Water Quality 101

Potable Water Micro-System Fundamentals

Version 1.1

Water Quality 101:

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WORK BOOK

Version 1.1

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Interdepartmental Water Quality Training Board

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FOREWORD

The federal government has or shares responsibility for the safety of drinking water in federal facilities both in Canada and abroad, Canadian Coast Guard vessels and in First Nation communities. Its legal obligations to its employees as a provider of drinking water are described in the Canada Labour Code and its related regulations, which require federal employers to provide potable water to employees in accordance with prescribed standards. The Occupational Health and Safety Regulations prescribe a specific version of the Guidelines for Canadian Drinking Water Quality as those standards.

There are many challenges in meeting these responsibilities, especially given that many federally owned systems are small scale and in remote locations. This is compounded with the lack of water quality training targeted specifically for these types of systems. Ensuring that appropriate competencies are supported through adequate training is not only an essential component of due diligence but it is also one barrier of a multi-barrier approach to delivering safe drinking water.

Federal departments recognized a need to develop a federal drinking water program that would incorporate an intake to tap approach to drinking water quality in all areas of federal jurisdiction. As a result, the Interdepartmental Working Group on Drinking Water (IWGDW) was formed in 2002. Its main objective was to develop the document Guidance to providing safe drinking water in areas of federal jurisdiction (Guidance Document). The document describes consistent approaches to activities including inspection and monitoring of drinking water systems, and operator training and certification, and places a particular focus on small and very small drinking water systems. It provides a road map to assist departments to achieve compliance with the Guidelines for Canadian Drinking Water Quality.

Although there is training available for municipal scale systems, there is much less training available of consistent quality for micro-systems – which are very small systems providing drinking water for up to and including 25 people. Departments have recognized that there is an opportunity to work together to develop and deliver training associated with implementing the Guidance Document and achieving the regulatory obligations and due diligence of providing potable water in locations served by micro-systems. It is recognized that while individual departments may have some unique training needs, there are substantial training needs that are shared by several departments.

Consequently, the Interdepartmental Water Quality Training Board (IWQTB) was formed as a subcommittee and complementary body to the IWGDW. It is composed of representatives from various federal departments and agencies, all having responsibilities related to providing safe drinking water to employees and others using their facilities. The Board works together to develop a common approach to meeting the micro-system training needs of federal drinking water providers.

As a result, this course - “Water Quality 101: Potable Water Micro-System Fundamentals” (WQ101) and several stand alone training modules have been developed. WQ101 is a comprehensive introduction to water quality in general and as it relates to the provision of potable water for micro-systems. Although this course might be a very good introduction for an individual who operates a municipal water treatment system, it is not directed at this level of audience. It is a basic introduction on water quality, with a focus on micro-systems. The course covers six theme areas: due diligence and the Canada Labour Code, water quality fundamentals, sampling and record keeping, data management and reporting, operation and maintenance and source water protection.

The Water Quality 101: Potable Water Micro-Systems Fundamentals course is composed of two parts: the e-Learning course and this accompanying work book. The principal learning tool is the e-Learning course, which is developed in modules so it can be customized to fit the training requirements of the learner. The e-Learning provides information about specific subjects, and provides the important key points to learn at an introductory level. This work book expands on the topics covered in the e-Learning course, to allow the learner to easily find more information on each topic.

1 Water Quality Overview

1.1 Introduction

Water treatment systems range in size, based on the number of people they serve. Various organizations in each jurisdiction provide provincially certified training for the operation and maintenance of larger systems. This training course could provide basic information for these systems, but is intended to provide understanding and guidance for the operation and maintenance of micro-systems. Micro-systems are defined as systems that provide water for up to and including 25 people. They can also be characterized as a system in a house where commercially available treatment devices are used to treat water. This work book is targeted to achieve three levels of training:

> **Did You Know:**
>
> Health problems related to water pollution are estimated to cost Canadians $300 million per year.

1. Basic Knowledge and Awareness – an understanding of the basic concepts involved in the provision of safe drinking water for micro-systems.
2. Demonstrated Understanding – a good understanding of the various subjects covered in the course as they relate to the provision of safe drinking water in micro-systems.
3. Tested Competency – demonstrated understanding, as above, and the successful completion of a set of questions that tests and demonstrates the student's comprehension.

The training is modular and is suitable for a range of students, from senior managers to responsible authorities, water system operators and individuals who are responsible for monitoring water quality (water quality monitors). The training incorporates the basics of water quality knowledge along with guidance from the federal document Guidance for Providing Safe Drinking Water in Areas of Federal Jurisdiction and content from the Guidelines for Canadian Drinking Water Quality (GCDWQ), published by Health Canada.

1.2 Regulations and Due Diligence

Simply put, water is necessary for life. Part II of the Canada Labour Code states that the employer (in this case the Government of Canada) is responsible for providing its employees with access to potable water for drinking, food preparation, and washing. In other words, federal departments have a legal obligation to make sure their employees have access to safe drinking water every day.

The employer must take appropriate steps to ensure the protection of the health and safety of employees who use water at federal facilities. In some cases, such as facilities used by the public, ensuring the safety of drinking water supplies is more a matter of due diligence than a legal obligation. Due diligence means taking every precaution in a situation to make sure nobody comes to harm.

The Interdepartmental Working Group on Drinking Water has developed a guidance document to assist departments to meet their obligations under the Canada Labour Code as well as exercise due diligence when providing potable water. This document, located on the Health Canada website, is called Guidance for Providing Safe Drinking Water in Areas of Federal Jurisdiction.

Health Canada also publishes and regularly updates the Guidelines for Canadian Drinking Water Quality, which establishes Maximum Acceptable Concentrations

(MACs), Aesthetic Objectives, and Operational Guidelines for various contaminants and other parameters found in drinking water. These Guidelines are based on currently available scientific knowledge and developed and approved in collaboration with provincial and territorial partners.

1.3 Natural Sources of Water

Did You Know:

Hardness in water can cause scaly deposits in pipes, water treatment equipment, water heaters and boilers. One sixteenth of an inch of scale can reduce efficiency of a water heater by 15%. Hardness can also increase soap consumption by as much as 50 to 90% by making it harder to lather.

Water – H_2O – is a simple compound in its pure form. Water exists naturally in three basic states; a solid (ice), a liquid and a vapour (fog, clouds, etc.). Water is continuously moving through these various states, from the atmosphere to the ground and below the ground, eventually returning to the atmosphere again. This cycle is called the hydrological cycle.

As water moves through this cycle it encounters a multitude of possible contaminants. Since water is one of the most universal solvents, it almost always contains other dissolved and suspended substances. These substances may be naturally-occurring or man-made. Some substances are unsafe for human health (e.g. arsenic, nitrate) while others may pose problems with water treatment (e.g. iron, calcium). Organic matter (e.g. Decaying plant material, small suspended soil particles) can cause treatment problems and interfere with disinfection processes. Water from the earth's surface (surface water – lakes, rivers, ponds) and water from below ground (groundwater – springs, wells, aquifers) may contain dissolved and suspended particulate matter.

