it is cold.

Similarly, a change in pressure will change the volume occupied by a substance. As a result, **DENSITY VARIES WITH PRESSURE**, increasing as pressure increases and decreasing as pressure decreases (Figure 2).

The effects of pressure and temperature on solids and liquids, are very small and are usually ignored. However, temperature and pressure have a significant effect on the density of gases and whenever the density of a gas is given, then the temperature and pressure at that density are usually also given.

RELATIVE DENSITY (Specific Gravity)

Although there may be many numbers that express the density of the same substance (depending on the unit used) there is only one relative density associated with each substance (for one particular temperature and pressure). The relative density of a substance is compared against a "Standard" density.

RELATIVE DENSITY OF SOLIDS & LIQUIDS

The standard density used for solids and liquids is that of water, which is one g/cm at 4 degrees C and a pressure of 101.3 kN/m or kilopascals (kPa), the pressure of the atmosphere at sea level. Therefore,

the relative density of a solid or liquid is the density of that solid or liquid COMPARED TO THE DENSITY OF WATER. It is the ratio of the density of that substance to the density of water. Let's look at an example. The density of SAE 30 motor oil is

$$\text{Relative Density} = \frac{\text{oil } 0.9 \text{ g/cm}^3}{\text{water } 1.0 \text{ g/cm}^3}$$

$$= 0.90$$

In other words, relative density in this example tells you that oil is only 9/10 as dense as water. Because a cm^3 of oil has a mass less than a cm^3 of water, oil floats on the surface of water.

Relative Density of Gases

The relative density of a gas is usually determined by comparing the density of the gas with the density of air, which is 1.2 g/L at a temperature of 20 degrees C and a pressure of 101.3 (kN/m) or kilopascals (kPa) the pressure of the atmosphere at sea level. For example, the density of chlorine gas is 2.99 g/L . Its relative density would be calculated as follows:

$$\text{Relative Density} = \frac{Cl_2 \text{ } 2.99 \text{ g/L}}{\text{air } 1.2 \text{ g/L}} = 2.49$$

This tells you that chlorine gas is approximately 2.5 times as dense as air. Therefore, when chlorine gas is introduced into a room it will concentrate at the bottom of the room. This is important to know since chlorine is a deadly toxic gas.

DOSAGE CALCULATIONS

It is most necessary for a plant operator to know how to calculate the dosages of the various chemicals used in water treatment. It is important to be accurate when calculating dosages as too little chemical

may be ineffective and too much a waste of money. In process control the exact dose of chemical must be determined through calculation for the purposes of efficient operation and economy.

EXAMPLE 1

The chlorine dosage of an effluent is 15 mg/L. How many kilograms of chlorine will be required to dose a flow of 8 500 m^3/d?

In this question, it will be necessary to utilize your knowledge of the metric system.

$$1 \text{ mg/L} = 1 \text{ kg/l } 000 \text{ m}^3$$

For every 1 000 m^3 of water of flow, we will need to use 15 kg chlorine.

$$\frac{15 \text{ kg } Cl_2}{1\ 000 \text{ m}^3} \times 8\ 500 \text{ m}^3\text{/d} = 127.5 \text{ kg } C1_2\text{/d}$$

Above we expressed 15 mg/L as 15 kg Cl_2 /1 000 m^3 and multiplied it by the flow to obtain the answer expressed as 127.5 kg $C1_2$/d

EXAMPLE 2:

A chlorinator is set to feed a 94.8 kg/d of chlorine. If the average daily flow through the plant is 7 900 m3/d, what is the DAILY AVERAGE CHLORINE DOSAGE IN MG/L?

We know that 1 mg/L = $\frac{1 \text{ kg}}{1\ 000 \text{ m}^3}$

We are told we use 94.8 kg chlorine for every 7900 m^3 water.

$$\frac{94.8 \text{ kg } Cl_2\text{/d}}{7.9 \times 1\ 000 \text{ m}^3\text{/d}} = \frac{12 \text{ kg } Cl_2}{1\ 000 \text{ m}^3} = 12 \text{ mg/L}$$

Above we divided the mass of chlorine used per day by the flow expressed in 1 000 m per day and

found we used 12 kg Cl_2 for every
1 000 m of flow or 12 mg/L.

HYPOCHLORINATION CALCULATIONS

Definition - Hypochlorination is the application of hypochlorite (a compound of chlorine and another chemical), usually in the form of solution, for disinfection purposes.

EXAMPLE 1

The treated product at a water treatment plant requires a chlorine dosage of 98 kg/d for disinfection purposes. If we are using a solution of hypochlorite containing 60% available chlorine, how many kg/d hypochlorite will be required?

SOLUTION

We are told in the problem that 60% of the hypochlorite is available chlorine which is the portion of the solution capable of disinfecting. Solving the equation we have;

$$\text{kg/d hypochlorite} = \frac{\text{98 kg/d of chlorine needed}}{\text{0.6 available chlorine in sol'n}}$$

= 163.3 kg/d hypochlorite solution

EXAMPLE 2

A hypochlorite solution contains 5% available chlorine. If 4 kg of available chlorine are needed to disinfect a watermain, how much 5% solution would be required?

We are told 4 kg of chlorine will do the job of disinfection. By a 5% solution we mean that 5% by mass of the solution is to be made up of chlorine. So 100 kg of 5% hypochlorite solution will contain 5 kg chlorine.

Using the formula for ratios $\frac{A}{B} = \frac{C}{D}$

we substitute:

$$\frac{\text{5 kg chlorine}}{\text{100 kg sol'n}} = \frac{\text{4 kg chlorine required}}{\text{? kg sol'n required}}$$

Since $D = \frac{C \times B}{A} = \frac{4 \text{ kg} \times 100 \text{ kg}}{5 \text{ kg}} = 80 \text{ kg solution}$

CHEMICAL FEEDING

Solution Preparation - Jar Tests

Jar tests are used to determine correct chemical dosages for such chemicals as alum, ferric chloride and polymers. These are chemicals utilized in water treatment facilities for coagulation and flocculation of colloidal particles. The jar test simulates, on a small scale, the activities going on in various sections of the full scale treatment process. Varying amounts of the chemicals are compared against each other to find out which chemical and dosage best accomplishes the desired results.

Stock solutions of coagulants, coagulant aids and other chemicals, should be prepared at concentrations such that quantities suitable for use in the jar tests can be measured accurately and conveniently. If one is dealing with dry chemicals the preparation of these stock solutions is straight forward. For example to prepare a 1 g/L stock solution using dry chemicals, 1 gram of the chemical is made up to 1 000 mL with water. However, with concentrated liquid solutions a dilution step is required. Any dilution step must take into account the **relative density** of the solution being diluted. For example, if one has a 48.5% alum solution with a relative density of 1.35 and wishes to make up a 1 g/L stock solution the following procedure should be followed:

1 mL 48.5% liquid alum has a mass of 1.35 g

1 mL contains 1.35 g x $\frac{48.5}{100}$ = 0.65 g alum

so 1.54 mL of the sol'n will contain 1 g Alum

Therefore, add 1.54 mL liquid alum to water and make up to 1 000 mL for a 1 g/L stock solution. 1 g/L solutions are easy to use because 1 mL of solution has a mass of 1 mg.

After jar tests have been carried out the type of chemical dosage and point of application best suited to the characteristics of the water or sewage to be treated should easily be established. The next step is to feed the chemical to be used at the dosage determined in the jar tests into the full scale treatment facility. The operator is faced with using a dry or liquid chemical which will be fed into the process by means of a dry or liquid chemical feeder. If feeding dry chemicals, the feeder will be calibrated, most likely, in **grams per minute** or, if liquid chemicals are being utilized, in **millilitres per minute.** Following is a detailed approach to establishing feed rates for chemicals.

EXAMPLE

Given a daily flow rate of 16 000 m^3/d and an alum dosage of 13 mg/L, what is the alum flow rate in g/min?

Step 1 Determine kg/d of Alum required.

1. Alum dosage of 13 mg/L = $\frac{13 \text{ kg}}{1\,000 \text{ m}^3}$

2. Feed Rate = Dosage x Flow

$$= \frac{13 \text{ kg}}{1\,000 \text{ m}^3} \times \frac{16\,000 \text{ m}^3}{\text{d}}$$

$$= 208 \text{ kg/d of alum}$$

Step 2 We are asked to give the flow rate in g/min

1. Convert kg/d to g/d. Since 1 kg = 1 000 g

$$\frac{208\ \text{kg}}{\text{d}} = \frac{208\ 000\ \text{g}}{\text{d}}$$

2. Convert kg/d to g/min. Since 1 day is equivalent to 1 440 min (24 h x 60 min)

$$\frac{208\ 000\ \text{g/d}}{1\ 440\ \text{min/d}} = 144.4\ \text{g/min}$$

EXERCISE 1

1. Calculate the surface area of a rectangular settling tank 18 m long and 4m wide.

2. Calculate the surface area of a circular sand filter with a diameter of 15m.

3. Calculate the volume of a raw water intake crib 8 m long, 3 m wide and 6m deep.

4. What is the volume of a circular storage tank that is 7 m in diameter and 15m high?

5. What is the volume of water contained in 84 m of pipe with an inside diameter of 10 cm:

   a) in m^3?
   b) in L?

6. If a pump delivers 1.44 m3 in 20 minutes, what is the pumping rate in:

   a) L/s?
   b) m^3/d?

7. How many m^3 of water will a 5 L/s pump deliver in 5 minutes?

8. A 12 m^3 storage tank supplies alum for coagulation at a rate of 330 mL/min. How often will the

tank need to be refilled?

9. The prechlorination chamber at a water treatment plant has a volume of 225m^3. If the flow rate from the tank is 11 L/s, what is the average detention time in hours?

10. How many kg of chlorine are required to treat 18 000 m^3 of water per day with chlorine at 5.0 mg/L?

11. A gas chlorinator treats 2 700 m^3 with 2 kg of chlorine per day. Calculate the dosage rate. The residual is measured at 0.27 mg/L. What is the chlorine demand:

    a) in mg/L?
    b) in kg/d?

12. In the chart below determine the mass of chemical in kg that will be required to feed at the rate indicated along the top of the chart in relationship to the volume of water flowing as indicated down the side.

13. In the chart below determine the dosage in mg/L that will coincide with the flow indicated on the vertical scale and the mass of alum on the horizontal scale.

14. A liquid solution with a total mass of 97 kg contains 84 kg of water and the remainder is alum.

    a) What percentage of the solution is water?
    b) What percentage of the solution is alum?

15. A mixture of water and powdered carbon is to be 85% water. If the total volume required is 3.6 m^3, what is the mass of the carbon?

16. A hypochlorite solution contains 12% available chlorine. If 3 kg of available chlorine are needed

to disinfect a main:

a) how many kg of solution are required?
b) how many litres of solution are required?

FILTER LOADING RATE

The "filter loading rate" is expressed as L or m^3 of water applied to each m^2 of surface area. This could also be described as the amount of water flowing down through each m^2 of filter surface. Filter design loading rates are expressed as $L/s/m^2$.

$$\text{Filter loading rate} = \frac{m^3/d \text{ Flow}}{m^2 \text{ Filter Area}} \times \frac{24 \text{ h}}{d}$$

NOTE: Design loading rates for filters are expressed in US gals at present. Using conversion factors to obtain S.I. units is necessary when studying American designed filters. Typical loading rates are shown below:

Rapid sand filter = 1.36 $L/s/m^2$, (2 US gpm/ft^2)

Dual Media = 0.136 - 0.272 $L/s/m^2$, (0.2 - 0.4 US gpm/ft^2)

Multi Media = 3.41 - 6.82 $L/s/m^2$, (5 - 10 US gpm/ft^2)

EXAMPLE

A rapid sand filter is 10 m wide and 15 m long. If the flow through the filter is 17 630 m^3/d what is the filter loading rate in $L/s/m^2$?

First, convert the flow to L/s

$$\frac{17\,630 \text{ m}^3}{\text{d}} \times \frac{1\,000 \text{ L}}{\text{m}} \div \frac{86\,400 \text{ s}}{\text{d}} = \frac{204 \text{ L}}{\text{s}}$$

Then express the filter loading rate mathematically as:

$$\text{Filter loading rate} = \frac{\text{flow}}{\text{filter area}}$$

$$= \frac{204 \text{ Ls}}{150 \text{ m}^2}$$

$$= 1.36 \text{ L/s/m}^2$$

FILTER BACKWASH RATE

There are two methods that may be used to calculate the filter backwash rate.

a) Filter Backwash Rate = $\frac{\text{flow L/s}}{\text{filter area m}^2}$

b) Filter Backwash Rate = $\frac{\text{meters of water rise}}{\text{hour}}$

NOTE: As with filter loading rates, filter backwash rates are also expressed in U.S. gals at present. Rates are shown below:

Minimum = 10.2 L/s/m^2, (15 US gpm/ft^2)
Maximum = 15.3 L/ms/m^2, (22.5 US gpm/ft^2)

This is equivalent to a rise in the water level of 36.67 m/h (2 ft/min) to 55.0 m/h (3 ft/min).

EXAMPLE 1

A rapid sand filter is 10 m wide and 12 m long. If backwash water is flowing upward at a rate of 1.56 m /s, what is the backwash rate in L/s/m^2 ?

Flow = $\frac{1.56\ m^3}{s} \times \frac{1\,000\ L}{m^2}$

= 1 560 L/s

Therefore, there are 1 560 L/s flowing upward through a filter with a surface area of 120 m . This can be written mathematically as:

Filter backwash rate = $\frac{\text{flow}}{\text{filter area}}$

$$= \frac{1\,560\ L/s}{120\ m^2}$$

$$= 13\ L/s/m^2$$

EXAMPLE 2

A mixed-media filter is 8 m wide and 11 m long. If the filter receives a backwash flow of 84 000 m^3/d, what is the filter backwash flow rate in $L/s/m^2$?

As in the last example, first convert the backwash flow to L/s.

$$\frac{84\,000\ m^3}{d} \times \frac{1\,000\ L}{m^3} \div \frac{86\,400\ s}{d} = \frac{972.22\ L}{s}$$

Filter backwash rate = flow filter area

$$= \frac{972.22\ L/s}{(8\ m)\ (11\ m)}$$

$$= \frac{972.2\ L/s}{88\ m^2}$$

$$= 11.05\ L/s/m^2$$

Filter backwash rates, as noted earlier, are sometimes expressed in terms of vertical rise of water in a time interval measured in hours, for example, metres per hour (m/h). The units of measure are directly related to each other as shown by the following proof:

$$= \frac{11.05\ L/m}{s} \times \frac{3\,600\ s}{h} \div \frac{1\,000\ L}{m^3}$$

$$= \frac{39.672\ m^3/m^2}{h}$$

$$= 39.672\ m/h$$

For simplification, a conversion factor can be extracted from the above proof.

$$\frac{3\,600\ s}{h} \div \frac{1\,000\ L}{m^3}$$

$= 3.6 \text{ s/m}^3\text{/h/L}$

Then by substitution back into the proof:

$$\frac{11.05 \text{ L/m}^2}{\text{s}} \times \frac{3.6 \text{ s/m}^3}{\text{h/L}} = \frac{39.672 \text{ m}^3\text{/m}^2}{\text{h}}$$

$$= 39.672 \text{ m/h}$$

EXERCISE 2

1. A rapid sand filter is 5 m wide and 10 m long. If the backwash water flow rate is 55 600 m^3, determine the filter backwash rate in m/h?

2. What is the filter backwash rate in $L/s/m^2$ corresponding to a filter backwash rate of 37 m/h?

3. During the operation of a multi media sand filter, the operator measured the flow rate to be 14.4 m/h. Express this flow rate in $L/s/m^2$?

4. A rapid sand filter system is 4 m wide and 7 m long. If the flow through the filter is 3 300 m^3/d what is the filter loading rate:

   a) in L/s/m^2?
   b) in m/h?

Chemical Feeding & Preparation of Stock Solutions

SOLUTIONS

A solution consists of two components, a **solvent** which is the dissolving medium and a **solute** which is the substance dissolved. The solute is dispersed as molecules and ions and the distribution of the solute is homogenous throughout the solution. A common example of solvent and solute is water and sugar.

A **concentrated** solution is one which contains a relatively large amount of solute per unit volume of solution. A **dilute** solution is one which contains a relatively small amount of solute per unit volume of solution. The words "strong" and "weak" should not be used when referring to the concentration of a solution. Strong and weak are terms that are more properly used to describe the chemical activity of a substance.

Solution Preparation - Jar Tests

Jar tests are used to determine correct chemical dosages for such chemicals as alum or polymers. These chemicals are utilized in water treatment for coagulation and flocculation of colloidal particles. The jar test simulates, on a small scale, the activities going on in the full scale treatment process. Varying amounts of the chemicals are compared to each other to see which chemical and dosage, best accomplishes the desired results.

Stock solutions of coagulants, coagulant aids and other chemicals, should be prepared at concentrations such that quantities suitable for use in the jar tests can be measured accurately and conveniently.

When making stock solutions from dry chemicals, a very straight forward approach is used. Dissolve 1

gram of solute in 1 litre of water to obtain a 1 g/L solution. Using the solution is easy because 1 gram of solute is contained in 1 litre solvent; therefore 1 mg of solute is contained in 1 mL of solvent. When a jar test requires dosages of solution, simply fill a pipet to the required dosage and the proper mass of chemical will be present in the contained volume of the solution.

EXAMPLE:

One gram of soda ash is contained in one litre of distilled water. We now have a 1 g/L solution of soda ash. A jar test requires dosages of 5 mg/L, 10 mg/L, 15 mg/L, 20 mg/L, 25 mg/L and one jar is a blank. How many mL of soda ash solution are required for each dosage?

1 g/L soda ash solution = 1 mg of soda ash/mL of solution

5 mg of soda ash / 5 mL of solution

Req'd dosages = 5 mg/L, 10 mg/L 15 mg/L, 20 mg/L, 25 mg/L

mL of solution = 5 mL, 10 mL, 15mL, 20 mL, 25 mL

Remember that the dosage is being added to 1 litre of raw water so now the dosage is expressed as 5 mg of soda ash/L of raw water. Conveniently 5 mg/L, and so on for each of the other required dosages.

When preparing solutions from liquid concentrates, the amount of chemical present in the solution needs to be known as well as the relative density of the original solution. The concentration and relative density are usually found on the product label.

A concentrated alum solution contains 48.5% alum and has a relative density of 1.35. To prepare a 1 g/L solution from the concentrated alum, we need to find out how many mL of concentrate contains 1 gram of pure alum.

1 mL of concentrated = 1.35 x 0.485 g of alum solution contains
= 0.65 g of alum

Then the volume occupied of 1 g of alum is:

$$= \frac{1\ g}{0.65\ g/mL}$$

$$= 1.54\ mL$$

1.54 mL of concentrated alum contains 1 gram of alum. To make a 1 g/L solution of alum simply dilute l.54 mL of concentrated solution to one litre with distilled water. Dosages can now be applied to jar tests as described earlier.

EXAMPLE

A water plant with a daily flow of 1 700 m^3 doses at 55 mg/L with a 48.5% liquid alum solution. What is the feed rate in mL/min?

Data: Flow 1.7 x 1000 m^3/d
48.5% alum by mass as active ingredient
1.34 g/cm^3 relative density

$$\text{mass of sol'n req'd} = \frac{(55\ kg/1\,000\ m^3)\ (1.7 \times 1000\ m^3/d)}{0.485}$$

$$= 192.8\ kg/d$$

$$\text{volume of sol'n} = \frac{192.8\ kg/d}{1.34\ kg/L}$$

$$= 143.9\ L/d$$

$$\text{Flow Rate} = \frac{143.9\ L}{d} \times \frac{1\,000\ mL}{L} \div \frac{1\,440\ min}{d}$$

$$= 99.9\ mL/min$$

It is important to mention that feed rates are properly expressed as mL/s but using mL/min is convenient

to calibrate and measure. To obtain mL/s simply divide mL/min by 60 s/min as shown with the above example.

$$\text{Flow rate} = \frac{99.9 \text{ mL}}{\text{min}} \div \frac{60 \text{ s}}{\text{min}}$$

$$= 1.665 \text{ mL/s}$$

CALCULATION OF FEED RATES USING A FORMULA

An alternate method of calculating feed rates in mL/min is through the use of a formula that takes into account all variables such as chemical concentrations, optimum dosages, plant flow, etc.

Below is a mathematical method for determining feed rates of chemical addition in millilitres per minute (mL/min), the normal units found on most liquid chemical feeders. These units of feed rate are utilized as they provide a convenient volume and time scale for calibration and accurate feeding of highly expensive and sometimes hazardous chemicals.

The formula takes into account variations in concentrations of chemicals and their relative densities. Once proper dosage has been established through jar tests and daily flows from the flow chart and the variations in the chemical's composition from the delivery tag this formula will provide the correct feed rate in millilitres per minute.

FEED RATE FORMULA (mL/min)

$$\text{mL/min} = \frac{\text{(Dosage mg/L) (flow/1 000 m}^3\text{/d) (1 000 mL/L)}}{\text{\% active chemical as decimal fraction} \times \text{relative density} \times 1\,400 \text{ min/d}}$$

This formula contains conversion factors that are constants. These are indicated by the boxes in the formula. For ease of calculation, we can reduce the two conversion factors to one. The constant would

be:

$$\frac{1\,000 \text{ mL/L}}{1\,440 \text{ min/d}} = 0.694$$

As a result, we can simplify the feed rate formula. Using the previous example, determination of the alum feed rate, the calculation can be shown as:

$$\text{mL/min} = \frac{\text{(Dosage mg/L) (Flow/1 000 m}^3\text{/d) (0.694)}}{\text{\% active chemical as a decimal fraction} \times \text{Relative Density}}$$

$$= \frac{\text{(55 mg/L) (1.7 x 1 000 m}^3\text{/d) (0.694)}}{\text{(0.485) (1.34 kg/L)}}$$

$$= 99.8 \text{ mL/min}$$

EXERCISE 3

1. How many mL of alum are needed to prepare 1 000 mL of a 1 g/L solution of alum if the concentrated solution is 42.3% by mass and the relative density is 1.42?

2. How many mL of alum are required to make up 1 L of a 1 g/L solution for jar tests if the alum is 48% by mass and the relative density is 1.34?

3. In a water treatment plant both alum and activated silica are being used in the coagulation stage to help precipitate the colloidal suspensions. Jar tests indicated that 50 mg/L alum and 5.5 mg/L activated silica is the optimum dosage. Calculate, using the formula, the feed rate needed for each chemical in mL/min.

DATA: Flow	1 000 m^3/d
Liquid Alum Relative Density	1.35 kg/L
Liquid Alum contains 48.5%	$Al_2(SO_4)_3 \cdot 14\ H_2O$
Activated Silica Rel. Dens.	1 kg/L
Activated Silica contains	1% solution

4. The dry alum dosage rate is 12 mg/L at a water treatment plant. The flow rate at this plant is 13 500 m^3/d. How many kilograms per day of alum are required?

CHEMISTRY, SOLUTION & PREPARATION

SUBJECT: BASIC CHEMICAL PRINCIPLES

OBJECTIVES:

The Student will be able to:

1. Select the correct definition from a given list for each of the following items:

    a. electron
    b. proton
    c. neutron
    d. atom
    e. element
    f. compound
    g. valence

2. Select the examples from a given list to indicate the following terms:

    a. ion i) anion ii) cation
    b. radical
    c. organic compound
    d. inorganic compound

3. Calculate molecular weight for specified compounds given a list of atomic weights.

4. Select from a given list, the correct name for a given simple compound.

BASIC CHEMICAL PRINCIPLES

CHEMISTRY

Chemistry might be defined as the science that deals with the composition, properties and changes undergone by matter under certain influences.

MATTER

Matter is defined as anything that occupies space and has mass.

The page these words are written on is a form of matter, as is the ink which forms the letters on the page.

Some forms of matter consist of a single kind of matter called a pure substance.

ATOMS

Pure substances are made up of one or more "atoms". An atom might be defined as the smallest particle we could separate which would still exhibit the characteristic properties of that pure substance.

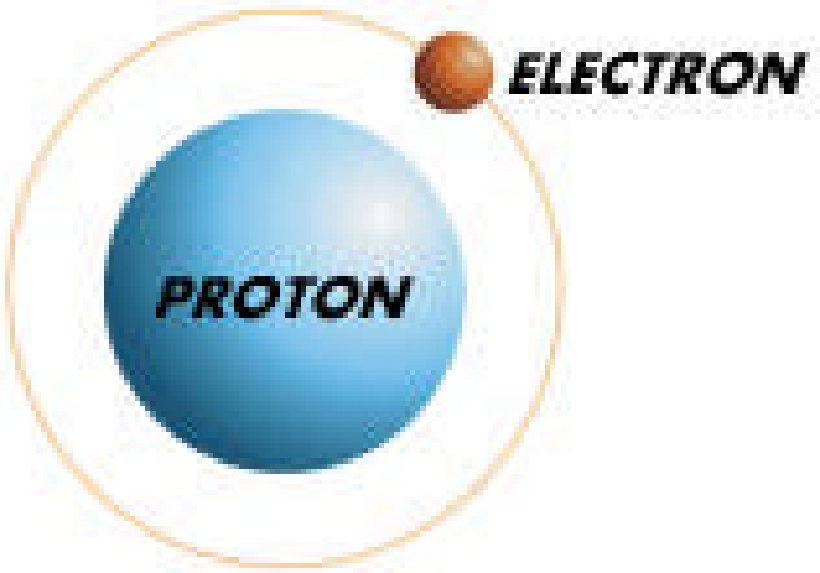
Pure substances can be either "elements" or "compounds". Elements are Pure Substances which contain only one kind of atom, whereas compounds are pure substances which contain more than one kind of atom.

Examples of common elements are gold (Au), chlorine (Cl), sulphur (S), oxygen (O) and hydrogen (H).

Examples of common compounds are sodium chloride (NaCl), water (H_2O), hydrogen sulphide (H_2S) and calcium hydroxide (CaOH).

ELEMENTS

We have established that matter is composed of one or more elements, but what is an element? An element is a pure substance which may be a solid, a liquid, or a gas. Since it will have only one kind of "atom" present, it will have certain characteristics not duplicated by any other element. What is an "atom"? One of the common elements is hydrogen which is a clear colourless gas, and is lighter than air. If it were possible to separate the smallest particle we could get, that would still have the characteristics of hydrogen, this tiny particle would be an atom. We might see something like this if it were possible to put it under a super-powerful microscope:

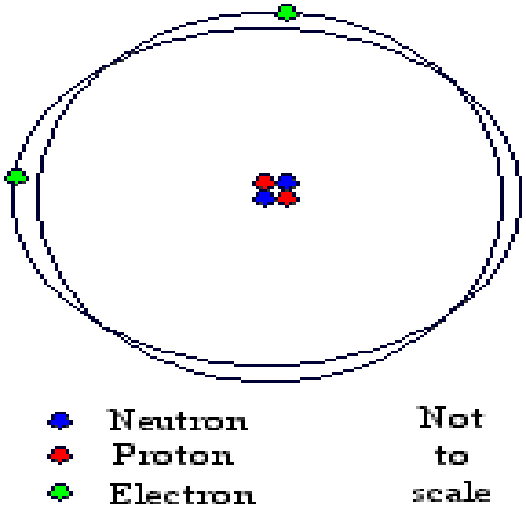


The centre is the nucleus. In this case, the nucleus contains only one thing - a proton. It is a tiny particle that always has a positive charge.

The small red spot is a satellite, and the circle represents its orbit. This satellite is called an electron. It is also a tiny particle but has a negative charge.

Since there is only one proton, we can say that hydrogen has a mass of 1. The electron, being so much smaller, is ignored as far as this mass is concerned.

Hydrogen is the lightest atom. Let us look at helium to show you why:



In the helium atom nucleus, the two black spots represent two protons. The orbit has two electrons. The two small circles in the nucleus represent something new, two neutrons. A neutron is a particle which has the same weight as a proton but has no electrical charge (neutral). If we say that hydrogen has a mass of 1, then helium will have a mass of 4. This relative mass is called the atomic weight of an element. If we proceed down the list of elements, we will discover that each one has a different atom with a different arrangement of protons, neutrons and electrons. Using the number of protons and neutrons present, we can make a list of theoretical atomic weights.

Every once in a while we will find an odd example of an element mixed in with its sisters. It will have a slightly different arrangement of the nucleus, such as an extra neutron. This atom will be exactly like the others except for weight and is called an isotope. An isotope might be described as a mutation of the usual atom.

Atomic	Atomic
Wt 2	Wt 1

Hydrogen "Heavy" Hydrogen
(an isotope)

If we could take a quantity of hydrogen atoms and weigh them, we would find that the average weight is not 1 but 1.008 due to the occasional presence of the heavier isotope. This explains why atomic weights are not all even numbers.

If you will turn to the accompanying table cataloguing the distribution of electrons in each orbit around the nucleus (Table 1-2), you will see that each orbit has only so many "parking spots" and once these are occupied, a new orbit shell is begun. An exception to this occurs in some of the outermost orbits where some "double parking" is overlooked. In any case, there are never more than 8 electrons in the outer-most shell.

On the basis of the distribution of electrons we can isolate four different structural types of atoms:

1. Inert elements - these with all orbit shells filled to the maximum.

2. Simple elements - those with only one unfilled shell.

3. Transition elements - those with two unfilled shells.

4. Rare earth elements - those with three unfilled shells.

You will notice that the elements are arranged in the table in order by their atomic number. This is nothing more than the sum of the number of electrons in the shells surrounding the nucleus. Each element differs from its immediate neighbours by one electron and therefore one proton in the nucleus (since all elements must be electrically neutral).

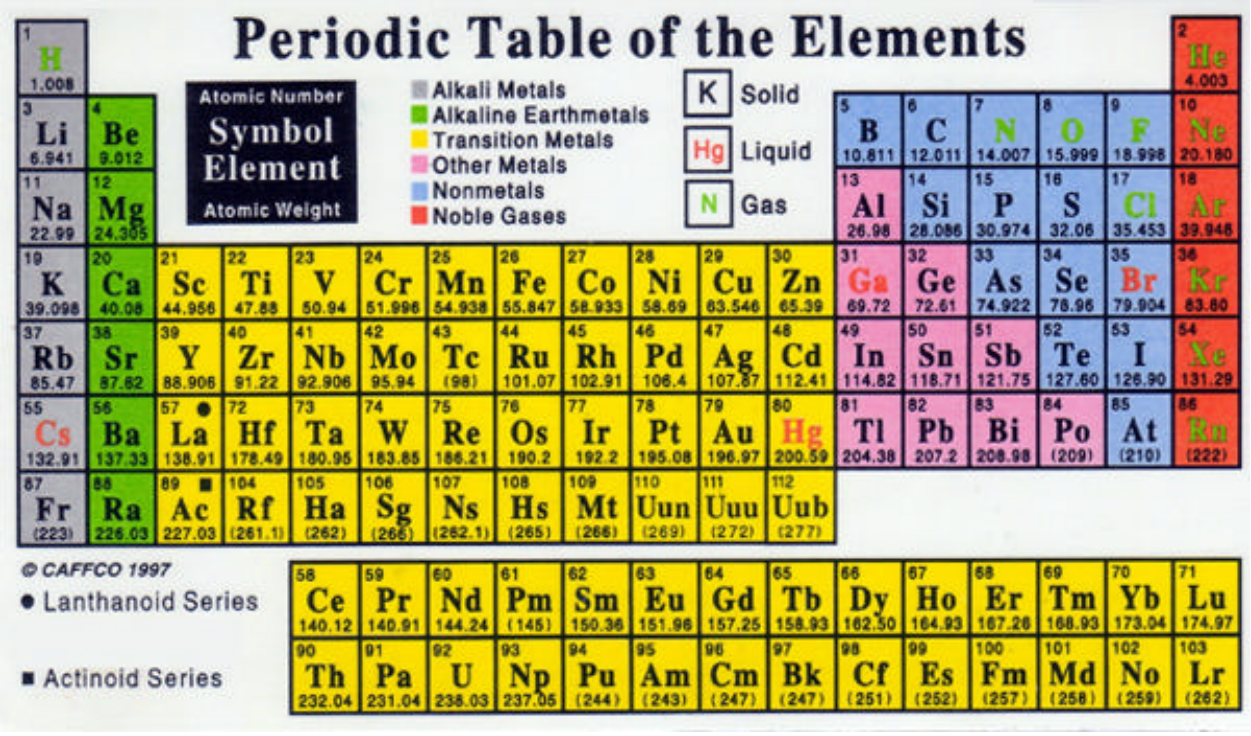


TABLE B-2

IONS

Some atoms, under certain circumstances can lose electrons and others can gain electrons. When an atom loses an electron, it will have an excess proton or one plus (+) charge and will be very active. Gaining an electron from another element causes an atom to become negatively (-) charged and also very active. This process is called ionization. Ions (electrically charged atoms) are formed. Ions are of two types depending on their charge:

1. Anions - negatively charged ions - e.g. Cl^-, I^-, Br^-

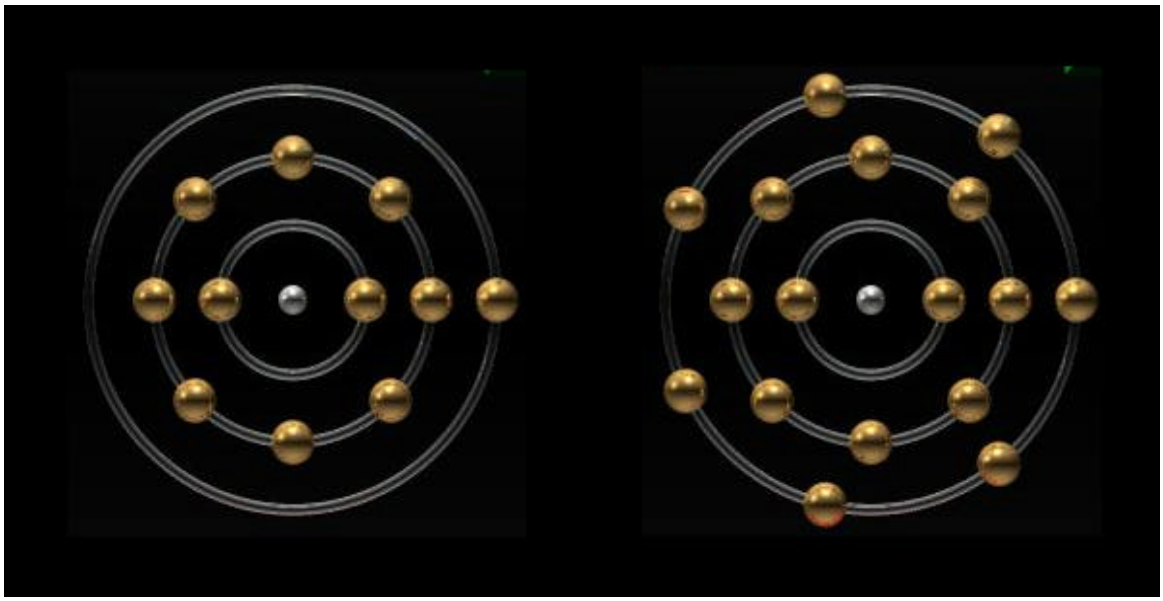
2. Cations - positively charged ions - e.g. H^+, Na^+, K^+

COMPOUNDS

As we have said, compounds are pure substances made up of atoms of more than one element. Atoms of two or more elements combine to form a molecule of a compound with distinctive properties of its

own. A molecule is the smallest particle of a compound which could be separated, that would still show all of the properties of that compound. A molecule is usually made up of atoms of more than one element and is therefore somewhat larger in size than an atom.

When atoms combine to form molecules, only the outer shells of electrons take part in the joining. The nuclei are not affected. Let us look at atoms of sodium and chlorine to see what makes them eager to join together to form a molecule of the compound sodium chloride (or table salt).

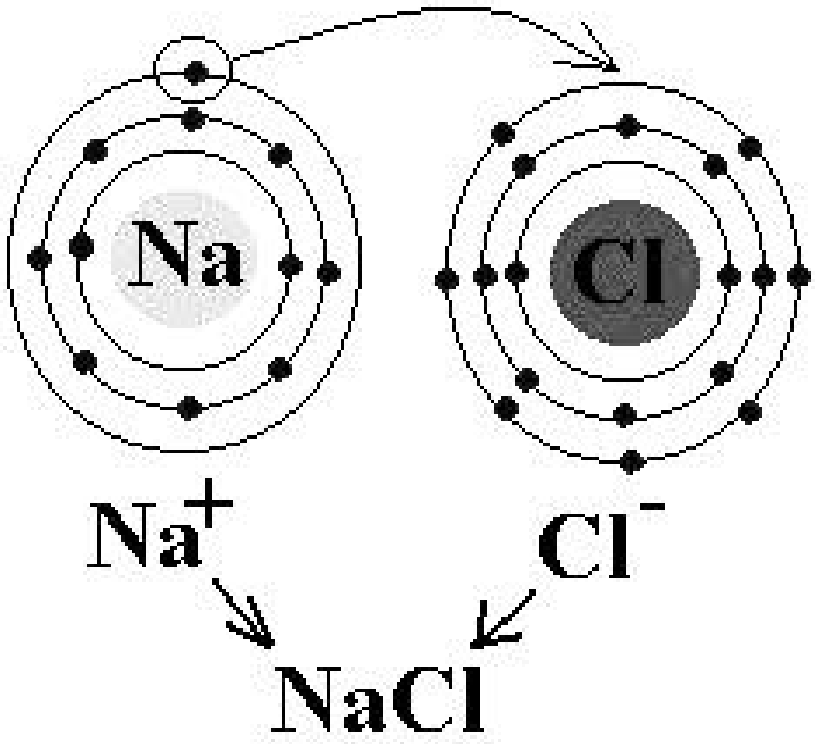


Sodium Chlorine

We can see that both atoms have completed inner electron shells with the maximum number of electrons. Neither has a complete outer orbit however. Chlorine has 7 electrons and is seeking one more electron to make a complete shell. This makes chlorine a very active element.

Sodium on the other hand has only one electron in its outer shell. It would gladly give up this electron to any atom that has a strong desire for it. This also makes sodium an active element.

If we could get the sodium atom and the chlorine atom to come together and make the transfer of a single electron, both would be happy. When these two elements contact each other, that is exactly what happens; two violently reactive elements combine to form a new, extremely stable compound.



SODIUM CHLORIDE

(table salt)

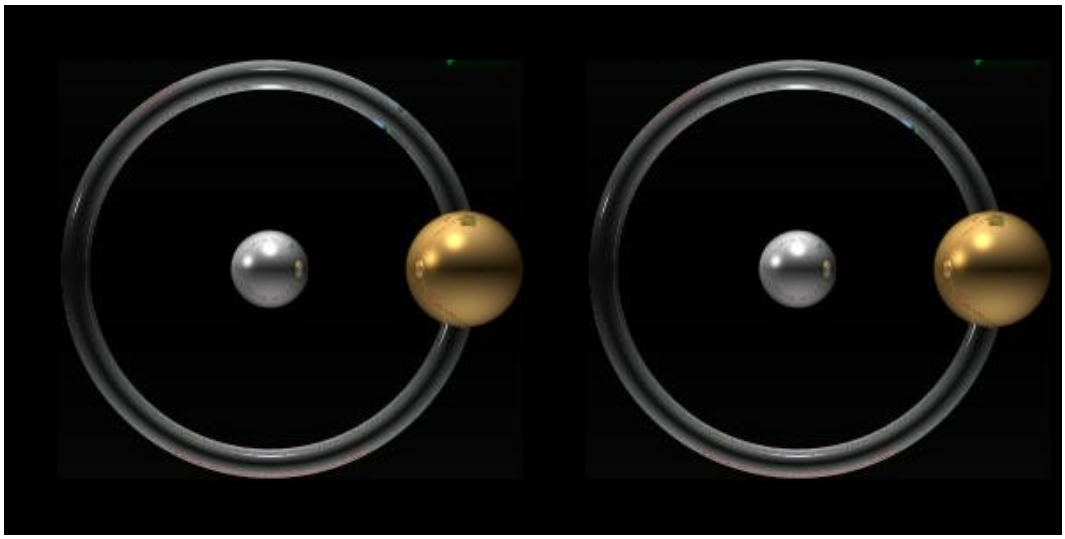
A few other examples of compounds formed this way are: HCl, KI, H_2S and HNO_3. With these last two, H_2S and HNO_3, you will notice that it is possible for several atoms to get into this exchanging act, if all of them will benefit by becoming more stable electrically.