Water naturally contains a wide range of living organisms, many of which are not visible to the naked eye – they are microscopic. Surface water almost always contains microbiological contaminants, some of which could be disease-causing or even deadly (pathogenic). This is also true of groundwater from shallow wells (generally those that are 30 m or less in depth) which can be under the influence of surface water. Water from deeper wells may also contain microbiological contaminants such as bacteria and viruses. The naturally occurring bacteria are normally not harmful, but viruses can be harmful and aquifers and wells can become contaminated. The best approach is to assume that untreated water is not safe to drink until tests prove otherwise.

1.4 Contaminants in the Water

There are a variety of substances that can negatively affect water quality. They are generally grouped by their characteristics: Microorganisms, inorganic and organic chemicals and radiological compounds.

Microorganisms are a group of living organisms that include protozoa, bacteria and viruses. They can live in water, soil and in the atmosphere and are found in surface water bodies, water wells, under the earths crust and even on rocks. While there are many microorganisms that are not harmful to humans others can make humans sick or even cause death. The identification of the type and number of microorganisms in water should be done by an accredited laboratory.

Inorganic chemicals are generally naturally occurring. Chemicals in this category are the result of non-living natural processes. Most of the earth is considered to be inorganic. Inorganic compounds are created by the elements that are found on the earth. Some of these compounds are toxic to human health while others may be considered a nuisance. Examples of inorganic chemicals (elements) found in water are arsenic, calcium, iron and sulphate. Even though most inorganic compounds occur naturally, some can be man-made. For example, nitrate occurs in both organic and inorganic forms. Two common inorganic forms, potassium nitrate and ammonium nitrate, are commonly used as fertilizers.

The definition of an organic compound is not exact, but generally refers to compounds which contain carbon as part of their structure. Organic chemicals can occur naturally in the environment from certain plants and sugars, but many occur as a result of man made production processes, such as petroleum products, agricultural pesticides, plastics and rubber manufacturing. A general rule of thumb is that organic chemicals are usually produced by man-made processes. Some examples of organic chemicals are atrazine (a herbicide), benzene (a solvent derived from crude oil) and polyvinyl chloride (PVC – a plastic).

Radionuclides are found in the environment (including water) as naturally occurring elements, and also are produced as by-products of nuclear technologies. The most common naturally occurring radiological compounds include radium, radon and uranium, but many more exist. Radionuclides commonly found in water include those associated with radium and lead.

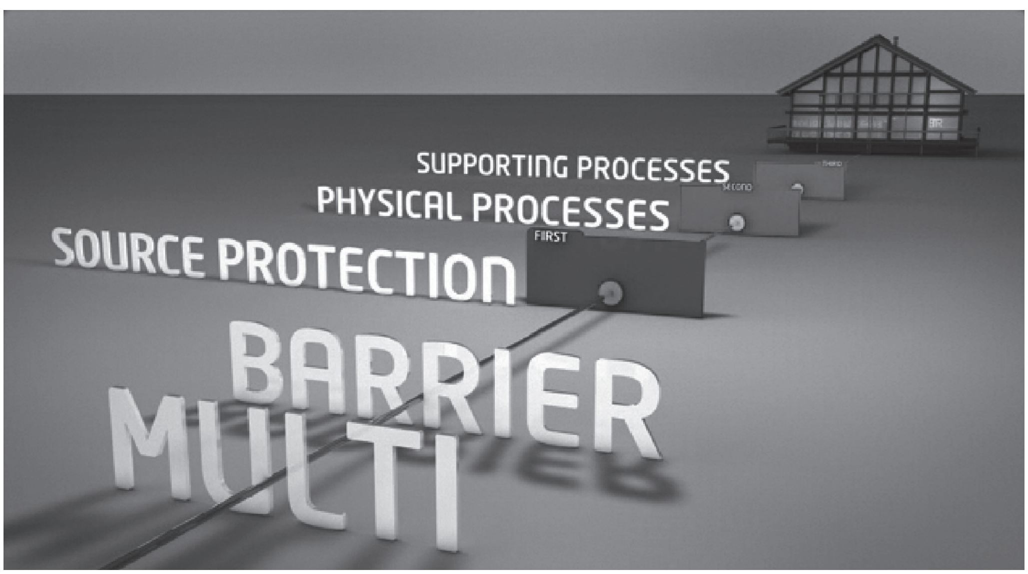
1.5 Multi-Barrier Approach

Without constant monitoring and testing of water quality, it is difficult to ensure that water is consistently safe and potable. A system that includes more than one barrier to contaminants will have a higher factor of safety than a system with a single barrier. For example, a system with a filter and a disinfection process would have two barriers to most microbiological contaminants, whereas a system with a filter alone would only have one barrier.

Did You Know:

The average Canadian uses approximately 343 litres of water per day for domestic purposes. Most of this water is used in the bathroom.

Fig 1.1 The Multi-barrier Approach



Barriers include not only physical devices or processes, but also actions to indirectly or directly affect or monitor the contaminants in water, such as taking actions to protect the water source, or a regular program of water quality sampling, testing, evaluation and reporting.

Full knowledge of the water supply system, from the source to the tap, is a key component of a multi-barrier approach. This knowledge is gained through a variety of tools as outlined in the Guidance document. A “vulnerabilities assessment” considers the water source, identifies any potential hazards from the environment and what affect those hazards will have on the water. This helps to identify actions that need to be taken in order to minimize the risks to deterioration in quality of the water source. Another tool is a “sanitary survey”, which is a comprehensive survey of the water supply system and the procedures use to operate and monitor the system. This survey identifies potential problems in the physical components of the water supply system and the operation, maintenance and monitoring activities. A third tool is a full analysis of the raw source water, called a “baseline analysis”. This analysis provides an understanding of the contaminants in the water and the treatment required, as well as information for monitoring requirements.

Other barriers include source protection (both surface and groundwater sources, including well development and decommissioning), treatment devices and processes, sampling and monitoring, regular operation and maintenance procedures, consistent reporting and ongoing training.

1.6 Treatment Processes

There are many conventional and innovative water treatment processes. Water treatment systems continue to be improved and complemented with new technologies and processes. Some examples of water treatment processes include:

Coagulation, a process where an added chemical attracts floating suspended particles to form larger and denser clumps of suspended material that will be heavy enough to settle to the bottom faster than the individual smaller particles would have.

Flocculation, a slow mixing process where a coagulant is added to water and mixed to bind the particles into a flocculent (the “floc”) so it increases in weight and settles by gravity to the bottom of the flocculation tank.

Filtration, a process which removes suspended particles by passing water through various types of filter media including sand, gravel, granular carbon, and a variety of cloth, fibre and ceramic filters. Most filters function by a physical sieving process, but some also rely on chemical mechanisms. For example, granular activated carbon filters trap dissolved organic matter in the carbon filter media by a process called adsorption, but only until the media reaches its adsorption capacity. Some filters also rely on biological processes (e.g. slow sand filtration and biological activated carbon filters).

Nanofiltration and reverse osmosis filtration are membrane filter processes which are capable of removing very small particles including minerals that are dissolved in the water.

Ion exchange systems remove specific chemical constituents from water using a resin media specifically designed to exchange one chemical compound for a different one. One of the most common ion exchange processes is a water softener, which exchanges sodium ions on the resin for calcium and magnesium ions. This ion exchange reduces water hardness but at the same time increases the sodium content in the treated water.