In nature, what we find is that elements that have highly reactive atoms, exist in their uncombined form only as long as it takes to find another atom that can be convinced to undertake an electron exchange with it. When they find another compound already formed with a weaker element having those desirable atoms, this highly reactive element can force the weaker element to change places with it. In this sense, justice doesn't exist in the chemical world.

MOLECULES

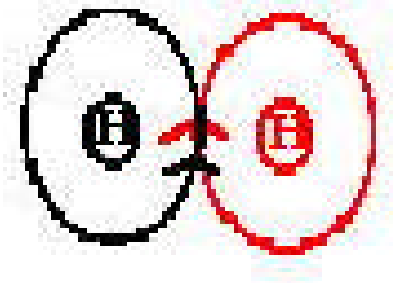
We have learned that atoms of two different elements can combine to form a molecule of a new compound, but a molecule can also be formed from atoms of the same element in some cases.

Certain elements, particularly those which are gases commonly combine with themselves to form molecules. Examples of this are: H_2, O_2 and $C1_2$. The subscript "2" indicates that two atoms have formed a molecule. Let us look at hydrogen to explain this.



Hydrogen Hydrogen

If these two atoms join together, they can share these two electrons and each will then have a stable outer shell of 2 electrons.



H_2

(Hydrogen Gas)

VALENCE

The tendency of elements to form compounds through a shift of electronic structures is known as valence. Let us examine two methods of attaining a stable electronic distribution.

A. Electrovalence

As we said earlier, under some conditions, an atom can lose one or more electrons, which leaves the atom with a corresponding number of tiny positive electrical charges. Other atoms can gain one or more electrons in a similar manner which will give them negative charges.

These positive and negative charges are equal and are attracted to each other by electrostatic action. Such atoms are said to be electrovalent and the term valence is used to describe the number of such bonds. Usually the ionized atoms of metals have positive charges (positive valence) and the symbols could be written as follows:

Na^{+} , K^{+} , Ca^{++} , Al^{+++}

(Cations)

On the other hand, the atoms of nonmetals tend to become negatively charged or have negative valence. For example:

Cl^{-} , O^{--} , S^{---}

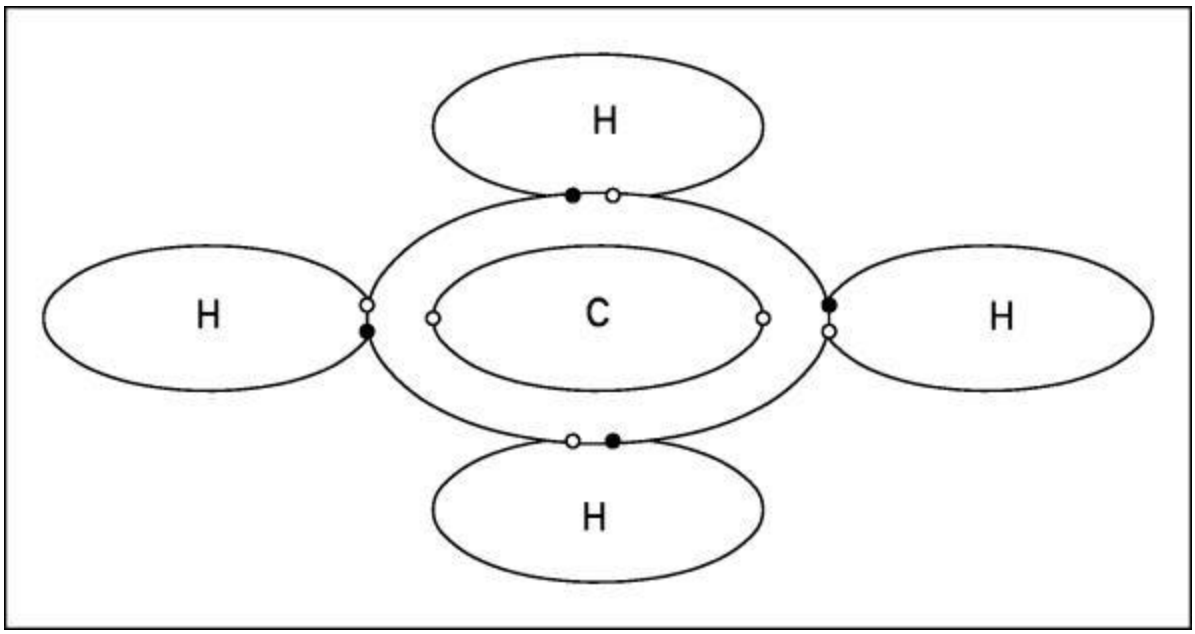
(Anions)

Electrovalent compounds are thus formed when anions and cations combine in the correct number to satisfy their valences. See Table B-3, Table of Electrovalence

B. Covalence

On the basis of electrovalence we would expect an element like carbon to be fairly inert and form few compounds; yet, this element forms more compounds than all the other elements put together. Obviously, there must be some other valence mechanism.

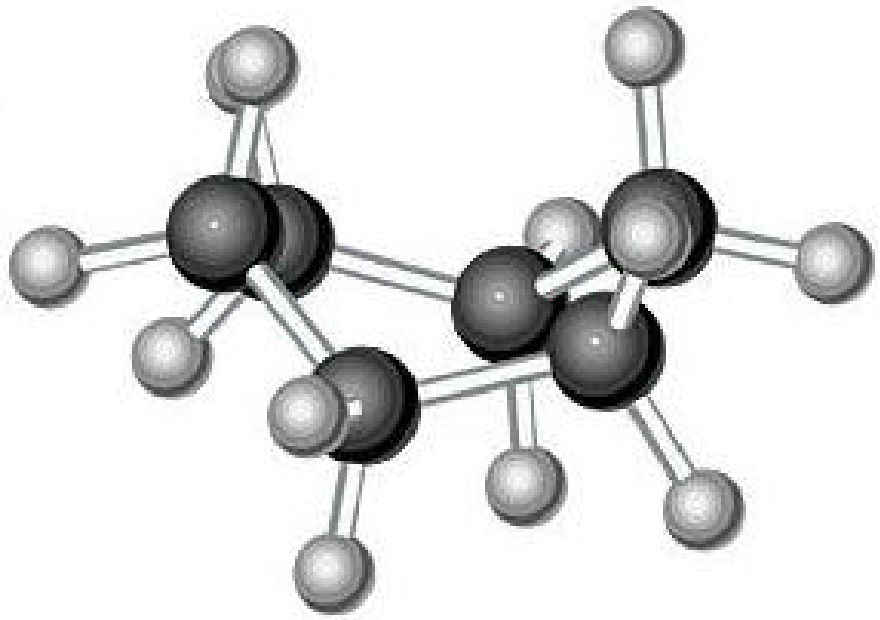
Carbon has four electrons in its outermost shell. Hydrogen has one electron in its only shell. If four hydrogen atoms were to approach a carbon atom so closely, that the shell of each hydrogen atom penetrated into the outermost shell of the carbon atom, the electrons in these interpenetrated shells would then be influenced by the nuclei of both types of atoms. Both atoms could then share these electrons. What we would have is a carbon atom sharing one electron with each of four hydrogen atoms. In effect, the hydrogen electron would be spending part of its time orbiting the hydrogen nucleus and part of its time orbiting the carbon nucleus.



Methane - Covalent Bonding

In methane, each hydrogen atom now has two electrons, giving it the stable helium configuration in its orbits, and eight electrons are now associated with the carbon atom giving it the stable neon configuration. Both types of atoms have benefited by attaining a stable structure through this sharing process. Covalent compounds are thus formed by the sharing of pairs of electrons.

When only one pair of electrons is shared by the same two atoms, the bond is said to be a single bond. When two pairs are shared, we describe this as a double bond and with three pairs, a triple bond.



ORGANIC COMPOUNDS

Most compounds which follow the covalent method of bonding just described and contain the element carbon, are, or have been at some time, part of the earth's life process. These are said to be organic compounds.

Compounds which do not fit into this category are labeled inorganic. For example:

Organic Compounds	Inorganic Compounds
CH_4	HCl
C_2H_2	Na_2SO_4
C_6H_5OH	NH_40H
$NaC_2H_3O_4$	$AgNO_3$

RADICALS

In many chemical compounds there are clusters of elements which behave as if they were a single element; such a group of elements is known as a radical.

Radicals exhibit some of the characteristics of ions, in that they all have an excess or a deficiency of electrons, causing the radical to posses an electrical charge. They will therefore combine with other ions or radicals to form compounds.

Common examples of radicals are:

NH_4^+	ammonium	NO_2^-	nitrite
$C_2H_3O_2^-$	acetate	CO_3^{--}	carbonate
HCO_3^-	bicarbonate	SO_4^{--}	sulphate
OH^-	hydroxide	SO_3^{--}	sulphite
NO_3^-	nitrate		

Since ammonium is a positive radical, it will form compounds with all negative ions or radicals. For example:

NH_4Cl	ammonium chloride
$(NH_4)_2CO_3$	ammonium carbonate

Note that it takes two ammonium radicals to satisfy the electrical charge (valence) of the carbonate radical.

If you look carefully at the names and formulas of the radicals you will notice that the suffixes -"ite" and "-ate" occur repeatedly. These suffixes are used only with radicals containing oxygen atoms. Notice that "-ite" radicals always contains fewer oxygen atoms that "-ate" radicals.

For example:

Sulphite SO_3^{--}	Sulphate SO_4^{--}
Nitrite NO_2^-	Nitrate NO_3^-

MOLECULAR WEIGHT

When we were discussing atoms, we said that the relative mass of one atom compared to another is known as its atomic weight. We also said that the elements relative mass must be the average of its

mass, taking into account the abundance of natural isotopes found.

Table B-3 is a list of International Relative Atomic Weights scaled to the relative atomic mass of carbon as 12.

International Relative Atomic Weights

Actinium Ac	227 **
Aluminum Al	26.981538
Americium Am	243
Antimony Sb	121.760
Argon Ar	39.948
Arsenic As	74.92160
Astatine At	210
Barium Ba	137.327
Berkelium Bk	247
Beryllium Be	9.012182
Bismuth Bi	208.98038
Bohrium Bh	264
Boron B	10.811
Bromine Br	79.904
Cadmium Cd	112.411
Calcium Ca	40.078
Californium Cf	251
Carbon C	12.0107
Cerium Cc	140.116
Cesium CS	132.9054
Chlorine C	l 35.453
Chromium Cr	51.9961
Cobalt Co	58.933200
Copper Cu	63.546
Curium Cm	247
Dubnium Db	262
Dyprosium Dy	162.50
Einsteinium Es	252
Erbium Er	167.259
Europium Eu	151.964
Fermium Fm	257
Fluorine F	18.9984032
Francium Fr	223
Gadolinium Gd	157.25
Gallium Ga	69.723
Germanium Ge	72.64
Gold An	196.96655
Hafnium Hf	178.49
Hassium Hs	277
Helium He	4.002602
Holmium Ho	164.93032
Hydrogen H	1.00794
Indium In	114.818
Iodine I	126.90447
Iridium Ir	192.217
Iron Fc	55.845
Krypton Kr	3.80
Lanthanum La	138.9055
Lawrencium Lr	262
Lead Pb	207.2
Lithium Li	6.941
Lutetium Lu	174.967
Magnesium M	24.3050
Manganese Mn	54.938049
Meitnerium Mt	268
Mendelevium Md	258
Mercury Hg	200.59
Molybdenum Mo	95.94
Neodymium Nd	144.24
Neon Ne	20.1797
Neptunium Np	237
Nickel Ni	58.6934
Niobium Nb	92.90638
Nitrogen N	14.0067
Nobelium No	259
Osmium Os	190.23
Oxygen Os	15.9994
Palladium Pd	106.42
Phosphorus P	30.973761
Platinum Pt	195.078
Plutonium Pu	244
Polonium Po	209
Potassium K	39.0983
Praseodymium Pr	140.90765
Promethium Pm	145
Protactinium Pa	231.03588
Radium Ra	226
Radon Rn	222
Rhenium Re	186.207
Rhodium Rh	102.90550
Rubidium Rb	85.4678
Ruthenium Ru	101.07
Rutherfordium Rf	267
Samarium Sm	150.36
Scandium Sc	44.955910
Selenium Se	78.96
Seaborgium Sg	266
Silicon Si	28.0855
Silver Ag	107.8682
Sodium Na	22.989770
Strontium Sr	87.62
Sulfur S	32.065
Tantalum Ta	180.9479
Technetium Tc	98
Tellurium Te	127.60
Terbium Tb	158.92534
Thallium TI	204.3833
Thorium Th	232.0381
Thulium Tm	168.93421
Tin Sn	118.710
Titanium Ti	47.867
Tungsten W	183.84
Ununilium Uun	281
Ununquadium Uuq	289
Uranium U	238.02891
Vanadium V	50.9415
Xenon Xe	131.293
Ytterbium Yh	173.04
Yttrium Y	88.90585
Zinc Zn	65.39
Zirconium Zr	91.22

To find the relative mass of any molecule or its molecular weight, one simply adds up the atomic weights of each of the atoms in the molecule. For example:

1. HOCl
(Hypochlorous Acid)

Molecular weight = H + O + Cl
= 1.008 + 15.999 + 35.453
= 52.460

2. $FeSO_4$ (Ferrous Sulphate)

Molecular weight = Fe + S + 4 (O)
= 55.847 + 32.064 + 4 (15.999)
= 151.907

3. $Ca(OH)_2$ (Hydrated Lime)

Molecular weight = Ca + 2 (O + H)
= 40.08 + 2 (15.999 + 1.008)
= 74.094

Since these weights are only relative masses, they have no units. However, the proportions of each atom which combine to form a molecule are always the same. For example, HCl, hydrochloric acid will always contain 1.008 parts by weight of hydrogen and 35.453 parts by weight of chlorine. If the parts or units we choose are grams, HCl will always contain 1.008 grams hydrogen and 35.453 grams of chlorine in every 36.461 grams of HCl. In this way we can express the relative masses of atoms as gram atomic weights and their combined weights as gram molecular weights. These terms will become especially important to us later when we discuss the preparation of standard solutions.

NAMING COMPOUNDS

Binary Compounds

Binary compounds are those which are made up of two elements; simple examples are the salts NaCl and KCl. The names of these compounds consist of the names of the two elements, the positive element first, with the ending of the second element changed to "ide".

eg:

NaCl - sodium chloride

KCl - potassium chloride

If the metal has two different oxidation numbers (valences) this is indicated by the use of the suffix "-ous" for the lower or weaker example and "-ic" for the highest or stronger one.

eg:

$FeCl_2$ - ferrous chloride

$FeCl_3$ - ferric chloride

Occasionally two elements can form into two or more compounds of different proportion and a different naming system is resorted to. The name of the second element is preceded by a prefix -eg- mono-(one), di-(two), tri-(three), tetra(four) etc. Oxides are good examples of this.

eg:

CO - carbon monoxide

CO_2 - carbon dioxide

P_2O_3 - phosphorous trioxide

P_2O_5 - phosphorous pentoxide

Compounds Containing Radicals

Naming compounds containing radicals is done in the same way as for binary compounds, except that the name for the radical is used rather than the names of its component elements

eg:

$CaCO_3$ - calcium carbonate

Na_2SO_4 - sodium sulfate

NH_4Cl - ammonium chloride

KOH	- potassium hydroxide
$Fe(OH)_2$	- ferrous hydroxide
$Fe(OH)_3$	- ferric hydroxide

Acids

Binary acids are named using the prefix "hydro-" in front of the name of the negative element, followed by the suffix "-ic".

eg:

HF	- hydrofluoric acid
HCl	- hydrochloric acid
HBr	- hydrobromic acid
HI	- hydroiodic acid

Many common acid molecules contain hydrogen, a nonmetal (negative element), and oxygen. Since the amount of oxygen often varies, the name of the most common form of the acid in the series consists of the stem of the name of the nonmetal with the suffix "-ic". The acid containing one less atom of oxygen than the common form has the suffix "-ous". The acid containing one more atom of oxygen than the common form has the prefix "per-" and the suffix "-ic". The acid containing two less atoms of oxygen than the common form has the prefix "hypo-" and the suffix "-ous".

eg:

HNO_3	- nitric acid
HNO_2	- nitrous acid
$HCl0_3$	- chloric acid
$HClO_2$	- chlorous acid
HClO	- hypochlorous acid
H_2SO_4	- sulfuric acid
H_2SO_3	- sulfurous acid
H_3PO_4	- phosphoric acid
H_3PO_3	- phosphorous acid
H_2CO_3	- carbonic acid
$H_2C_2O_4$	- oxalic acid
H_3BO_3	- boric acid

SUBJECT: SOLUTION PREPARATION

OBJECTIVES:

The student will be able to:

1. Select the correct definition from a given list for each of the following items:

    a. solute
    b. solvent
    c. normality
    d. molarity
    e. percentage composition

2. Calculate the weight in grams of a given compound required to make a litre of 3 normal solution.

3. List the quantities represented in an indicated list of S.I. prefixes, by a given quantity in grams

SOLUTIONS

A solution consists of two components, a solvent which is the dissolving medium and a solute which is the substance dissolved. The solute is dispersed as molecules or ions and the distribution of the solute is perfectly homogenous throughout the solution. Common examples of solvent and solute are:

SOLVENT	SOLUTE
water	sugar
alcohol	table salt
chloroform	baking soda
vinegar	starch

A concentrated solution is one which contains a relatively large amount of solute per unit volume of solution. A dilute solution is one which contains a relatively small amount of solute per unit volume of solution. The words "strong" and "weak" should not be used when referring to the concentration of a solution. Strong and weak are terms that are more properly used to describe the chemical activity of a substance.

CONCENTRATION

The concentration of a solution can be expressed in a number of ways. The units of expression give an indication of the way in which a solution of this concentration would be made up. The most common units of expression for concentration are:

1. Molarity
2. Normality
3. Molality
4. Percentage Composition

MOLARITY

The molarity of a solution is the number of gram molecular weights of solute per litre of solution. "Gram molecular weight" is sometimes abbreviated as mole, so molarity becomes

$$\text{Molarity (M)} = \frac{\text{Number of moles of solute}}{\text{Litre of solution}}$$

A solution which contains a half mole of solute per litre of solution would therefore be a 0.5 M solution.

NORMALITY

The normality of a solution is the number of gram equivalent weights of solute per litre of solution. "Gram equivalent weight" is a new term and is often abbreviated as equivalent.

$$\text{Normality (N)} = \frac{\text{Number of equivalents of solute}}{\text{Litre of solution}}$$

The equivalent weight of a compound is found from the net positive valance of the compound. If we take the valance of the positive (+) part of the compound and multiply it by its subscript we will have the total number of positive charges available, or net positive valence.

net positive valence = (valence of + element) x (its subscript if any)

The equivalent weight of any compound is then found from the relationship

$$\text{equivalent weight} = \frac{\text{molecular weight}}{\text{net positive valence}}$$

Let us use solutions of NaCl and K_2CO_3 in water to illustrate this principle. To make up a 1 N solution of either salt we will need 1 gram equivalent weight (equivalent) of each dissolved in 1 litre of solution.

For NaCl, the net positive valence is 1 so the equivalent weight of NaCl is the same as its molecular weight.

For K_2CO_3 however, the net positive valence is 2 so the equivalent weight of K_2C0_3 is its molecular weight over 2.

MOLALITY

The molality of a solution is the number of moles of solute per 1000 grams of solvent. Since the solvent will not always be water, this method of expression is considerably different from molarity.

$$\text{molality (m)} = \frac{\text{Number of moles of solute}}{\text{1000 grams of solvent}}$$

PERCENTAGE COMPOSITION

This method of expression of concentration may use either percentage by weight or percentage by volume as its units.

$$\%\text{ by weight} = \frac{\text{weight of solute}}{\text{weight of solution}} \times 100$$

$$\%\text{ by volume} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100$$

Percentage by weight is usually used in referring to solids dissolved in liquids. Percentage by volume is normally used with reference to gases in gases, or liquids in liquids.

CONCENTRATION EXAMPLE

If we were given the task of preparing a 3 N solution of K_2CO_3, we must start with the fact that

$$3N = \frac{\text{3 equivalents of solute}}{\text{Litre of solution}}$$

What we now need to know is the gram equivalent weight of K_2CO_3. Let's start out by finding the gram molecular weight of K_2CO_3:

gm molecular wt K_2CO_3 = 2 (39.102) + 12.011 + 3 (15.999)

= 138.212 gm

Since the valence of K is 1, the net positive valence of K_2CO_3 is 2.

$$\text{gm equivalent wt of } K_2CO_3 = \frac{\text{gm molecular wt}}{\text{net positive valence}}$$

$$= \frac{138.212 \text{ gm}}{2}$$

$$= 69.106 \text{ gm}$$

Since, as we said earlier,

$$3N = \frac{3 \text{ equivalents of solute}}{\text{Litre of solution}}$$

we can now substitute

$$3N = \frac{3 (69.106 \text{ gm})}{\text{Litre of solution}}$$

$$= \frac{207.218 \text{ gm } K_2CO_3}{\text{Litre of solution}}$$

We can now make up this solution by weighing accurately 207.218 gm of dried K_2CO_3, placing this amount in a l-litre volumetric flask and diluting the solution to occupy exactly 1 litre.

SOLUTION PREPARATION

Where solutions of known concentration are used as standards in the analysis of other compounds, the preparation of these solutions must be undertaken with great care.

Atomic weights are given in the tables with great precision, and gram molecular or gram equivalent weights can be calculated to at least 4 decimal places. It is our responsibility then to see that only devices and procedures capable of continuing this precision are used in the preparation of standard solutions.

To prepare a standard solution, approximate desired quantities of granular or powdered solute are deposited in a weighing bottle, paper weigh-boat or aluminum weighing dish and dried for at least one hour in a laboratory oven at 103^{o}C.

After drying, the weighing bottle containing the sample is placed in a laboratory desiccator to cool to room temperature in a dry atmosphere.

The net weight of the solute is then determined using an analytical balance capable of 0.1 mg precision (0.0001 g). If any minor changes in the finished weight are desired, small amounts of solute may be removed at this time and the sample redried and cooled.

The sample is considered to have reached stable weight when three consecutive desiccating and weighing cycles results in a difference of less than 1 mg. The mean of the three weight values is then taken as the weight of the sample.

When the desired final weight is reached, the solute is transferred, using a powder funnel, from the weighing container to a 1 litre volumetric flask. A "rubber policeman" may be used to push the last few grains of powder into the funnel. A stream of distilled water from a wash bottle is then used to flush the weighing container and the powder funnel to dislodge and dissolve any stubborn powder.

The powder in the volumetric flask is dissolved in a small amount of distilled water by inverting or swirling the flask. When all of the powder is dissolved, enough distilled water is added to bring the level in the flask almost to the engraved line on the neck. The contents of the flask are then mixed by inverting several times.

When the solution is considered to be well mixed, it is allowed to stand for sometime so that all of the solution will drain back into the bottom of the flask. Then, using a fine-tipped wash bottle, distilled water is added slowly to bring the bottom of the meniscus curve exactly level with the engraved line.

After mixing the solution again by inverting at least twenty times, the solution must be standardized against some known laboratory standard solution to prove its concentration. The proven concentration of the solution is then marked clearly on the label of its container.

THE S.I. (METRIC) SYSTEM

The S.I. system of weights and measures is used in all laboratory work. The entire system is based upon the length of the metre, a bar of special metal which is carefully preserved in Paris (see Math unit for more recent definition). This bar represents one-ten ten millionth of the distance from the equator to the North Pole. It serves as a standard for measuring distance, area and dry volume.

The unit of measure for weight is the gram. The units for weight, distance and liquid volume are related, in that the unit of measure for liquid volume is the litre, and 1/1000 litre (1 millilitre) of water at 39.2° F weighs one gram and occupies 1 cubic centimetre.

The system uses a variety of prefixes attached to these basic units in order to scale the units up or down conveniently. A list of the common prefixes appears in Table 2-1.

TABLE B-4 Prefixes Most Commonly Used with S.I.

Prefix	Meaning	Symbol
mega-	10^6	M
kilo-	10^3	k

deci-	10^{-1}	d
milli-	10^{-3}	m
micro-	10^{-6}	u

By our choice of prefix we can change very large numbers or very small numbers into convenient-sized readable numbers. For example:

35 000 metres = 36 kilometres
0.0016 litres = 1.6 millilitres
0.0000032 grams = 3.2 micrograms

To change a number from one unit of the system to one with a different prefix, one simply moves the decimal point to the right or left the correct number of places. Using the prefixes in Table B-5.

365 grams = 0.000365 megagrams
= 0.365 kilograms
= 3650 decigrams
= 365000 milligrams
= 365 000 000 micrograms

ADDENDUM C

GUIDELINES FOR CANADIAN DRINKING WATER QUALITY

Summary of Guidelines for Canadian Drinking Water Quality

Prepared by the
Federal–Provincial–Territorial Committee on Drinking Water
of the
Federal–Provincial–Territorial Committee
on Environmental and Occupational Health

April 2002

The *Guidelines for Canadian Drinking Water Quality* are published by Health Canada. In order to keep interested parties informed of changes to the Guidelines between publication of new editions, this summary table is updated and published every spring on Health Canada's website (www.hc-sc.gc.ca/waterquality). The April 2002 "Summary of Guidelines for Canadian Drinking Water Quality" supercedes all previous versions, including that contained in the published booklet.

Membership of the Federal–Provincial–Territorial Committee on Drinking Water and Secretariat

Provincial and Territorial Representatives

Alberta	Department of Environment	Mr. Karu Chinniah
British Columbia	Ministry of Health Planning	Mr. Barry Boettger
Manitoba	Department of Conservation	Mr. Don Rocan
New Brunswick	Department of Health and Wellness	Mr. Ivan Brophy
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Northwest Territories	Department of Health and Social Services	Mr. Duane Fleming
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Nunavut Territory	Department of Health and Social Services	Mr. Bruce Trotter
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Mr. Tim Macaulay	Canadian Advisory Council on Plumbing

Committee Secretary

Health Canada (Water Quality and Health Bureau, Safe Environments Programme, Healthy Environments and Consumer Safety Branch)	Mr. David Green

New, Revised and Reaffirmed Guidelines

New, revised and reaffirmed guidelines for chemical, physical and microbiological parameters are presented in Table 1.

Table 1
New, Revised and Reaffirmed Guidelines* for Chemical, Physical and Microbiological Parameters since the Publication of the Sixth Edition of the *Guidelines for Canadian Drinking Water Quality*

Parameter	Guideline (mg/L)	Previous guideline (mg/L)	Year approved
Chemical and Physical Parameters			
Aluminum	0.1**	None	1998
Antimony	IMAC 0.006	None	1997
Bromate	IMAC 0.01	None	1998
Cyanobacterial toxins (as Microcystin-LR)	0.0015	None	2002
Fluoride	MAC 1.5	MAC 1.5	1996
Formaldehyde	None required – see Table 3	None	1997
Uranium	IMAC 0.02	MAC 0.1	1999
Microbiological Parameters			
Bacteria	***		Ongoing
Protozoa	***		Ongoing
Viruses	***		Ongoing

* MAC = maximum acceptable concentration; IMAC = interim maximum acceptable concentration.
** Refer to note 1 in Table 2.
*** Refer to section on Summary of Guidelines for Microbiological Parameters.

Summary of Guidelines for Microbiological Parameters

Bacteria (Under Review)

The maximum acceptable concentration (MAC) for bacteriological quality of public, semi-public, and private drinking water systems is no coliforms detectable per 100 mL. However, because coliforms are not uniformly distributed in water and are subject to considerable variation in public health significance, drinking water that fulfills the following conditions is considered to conform to this MAC:

Public Drinking Water Systems

1. No sample should contain *Escherichia coli*. *E. coli* indicates recent faecal contamination and the possible presence of enteric pathogens that may adversly affect human health. If *E. coli* is confirmed, the appropriate agencies should be notified, a boil water advisory should be issued, and corrective actions taken.

2. No consecutive samples from the same site or not more than 10% of samples from the distribution system in a given calendar month should show the presence of total coliform bacteria. The ability of total coliforms to indicate the presence of faecal pollution is less reliable than *E. coli*. However, this group of bacteria is a good indicator of quality control. The presence of total coliforms does not necessarily require the issuance of a boil water advisory but corrective actions should be taken.

Semi-public and Private Drinking Water Supply Systems

1. No sample should contain *E. coli*. As stated above, the presence of *E. coli* indicates faecal contamination and the possible presence of enteric pathogens; therefore the water is unsafe to drink. If *E. coli* is detected, a boil water advisory should be issued and corrective actions taken.

2. No sample should contain total coliform bacteria. In non-disinfected well water, the presence of total coliform bacteria in the absence of *E. coli* indicates the well is prone to surface water infiltration and therefore at risk of faecal contamination. In disinfected water systems, the presence of total coliform bacteria indicates a failure in the disinfection process. In both disinfected and non-disinfected systems, total coliform detection may also indicate the presence of biofilm in the well or plumbing system. The degree of response to the presence of total coliform bacteria, in the absence of *E. coli*, may be site specific and can vary between jurisdictions.

Protozoa (Under Review)

Numerical guidelines for the protozoa *Giardia* and *Cryptosporidium* are not proposed at this time. Routine methods available for the detection of protozoan cysts and oocysts suffer from low recovery rates and do not provide any information on their viability or human infectivity. Nevertheless, until better monitoring data and information on the viability and infectivity of cysts and oocysts present in drinking water are available, measures to reduce the risk of illness as much as possible should be implemented. If viable, human-infectious cysts or oocysts are present or suspected to be present in source waters or if *Giardia* or *Cryptosporidium* has been responsible for past waterborne outbreaks in a community, a treatment regime and a watershed or wellhead protection plan (where feasible) or other measures known to reduce the risk of illness should be implemented.

Viruses (Under Review)

Numerical guidelines for human enteric viruses are not proposed at this time. There are more than 120 types of human enteric viruses, many of which are non-culturable. Testing is complicated, expensive, not available for all viruses, and beyond the capabilities of most laboratories involved in routine water quality monitoring. The best means of safeguarding against the presence of human enteric viruses are based upon the application of adequate treatment and the absence of faecal indicator organisms, such as *Escherichia coli*.

Boil Water Advisories

General guidance on the issuing and rescinding of boil water advisories is provided. In the event of an advisory, a rolling boil for 1 minute is considered adequate.

Summary of Guidelines for Chemical and Physical Parameters

Parameters with Guidelines

Guidelines for all chemical and physical parameters, including all new, revised and reaffirmed maximum acceptable concentrations (MACs), interim maximum acceptable concentrations (IMACs) and aesthetic objectives (AOs), are listed in Table 2. For more information on the drinking water guideline for any particular compound, please refer to the Supporting Documentation for the parameter of concern.

Table 2
Summary of Guidelines for Chemical and Physical Parameters

Parameter	MAC (mg/L)	IMAC (mg/L)	AO (mg/L)
aldicarb	0.009		
aldrin + dieldrin	0.0007		
aluminum [1]			
antimony		0.006 [2]	
arsenic		0.025	
atrazine + metabolites		0.005	
azinphos-methyl	0.02		
barium	1.0		
bendiocarb	0.04		
benzene	0.005		
benzo[a]pyrene	0.00001		
boron		5	
bromate		0.01	
bromoxynil		0.005	
cadmium	0.005		
carbaryl	0.09		
carbofuran	0.09		
carbon tetrachloride	0.005		
chloramines (total)	3.0		
chloride			≤250
chlorpyrifos	0.09		
chromium	0.05		
colour			≤15 TCU [4]
copper [2]			≤1.0
cyanazine		0.01	
cyanide	0.2		
cyanobacterial toxins (as microcystin-LR) [3]	0.0015		
diazinon	0.02		
dicamba	0.12		
dichlorobenzene, 1,2- [5]	0.20		≤0.003
dichlorobenzene, 1,4- [5]	0.005		≤0.001
dichloroethane, 1,2-		0.005	
dichloroethylene, 1,1-	0.014		
dichloromethane	0.05		
dichlorophenol, 2,4-	0.9		≤0.0003
dichlorophenoxyacetic acid, 2,4- (2,4-D)		0.1	
diclofop-methyl	0.009		
dimethoate		0.02	
dinoseb	0.01		
diquat	0.07		
diuron	0.15		
ethylbenzene			≤0.0024
fluoride [6]	1.5		
glyphosate		0.28	

Parameter	MAC (mg/L)	IMAC (mg/L)	AO (mg/L)
iron			≤0.3
lead [2]	0.010		
malathion	0.19		
manganese			≤0.05
mercury	0.001		
methoxychlor	0.9		
metolachlor		0.05	
metribuzin	0.08		
monochlorobenzene	0.08		≤0.03
nitrate [7]	45		
nitrilotriacetic acid (NTA)	0.4		
odour			Inoffensive
paraquat (as dichloride)		0.01 [8]	
parathion	0.05		
pentachlorophenol	0.06		≤0.030
pH			6.5–8.5 [9]
phorate	0.002		
picloram		0.19	
selenium	0.01		
simazine		0.01	
sodium [10]			≤200
sulphate [11]			≤500
sulphide (as H_2S)			≤0.05
taste			Inoffensive
temperature			≤15°C
terbufos		0.001	
tetrachloroethylene	0.03		
tetrachlorophenol, 2,3,4,6-	0.1		≤0.001
toluene			≤0.024
total dissolved solids (TDS)			≤500
trichloroethylene	0.05		
trichlorophenol, 2,4,6-	0.005		≤0.002
trifluralin		0.045	
trihalomethanes (total) [12]		0.1	
turbidity	1 NTU [13]		≤5 NTU [13,14]
uranium		0.02	
vinyl chloride	0.002		
xylenes (total)			≤0.3
zinc [2]			≤5.0

Notes:

1. A health-based guideline for aluminum in drinking water has not been established. However, water treatment plants using aluminum-based coagulants should optimize their operations to reduce residual aluminum levels in treated water to the lowest extent possible as a precautionary measure. *Operational guidance values* of less than 100 µg/L total aluminum for conventional treatment plants and less than 200 µg/L total aluminum for other types of treatment systems are recommended. Any attempt to minimize aluminum residuals must not compromise the effectiveness of disinfection processes or interfere with the removal of disinfection by-product precursors.
2. Because first-drawn water may contain higher concentrations of metals than are found in running water after flushing, faucets should be thoroughly flushed before water is taken for consumption or analysis.
3. The guideline is considered protective of human health against exposure to other microcystins (total microcystins) that may also be present.
4. TCU = true colour unit.
5. In cases where total dichlorobenzenes are measured and concentrations exceed the most stringent value (0.005 mg/L), the concentrations of the individual isomers should be established.
6. It is recommended, however, that the concentration of fluoride be adjusted to 0.8–1.0 mg/L, which is the optimum range for the control of dental caries.
7. Equivalent to 10 mg/L as nitrate–nitrogen. Where nitrate and nitrite are determined separately, levels of nitrite should not exceed 3.2 mg/L.
8. Equivalent to 0.007 mg/L for paraquat ion.
9. No units.
10. It is recommended that sodium be included in routine monitoring programmes, as levels may be of interest to authorities who wish to prescribe sodium-restricted diets for their patients.
11. There may be a laxative effect in some individuals when sulphate levels exceed 500 mg/L.
12. The IMAC for trihalomethanes is expressed as a running annual average. It is based on the risk associated with chloroform, the trihalomethane most often present and in greatest concentration in drinking water. The guideline is designated as interim until such time as the risks from other disinfection by-products are ascertained. The preferred method of controlling disinfection by-products is precursor removal; however, any method of control employed must not compromise the effectiveness of water disinfection.
13. NTU = nephelometric turbidity unit.
14. At the point of consumption.

Parameters without Guidelines

Since 1978, some chemical and physical parameters have been identified as not requiring a numerical guideline. Table 3 lists these parameters.

The reasons for parameters having no numerical guideline include the following:

- currently available data indicate no health risk or aesthetic problem (e.g., calcium);
- data indicate the compound, which may be harmful, is not registered for use in Canada (e.g., 2,4,5-TP) or is not likely to occur in drinking water at levels that present a health risk (e.g., silver); or
- the parameter is composed of several compounds for which individual guidelines may be required (e.g., pesticides [total]).

Table 3
Summary List of Parameters without Guidelines

Parameter	Parameter
ammonia	pesticides (total)
asbestos	phenols
calcium	phthalic acid esters (PAE)
chlordane (total isomers)	polycyclic aromatic hydrocarbons (PAH) [2]
dichlorodiphenyltrichloroethane (DDT) + metabolites	radon
endrin	resin acids
formaldehyde	silver
gasoline	tannin
hardness [1]	temephos
heptachlor + heptachlor epoxide	total organic carbon
lignin	toxaphene
lindane	triallate
magnesium	trichlorophenoxyacetic acid, 2,4,5- (2,4,5-T)
methyl-parathion	trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)
mirex	

Notes:

1. Public acceptance of hardness varies considerably. Generally, hardness levels between 80 and 100 mg/L (as $CaCO_3$) are considered acceptable; levels greater than 200 mg/L are considered poor but can be tolerated; those in excess of 500 mg/L are normally considered unacceptable. Where water is softened by sodium ion exchange, it is recommended that a separate, unsoftened supply be retained for culinary and drinking purposes.
2. Other than benzo[a]pyrene.

Summary of Guidelines for Radiological Parameters

In setting dose guidelines for radionuclides in drinking water, it is recognized that water consumption contributes only a portion of the total radiation dose and that some radionuclides present are natural in origin and therefore cannot be excluded. Consequently, maximum acceptable concentrations (MACs) for radionuclides in drinking water have been derived based on a committed effective dose of 0.1 mSv* from one year's consumption of drinking water. This dose represents less than 5% of the average annual dose attributable to natural background radiation.

To facilitate the monitoring of radionuclides in drinking water, the reference level of dose is expressed as an activity concentration, which can be derived for each radionuclide from published radiological data. The National Radiological Protection Board has calculated dose conversion factors (DCFs) for radionuclides based on metabolic and dosimetric models for adults and children. Each DCF provides an estimate of the 50-year committed effective dose resulting from a single intake of 1 Bq** of a given radionuclide.

The MACs of radionuclides in public water supplies are derived from adult DCFs, assuming a daily water intake of 2 L, or 730 L/year, and a maximum committed effective dose of 0.1 mSv, or 10% of the International Commission on Radiological Protection limit on public exposure:

$$\text{MAC (Bq/L)} = \frac{1 \times 10^{-4}\ \text{(Sv/year)}}{730\ \text{(L/year)} \times \text{DCF (Sv/Bq)}}$$

* Sievert (Sv) is the unit of radiation dose. It replaces the old unit, rem (1 rem = 0.01 Sv).