Disinfection processes rely on either destroying disease-causing microbiological contaminants at the cellular level (usually by oxidation using compounds such as chlorine, ozone and in some cases like emergency situations, iodine), or disrupting or damaging the cells genetic ability to reproduce (via radiation from an ultraviolet light). Chlorination is the most common form of disinfection. In order to ensure that treated water remains safe throughout distribution pipes, it is important that a small amount of residual chlorine is present after the disinfection process.

While there are other treatment processes, the processes listed above tend to be amongst the most commonly used in conventional water treatment systems in towns and cities. All of these processes are suitable for smaller-scale treatment systems or devices available for micro-systems.

1.7 Targets for Safe Drinking Water

The Guidelines for Canadian Drinking Water Quality (GCDWQ) published by Health Canada on behalf of the Federal-Provincial-Territorial committee on Drinking Water, establishes health-based limits, called Maximum Acceptable Concentrations (MACs) for many of these contaminants. These MACs are based on current, published scientific research that determines the effect of a particular contaminant on human health and a level of acceptable exposure. It is important to know the levels of contaminants in source water in order to know how the water must be treated to remove the contaminants and make it potable. It is also important to know the MACs for these contaminants so that their reduced levels can be verified in the treated water. Both surface and groundwater can contain some or all of the groups of contaminants. Groundwater from wells deeper than 30 m will likely not contain organic or bacteriological contaminants; however, a baseline chemical analysis should be carried out to verify that they are not present. The GCDWQ also establish values for Aesthetic Objectives (AO) and Operational Guidelines (OG). While these guidelines are not health-based, they are important factors in domestic water use and treatment system performance.

1.8 Distribution Systems

Once water is treated it is delivered to the point of use by a distribution system. The distribution system often includes some type of water storage reservoir such as a pressure tank or a cistern. There may also be a pump to maintain distribution system pressure and there will be piping and valves. Depending on the system design, there may be devices incorporated to release air when necessary or other devices to prevent backflow and siphoning in the system. Note that a micro-system may have little or no distribution system.

In order to ensure that water remains potable in the distribution system it should have enough chlorine residual everywhere in the pipeline system to prevent the re-growth of microbiological contaminants. This is particularly important at the end of the distribution pipes where water may not be used that often – the chlorine residual helps protect water quality in these "dead end" parts of the distribution system.

For those micro-systems where treated potable water is delivered into the distribution system by water haulers (tanks on trucks) rather than local treated water, extra care needs to be taken to ensure that the water delivered is not contaminated during transport or delivery to the on-site storage tank.

Bottled water may also be used as a source of drinking water, and demands special care and attention to ensure that the water remains potable up until its use.

1.9 Notes on Chapter 1

2 Sources of Fresh Water

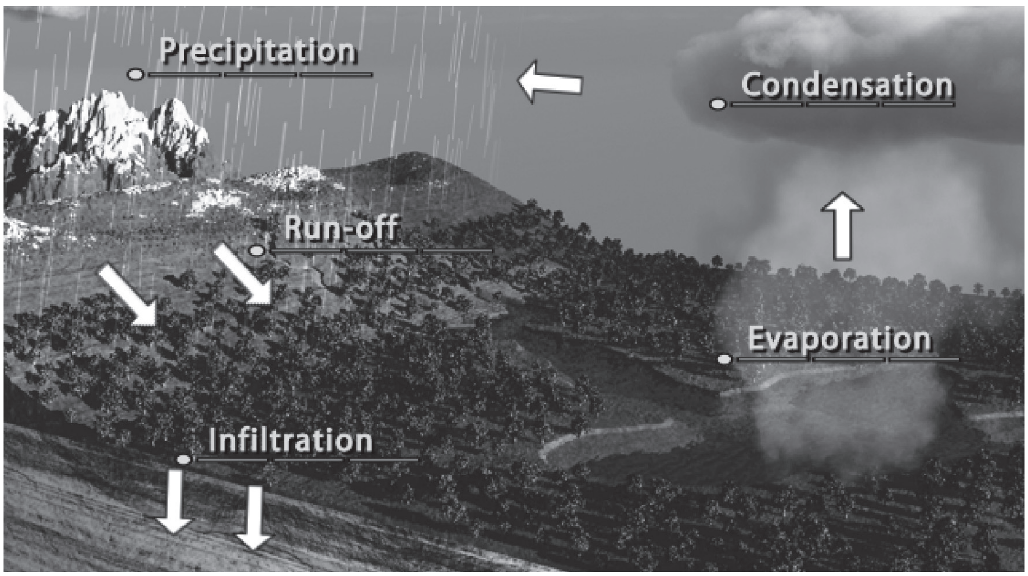
2.1 Introduction

Water is mobile - it moves through the atmosphere, over and through the land, and it moves within ocean currents. This movement of water between air, land and sea is called the hydrologic cycle. An understanding of this cycle will help to gauge the safety and treatment requirements needed for raw water taken from any one of these sources.

Did You Know:

Canada is fortunate. It has only 0.5% of the world's population, but its landmass contains approximately 7% of the world's renewable water supply.

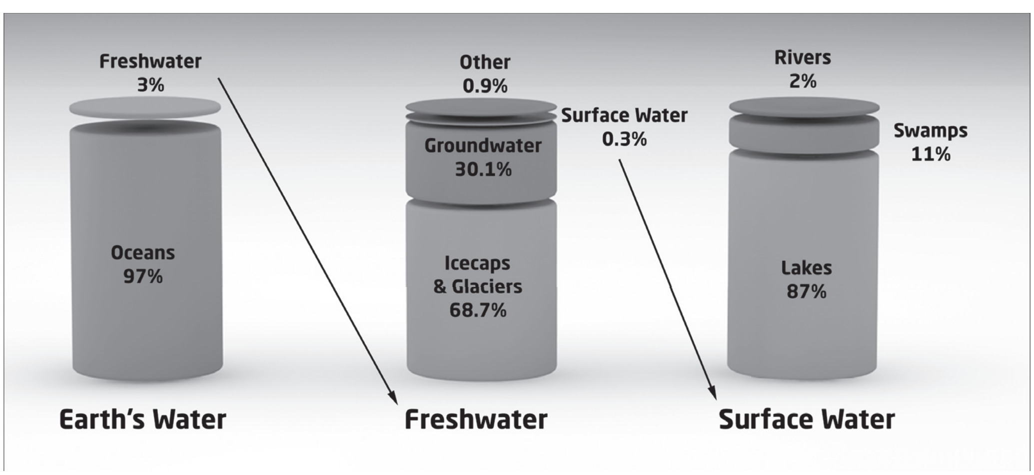
Fig. 2.1 The Hydrological Cycle



2.2 Distribution of Water On Earth

Of all the Earth's water, only 3% is fresh water, with the other 97% being salt water. Of the Earth's total fresh water supply, approximately 69% is frozen as ice-caps and glaciers, 30% is groundwater and only about 0.3% is surface water. Of that 0.3% surface water, 2% is found in rivers, 11% in swamps, and 87% in lakes. The North American Great Lakes basin is the world's largest freshwater lake system.