** Becquerel (Bq) is the unit of activity of a radioactive substance, or the rate at which transformations occur in the substance. One becquerel is equal to one transformation per second and is approximately equal to 27 picocuries (pCi).

When two or more radionuclides are found in drinking water, the following relationship should be satisfied:

$$\frac{C_1}{MAC_1} + \frac{c_2}{MAC_2} + \ldots \frac{c_i}{MAC_i} \leq 1$$

where c_i and MAC_i are the observed and maximum acceptable concentrations, respectively, for each contributing radionuclide.

MACs for radionuclides that should be monitored in water samples are listed in Table 4. If a sample is analysed by gamma-spectroscopy, additional screening for radionuclides that may be present under certain conditions can be performed. MACs for these radionuclides are given in Table 5. MACs for a number of additional radionuclides, both natural and artificial, can be found in the sixth edition of the guidelines booklet.

Water samples may be initially screened for radioactivity using techniques for gross alpha and gross beta activity determinations. Compliance with the guidelines may be inferred if the measurements for gross alpha and gross beta activity are less than 0.1 Bq/L and 1 Bq/L, respectively, as these are lower than the strictest MACs. Sampling and analyses should be carried out often enough to accurately characterize the annual exposure. If the source of the activity is known, or expected, to be changing rapidly with time, then the sampling frequency should reflect this factor. If there is no reason to suppose that the source varies with time, then the sampling may be done annually. If measured concentrations are consistent and well below the reference levels, this would be an argument for reducing the sampling frequency. On the other hand, the sampling frequency should be maintained, or even increased, if concentrations are approaching the reference levels. In such a case, the specific radionuclides should be identified and individual activity concentrations measured.

Table 4
Primary List of Radionuclides – Maximum Acceptable Concentrations

Radionuclide		Half-life $t_{½}$	DCF (Sv/Bq)	MAC (Bq/L)
Natural Radionuclides				
Lead-210	^{210}Pb	22.3 years	1.3×10^{-6}	0.1
Radium-224	^{224}Ra	3.66 days	8.0×10^{-8}	2
Radium-226	^{226}Ra	1600 years	2.2×10^{-7}	0.6
Radium-228	^{228}Ra	5.76 years	2.7×10^{-7}	0.5
Thorium-228	^{228}Th	1.91 years	6.7×10^{-8}	2
Thorium-230	^{230}Th	7.54×10^{4} years	3.5×10^{-7}	0.4
Thorium-232	^{232}Th	1.40×10^{10} years	1.8×10^{-6}	0.1
Thorium-234	^{234}Th	24.1 days	5.7×10^{-9}	20
Uranium-234	^{234}U	2.45×10^{5} years	3.9×10^{-8}	4*
Uranium-235	^{235}U	7.04×10^{8} years	3.8×10^{-8}	4*
Uranium-238	^{238}U	4.47×10^{9} years	3.6×10^{-8}	4*
Artificial Radionuclides				
Cesium-134	^{134}Cs	2.07 years	1.9×10^{-8}	7
Cesium-137	^{137}Cs	30.2 years	1.3×10^{-8}	10
Iodine-125	^{125}I	59.9 days	1.5×10^{-8}	10
Iodine-131	^{131}I	8.04 days	2.2×10^{-8}	6
Molybdenum-99	^{99}Mo	65.9 hours	1.9×10^{-9}	70
Strontium-90	^{90}Sr	29 years	2.8×10^{-8}	5
Tritium**	^{3}H	12.3 years	1.8×10^{-11}	7000

* The activity concentration of natural uranium corresponding to the chemical guideline of 0.02 mg/L is about 0.5 Bq/L.
** Tritium is also produced naturally in the atmosphere in significant quantities.

Table 5
Secondary List of Radionuclides – Maximum Acceptable Concentrations (MACs)

Radionuclide		Half-life $t_{½}$	DCF (Sv/Bq)	MAC (Bq/L)
Natural Radionuclides				
Beryllium-7	^{7}Be	53.3 days	3.3×10^{-11}	4000
Bismurh-210	^{210}Bi	5.01 days	2.1×10^{-9}	70
Polonium-210	^{210}Po	138.4 days	6.2×10^{-7}	0.2
*Artificial Radionuclides***				
Americium-241	^{241}Am	432 years	5.7×10^{-7}	0.2
Antimony-122	^{122}Sb	2.71 days	2.8×10^{-9}	50
Antimony-124	^{124}Sb	60.2 days	3.6×10^{-9}	40
Antimony-125	^{125}Sb	2.76 years	9.8×10^{-10}	100
Barium-140	^{140}Ba	12.8 days	3.7×10^{-9}	40
Bromine-82	^{82}Br	35.3 hours	4.8×10^{-10}	300
Calcium-45	^{45}Ca	165 days	8.9×10^{-10}	200
Calcium-47	^{47}Ca	4.54 days	2.2×10^{-9}	60
Carbon-14	^{14}C	5730 years	5.6×10^{-10}	200
Cerium-141	^{141}Ce	32.5 days	1.2×10^{-9}	100
Cerium-144	^{144}Ce	284.4 days	8.8×10^{-9}	20
Cesium-131	^{131}Cs	9.69 days	6.6×10^{-11}	2000
Cesium-136	^{136}Cs	13.1 days	3.0×10^{-9}	50
Chromium-51	^{51}Cr	27.7 days	5.3×10^{-11}	3000
Cobalt-57	^{57}Co	271.8 days	3.5×10^{-9}	40
Cobalt-58	^{58}Co	70.9 days	6.8×10^{-9}	20
Cobalt-60	^{60}Co	5.27 years	9.2×10^{-8}	2
Gallium-67	^{67}Ga	78.3 hours	2.6×10^{-10}	500
Gold-198	^{198}Au	2.69 days	1.6×10^{-9}	90
Indium-111	^{111}In	2.81 days	3.9×10^{-10}	400
Iodine-129	^{129}I	1.60×10^{7} years	1.1×10^{-7}	1
Iron-55	^{55}Fe	2.68 years	4.0×10^{-10}	300
Iron-59	^{59}Fe	44.5 days	3.1×10^{-9}	40
Manganese-54	^{54}Mn	312.2 days	7.3×10^{-10}	200
Mercury-197	^{197}Hg	64.1 hours	3.3×10^{-10}	400
Mercury-203	^{203}Hg	46.6 days	1.8×10^{-9}	80
Neptunium-239	^{239}Np	2.35 days	1.2×10^{-9}	100
Niobium-95	^{95}Nb	35.0 days	7.7×10^{-10}	200
Phosphorus-32	^{32}P	14.3 days	2.6×10^{-9}	50
Plutonium-238	^{238}Pu	87.7 years	5.1×10^{-7}	0.3
Plutonium-239	^{239}Pu	2.41×10^{4} years	5.6×10^{-7}	0.2
Plutonium-240	^{240}Pu	6560 years	5.6×10^{-7}	0.2
Plutonium-241	^{241}Pu	14.4 years	1.1×10^{-8}	10

* The activity concentration of natural uranium corresponding to the chemical guideline of 0.1 mg/L (see separate criteria summary on uranium in the Supporting Documentation) is about 2.6 Bq/L.

** Tritium and ^{14}C are also produced naturally in the atmosphere in significant quantities.

Table 5 (cont'd)

Radionuclide		Half-life $t_{½}$	DCF (Sv/Bq)	MAC (Bq/L)
Rhodium-105	^{105}Rh	35.4 hours	5.4×10^{-10}	300
Rubidium-81	^{81}Rb	4.58 hours	5.3×10^{-11}	3000
Rubidium-86	^{86}Rb	18.6 days	2.5×10^{-9}	50
Ruthenium-103	^{103}Ru	39.2 days	1.1×10^{-9}	100
Ruthenium-106	^{106}Ru	372.6 days	1.1×10^{-8}	10
Selenium-75	^{75}Se	119.8 days	2.1×10^{-9}	70
Silver-108m	^{108m}Ag	127 years	2.1×10^{-9}	70
Silver-110m	^{110m}Ag	249.8 days	3.0×10^{-9}	50
Silver-111	^{111}Ag	7.47 days	2.0×10^{-9}	70
Sodium-22	^{22}Na	2.61 years	3.0×10^{-9}	50
Strontium-85	^{85}Sr	64.8 days	5.3×10^{-10}	300
Strontium-89	^{89}Sr	50.5 days	3.8×10^{-9}	40
Sulphur-35	^{35}S	87.2 days	3.0×10^{-10}	500
Technetium-99	^{99}Tc	2.13×10^{5} years	6.7×10^{-10}	200
Technetium-99m	^{99m}Tc	6.01 hours	2.1×10^{-11}	7000
Tellurium-129m	^{129m}Te	33.4 days	3.9×10^{-9}	40
Tellurium-131m	^{131m}Te	32.4 hours	3.4×10^{-9}	40
Tellurium-132	^{132}Te	78.2 hours	3.5×10^{-9}	40
Thallium-201	^{201}Tl	3.04 days	7.4×10^{-11}	2000
Ytterbium-169	^{169}Yb	32.0 days	1.1×10^{-9}	100
Yttrium-90	^{90}Y	64 hours	4.2×10^{-9}	30
Yttrium-91	^{91}Y	58.5 days	4.0×10^{-9}	30
Zinc-65	^{65}Zn	243.8 days	3.8×10^{-9}	40
Zirconium-95	^{95}Zr	64.0 days	1.3×10^{-9}	100

ADDENDUM D

CWMS WATER SUPPLY AND DISTRIBUTION SHEETS

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

General Remarks

The major objectives for Community Water Supply System maintenance are:

1. To provide the community with water that conforms to the Guidelines for Canadian Drinking Water Quality and Department of Health Regulations on potable water quality.
2. To provide an adequate water supply for fire protection purposes as directed by Government of the NWT, Municipal and Community Affairs and the Office of the Fire Marshal.
3. To keep the system functioning reliably and operating efficiently.
4. To protect the capital investment.
5. To minimize annual operations and maintenance costs.
6. To ensure that there will be no cross-connections or back flow conditions permitted in the system.

The maintenance of the Community Water Supply System shall meet the most current issue of all applicable Federal, Territorial, and Municipal codes and regulations, such as:

1. The community's Water Licence (issued by the applicable Water Board).
2. Public Health Act, Consolidation of Public Water Supply Regulations, RRNWT 1990, c.p-23.
3. Safety Act, General Safety Regulations.
4. Safety Act, Consolidation of Work Site Hazardous Materials Information System Regulations, RRNWT 1990, c.S-2.
5. Community Bylaws.
6. Guidelines for Canadian Drinking Water Quality, Health and Welfare Canada.
7. National Fire Code of Canada, Canadian Commission on Building and Fire Codes, National Research Council of Canada, AWWA Standards for public water systems.

> ***NOTE**: The maintenance of specific components of a particular section of the system shall meet the requirements and objectives hereafter specified. However, all procedures outlined in an Operation and Maintenance Manual (O&M) for the facility should be followed in addition to the requirements of this CWMS Manual.*

Open Reservoirs (Raw Water)

1. Synthetic liners shall be maintained to prevent leakage from or infiltration into the reservoir and shall be of a material approved for potable water.
2. Water shall be free of polluting material (e.g. garbage).
3. Reservoirs shall maintain adequate capacity.
4. Organic growth (algae, grass, weeds or trees) in reservoirs shall be controlled. Herbicides **must not** be allowed to enter the reservoir unless they are approved for potable water. It is recommended that vegetation be controlled by mechanical/ hand means only.
5. Reservoir shall be completely fenced to prevent unauthorized entry and possible deliberate or accidental contamination of water supply.
6. Subdrain systems shall be maintained to prevent groundwater from seeping into reservoir, reduce hydrostatic pressure in the berms and prevent ponding in areas adjacent to the berms.
7. Public motorized vehicles (boats/snowmobiles) shall not be allowed on the reservoir.
8. Reservoirs should be checked twice a year for animal burrows. Burrows must not be permitted

in an earthen dyke.
9. Landscaping shall be kept attractive.
10. Freeze protection systems for piping shall be maintained in good operating condition. If a heat transfer fluid is used for freeze protection, it must be non-toxic and fail-safe isolated from potable water.
11. Pump inlet screens and reservoir overflows shall be kept clean and free of blockages.
12. Periodic inspection by divers should be scheduled.

Treated Water Storage

1. Water storage tanks will be constructed of or lined with a material approved for potable water.
2. Water storage facilities shall not leak.
3. Water reservoirs, tanks and standpipes shall be kept free of organic growth, corrosion and sludge.
4. Exterior surfaces shall be kept clean and attractive and free of rust, scale or peeling and chipped paint.
5. Water-level controls shall be maintained and kept free of rust, dirt, scale, etc.
6. Structural integrity shall be maintained.
7. Landscaping shall be kept attractive and shall not cover or hide any of the tank unless the tank is specifically designed to allow for landscape cover or partial cover.
8. Integrity of all insulation shall be maintained.
9. Positive drainage away from storage facility shall be maintained to prevent ponding in areas adjacent to the tank.
10. Freeze protection systems for piping shall be maintained in good operating condition.
11. Pump inlet screens and tank overflows shall be kept clean and free of blockages.
12. Tank vent screens shall be kept clean and free from blockages and ice and/or frost formation.

Intake Structures

1. Intake structures, wet wells, and screens shall be kept free of sludge, growths and debris.
2. Water intakes shall be maintained in a physical condition compatible with the original installations.
3. Intakes shall be protected from ice blockage, damage and freezing.
4. Periodic diving inspection of intakes should be scheduled.

Wells

1. Well water quality shall be checked for changes in water chemistry or new contaminants.
2. Freeze protection systems and procedures for wells and supply lines shall be maintained.
3. Well structures and surrounding area shall be maintained to ensure positive drainage away from the well.
4. Each well shall be used regularly to prevent stagnant water and the growth of organic's in the water.
5. The electrical system for the well pumps shall be maintained.
6. Well water shall be analyzed for chemical water quality.
7. The well head shall be sealed at all times.

Community Works Management System

Technical Specifications

Water Treatment

1. Water treatment plant operators should be trained and certified to the required level.
2. Water quality shall meet or exceed the requirements of the Public Health Act, the Water Licence, and the Guidelines for Canadian Drinking Water Quality.
3. Raw and treated water shall be tested regularly in accordance with the Public Health Act, the Water License and the facility O&M Manual.
4. Water treatment equipment shall be capable of controlled and accurate addition of chemicals.
5. Any contamination from chemical solutions shall be removed from the equipment and work area in a safe manner.
6. WHMIS regulations for chemical use, handling, storage and disposal shall be posted in a conspicuous location and followed.
7. First aid kits shall be maintained and restocked in accordance with the Safety Act, General Safety Regulations.
8. Test equipment shall be maintained in good condition.
9. The operators shall read and understand available water treatment equipment manufacturers data on proper operation and maintenance located in the O&M Manual.
10. Water treatment and associated equipment shall be regularly inspected and maintained in good, efficient operating condition in accordance with the O&M Manual and manufacturer's recommendations.
11. All equipment shall be kept clear of corrosion, organic growth, scaling or sludge buildups.
12. Treatment equipment should generally not be left full of water and inactive for any extended period of time as this may result in bacterial growth in the equipment.
13. Disposal of sludge and backwash wastewater shall be in accordance with all environmental, public health and local bylaw regulations.
14. Freeze protection and water tempering systems shall be maintained.
15. Sufficient spare parts shall be maintained to prevent extended interruptions in the supply of treated water.
16. Duplicate chlorination devices shall be maintained at all times, in accordance with the Public Water Supply Regulations, in order to ensure that water is treated with out interruption.
17. Water test results, instrument readings, equipment maintenance and chemical usage shall be recorded in accordance with the Public Health Act, the Water License and the facility O&M Manual.

Heating Systems

1. Water heating systems shall be maintained and operated to prevent freezing of the water systems and for optimal water treatment.
2. Building heating systems shall be maintained to keep building above freezing when unoccupied and at a comfortable temperature when personnel are working in the building.
3. Heating systems shall be maintained to operate safely and efficiently at minimum costs.
4. An adequate fuel supply shall be maintained.
5. Building ventilation systems shall be maintained for a safe working environment. Adequate combustion air for fuel burning equipment and humidity control shall be maintained.
6. Filters shall be maintained to maximize the efficiency of heating and ventilation equipment.
7. Fuel supply systems shall be maintained leak free to prevent contamination of the water supply and the environment. Secondary containment storage should be used exclusively.
8. Alarm systems shall be maintained to warn of equipment failures which could result in system freeze ups or overheating.

9. Oil burning equipment shall be maintained in accordance with applicable CWMS Building Services Standards.

Water Mains

1. Water mains shall be kept clean, disinfected and free of potential sources of contamination.
2. Water mains shall maintain acceptable water tightness.
3. **Note:** For various pipe materials and pressures there are established allowable leakages for newly installed mains. It is assumed that this allowance has not been exceeded in the original installation. An acceptable degree of water tightness shall therefore not exceed the original leakage allowance by more than 20 per cent. Refer to the system O&M Manual and obtain manufacturer's recommendations on allowable leakage rates for specific piping materials.
4. Water mains shall be capable of delivering the fire flows which satisfy the recommendations of NWT Fire Code while maintaining a minimum working pressure of 140 kPa (Public Health Act) throughout the entire system. Pressure should be monitored regularly.
5. Water mains shall not degrade the quality of water by adding rust, organic matter or undesirable odours, tastes and colour.
6. Water mains will be constructed and maintained separated from sewerage lines and in all other respects be in accordance with the Public Water Supply regulations.
7. For recirculating flow type water main systems, a minimum flow shall be maintained to prevent freeze-up during low water demand periods. Minimum flow is established as part of the system design but may be field adjusted due to changes in pipe insulation, water temperature, exterior temperature, ground temperature, and demand.
8. The use of water main systems using bleeders into the sewer main system (at access vaults) for freeze protection of non-circulating type water main systems are discouraged, however, where utilized ensure that system is not a source of potential contamination of the water system through accidental or intentional acts. Air gaps and/or backflow preventer must be incorporated into bleeders and must be maintained.
9. For non-recirculating type water main systems using bleeders into the sewer main system, bleeder control valves shall be field set to maintain the minimum flow to prevent freeze-up during low water demand periods and backflow preventer valves maintained to prevent contamination of the water main.
10. All water control and monitoring systems shall be maintained for proper operation of the water main system.
11. Water main temperatures shall be monitored.
12. Free residual Cl_2 will be maintained for disinfection purposes (Health regulations).
13. Daily sampling shall be done to ensure adequate level of Cl_2.

Buried Valves

1. Valves shall be maintained to be fully operational.
2. Valve indicators shall be clean and easily visible.
3. Valve boxes shall be clean and set at proper grade and angle.
4. Valves shall be protected from freezing and physical damage.

Water Pumps

1. Water pumps, piping and fittings shall not leak.
2. Pumping equipment shall be fastened securely to solid bases to prevent vibration. Checks must be done for vibration which can cause serious damage to the pump.
3. Pumps not located in a heated building shall be protected against freezing.
4. Pump failure alarms shall be maintained.
5. Electric motors shall be maintained and/or serviced so that they operate at or near their original efficiency and motor amperage draw condition.
6. Pumps shall be maintained and/or serviced so that they operate at or near their original efficiency. This shall include inspection and adjustment of stuffing boxes and glands, scheduled lubrication, and proper adjustment of water seals.

Loading Arms

1. Piping, fittings and seals shall be maintained leak free.
2. Water spillage shall be minimized.
3. Adequate lighting shall be maintained.
4. Site drainage away from truck-fill area shall be maintained.
5. Operation of truck-fill system and alarms shall be maintained.
6. Pipe insulation and jacket shall be maintained securely attached to the piping.
7. Arm heat trace systems shall be checked for operation and maintained in working order.