Fig. 2.2 The Distribution of Water on Earth

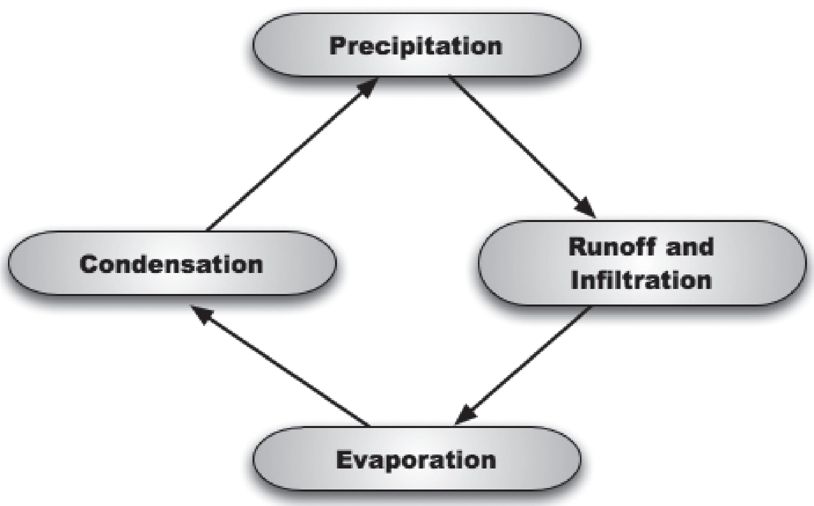


In Canada, approximately 60% of the fresh water drains to the north, yet 85% of the population lives in the south, within several hundred kilometres of the Canada-United States border. While Canada is fortunate to have fairly dependable supplies and good quality water, its overall availability cannot be taken for granted. Some regions are experiencing water availability issues and frequently have water use restrictions in place. Fresh water must be carefully managed in a sustainable way so that the water supplies above or below ground are not depleted and the quality of the source water is not affected.

2.3 The Cycle of Water in the Environment

We see water emerge, seemingly out of nowhere, when it falls from the sky in the form of precipitation - rain or snow. When rain falls to the Earth, a number of things can happen to it. When it hits land, the water may travel as runoff across impermeable surfaces (such as rock, hard soils and pavements) and ends up in streams, lakes, and oceans. Some water soaks into the ground (a process called infiltration) to replenish groundwater or it is drawn into plants through their roots. The water that does not infiltrate the ground eventually ends back up in the atmosphere through the processes of evaporation and plant transpiration (the evaporation of water from exposed surfaces of plants). The combination of these two processes (evaporation and transpiration) is called evapotranspiration.

A simplified version of the hydrologic cycle might look something like this:



Did You Know:

In May of 2000, residents of Walkerton Ontario began to feel ill. For days the Walkerton Public Utilities Commission insisted the town's water was safe to drink despite having lab results showing contamination in the water.

On May 21, 2000 the regions Medical Health Officer issued a boil water advisory for the region. At least 7 people died as a direct result of drinking water contaminated with *E. coli* and many of the town's residents became ill.

Hydrologic Cycle Terms:

Precipitation is condensed water vapour that falls to the Earth's surface. Most precipitation occurs as rain, but also includes snow, hail, fog drip, ice droplets and sleet.

Snowmelt refers to the runoff produced by melting snow.

Runoff includes the variety of ways by which water moves across the surface of the land. This includes both surface runoff and when surface runoff begins to concentrate, channel runoff.

Infiltration is the flow of water from the earth's surface into the ground. Once infiltrated, the water becomes soil moisture or groundwater.

Evaporation is the transformation of water from the liquid to the gas phase as it moves from the ground or the earth's water bodies into the atmosphere. The primary energy source for evaporation is the Sun.

Condensation is the transformation of water vapour to liquid water droplets in the air, producing clouds and fog.

Rain water (precipitation) is often far from pure. Rain droplets form around dust particles and because of this the rain water will contain the dust particle and any contaminants attached to it. If clouds and rain originate above sources of industrial or agricultural contaminants it is possible that these contaminants will be found in the rainfall water.

2.4 Surface Water

Because the water sources for micro-systems may be streams and lakes, understanding how water finds its way into those surface water sources and the kinds of contaminants found in them is important. As stated earlier runoff is water that moves across the land. The runoff that does not evaporate or become stored as groundwater flows throughout a land system known as a watershed. Watersheds are formed by land that slopes toward a specific stream, river, lake or wetland. Watersheds are water basins which move water from a higher elevation to a lower elevation. Water bodies in these lower elevations are potential water supplies for micro-systems.

> **Did You Know:**
>
> The length of time water can reside as groundwater in an aquifer can be as little as a few days or as long as tens of thousands of years.

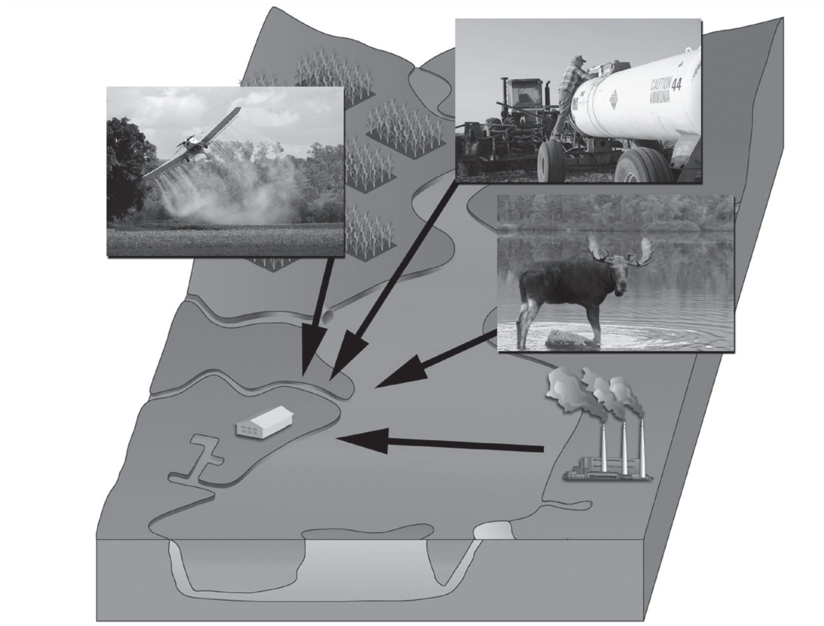
Precipitation events deposit water into a watershed and this water eventually flows into a surface water body. The timing and quantity of this water flow varies due to the size and length of the precipitation event and seasonal effects. During heavy rainfalls, runoff volume is high and it may travel great distances. A longer and lighter rainfall might produce less runoff but may provide more infiltration into the ground. During the spring, warmer temperatures convert the winter accumulation of snow into flowing water, which normally flows across frozen land. This event, known as spring runoff from snowmelt, results in peak stream flows and changes the surface water characteristics. For many regions in Canada, spring runoff is the dominant annual hydrological event, affecting water supply and water quality.

All these variations in flow affect the characteristics of surface water bodies that might be used as water sources. The nature and location of the flow affects the temperature, turbidity, and the overall chemical, physical and biological characteristics of the water source. This in turn affects the treatment requirements.

Often streams, rivers, and lakes are considered as pristine sources of water but in reality, this is not the case. As runoff makes its way across a variety of surfaces into a water source, it passes countless potential contamination threats. Some threats of contamination are natural (wildlife waste, disease-causing microbes, natural chemicals in sediments and the Earth's geology) and some are man-made (chemical pollutants, human waste, industrial and recreational activities).