Access Vaults

1. Access vaults shall be kept clean and in good repair, including access seals and insulation.
2. Access vaults shall be kept dry.
3. Infiltration shall be minimized. Water buildup shall be removed immediately to reduce the risk of contaminating the water mains. Freezing of water within the access vault may cause damage to the vault or piping within, or prevent operation of the water or sewer piping.
4. Access vault inspection plates must be kept closed. Any piping leaks must be repaired immediately.
5. Bollards to protect the access vaults shall be maintained to prevent damage to the vaults.

Hydrants

1. Fire hydrants shall be kept in good operating condition in accordance with the National Fire Code of Canada.
2. Freeze protective measures such as the filling of hydrant cavities with food grade glycol shall be maintained.
3. Proper hydrant flow and pressure shall be maintained.
4. Hydrants shall be maintained to an acceptable finish and appearance standard.
5. Location of hydrants shall be clearly marked year round.

Standby Generators

1. Standby electrical generating systems shall be maintained and tested to provide a reliable power supply if line power is lost.
2. An adequate fuel supply shall be maintained.

3. Fuel Supply systems shall be maintained leak free to prevent contamination of the water supply and the environment. Secondary containment storage should be used exclusively.
4. Control and alarm systems shall be maintained for reliable operation and to prevent damage to equipment.

Water-Trucked Delivery

1. Water trucks and water mounted tanks shall be maintained to be functional on demand.
2. Water tanks shall not alter water quality.
3. Water tanks shall be free from structural damage.
4. Water tank plumbing shall operate in the manner intended.
6. 7 deliveries per week (water barrels), 3 deliveries per week (0 - 1400 litre tanks), 3 - 2 deliveries per week (1400 litre tanks and larger)
7. A scheduled water delivery should be implemented and maintained.

Water-Fire Protection

1. Water trucks shall accompany Fire Trucks to all fires.
2. The driver will be under the direction of the fire chief.

Recreation

1. Water will be required by the Recreation Department to flood ice hockey and curling surfaces.
2. Water will be required for the swimming pool.
3. Maintain accurate water tickets for quantity of treated water used.

Meter-Insp./Replace/Repair

1. Truck water meters should be tested for accuracy once a year, simply by filling a water tank to desired level and checking meter reading to tank level.
2. Truck water meters should be maintained, replaced as per manufacture's specification.

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

Activity Code:	Activity Description	Activity Code:	Activity Description
☒ **101**	**Water Trucked Delivery**	☐ 109	Hydrants
☐ 102	Water Sampling	☐ 110	Water Tempering (includes boilers, etc.)
☐ 103	Water Treatment	☐ 111	Meter Inspection/Replacement/ Repair
☐ 104	Water Reservoir	☐ 112	Water Meter Reading
☐ 105	Water Intake	☐ 113	Water Fire Protection
☐ 106	Pumps O&M Pumping Equipment	☐ 114	Water Recreation
☐ 107	Water Mains	☐ 115	Water – Other
☐ 108	Water Access Vaults		

1. Facility: truck service

2. Crew Size:	3. Equipment:	4. Materials:
1 – Light Equipment Operator	1 – Water Truck	Water

5. Activities to complete

50 deliveries per day

6. Time to Complete each Activity

9 minutes per delivery

7. Quality Standard:

1 – 7 deliveries per week (water barrels)

2 - 3 deliveries per week (0 - 1400 litre tanks)

3 - 2 deliveries per week (1400 litre tanks and larger)

8. Work Method:

1. Using scheduled routes, water will be delivered in an efficient and cost effective manner.
2. Each delivery, including amount delivered will be recorded on the form provided.
3. The water truck will be returned to the parking garage full at the end of each shift.

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

Activity Code:	Activity Description	Activity Code:	Activity Description
☐101	Water Trucked Delivery	☐109	Hydrants
☒**102**	**Water Sampling**	☐110	Water Tempering (includes boilers, etc.)
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☐104	Water Reservoir	☐112	Water Meter Reading
☐105	Water Intake	☐113	Water Fire Protection
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☐107	Water Mains	☐115	Water – Other
☐108	Water Access Vaults		

1. Facility: truck or piped

2. Crew Size:	**3. Equipment:**	**4. Materials:**
1 – Water Treatment Plant Operator or CW Foreman	Water sample Kit	Water

5. Activities to complete

As required

6. Time to Complete each Activity

7. Quality Standard:

The frequency of sampling and the number of samples required each time samples are taken will vary depending on the population, water quality history, integrity of the system, complexity of the system and laboratory services available. Contact the Regional Environmental Health Officer to establish a sampling protocol for your community.

8. Work Method: Samples for bacteriological testing

1. Flame the faucet rim or pump spout with a match or lighter.
2. Let the water run for two minutes.
3. Remove the top from the STERILE sample bottle, fill until nearly full, and replace top tightly. **DO NOT RINSE THE BOTTLE FIRST. DO NOT LET ANYTHING TOUCH THE LIP OF THE BOTTLE OR THE INSIDE OF THE BOTTLE CAP.**
4. Fill out the sample form as instructed by the Regional Environmental Health Officer.
5. Send the sample to the laboratory as designated by the Regional Environmental Health Officer.
6. Follow shipping instructions exactly.

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

Activity Code:	Activity Description	Activity Code:	Activity Description
☐101	Water Trucked Delivery	☐109	Hydrants
☐102	Water Sampling	☐110	Water Tempering (includes boilers, etc.)
☒**103**	**Water Treatment**	☐111	Meter Inspection/Replacement/ Repair
☐104	Water Reservoir	☐112	Water Meter Reading
☐105	Water Intake	☐113	Water Fire Protection
☐106	Pumps O&M Pumping Equipment	☐114	Water Recreation
☐107	Water Mains	☐115	Water – Other
☐108	Water Access Vaults		

1. Facility: Water Treatment Plant

2. Crew Size:	3. Equipment:	4. Materials:
1 – Water Treatment Plant Operator or CW Foreman	Safety equipment and practices, disinfectant, record forms and pen/pencils, camera, hand tools, water sample kit	

5. Activities to complete	6. Time to Complete each Activity
Daily	D 4.0 hrs
Weekly	W 4.0 hrs
Monthly	M 20.0 hrs
Semi-Annual	S/A 6.0 hrs
Annual	A 10.0 hrs

7. Quality Standard:

See O & M Manual

8. Work Method:

Prior to performing any maintenance ensure equipment is in a safe condition for this work.

This may include:

- Disconnecting power source and ensure it cannot be reconnected accidentally.
- Equipment is isolated from pressure sources then depressurized.
- Harmful chemicals are removed and flushed from equipment.
- Protective shields are in place.
- Fire extinguishers are available.
- Sources of ignition are removed from the area or turned off.
- Personnel safety equipment and clothing is at the site and used appropriately in accordance with WHIMS and the GNWT Safety Act and General Safety Regulations.
- All safety procedures in the GNWT Safety Act and General Safety Regulations and O&M manual or manufacturer's instructions are followed.

Follow O&M manual and equipment manufacturer's recommended procedures where manuals exist.

Work Method Continued:

General

D 1. Perform walk through of entire facility, check operation of all equipment, note any problems, initiate corrective action as required.
D 2. Check all equipment for leaks and clean up any spilled fluid.
D 3. Check temperature of raw water into the building (when raw water pump is running). Record results.
D 4. Check reading of meter for raw water entering the facility. Record results.
D 5. Check reading of meter for treated water leaving facility. Record results.
D 6. Check wet well level.
D 7. Check all pressure gauges and site gauges, and record all readings.
D 8. Check control panels for alarms and perform lamp test for all lamps.
D 9. Test treated water for total and free chlorine residual and record readings.
D 10. Check all water treatment chemical feed systems, including flexible chemical injection tubing, connections and injectors, for leaks, blockages and proper operation. Clean or repair as required.
D 11. Maintain water test equipment in clean operable condition in accordance with manufacturer's instructions.
D 12. Check and record levels in chemical solution tanks and prepare more solution as required.
D 13. Check that building is secure and locked.
D 14. Check all floor and equipment drains.
D 15. Check chlorine system injection rate (pulse and stroke for liquid solution type; gas is by unit volume); record readings and chemical solution strengths.
D 16. Check all chemical feed pumps for proper operation. Service when required. Record pump settings and reasons for changing settings.
W 17. Check automatic control systems, ensure proper operation of all equipment.
W 18. Check all alarms for proper operation.
W 19. Check all safety guards are securely in place.
W 20. Check operation of pump control valves, air relief valves, pressure gauges, etc.
M 21. Clean chlorine chemical mixing tank.
M 22. Clean chemical pump heads by flushing with clean, warm water.
M 23. Check all gauges, sensors, control switches and recording devices for proper operation.
M 24. Check all flow control systems (electronic, mechanical, hydraulic, pneumatic) for proper operation.
M 25. Wash floor and clean equipment, piping and tanks, etc.
M 26. Service all control valves in accordance with manufacturer=s maintenance procedures.
M 27. Check and replace all burned out lights.

Work Method Continued:

M 28. Check valves to ensure they are in the proper position - normally open, normally closed, or modulating properly (use a check list and record positions).

M 29. Check, service and operate all valves (isolation, modulation, flow control) for proper operation.

M 30. Check for proper storage of treatment chemicals.

M 31. Check that WHMIS sheets are available for all chemicals, are complete and are in a visible location.

S/A 32. Clean deposits from orifices, valves and strainers. Inspect and repair injectors.

S/A 33. Check safety equipment, note expiry date, and replace as necessary.

A/R 34. Sample treated water and submit to approved laboratory for testing of the substances listed in the water licence.

A/R 35. Verify stock of essential replacement parts.

A/R 36. Re-order chemicals. Record on log sheet.

A/R 37. Check and restock first aid kit and keep in visible location.

A/R 38. Notify the Water Board, in writing, of any changes to the water treatment system which would affect the community's water licence.

A/R 39. Perform general outside clean-up and maintenance. Cut grass or remove snow

Filtration System

A/R 1. Backwash filters in accordance with the O&M manual if not done automatically. Record day, time, flow rate, inlet and outlet pressures, and duration of backwash.

A 2. Inspect water treatment filter media and check for cracking, unevenness, sludge buildup or mud-ball formation.

A 3. Check interior surfaces of all water treatment filters. Repair or replace as necessary.

A 4. Check filter media depth - top-up as necessary.

A 5. Clean out wastewater sump.

A/R 6. Service pumps according to manufacturer=s recommended procedure and record on log sheet.

A/R 7. Replace filter media when required or as recommended. Backwash twice before putting into operation.

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

Activity Code:	Activity Description	Activity Code:	Activity Description
☐101	Water Trucked Delivery	☐109	Hydrants
☐102	Water Sampling	☐110	Water Tempering (includes boilers, etc.)
☐103	Water Treatment	☐111	Meter Inspection/Replacement/ Repair
☒**104**	**Water Reservoir**	☐112	Water Meter Reading
☐105	Water Intake	☐113	Water Fire Protection
☐106	Pumps O&M Pumping Equipment	☐114	Water Recreation
☐107	Water Mains	☐115	Water – Other
☐108	Water Access Vaults		

1. Facility: Water Treatment Plant

2. Crew Size:	3. Equipment:	4. Materials:
1 – Water Treatment Plant Operator or CW Foreman	Safety equipment and practices, disinfectant, record forms and pen/pencils, camera, water truck and hose, tape measure or stick, hand tools, water sample kit	

5. Activities to complete	6. Time to Complete each Activity
Daily	D 0.5 hrs
Weekly	W 0.5 hrs
Monthly	M 5.5hrs
Semi-Annual	S/A 0.5 hrs
Annual	A 30.0 hrs

7. Quality Standard:

See O & M Manual

8. Work Method:

D 1. Check water level as indicated by monitoring equipment. Record reading.

D 2. Check water quality as directed by the O&M Manual

D 3. Check that fence is secure and locked.

M 4. Measure water level and compare results to level monitoring equipment. Record levels and any incidents.

M 5. Check for and remove garbage in and around reservoir. Check that warning/information signs are in place.

Work Method Continued:

M 6. Check for animal burrows, control as necessary. Check vegetation growth in and around reservoir. Control as necessary. Visually check for algae, disturbed sediment and any other condition that could be increasing turbidity and creating an excessive chlorine demand. If the problem persists contact Environmental Health Officer.

M 7. Sample raw water and submit for bacteriological analysis.

S/A 8. Check raw water quality - spring and fall.

A 9. Check subdrain system for blockages and accumulation of water.

A 10. Check freeze protection system for proper operation. Check system failure alarms - fall.

A 11. Check exposed liners for leaks or damage.

A 12. Check drain valves, drains, pump inlet screens, reservoir overflows and piping for damage and proper operation. Clean as required.

A 13. For liners covered with gravel or earth, check for areas of uncovered liner.

A 14. Check aerator equipment, airlines and diffusers for damage.

A 15. Check berms for signs of erosion or failure. Repair immediately.

A/R 16. Clean reservoir by flushing and cleaning exposed areas of reservoir walls. On open reservoirs this is not usually practical but may be required in special circumstances.

A/R 17. Note or photograph any problems and initiate corrective action as required. Follow O&M manual procedures.

Enclosed Reservoir & Storage Tanks

A 18. Check supports and ladders for condition and safety problems.

A 19. Ensure positive drainage is maintained away from structure.

A 20. Check tanks for deformation or damage and condition of exterior coating or cover.

A 21. Check condition of concrete in concrete reservoirs.

A 22. Check drain valves, drains, pump inlet screens, tank overflows, piping, breather caps and vents for damage and proper operation. Clean as required.

A 23. Drain, clean and inspect tank liner or interior coating and surfaces. Remove rust and other foreign matter.

A 24. Clean tanks as per manufacturers recommendations.

A 25. Check insulation. Initiate repair as required.

A/R 26. Re-apply/repair coating if necessary.

A/R 27. Note any problems and initiate corrective action as required.

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

Activity Code:	Activity Description	Activity Code:	Activity Description
☐101	Water Trucked Delivery	☐109	Hydrants
☐102	Water Sampling	☐110	Water Tempering (includes boilers, etc.)
☐103	Water Treatment	☐111	Meter Inspection/Replacement/ Repair
☐104	Water Reservoir	☐112	Water Meter Reading
☒**105**	**Water Intake**	☐113	Water Fire Protection
☐106	Pumps O&M Pumping Equipment	☐114	Water Recreation
☐107	Water Mains	☐115	Water – Other
☐108	Water Access Vaults		

1. Facility: Water Treatment Plant

2. Crew Size:	3. Equipment:	4. Materials:
1 – Water Treatment Plant Operator or CW Foreman	Safety equipment and practices, hand tools,	

5. Activities to complete	6. Time to Complete each Activity
Daily	D .25 hrs
Monthly	M 8.0hrs
Annual	A 16.0 hrs

7. Quality Standard:

See O & M Manual

8. Work Method:

D 1. Check flow rates.

M 2. Backwash intake. Where feasible.

M 3. Check freeze protection systems for proper operation and check system failure alarms.

A 4. Check intake structure, protective equipment, wet well, screen and intake valves. Clean as required.

A 5. Check condition of intake. (May require divers).

A 6. Check intake pump and piping removal mechanism.

A 7. Check operation of level sensors, alarms and low level shut off.

A/R 8. Note any problems and initiate corrective action as required.

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

Activity Code:	Activity Description	Activity Code:	Activity Description
☐101	Water Trucked Delivery	☐109	Hydrants
☐102	Water Sampling	☐110	Water Tempering (includes boilers, etc.)
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☐104	Water Reservoir	☐112	Water Meter Reading
☐105	Water Intake	☐113	Water Fire Protection
☒**106**	**Pumps O&M Pumping Equipment**	☐114	Water Recreation
☐107	Water Mains	☐115	Water – Other
☐108	Water Access Vaults		

1. Facility: Water Treatment Plant

2. Crew Size:	3. Equipment:	4. Materials:
1 – Water Treatment Plant Operator or CW Foreman	Safety equipment and practices, lubricants, recording form (flow, pressure, temperature, maintenance), hand tools.	

5. Activities to complete	6. Time to Complete each Activity
Daily	D 1.0 hrs
Weekly	W 1.0 hrs
Monthly	M 1.0 hrs
Quarterly	Q 2.0 hrs
Annual	A 1.0 hrs (per pumping station)

7. Quality Standard:

See O & M Manual

8. Work Method:

D 1. Check operation of pump(s).

D 2. Check pumps and fittings for leaks.

D 3. Listen for abnormal noise while equipment is operating.

D 4. Check flow meters, record flow, and abnormal flows.

D 5. Check pump suction and discharge pressure gauges and record results.

D 6. Check operation of all controls.

D 7. Check pump packing glands & mechanical seals for abnormal leaks & adjust as necessary.

W 8. Check lubrication reservoir if applicable, top up as required.

Work Method Continued:

W 9. Check freeze protection devices for proper operation.

M 10. Check pump anchor bolts and pump base.

M 11. Switch primary duty (lead) and standby (lag) pump.

Q 12. Manually run standby pump(s) if the standby pumps are not regularly run as duty pump.

Q 13. Check all electrical components and controls for operation, motor amperage draw and voltage, and record.

Q 14. Check pump alarms.

Q 15. Clean pipeline strainers as required.

A 16. Check ancillary equipment such as foot valves, check valves, and control valves.

A/R 17. Note any problems and initiate corrective action as required

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

Activity Code:	Activity Description	Activity Code:	Activity Description
☐101	Water Trucked Delivery	☐109	Hydrants
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☐104	Water Reservoir	☐112	Water Meter Reading
☐105	Water Intake	☐113	Water Fire Protection
☐106	Pumps O&M Pumping Equipment	☐114	Water Recreation
☒**107**	**Water Mains**	☐115	Water – Other
☐108	Water Access Vaults		

1. Facility: Water Distribution System

2. Crew Size:	3. Equipment:	4. Materials:
1 – Water Treatment Plant Operator or CW Foreman	Safety equipment and practices, water main flushing equipment, water test equipment, water sampling kit.	

5. Activities to complete	6. Time to Complete each Activity
Annual	A 15.0 hrs (per 100 M pipe)
Annual	A 8.0 hrs (per 100 M pipe flush)

7. Quality Standard:

See O & M Manual

8. Work Method:

A 1. Check, service and exercise all valves

A 2. Check for ground settlement over mains.

A 3. Check for signs of leakage along line.

A 4. Check all supports and insulation on above ground piping.

A 5. Check all freeze protection and recovery systems including heat trace and bleeder systems.

A 6. Check all pipe corrosion protection systems and replace when necessary.

A 7. Check condition and operation of backflow preventer valves.

A 8. Flush water mains.

A/R 9. Bleeder flows should be adjusted according to water temperatures and minimum flows required.

A/R 10. Note any problems and initiate corrective action as required.

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

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☐105	Water Intake	☐113	Water Fire Protection
☐106	Pumps O&M Pumping Equipment	☐114	Water Recreation
☐107	Water Mains	☐115	Water – Other
☒**108**	**Water Access Vaults**		

1. Facility: Water Distribution System

2. Crew Size:	3. Equipment:	4. Materials:
1 – Water Treatment Plant Operator or CW Foreman	Safety equipment and practices, hand tools.	

5. Activities to complete	6. Time to Complete each Activity
Weekly Monthly Annual	W .25 hrs M .50 hrs A .50 hrs (per vault)

7. Quality Standard:

See O & M Manual

8. Work Method:

Check for water in bottom of access vaults. Remove water and fix source of leak.

W	2	Check that locking devices are securely fastened.
M	3	Check that water and sewer piping and fittings are tight and secure.
M	4	Check covers over sewer cleanouts are properly installed with gaskets in place.
A	5	Check interior and exterior surfaces of access vaults for signs of structural damage.
A	6	Check coatings on interior and exterior. Repair damaged coatings.
A/R	7	Note any problems and initiate corrective action as required.