One major source of potential contamination is wildlife, both living and dead. Animals will deposit excrement both on the land and in the water. In addition, the decaying bodies of animals can contribute to poor water quality or the growth of living disease-causing microorganisms. This potential for contamination is true not just for wild animals, but for domesticated ones as well, especially agricultural livestock and in cities and towns, pets.

Fig 2.3 Contamination of Surface Waters



Another natural source of contamination of surface water is plants and plant material. Both living plants and decaying plant material can add contaminants to the water. This is true not only of plants that grow on the land surface but also those that grow in the water. During the summer months surface water warms up which can promote algae growth, the release of harmful toxins from blue-green algae blooms and the increase of other naturally-occurring bacteria and microorganisms.

In some cases, surface water may have groundwater flowing into it, (e.g. from the discharge of springs). Groundwater is normally more heavily mineralized than surface waters and can add undesirable concentrations of natural substances such as iron, manganese, sulphate and many other minerals.

Given all the potential contaminants that surface water is exposed to from the time it falls as precipitation until the time it is used as a source of water for a micro-system, an understanding of the characteristics of the surface water source is an important part of being able to continually provide a safe supply of drinking water. There will be seasonal variations in both the quantity of water available as well as the quality of the water. Extreme weather events such as heavy rainfalls or prolonged dry spells will also affect the quantity and quality of the sources water. Understanding these variations and their impact on the treatment system is one of the key factors in providing safe drinking water on a continuous basis.

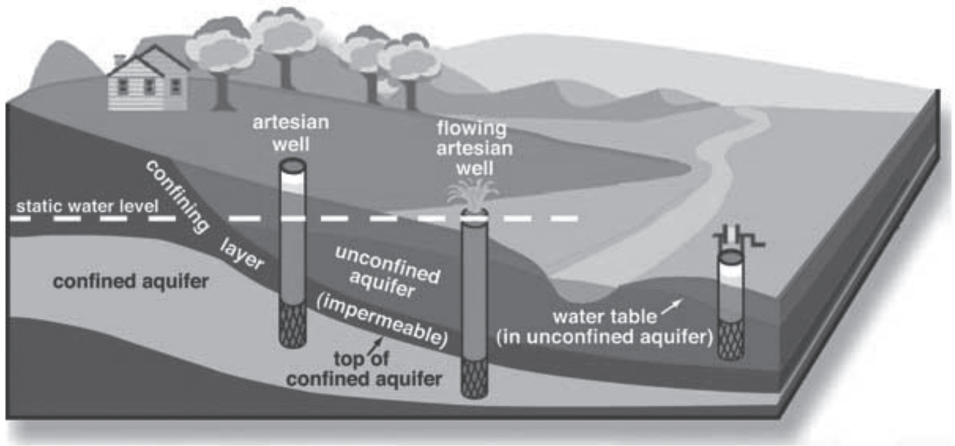
2.5 Groundwater

Did You Know:

In developing nations , 80% of diseases are water related.

Groundwater, like surface water, is also part of the hydrologic cycle. As water infiltrates the ground, some of it is trapped and stored by aquifers. As it percolates through the Earth's geologic formations, and is stored within the aquifer, water dissolves the chemical constituents from the soil and rocks. This changes the water quality and adds concentrations of dissolved compounds (like calcium carbonate) and elements (like iron, manganese, arsenic and radium) to the water. Of course the concentrations of dissolved matter depend on time and geologic exposure and the biological, chemical and physical processes within the aquifer and the water movement in the aquifer.

Fig 2.4 Aquifers



Water may spend a long time in an aquifer before being pumped to the surface or discharging naturally. Residence time (the amount of time water spends in an aquifer on average) may be hours to months to years – even thousands of years. This leaves a lot of time for the water to dissolve surrounding elements and acquire different characteristics. In an undeveloped area (an area free from human impacts) these compounds and elements may represent the only treatment challenges facing a micro-system using groundwater. Some of these characteristics, while naturally-occurring, can be harmful to human health (e.g. arsenic, nitrate) or may interfere with treatment or cause harmful by-products (e.g. ammonia, organic matter).

Did You Know:

In Canada pre-packaged water (bottled water) is considered to be a food and is regulated under Division 12 of the Food and Drug Regulations.

Aquifers sufficiently protected from human and animal influences are generally protected from disease-causing microbiological contaminants, and may only require treatment for a few characteristics. The protection occurs from impervious confining layers (layers or rock or clay), or simply by their depth and natural ground filtration, since a significant amount of contamination will be filtered out as water percolates downward through soil and rocks. Generally, since groundwater flows are much less variable than surface water, groundwater water quality characteristics are also more constant than those of surface water.

Shallow aquifers (generally those shallower than 30 m) represent a much greater contamination risk, especially from harmful bacteria. (For a more in-depth discussion of harmful bacteria, review Section 3.3 - Microbiological Contaminants.) These aquifers are often unconfined aquifers, sometimes called water table aquifers. Shallow aquifers are highly influenced by the above-ground environment, and its sources of contamination ranging from natural environmental sources to those from human land use activities. Changes in snowmelt or precipitation can cause large fluctuations in the amount of water residing in these aquifers. Recharge (water entering the aquifer) takes place so quickly that few, if any, contaminants are filtered out by infiltration and percolation processes. Water entering the aquifer is little different from the runoff water that enters surface water sources. For this reason, shallow aquifers are often classified as Groundwater Under the Direct Influence of surface water (GUDI). These sources are considered as surface water bodies from a treatment and health perspective, due to their susceptibility to harmful microbiological and other types of contaminants. These other contaminants include organic matter which can form harmful disinfection by-products if not removed prior to disinfection. (Note: some shallow aquifers may be confined by layers of impermeable rock or clay and might be considered a low contamination risk.)

Fig 2.5 A Shallow Aquifer

2.6 Municipal Water

In some cases the source of water supply for a micro-system may be a municipal water supply. Although this type of source may provide potable water at the treatment plant, it is still necessary to ensure that the water is safe after it makes its way through the distribution system to the federally owned facility. In some cases there may still be a need for additional water treatment measures. If treatment is required, a water quality professional will determine the configuration of the system. They will also establish the type and frequency of water quality testing required.

Even with a municipal water supply as a source it is important to know where the water originates. Knowing whether it is from a surface water or groundwater source (or a blend of both) helps to understand if and when there might be potential for source water contamination. Equally important is knowing the municipal supplier, what treatment process is in place, the frequency of testing of the treated water and where the test results can be viewed. Make sure that the supplier will make contact with the federal facility in the event there is a problem with the quality of the water they are supplying.

Fig 2.6 A Municipal Water Supply

Operators of micro-systems treating and distributing water at a federal facility are required to ensure the safety of the drinking water, even if the source is from a treated municipal supply. Treatment by the municipality does not exclude the micro-system from the need to conduct water quality tests. In order to ensure the safety of the water supply it is important to follow the established water quality monitoring program.

2.7 Bottled Water

In Canada, pre-packaged water (bottled water) is regulated as a food under Division 12 of the Food and Drug Regulations. These regulations indicate how bottled water can be labelled and what it can contain.

Bottled water labelled mineral or spring water is a potable water (fit for human consumption) that comes from an underground source. It cannot come from a public water supply. Mineral water is spring water with a larger amount of dissolved mineral salts, usually above 500 milligrams per litre of total dissolved solids. Mineral and spring waters must not have their composition modified through the use of chemicals, except that carbon dioxide and ozone can be added during the bottling process to protect the freshness, and fluoride can be added for dental health reasons.

Bottled water not specifically identified as mineral or spring water, is water from any source (municipal water, well water, etc) that can be treated to make it fit for human consumption or to modify its composition. Treatments include carbonation, ozonation, ultraviolet irradiation, and filtration to remove harmful bacteria or contaminants. These bottled waters can be distilled or passed through different deionization processes to remove their minerals, or they are simply municipal tap waters bottled for sale. The label on these water containers must show how they have been treated, for example "carbonated," "demineralised," "distilled," etc.

All bottled water offered for sale must be safe for people to consume. Mineral or spring water must not contain any coliform bacteria or harmful levels of substances at the source. Other bottled waters may undergo a variety of treatments and should meet the regulatory requirements for coliform and aerobic bacteria. Pre-packaged ice also has to

Did You Know:

Provincial and Territorial regulations require all municipal drinking water supplies to be tested for numerous parameters on a frequent basis. Private water supplies (wells, dugouts and ponds) are not subject to such regulations. For private water supplies, it is the responsibility of the owners/users to have their water tested.

comply with the regulations. Because they are foods, pre-packaged (bottled) water and ice also have to comply with all of the provisions of the Canadian Food and Drugs Act, which are generally based on the GCDWQ. More information on the subject of bottled water can be found at the Health Canada website, on the page entitled "Frequently Asked Questions about Bottled Water" (Health Canada, 2009).

2.8 Understanding the Water Source

Knowing the source of your water and the characteristics that influence it (the watershed for surface water, the aquifer for groundwater) is the first step in understanding the water supply and the treatment system required to deliver safe drinking water. In order to make sound decisions concerning treatment, it is important to know the vulnerabilities of the source water to environmental effects and the water's biological, chemical and physical characteristics.

The quality of a water source very rarely remains constant over time. For this reason, it's important to monitor changes, not just in the water itself, but in any area that has the ability to impact the water source. Treatment systems are designed to treat water for targeted characteristics, usually within a narrow range of concentrations. If the source water quality varies significantly, the treatment process can fail to deliver safe drinking water (e.g. a major flood or pollution event can impair treatment). Regular water quality monitoring and testing of source water and treated water are essential components of micros-system operation and help to ensure that the source water is within an acceptable range for the treatment limitations of the micro-system.

2.9 Notes on Chapter 2

3 What's In the Water

3.1 Introduction

Did You Know:

In 1854, the first linkage of disease caused by water, was made in London. Previous medical opinion was that cholera was an air borne disease. Dr. John Snow linked the spread of cholera to the use of water from the Broad Street pump.

Water that occurs naturally in the environment contains much more than just water. In addition to the hydrogen and oxygen that combine to form water molecules (H_2O), there are also many contaminants. Some of these contaminants are visible, and can make the water cloudy or murky. These contaminants are not dissolved into the water, but rather, they are suspended. But even if water looks perfectly clear it can contain a variety of contaminants that are either microscopic in size or are dissolved in the water.

Contaminants in water are generally grouped by their characteristics: microorganisms, organic and inorganic chemicals and radiological compounds. Water is generally described by its various chemical, biological, physical and radiological characteristics. It is unusual to find several sources of water that are exactly the same; all water supplies have different characteristics.

Microorganisms occur in water in three main groups: bacteria, viruses and protozoa. These groups will be discussed in detail in later sections. They may be in the water from natural sources or as a result of human or animal activities. While some of these microorganisms are harmless, others are capable of causing serious illness in humans.

Organic chemicals are generally those that contain carbon in their atomic structure, such as naturally occurring dissolved organic matter or synthetic organics such as pesticides, gasoline and plastics like vinyl chloride. Many organic chemicals are man-made (anthropogenic) in origin. Inorganic chemicals typically do not contain carbon and are generally natural in origin. They include compounds such as nitrate and sulphate and elements such as iron, manganese, copper, and arsenic. Radiological contaminants are generally derived from the weathering, erosion and mining of rock materials containing these elements, or may be the result of nuclear processes (e.g., tritium). Radionuclide exposure is a known health risk to humans.

There are also many other key measurements that indicate the condition of the water. These include pH, a measurement of the water's acidity, alkalinity which is a measure of the ability of water to neutralize acids, and hardness which is a measurement of specific dissolved minerals, primarily calcium and magnesium.

In addition to measuring the individual concentrations of contaminants described here, the measurement of groups of contaminants are also parameters that help to understand water quality. Measures of Total Dissolved Solids (TDS) and Total Suspended Solids (TSS) are used as important parameters for understanding source water quality and the amount and type of treatment required.

It is important to remember that harmful contaminants in the water that are of concern are rarely visible! In many cases, the most harmful contaminants are those that can not be seen. This is why it is extremely important to have a basic understanding of water treatment.

3.2 Guidelines for Canadian Drinking Water Quality

There are many substances in water besides water molecules. Some of these substances have no health effects on humans, while others can have effects based on long-term (chronic) exposure or even single event (acute) exposure. ***The Guidelines for Canadian Drinking Water Quality (GCDWQ)***, published by Health Canada provides acceptable limits, called Maximum Acceptable Concentrations (MACs) for the contaminants that have a human health impact. Drinking water that continually contains a substance at a concentration greater than the MAC can contribute significantly to consumers' exposure to that substance and may, in some instances, be capable of inducing harmful effects on health. These MACs are based on current, published scientific research and are reviewed on a regular basis and Health Canada either reaffirms existing MACs or establishes new ones. Both the Canada Labour Code and the ***Guidance for Providing Safe Drinking Water in Areas of Federal Jurisdiction*** reference the GCDWQ documents for acceptable concentrations of contaminants. This chapter discusses some of the parameters covered in the GCDWQ, but not all of them. It is important to know all of the contaminants in the source water and their specific MACs so that their reduced levels can be verified in the treated water.

In addition to the MACs for contaminants that have health impacts, the GCDWQ also contains operational guidelines and aesthetic objectives for drinking water. These are established to identify the maximum concentrations of a contaminant that should not adversely affect the operation of a treatment system or the aesthetic quality of the water.

Operational guidelines and their technical documents are designed to keep the concentration of the contaminant at safe levels while at the same time permitting efficient and effective micro-system operation.