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

Activity Code:	Activity Description	Activity Code:	Activity Description
☐101	Water Trucked Delivery	☒**109**	**Hydrants**
☐102	Water Sampling	☐110	Water Tempering (includes boilers, etc.)
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☐104	Water Reservoir	☐112	Water Meter Reading
☐105	Water Intake	☐113	Water Fire Protection
☐106	Pumps O&M Pumping Equipment	☐114	Water Recreation
☐107	Water Mains	☐115	Water – Other
☐108	Water Access Vaults		

1. Facility: Water Distribution System

2. Crew Size:	3. Equipment:	4. Materials:
1 – Water Treatment Plant Operator or CW Foreman	Safety equipment and practices, lubricants, paint, food grade glycol, Flow testing equipment and documentation forms.	

5. Activities to complete	6. Time to Complete each Activity
Semi-Annual Annual Six Year	SA .25 hrs A 6.0 hrs 6yr 2.0 hrs (per hydrant)

7. Quality Standard:

GNWT FIRE CODE

8. Work Method:

Check for leaks (seals, joints) and signs of damage.

SA 2 Check operating nut for wear, rounded corners and function. Lubricate threads.

SA 3 Check connection caps, threads, and chains. All caps shall be in place. Caps with rusted, damaged or worn threads that prevent easy removal shall be repaired or replaced. Ensure chains are in place and do not prevent cap removal.

SA 4 Check all valves for proper operation and exercise.

SA 5 Drain to the ground or pump out hydrant barrel. For self-draining hydrants make sure they drain completely. Repair main valve or drain valve if water is present prior to draining or pumping out.

Work Method Continued:

SA	6	Check glycol level and concentration (for non self-draining units). Ensure glycol is food grade. Adjust or replace as necessary.
SA	7	Check that hydrant locations are clearly identified under all conditions.
A	8	Flush hydrant with main valve and any outlet valves fully opened until water runs clear.
A	9	Contact the Office of the Fire Marshal to confirm required fire flow requirements for the community, fire code updates that affect hydrant maintenance, and arrange for flow testing of fire hydrants. Record test results.
A	10	Inspect breakaway component of hydrant if possible.
A/R	11	Check for access obstructions. Remove or minimize obstruction.
A/R	12	Note any problems and initiate corrective action as required.
A/R	13	Records of inspections and tests shall be retained for examination by the Office of the Fire Marshal.
6 YR.	14	Clean and paint hydrant.

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

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☐105	Water Intake	☐113	Water Fire Protection
☐106	Pumps O&M Pumping Equipment	☐114	Water Recreation
☐107	Water Mains	☐115	Water – Other
☐108	Water Access Vaults		

1. Facility:		
2. Crew Size:	**3. Equipment:**	**4. Materials:**
5. Activities to complete	**6. Time to Complete each Activity**	
7. Quality Standard:		
8. Work Method:		

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

Activity Code:	Activity Description	Activity Code:	Activity Description
☐101	Water Trucked Delivery	☐109	Hydrants
☐102	Water Sampling	☐110	Water Tempering (includes boilers, etc.)
☐103	Water Treatment	☒**111**	**Meter Inspection/Replacement/ Repair**
☐104	Water Reservoir	☐112	Water Meter Reading
☐105	Water Intake	☐113	Water Fire Protection
☐106	Pumps O&M Pumping Equipment	☐114	Water Recreation
☐107	Water Mains	☐115	Water – Other
☐108	Water Access Vaults		

1. Facility: Water Truck, Water Distribution System

2. Crew Size:	3. Equipment:	4. Materials:
1-Light Equipment Operator, Water Treatment Plant Operator, CW Foreman or Mechanic	Hand tools	

5. Activities to complete	6. Time to Complete each Activity

7. Quality Standard:

This activity is used for any repair/replace of Truck Water Meter of House Water Meter

8. Work Method:

As per manufacture's specifications

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

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☐101	Water Trucked Delivery	☐109	Hydrants
☐102	Water Sampling	☐110	Water Tempering (includes boilers, etc.)
☐103	Water Treatment	☐111	Meter Inspection/Replacement/ Repair
☐104	Water Reservoir	☒**112**	**Water Meter Reading**
☐105	Water Intake	☐113	Water Fire Protection
☐106	Pumps O&M Pumping Equipment	☐114	Water Recreation
☐107	Water Mains	☐115	Water – Other
☐108	Water Access Vaults		

1. Facility: Water Distribution System

2. Crew Size:	3. Equipment:	4. Materials:
1- Water Treatment Plant Operator, CW Foreman or W&S Clerk	Light vehicle, Recording form	

5. Activities to complete	6. Time to Complete each Activity
Monthly	M .25 (meter)

7. Quality Standard:

This activity is used for monthly recordings of water meters in residential, commercial & government buildings.

8. Work Method:

M 1 Record the reading from the Water Meter

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

Activity Code:	Activity Description	Activity Code:	Activity Description
☐101	Water Trucked Delivery	☐109	Hydrants
☐102	Water Sampling	☐110	Water Tempering (includes boilers, etc.)
☐103	Water Treatment	☐111	Meter Inspection/Replacement/ Repair
☐104	Water Reservoir	☐112	Water Meter Reading
☐105	Water Intake	☒**113**	**Water Fire Protection**
☐106	Pumps O&M Pumping Equipment	☐114	Water Recreation
☐107	Water Mains	☐115	Water – Other
☐108	Water Access Vaults		

1. Facility: Truck Service

2. Crew Size:	**3. Equipment:**	**4. Materials:**
1- Light Equipment Operator	1 – water Truck	Water

5. Activities to complete	**6. Time to Complete each Activity**
As required	

7. Quality Standard:

8. Work Method:

1. The designated water truck(s) shall accompany Fire Pumpers to all fires for the provision of extra water as required.

2. The water truck driver will be under the direction of the Fire Chief during this activity.

3. Water trucks will be filled up before returning to the parking garage.

** Extra care during this activity will be required.

Community Works Management System

Technical Specifications

WATER SUPPLY AND DISTRIBUTION SYSTEM

Activity Code:	Activity Description	Activity Code:	Activity Description
☐101	Water Trucked Delivery	☐109	Hydrants
☐102	Water Sampling	☐110	Water Tempering (includes boilers, etc.)
☐103	Water Treatment	☐111	Meter Inspection/Replacement/ Repair
☐104	Water Reservoir	☐112	Water Meter Reading
☐105	Water Intake	☐113	Water Fire Protection
☐106	Pumps O&M Pumping Equipment	☒**114**	**Water Recreation**
☐107	Water Mains	☐115	Water – Other
☐108	Water Access Vaults		

1. Facility: Truck Service

2. Crew Size:	**3. Equipment:**	**4. Materials:**
1- Light Equipment Operator	1 – water Truck	Water

5. Activities to complete	**6. Time to Complete each Activity**
As required	

7. Quality Standard:

8. Work Method:

1. Water will be required by the Recreation Department to flood ice hockey and curling surfaces.

2. Water will be required for the swimming pool.

3. Water will be applied under the direction of the Recreation Coordinator

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☐106	Pumps O&M Pumping Equipment	☐114	Water Recreation
☐107	Water Mains	☒**115**	**Water – Other**
☐108	Water Access Vaults		

1. Facility: Truck Service or Water Distribution system

2. Crew Size:	**3. Equipment:**	**4. Materials:**

5. Activities to complete	**6. Time to Complete each Activity**
As required	

7. Quality Standard:

8. Work Method:

Any work related to the water supply and distribution system that is not covered by other defined activities.

ADDENDUM E

ABC NEED-TO-KNOW CRITERIA

Water Treatment "Need-to-Know" Criteria

Association of Boards of Certification

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Foreword

The Association of Boards of Certification (ABC) first promoted the "Need-to-Know" concept for operators in the 1970s. Job titles and descriptions, personnel charts, and career paths were published in 1976 in A Classification System for Water and Wastewater Facilities and Personnel, Part 2—Personnel Certification and Examination System. In 1981, ABC validated "Need-to-Know" Job Analyses for water treatment operators, distribution system operators, collection system operators, and wastewater treatment operators.

At the October 1991 Executive Committee meeting, President-Elect John Krantz recommended simplifying and standardizing the "Need-to-Know" Job Analyses in support of the recommendations of the Training/Testing Liaison/Coordinating (TLC) Committee and the Provinces of Alberta and Ontario. The Executive Committee approved his recommendation and authorized the BOCR and the TLC Committee to update, simplify, and standardize the "Need-to-Know."

At the January 1993 meeting, the Executive Committee approved the updated and standardized operator "Need-to-Know" Job Analyses, Job Titles, and Job Descriptions and the establishment of the Professional Growth Map.

At the August 1993 meeting, the Executive Committee approved the updated and standardized Utility Personnel Charts and Career Paths.

The **"Need-to-Know" Criteria** replaces A Classification System for Water and Wastewater Facilities and Personnel, Part 2—Personnel Certification and Examination System, 1976 and the Water Treatment Operator "Need-to-Know" Users Guide, 1982.

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Introduction

This document highlights the work accomplished through the "Need-to-Know" Criteria project conducted by the Uniform Program for Reciprocity Board of Certification and Registration and the Training/Testing Liaison/Coordination Committee from 1991 to 1994. The Job Analyses for water treatment, distribution system, very small water system, collection system, wastewater treatment, small wastewater system, and industrial waste operators were revised, updated, simplified, combined, and standardized into a single job analysis. The Professional Growth Map concept was developed and prepared for water treatment, distribution system, very small/small water system, collection system, wastewater treatment, small wastewater system, and industrial waste operators. Job titles and descriptions, utility personnel charts, and career paths were updated. The apprentice, journeyman, master proficiency rating system was developed and ratings were assigned to the Job Analysis and Professional Growth Maps.

The "Need-to-Know" Criteria defines the content basis for the operator certification process and career development. It contains Professional Growth Maps, Job Analyses, and Job Titles and Descriptions. The Professional Growth Map lists the skill, knowledge, equipment, process, laboratory analysis, and administrative components of the operator's job. The Job Analysis lists duties of the operator's job.

How ABC Uses the "Need-to-Know" Criteria

The "Need-to-Know" Criteria provides the basis for ABC's certification process. It will be used to validate the education, experience, and evaluation requirements for certification; to evaluate existing exam questions; and to develop new exam questions and future evaluation techniques. Specifically, it allows ABC to demonstrate the relevancy of Testing Service questions and standardized exams. The "Need-to-Know" Criteria also establishes a basis for ABC to make recommendations regarding reciprocity.

ABC will use the Standardized Exam Specifications and the proficiency ratings from the Professional Growth Maps to randomly select questions when developing the four classes of standardized exams. The examinations are progressive in nature—everything required at a lower class is also required at the upper classes. For example, a Class II operator must demonstrate proficiency for all Class II topics as well as the Class I topics. Topics are tested at higher levels of difficulty as the class level advances; this corresponds to the cumulative progression of the proficiency ratings.

Career Development and the "Need-to-Know" Criteria

Certification was developed and is administered to protect the public health and the public's investment, but certification must also provide entry and advancement in the field for all qualified personnel. Certification must have the support and cooperation of operations personnel in the field to be effective. Certification cannot be implemented properly without the support of a majority of those people affected by regulations or law.

The need for more proficient operating personnel becomes greater as plants become more complex to meet new standards and regulations. If there is no opportunity for advancement, personnel may have no motivation to improve their skills. Certification must provide mobility for qualified personnel. While it is understood that some small plant operators will not want to relocate, those desiring to advance themselves must know that starting in a Class I plant is not a dead-end.

With the constant improvement in technology and the increasingly stringent drinking water standards, the concept of only one certified person per plant or shift is no longer valid, feasible, or recommended. Instead, all personnel should be encouraged to be certified to their highest degree

of proficiency based on their responsibilities and particular specialties. In larger plants, different levels of certification are required because of job level variations and responsibilities. This provides the public with greater assurance of competency and provides the operator with a greater means for self-improvement and advancement.

The "Need-to-Know" Criteria is designed to chart an operator's career development. The Professional Growth Maps can be used to track career development and to identify and establish priorities for future training events.

Standardized Exam Specifications

Every ABC standardized exam meets the following specifications. The percentages indicate the number of questions on a 100 question exam from each module.

Module	Class I	Class II	Class III	Class IV
General	25%	15%	5%	5%
Support Systems	20%	15%	15%	10%
Quality Control	50%	60%	60%	60%
Administration	5%	10%	20%	25%
Total	100%	100%	100%	100%

How to Use the "Need-to-Know" Criteria

The "Need-to-Know" Criteria contains two sections: 1) the Professional Growth Map and 2) the Job Analysis.

Professional Growth Map

The Professional Growth Map lists the skill, knowledge, equipment, process, laboratory analysis, and administrative components of the water treatment operator's job. It is a table of the seventy-two standardized exam *topics* with proficiency ratings of:

Apprentice (A) **Journeyman (J)** **Master (M)**

Some of the standardized exam topics have *footnotes* with more detailed information; the footnotes are indicated by a letter in parentheses. The footnotes are listed immediately after the Professional Growth Map. For example,

Header →	[illegible]	[illegible]
Standardized Exam Topic →	Safety Equipment (o)	A

Proficiency Rating ↑

Footnote → o) Safety Equipment—Personal Protection Gear, Traffic Control/Public Safety (Warning Devices, Barricades), Hazard Detection, First Aid/Hygiene

Note: The proficiencies are **cumulative**. Journeyman proficiencies include all Apprentice proficiencies. Master proficiencies include all Journeyman and Apprentice proficiencies. Therefore, a Journeyman is responsible for Apprentice tasks as well as Journeyman tasks. A Master is responsible for Apprentice, Journeyman, and Master tasks.

Job Analysis

The Job Analysis, which follows the Professional Growth Map, lists the *job duty statements*; these statements are indicated by letters. The Job Analysis also contains numbered statements which are the *task elements*. Task elements are grouped by *proficiency rating*. Task elements list the specific actions covered by each of the job duty statements. For example,

Job duty statement →	H. Perform operating procedures associated with normal and abnormal conditions.
Proficiency rating →	Apprentice Tasks
Task element →	1. Identify safety hazards.

Using the Professional Growth Map and the Job Analysis

The job duty statements listed in the Job Analysis are used with the topics in the Professional Growth Map to define what an operator needs to know. The Professional Growth Map indicates the level of mastery (the proficiency rating) of the standardized exam topics. Job Analysis task elements describe the actions performed by the operator and are organized by proficiency rating.

To successfully take an ABC exam, an operator must demonstrate knowledge of the Job Analysis task elements for each Professional Growth Map topic according to the proficiency rating assigned to the topic. Following is an example of this procedure:

1. The Professional Growth Map topic is Electrical Controls.
2. The proficiency rating for Class I is A (apprentice).
3. A Class I operator must know how to perform all apprentice tasks for Electrical Controls.
4. The operator refers to the Job Analysis.
5. The job duty statement reads "H. Perform operating procedures associated with normal and abnormal conditions."
6. For job duty statement H, the first apprentice task is "Identify safety hazards."
7. The operator must be able to identify safety hazards for Electrical Controls.
8. The operator refers to the next job duty statement and repeats this procedure.

Modules

The **"Need-to-Know" Criteria** is organized into modules that contain a Professional Growth Map and a Job Analysis. There are four modules:

1) The General Module identifies the set of underlying skills and knowledge necessary to properly operate a plant. The Professional Growth Map and Job Analysis in this module are *not* the same as the other modules. Each topic in this Professional Growth Map correlates directly to one job duty statement in this Job Analysis.
2) The Support Systems Module lists the equipment necessary to enable the plant to properly function.
3) The Quality Control Module focuses on processes that change the quality and location of the water and solids from the point of entry to the point of discharge. It contains *three* sections: 1) Fundamental, 2) Processes/Units, and 3) Laboratory. The Professional Growth Map and Job Analysis in the Fundamental section is *not* the same as the other sections. Each topic in this Professional Growth Map correlates directly to one job duty statement in this Job Analysis.
4) The Administration Module lists the management/supervisory functions.

Professional Growth Map

Topics	Class I	Class II	Class III	Class IV
Basic and applied math	J	M	M	M
Basic and applied science	A	J	M	M
Electrical concepts	A	J	M	M
Hydraulic concepts	A	J	M	M
Maps and plans	A	J	M	M
Safety	M	M	M	M
Units of expression	M	M	M	M

Job Analysis

Demonstrate knowledge of the following tasks for each Professional Growth Map topic according to the proficiency rating assigned.

A. Basic and applied math

Apprentice Tasks

1. Perform addition, subtraction, multiplication and division of whole numbers and decimals.
2. Square and cube whole numbers, proper fractions, improper fractions, mixed numbers and decimals.
3. Using conventional formulas, solve for:
   - Area of rectangles, triangles, and circles
   - Surface area of cylinders, cones, and spheres
   - Volume of cubes, prisms, cylinders, cones, and spheres

Journeyman and Master Tasks

4. Convert fractions to percentage and vice-versa.
5. Plot and interpret graphs including line, bar, percentage, and broken line.
6. Develop and read tables.
7. Using conventional formulas, solve for:
   - Direct and inverse proportions
8. Using conversion references, convert from English to metric and vice-versa.
9. Calculate percent removal.

B. Basic and applied science

Apprentice, Journeyman, and Master Tasks

1. Define concepts in basic chemistry.
2. Identify and describe chemicals used in water/wastewater.
3. Define and describe the significance of basic concepts in water/wastewater chemistry.
4. Define and describe the significance of basic concepts in microbiology, including viruses, bacteria, and protozoa.

C. Electrical concepts

Apprentice, Journeyman, and Master Tasks

1. Define basic concepts.

D. Hydraulic concepts

Apprentice, Journeyman, and Master Tasks

1. Define basic concepts.

E. Maps and plans

Apprentice, Journeyman, and Master Tasks

1. Interpret and use maps and plans.

F. Safety

Apprentice, Journeyman, and Master Tasks

1. Identify basic categories of safety hazards.
2. Identify basic safety procedures.
3. Identify violations of personal hygiene.
4. Describe personal safety procedures.
5. Describe fire safety procedures.
6. Describe chemical safety procedures.
7. Describe confined space safety procedures.

G. Units of expression

Apprentice Tasks

1. Define units of expression (e.g. ppm, mg/L, lb/mg).

Journeyman and Master Tasks

2. Convert from one unit to another using appropriate references or formulas.

Professional Growth Map

Topics	Class	Class	Class	Class
Battery banks	J	M	M	M
Blowers and compressors (a)	J	M	M	M
Cathodic protection devices (b)	A	J	M	M
Chemical feeders (c)	A	J	M	M
Cross-connection and backflow	J	M	M	M
Drives (d)	J	M	M	M
Electrical controls	A	J	M	M
Engines (e)	J	M	M	M
Fittings (f)	M	M	M	M
Generators (g)	J	M	M	M
Hydrants	M	M	M	M
HVAC (h)	A	J	M	M
Joints (i)	M	M	M	M
Measuring and control systems (j)	A	J	M	M
Motors (k)	J	M	M	M
Pumps				
Air lift	M	M	M	M
Centrifugal	J	M	M	M
Positive displacement (l)	J	M	M	M
Screw	M	M	M	M
Turbine	J	M	M	M
Metering	M	M	M	M
Pneumatic ejector	J	M	M	M
Pipes	M	M	M	M
Rolling stock (m)	A	J	M	M
Safety equipment (n)	M	M	M	M
Transformers	A	J	M	M
Valves (o)	J	M	M	M

Footnotes

a) Blowers and compressors—centrifugal, positive displacement (rotary, piston)
b) Cathodic protection devices—anode rod/bags, cathode rod/bags, rectifiers, potentiometers
c) Chemical feeders—solids, liquids, evaporators, gas, slurry
d) Drives—coupled, direct (shaft, gear), speed reducer (fixed, variable), right angle
e) Engines—gasoline, diesel, gas
f) Fittings—coupling, union, plug/caps, corporation (ferrell/cock), curb stop, special
g) Generators—AC, DC
h) HVAC—heat exchangers, dehumidifiers, fans, compressors, condensers, boilers

i) Joints—flanged, compression, dresser, victaulic, fused, threaded

j) Measuring and control—signal generators (Kennison nozzle, magnetic flowmeter, Parshall Flume, proportional weir, rectangular weir, Venturi, propellor meter, ultrasonic, Pitot tube), signal transmitters (electric, pneumatic, hydraulic, mechanical, telemetry), signal receivers (counters, indicators, log scale indicators, totalizers, recorders, combination recorders), meters (hydraulic-rotameter, electrical-amp, electrical-watt [watt hour meter], electrical-multitester [VOM], electrical-megger, mechanical-RPM), alarms, controls (pneumatic, float, hydraulic, electrical, telemetry, timers)

k) Motors—single phase, poly phase, variable speed

l) Positive displacement pumps—piston plunger, progressive cavity, diaphragm

m) Rolling stock service vehicles, forklifts, trucks, tractors, trailers, lawnmowers, loaders, portable pumps, generators

n) Safety equipment—personal protection gear, traffic control/public safety (warning devices, barricades), hazard detection, first aid/hygiene

o) Valves—ball, check, globe, gate, plug, petcock, pressure control, vacuum relief, mud, butterfly, multiport, telescoping, sluice gate, air release, foot, altitude

Job Analysis

Demonstrate knowledge of the following tasks for each Professional Growth Map topic according to the proficiency rating assigned.