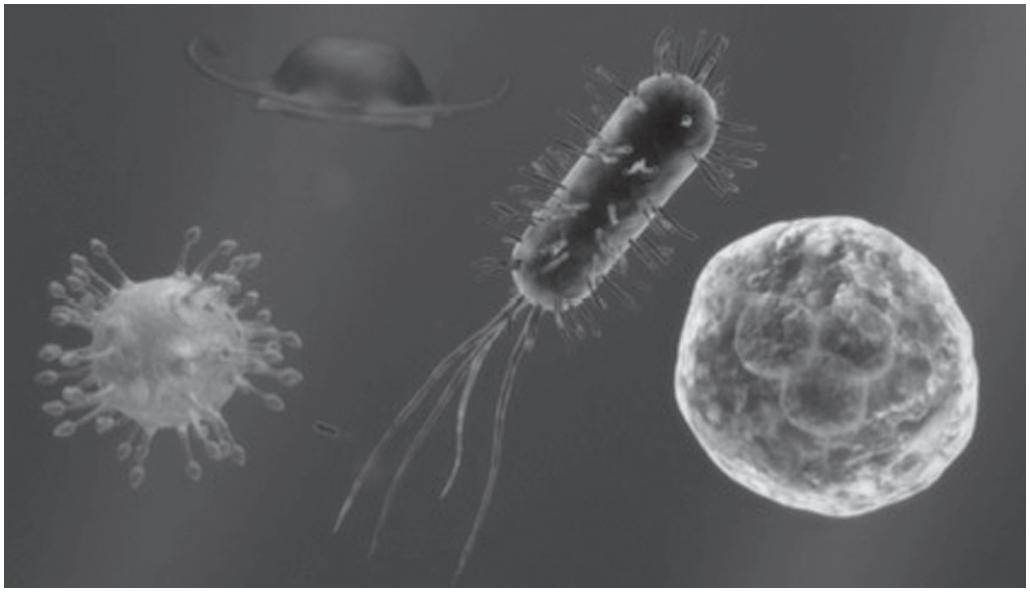
Aesthetic objectives are developed to provide guidance on how to produce water that is nice to drink. If a glass of water looked bad or smelled like rotten eggs, it is unlikely that anyone would want to drink the water. In such a case a person might even seek out an alternative source, one that tastes or smells better, but perhaps one that is chemically or biologically contaminated. When the time and effort has been taken to make sure water is SAFE to drink through various treatment techniques, it is also important to make sure the water is palatable to ensure that people actually WANT to drink it.

This chapter covers certain water contaminants in greater detail and can be used as a reference tool later on as well. The contaminants covered include those that occur frequently in either surface water or groundwater. A table showing the GCDWQ values for these parameters can be found in Appendix A. As the guidelines are periodically updated, always check the Health Canada website for the most current values.

3.3 Microbiological Contamination

The most significant health risk from drinking water is microorganisms. Of course this opens the door for many questions: What are microorganisms? Are there different types of microorganisms? Are all microorganisms harmful? The word microorganism is a very general term that is used to describe a multitude of different, tiny living organisms. When it comes to drinking water, the 3 main groups of microorganisms of concern are: bacteria, protozoa, and viruses.

Fig 3.1 Microorganisms pose the greatest risk to health



Did You Know:

E.Coli is a natural bacterial resident in the intestines of all animals, including humans. When *E.Coli* is detected in water it usually indicates fecal contamination from human, agricultural or wildlife sources.

It would be extremely difficult and time-consuming to individually test for all of the known harmful microorganisms, so drinking water experts use an indicator approach to make the process a bit easier. Microbiologists (scientists who study bacteria and other microorganisms) have found that microorganisms found in water are often linked to faecal contamination. Coliforms are a group of bacteria that are naturally found on plants and in soils, water, and in the intestines of humans and warm-blooded animals. What microbiologists and drinking water experts have also discovered is that coliform bacteria are fairly easy to grow and test for in a laboratory. Because coliforms are widespread in the environment, they can be used as one of the many operational tools to determine the efficacy of a drinking water treatment system.

So why is this group, coliform bacteria, so important? Not all coliform bacteria are harmful. In fact, most are harmless. But if a water sample from a treated micro-system tests positive for coliform bacteria, then it MAY contain some of those harmful bacteria outlined later in this chapter, because their presence in the treated water indicates a breakdown in the treatment cycle. In other words, if the treatment cycle failed to kill or inactivate (making it so the bacteria cannot reproduce in your body causing illness) these indicator bacteria, then it very likely failed to kill or inactivate any harmful bacteria that were present in the water. The ability to detect faecal contamination in drinking water is a necessity, as pathogenic microorganisms from human and animal faeces in drinking water pose the greatest danger to public health.

Escherichia coli (*E. coli*) is a member of the coliform group of bacteria that is naturally found in the intestines of humans and warm-blooded animals. As it is not usually found naturally in other environments such as on plants or in soils or water, the presence of *E. coli* in a water sample is a good indicator of recent faecal contamination.

If a water sample tests positive for total coliforms, then it may or may not contain harmful bacteria, and further action is needed before the water can be considered safe, including additional testing. The presence of total coliforms in the distribution system or plumbing system samples indicates a problem with the integrity or operation of these systems. If a test is positive for *E. coli*, that water sample has certainly come into contact with animal faeces and is therefore unsafe to drink. Whereas the Total Coliform test by itself can show that a sample might be harmful, an *E. coli* test can confirm that a sample definitely IS harmful. For a micro-system (a single source and small distribution system) a positive *E. coli* test would indicate that immediate action needs to be taken – issuing a boil water advisory. Consult with a water quality specialist, standard operating procedures or the Health Canada website for what needs to be done. The Health Canada website provides a decision tree to help choose a course of action when microbiological indicator tests are positive.

In order for water to be treated for microorganisms it must first be treated through various processes to remove other contaminants so that the disinfection treatment process used to kill or inactivate the microorganisms will be effective. Turbidity is a measurement of suspended matter in the water – the lower the turbidity, the lower the concentration of suspended particles. The suspended matter can include substances such as inorganic clay and silt, organic particles and compounds, plankton and microscopic organisms (some of which may be disease-causing pathogenic micro-organisms such as bacteria, viruses and protozoa). All surface water and groundwater will have some degree of turbidity.

Turbidity is a key indicator because it identifies how well the treatment process has removed all the suspended particles in the source water before the disinfection process is applied. Water treatment plants are designed to deliver water with the lowest turbidity possible. If turbidity values change or fluctuate, this is a key indicator that the source water quality has worsened, and/or treatment processes have been compromised or are not optimized, and/or water treatment distribution pipes may be sloughing off dirt or micro-organisms.

Fig 3.2 A flask containing suspended solids, showing turbidity

Turbid water can potentially harbour and shield disease-causing micro-organisms, reduce the effectiveness of disinfection or other treatment processes, and provide nutrients for the re-growth of micro-organisms in water distribution pipelines.

3.3.1 Bacteria

Did You Know:

Boiling water for several minutes will kill bacteria but will not reduce the amount of minerals such as nitrate or metals such as lead.

Bacteria are probably the most well known of the three groups mentioned here. Most people have at least heard of bacteria and perhaps even heard of some different types of bacteria. Bacteria are single celled organisms that range in size from about 0.5 microns to several microns long. To give an idea of just how small that is, 1 micron (short for micrometre) is 1/1000th of a millimetre. In other words, if a single bacterium happened to be 1 or 2 microns in length, it would take between 500 and 1000 of them stacked end to end to reach the length of a single millimetre.

Scientists often group bacteria by their morphology or in other words, their form and shape. Bacteria come in three different shapes: rod shaped (bacillus), spherical shaped (coccus), and spiral shaped (spirillum). This type of grouping makes it easier for scientists to view bacteria under a microscope and quickly narrow down which group they are looking at.

Bacteria can be found everywhere on the planet, and that really does mean EVERYWHERE. Bacteria live inside the bodies of animals and help them digest food. Bacteria are on the roots of plants helping them gather nutrients. Bacteria are on every surface and inside every object and organism imaginable. There is not a single place on Earth that does not contain bacteria of one form or another. Of course this includes the water sources commonly used by micro-systems such as streams, ponds, rivers, lakes, and even aquifers. Bacteria require specific nutrients (food) to reproduce, so they are typically more prevalent in surface water (as opposed to groundwater) where those nutrients are easily available. When streams and lakes are used as water supply sources for micro-systems, the need to treat the water for bacteria is inevitable.