H. Perform operating procedures associated with normal and abnormal conditions

Apprentice Tasks

1. Identify safety hazards.
2. Conform to safety procedures.
3. Perform necessary calculations.
4. Record necessary information.
5. Describe purpose of system/equipment/components.
6. Relate necessary information to others.

Journeyman Tasks

7. Recognize indicators of normal and abnormal conditions.
8. Perform necessary actions at appropriate time, location, and frequency.
9. Use necessary tools/test equipment/reference manuals.

Master Tasks

10. Identify causes of abnormal conditions using proper troubleshooting techniques.
11. Explain reasons for taking these actions, including consequences of not taking action.
12. Explain interaction with other support systems/equipment and the total treatment process.
13. Conform to standards imposed by process parameters, laws, and regulations.

I. Perform preventive and corrective maintenance procedures

Apprentice Tasks

1. Identify and locate each part requiring maintenance.
2. Identify safety hazards.
3. Conform to safety procedures.
4. Perform necessary calculations.
5. Record necessary information.

6. Relate necessary information to others.

Journeyman Tasks

7. Recognize when maintenance is indicated.
8. Perform the necessary actions at the appropriate time, location and frequency.
9. Use necessary tools/test equipment/reference manuals.

Master Tasks

10. Locate causes of malfunction using proper troubleshooting techniques.
11. Explain reasons for taking these actions, including consequences of not taking action.
12. Explain interaction with other support systems/equipment and the total treatment process.
13. Conform to standards imposed by process parameters, laws, rules and regulations.

J. Perform start up/shut down procedures

Apprentice Tasks

1. Identify safety hazards.
2. Conform to safety procedures.
3. Perform necessary calculations.
4. Record necessary information.
5. Relate necessary information to others.

Journeyman Tasks

6. Identify conditions requiring start up/shut down of the support system/equipment.
7. Perform the necessary actions at the appropriate time, location and frequency.
8. Use necessary tools/test equipment/reference manuals.

Master Tasks

9. Explain reasons for taking these actions, including consequences of not taking action.
10. Explain interaction with other support systems/equipment and the total treatment process.
11. Conform to standards imposed by process parameters, laws, and regulations.

Quality Control Module

The Quality Control Module contains three sections:

1) Fundamental Professional Growth Map and Job Analysis (This section is organized the same as the General Module.)
2) Processes/Units Professional Growth Map and Job Analysis
3) Laboratory Professional Growth Map and Job Analysis

Fundamental Professional Growth Map

Topics	Class I	Class II	Class III	Class IV
Compliance	M	M	M	M
Public health principles	J	M	M	M
Quality control and assurance	M	M	M	M
Sources and characteristics	A	J	M	M

Fundamental Job Analysis

Demonstrate knowledge of the following tasks for each Professional Growth Map topic according to the proficiency rating assigned:

K. Sources and characteristics

Apprentice Tasks

1. Identify sources.
2. Describe source quality and quantity.

Journeyman Tasks

3. Identify physical, chemical, and biological characteristics.

Master Tasks

4. Describe effects of physical, chemical, and biological characteristics.

L. Public health principles

Apprentice, Journeyman, and Master Tasks

1. Describe public health principles, laws, and regulations.

M. Quality control and assurance

Apprentice, Journeyman, and Master Tasks

1. Perform quality control and assurance procedures.

N. Compliance

Apprentice, Journeyman, and Master Tasks

1. Perform duties and tasks in compliance with laws and regulations.

Processes/Units Professional Growth Map

Topic	Class I	Class II	Class III	Class IV
Aeration (p)	J	M	M	M
Chemical precipitation softening	—	A	J	M
Clarification				
Presedimentation	A	J	M	M
Sedimentation basins	A	J	M	M
Upflow solids contactors	—	A	J	M
Tube settlers	A	J	M	M
Coagulation and flocculation (q)	A	J	M	M
Corrosion control (r)	J	M	M	M
Dechlorination	A	J	M	M
Defluoridation	A	A	J	M
Demineralization	—	A	J	M
Desalinization	—	A	J	M
Disinfection				
Gas chlorinators	J	M	M	M
Ozonators	—	A	J	M
Ammoniators	A	J	M	M
Ultraviolet units	J	M	M	M
Chlorine dioxide feeders	A	J	M	M
Hypochlorinators	M	M	M	M
Iodinization processors	J	M	M	M
Evaporators	—	A	J	M
Electrodialysis	A	A	J	M
Filtration				
Rapid sand	A	J	M	M
Mixed or multimedia	A	J	M	M
Pressure	J	M	M	M
Diatomaceous earth	J	M	M	M
Granular activated carbon	A	J	M	M
Slow sand	J	M	M	M
Membrane technology	A	A	J	M
Disposable technology	A	J	M	M
Flow measurement	A	J	M	M
Fluoridation	J	M	M	M
Ion exchange	J	M	M	M
Iron and manganese removal (s)	J	M	M	M
Landfill solids	J	M	M	M
Land application of solids	J	M	M	M
Microscreens	A	J	M	M

Recirculation (t)	A	J	M	M
Reverse osmosis	A	A	J	M
Screening				
Well screens	M	M	M	M
Intake ports/bar screens	A	J	M	M
Hand cleaned screens (u)	A	J	M	M
Mechanically cleaned screens	A	J	M	M
Sludge conditioning	A	J	M	M
Sludge drying beds	J	M	M	M
Sludge vacuum filters	A	J	M	M
Sludge filter press	A	J	M	M
Sludge belt press	A	J	M	M
Sludge centrifuges	A	J	M	M
Storage				
Ground storage tanks	M	M	M	M
Elevated tanks	J	M	M	M
Standpipes	J	M	M	M
Hydropneumatic pressure tanks	J	M	M	M
Taste and odor control				
Feeders	A	J	M	M
Aerators	J	M	M	M
Contactor beds	A	J	M	M

Footnotes

p) Aeration—diffused aerators, mechanical aerators-mixer, cascade aerators
q) Coagulation and flocculation--mixers, air injectors/diffusers, hydraulic (static mixer), baffles
r) Corrosion control—feeders, reaction basins
s) Iron and manganese removal—chemical precipitation units, aerators, filter units
t) Recirculation—water systems, sludge systems
u) Hand cleaned screens—fine mesh, secondary screens

Processes/Units Job Analysis

Demonstrate knowledge of the following tasks for each Professional Growth Map topic according to the proficiency rating assigned:

O. Perform operating procedures associated with normal/abnormal conditions

Apprentice Tasks

1. Identify safety hazards.
2. Conform to safety procedures.
3. Perform necessary calculations.
4. Record necessary information.
5. Sketch and describe each element.
6. Describe the purpose of the process/units/components.
7. Relate necessary information to others.

Journeyman Tasks

8. Recognize indicators of normal and abnormal conditions.
9. Perform necessary actions at appropriate time, location, and frequency.
10. Use necessary tools/test equipment/reference manuals.

Master Tasks

11. Identify causes of abnormal conditions using proper troubleshooting techniques.
12. Explain reasons for taking actions including consequences of not taking action.
13. Explain interaction with other processes/units and total treatment process.
14. Conform to standards imposed by process parameters, laws, and regulations.

P. Perform start up/shut down procedures

Apprentice Tasks

1. Identify safety hazards.
2. Conform to safety procedures.
3. Perform necessary calculations.
4. Record necessary information.
5. Relate necessary information to others.

Journeyman Tasks

6. Identify conditions requiring start up/shut down of the process/unit.
7. Perform necessary actions at appropriate time, location, and frequency.
8. Use necessary tools/test equipment/reference manuals.

Master Tasks

9. Explain reasons for taking actions, including consequences of not taking action.
10. Explain interaction with other processes/units and total treatment process.
11. Conform to standards imposed by process parameters, laws, and regulations.

Laboratory Professional Growth Map

Topics	Class I	Class II	Class III	Class IV
Algae	A	J	M	M
Alkalinity	J	M	M	M
Aluminum	A	J	M	M
Ammonia	A	J	M	M
Biomass	A	J	M	M
Calcium	J	M	M	M
Chloride	J	M	M	M
Chlorine	M	M	M	M
Coliforms	M	M	M	M
Color	J	M	M	M
Fluoride	M	M	M	M
Iron	J	M	M	M
Jar test	A	J	M	M
Manganese	J	M	M	M
Nitrate	J	M	M	M

Orthophosphate	A	J	M	M
Particle count	—	A	J	M
pH	M	M	M	M
Phosphate	M	M	M	M
Specific conductance	J	M	M	M
Sulfate	J	M	M	M
Sulfide	J	M	M	M
Temperature	M	M	M	M
Threshold odor number	A	J	M	M
TOC	—	A	J	M
Total hardness	J	M	M	M
Total solids	A	J	M	M
Turbidity (NTU)	M	M	M	M

Laboratory Job Analysis

Demonstrate knowledge of the following tasks for each Professional Growth Map topic according to the proficiency rating assigned:

Q. Perform analysis

Apprentice Tasks

1. Interpret chemical labels and the standard shipping labels of chemicals received.
2. Label containers.
3. Describe the proper use and care of laboratory equipment and glassware.
4. Take samples using proper procedures.
5. Transport samples using proper procedures.
6. Store sample using proper procedures.
7. Identify safety hazards.
8. Conform to safety procedures.
9. Perform necessary calculations.
10. Record necessary information on all required reports.
11. Relate necessary information to others.

Journeyman Tasks

12. Prepare sample containers using proper procedures.
13. Specify time and frequency for taking samples.
14. Select sample location using proper procedures.
15. Analyze sample using proper procedures.
16. Interpret data.
17. Use laboratory equipment and reference manuals.
18. Describe purpose of test/procedures.

Master Tasks

19. Prepare or obtain reagents using proper procedures.
20. Make appropriate decision(s) concerning results indicating abnormal conditions.
21. Explain reasons for using proper procedures and consequences of not using these procedures.
22. Conform to standards imposed by process parameters, laws, and regulations.

Professional Growth Map

Topic	Class I	Class II	Class III	Class IV
Emergency response	A	J	M	M
Finances	A	J	M	M
Information	A	J	M	M
Maintenance management	A	J	M	M
Personnel	—	A	J	M
Planning	A	J	M	M
Public relations	A	J	M	M
Safety	J	M	M	M
Security	A	J	M	M

Job Analysis

Demonstrate knowledge of the following tasks for each Professional Growth Map topic according to the proficiency rating assigned.

R. Develop a master plan to include objectives (short and long-term, review, update), strategies, financial support, and presentation to key personnel. Prepare management systems to implement master plan's objectives and strategies. Implement the management systems to accomplish master plan objectives to organize, coordinate, direct, and control. Evaluate effectiveness of master plan and management systems.

Apprentice Tasks

1. Perform necessary calculations.
2. Record necessary information.
3. Use necessary reference materials.
4. Describe purpose of the management system.

Journeyman Tasks

5. Recognize indicators of good management practices.
6. Perform actions at appropriate time, location, and frequency.
7. Relate management systems to others within the plant.

Master Tasks

8. Explain reasons for taking actions including the consequences of not taking actions.
9. Explain interaction of management system.
10. Conform to process standards, laws, and regulations.

Superintendent (Class I and II)

Operates water treatment equipment to regulate flow and processing of water and the waste solids produced. Monitors control panels and adjusts valves and gates manually or by remote control to regulate flow of water and the waste solids. Observes variations in operating conditions and interprets meter and gauge readings and test results to determine processing requirements. Starts and stops pumps, engines, and generators to control flows of chemicals and water and the waste solids through the unit processes. May operate and maintain power generating equipment to provide heat and electricity for plant. Operates automotive equipment. Analyzes and evaluates operation and maintenance functions for water treatment plants processing an average daily flow of less than one million gallons; initiates or recommends new or improved practices. Controls expenditures of budgeted funds and requests approval for major expenditures as required. Maintains effective communications and working relationships with other utility employees, government officials, and general public. Composes routine correspondence and handles routine inquiries from the public. Maintains shift log and records meter and gauge readings. Performs and/or supervises all preventive and corrective maintenance on plant and equipment except where he/she decides the work must be done by an outside contract. Responsible for maintaining buildings, structures, and grounds. Establishes preventive maintenance program and regularly inspects plant and mechanical equipment for malfunctions and needed repair. Keeps maintenance records. Performs craft-oriented duties (e.g. electrician, painter, plumber), along with general custodial tasks as required. Requisitions chemicals, materials, and supplies.

Superintendent (Class III and IV)

Responsible for administration, operation, and maintenance of entire plant. Exercises direct authority over all plant functions and personnel in accordance with approved policies and procedures. Inspects plant regularly. Analyzes and evaluates operation and maintenance functions; initiates or recommends new or improved practices. Develops plans and procedures to insure efficient plant operation. Recommends plant improvements and additions. Coordinates data and prepares or reviews and approves operation reports and budget requests. Controls expenditure of budgeted funds and requests approval for major expenditures as required. Recommends specifications for major equipment and material purchases. Organizes and directs activities of plant personnel, including training programs. Maintains effective communications and working relationships with employees, government officials, and the general public.

Assistant Superintendent (Class III and IV)

Assists in administrative and supervisory duties under the general direction of the superintendent. Serves as superintendent in his/her absence. Aids in analyzing and evaluating operation and maintenance procedures and in developing new or improved practices. Participates in maintenance of operating records, compilation of data, and report preparation. Assists with employee training. Inspects plant. Assists in planning special maintenance work and minor plant alterations.

Staff Assistant

Assists in administrative and supervisory duties under general direction of the assistant superintendent. Aids in analyzing and evaluating operations and maintenance procedures and in developing new or improved practices. Participates in maintenance of records, compilation of data, and plan and report preparation. Assists with employee training. Inspects plant. Assists with plan preparation for minor plant alterations and with special maintenance work. May represent superintendent or assistant superintendent in administrative meetings.

Operations Supervisor

Supervises and coordinates activities of plant operators, maintenance personnel, laborers, custodians, and other plant personnel. Prepares work schedules subject to approval of superintendent or assistant superintendent. Analyzes recording instrument readings and laboratory test results and makes necessary adjustments. Prepares reports and maintains records. Inspects plant to determine efficiency of operation, cleanliness, and maintenance requirements. Determines remedial action in emergencies. Conducts training programs. Requisitions chemicals, materials, and supplies. Performs duties of assistant superintendent if absent.

Shift Supervisor

Supervises operation of plant under general direction of superiors. Performs duties of operations or maintenance supervisor in his/her absence. Supervises, instructs, and assigns specific duties to shift workers. Reviews and evaluates work performance. Participates in training programs. Inspects plant equipment and processes regularly. Analyzes instrument readings and laboratory test results. Determines site and causes of malfunctions. Orders, supervises, or participates in required adjustments or repairs. Maintains and evaluates operating records. Replaces operator or maintenance worker during emergency situations. Communicates with other shift supervisors regarding plant conditions.

Operator (Large Plant)

Performs any combination of the following tasks pertinent to controlling operation of plant. Operates treatment facilities to control flow and processing of raw and finished water. Monitors gauges, meters, and control panels. Observes variations in operating conditions. Interprets meter and gauge readings. Interprets test results to determine processing requirements. Operates valves and gates either manually or by remote control. Starts and stops pumps, engines, and generators to control and adjust flow and treatment processes. Maintains shift log and records meter and gauge readings. Collects samples and performs routine laboratory tests and analyses. Performs routine maintenance functions and custodial duties. Operates power generating equipment. Makes operating decisions in absence of supervisory personnel. May perform duties of shift supervisor if absent.

Chemist/Bacteriologist

Supervises and performs specialized and complex chemical, bacteriological, and physical tests and analyses of raw, partially treated, and treated water and by-products to determine efficiency of plant processes and to insure treated water meets local, state, and federal requirements. Conducts or supervises less complex routine tests. Supervises collection of

laboratory samples. Supervises laboratory technicians and provides routine procedures to be followed. Evaluates and interprets test results, establishes test priorities, and prepares reports. Assembles data, maintains records, and prepares periodic reports. Sets up pilot processes when conducting research on improved procedures. Provides direct or indirect instructions to operating personnel regarding chemical requirements and adjustments, changes, or additions to various treatment processes.

Laboratory Technician

Performs any combination of routine laboratory tasks. Collects samples of raw, partially treated, and treated water and by-products within plant and treated water throughout system. Assembles instruments and equipment for analytical or research work. Prepares chemical and bacteriological media, stains, reagents, and test solutions routinely used in laboratory. Operates equipment and performs routine chemical, bacteriological, and physical tests as directed. Maintains test result reports and prepares data sheets. Prepares or assists in preparation of reports. Cleans, maintains, and stores instruments and equipment. Maintains inventory and orders supplies. Performs laboratory custodial duties.

ADDENDUM F

ADDITIONAL SOURCES OF INFORMATION

Contacts & Additional Sources of Information

Internet

Water Boards in the NWT

Board	Website
Mackenzie Valley Land and Water Board	www.mvlwb.com
Mackenzie Valley Environmental Impact Review Board	www.mveirb.nt.ca
Gwich'in Land and Water Board	www. glwb.com
Gwich'in Land Use Planning Board	www.gwichinplanning.nt.ca
Gwich'in Renewable Resources Board	www.grrb.nt.ca
Sahtu Land and Water Board	www.slwb.com
Sahtu Land Use Planning Board	www.sahtulanduseplan.com

The NWT Water Board retains responsibility for the Inuvialuit Settlement Region.

Guidelines for Canadian Drinking Water Quality - Supporting Documentation.
These documents represent the technical or scientific supporting documentation used by the Federal-Provincial Subcommittee on Drinking Water in developing and approving guidelines for contaminants found in drinking water.
http://www.hc-sc.gc.ca/ehp/ehd/catalogue/bch.htm

NWT Water Quality Database
The NWT Water Quality database is a joint project between the departments of Health & Social Services, Municipal & Community Affairs, and Public Works & Services of the Government of the Northwest Territories located at: http://www.pws.gov.nt.ca/WaterAndSanitation/Index.htm

Chlorination
http://www.hc-sc.gc.ca/english/iyh/environment/chlorine.html

Workers Compensation Board of the Northwest Territories and Nunavut
http://www.wcb.nt.ca
1-800-661-0792 (in the NWT)
1-877-404-4407 (in Nunvaut)

Environmental Health Officer Contacts

Region	Phone number
Inuvik Regional Health/Social Services Authority	(867) 777-8184
Stanton Territorial Health Protection, Health Promotion & Protection	(867) 873-2183 (867) 873-2940 (867) 669-6722
Hay River Community Health Board	(867) 874-7135

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17) Algal in water Supplies _ U .S . Department of Health Education and Welfare, Public Health Service Publication No: 657, Reprinted 1962

18) Standard Methods for the Examination of Water and Wastewater _ American Public Health Association Inc .

19) Ministry of the Environment, Ontario Drinking Water objectives, revised 1983

20) Ground Water & Wells, Edward E . Johnson Inc .