The vast majority of these bacteria are completely harmless to humans, but unfortunately, those harmless bacteria share their habitat with some very harmful bacteria as well. Exposure to these harmful bacteria through drinking water can lead to severe illness or in some instances even death. Health problems, mainly related to the stomach and intestines (gastrointestinal), from just one exposure to bacteria can happen in a few days, or even a few hours. For this reason, it is extremely important to ensure that the water produced by a micro-system is tested and considered to be free of all bacteriological contaminants.

Indicator Organisms (*E. coli* and Total Coliforms)

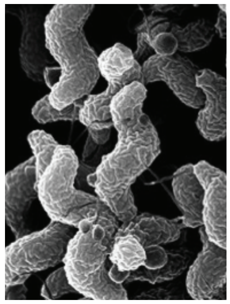
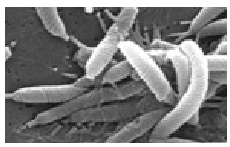
Although modern microbiological techniques have made the detection of pathogenic bacteria, viruses, and protozoa possible, it is currently not practical to attempt to routinely isolate them from drinking water. It is better to use indicators that are less difficult, less expensive, and less time consuming to monitor. This should encourage a higher number of samples to be tested, giving a better overall picture of the water quality and, therefore better protection of public health. Of the contaminants that may be regularly found in surface and groundwater sources, pathogenic microorganisms from human and animal faeces pose the greatest danger to public health. For this reason, the ability to detect faecal contamination in drinking water is a necessity for ensuring public safety.

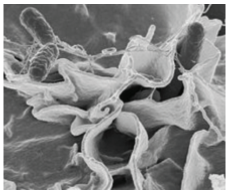
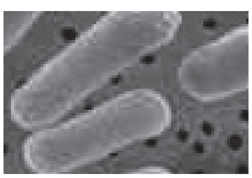
Total Coliforms

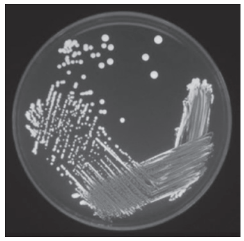
Coliforms are a group of closely related bacteria that are generally free-living in the environment, but their presence in water is a possible indication of contamination of the water system. The presence of coliforms in a treated water sample may be an indication of biological growth in a water distribution system or another point of contamination. Testing for total coliforms is part of good practice and an indication of this organism may be a sign of the presence of other pathogenic bacteria.

Table 3.1 Bacteria of Concern to Micro-system Operators

Name of Bacteria	Description
Escherichia coli (*E. coli*) 	*Escherichia coli* (*E. coli*) are microorganisms that make up a family of common bacteria found in the intestines of humans and animals, where the bacteria assist in the breakdown and fermentation of food. There are hundreds of different strains of *E. coli*, most of which are harmless to human health. Of the coliform group of organisms, *E. coli* are considered a more specific indicator of faecal contamination and tests have been developed that can rapidly and easily determine their presence in water. In addition to being faecal specific, *E. coli* do not usually multiply in the environment, are excreted in the faeces in high numbers (approximately 109 cells per gram) making detection possible even when greatly diluted, and have a life span on the same order of magnitude as those of other enteric (meaning of, relating to, or affecting the intestines) bacterial pathogens. These features make *E. coli* the best available indicator of faecal contamination. *E. coli* is released from faecal matter that may be washed into water by rain, snowmelt, and other forms of precipitation. As such, *E. coli* is a type of faecal coliform, and its presence in water indicates contamination with sewage or animal wastes. Among other causes, sources of such contamination may include naturally occurring wildlife, agricultural runoff and sewage contamination of the source water or the accidental mixing of sewage with drinking water in the water distribution system either through a cross-connection or because of an integrity breach or failure in the distribution system (e.g. pipe break). As a general rule, groundwater tends to have lower levels of *E. coli* than does surface water, due to filtering action of soil and rock.

Name of Bacteria	Description
Campylobacter spp. 	*Campylobacters* are pathogenic bacteria found primarily in the intestinal tract of domestic and wild animals, especially birds. Human sewage also contains large number of these organisms. *Campylobacter* is transmitted through the faecal-oral route, mostly through contaminated food, and sometimes through water. Waterborne outbreaks of gastroenteritis involving *Campylobacter* jejuni have been recorded on numerous occasions, with improper treatment, post-treatment contamination or consumption of untreated water supplies being the most frequent causes. *Campylobacter* enteritis typically presents as flu-like symptoms and/or abdominal pain, followed by a profuse watery diarrhoea. Treatment technologies effective in the removal and inactivation of *E. coli* are effective against *Campylobacters*.
Helicobacter **spp.** 	The genus *Helicobacter* has at least 25 species, of which *Helicobacter* pylori is the species of relevance for the water industry. *H. pylori* is a recognized human pathogen, and it is believed that there are a few routes of transmission, including through drinking water. Disease is benign for the most part in the majority of persons infected, but more serious disorders such as peptic ulcers or stomach cancer can develop in a small percentage of cases. In the majority of *H. pylori* infections there are no outward telltale signs of disease. Infection is considered to be lifelong unless treated. Like other bacteria, a proportion of the *H. pylori* present in the source water will be removed using physical methods, such as coagulation, sedimentation, and filtration. *H. pylori* is also susceptible to disinfectants commonly used in drinking water treatment (e.g., chlorine, UV, ozone and monochloramine). The current body of research suggests that the concentration and time of contact for disinfection provided by a typical water treatment plant is sufficient to inactivate *H. pylori* in the finished water. However, if *H. pylori* does enter the distribution system, potentially through a breakdown in treatment or infiltration into the system, disinfectant residuals maintained in the distribution system are probably insufficient for inactivation. Overall, the predominant transmission route for *H. pylori* seems to be situation dependent, with person-to-person transmission playing a key role in many circumstances. Water and food appear to be of lesser direct importance.

Name of Bacteria	Description
***Salmonella* spp.** 	*Salmonella* is a complex grouping of bacteria (taxonomic genus) consisting of over 2000 different varieties and types that can cause infections in animals and humans. *Salmonella* enterica is the species of most relevance for human infection. As *Salmonella* is a pathogen that normally exists in animals but can infect humans (a zoonotic pathogen), runoff from agricultural lands can provide a mechanism for the transfer of animal faecal wastes to source waters. Infected humans and as a result, sewage, are also a source of *Salmonella*. Transmission of *Salmonella* occurs through the faecal-oral route, predominantly through food. Drinking water is not often implicated as a source of *Salmonella* infection. *Salmonella* survival characteristics in water and their susceptibility to disinfection have been demonstrated to be similar to those of coliform bacteria, including *E. coli*. It is generally recognized that well-operated disinfection will be sufficient in controlling *Salmonella* in treated drinking water. Most people infected with *Salmonella* develop diarrhoea, fever and abdominal cramps 6 to 72 hours after being infected. The illness usually lasts four to seven days and most people recover without treatment. As with any disease causing diarrhoea or vomiting, those infected should drink plenty of liquids to replace lost body fluids. This is particularly important with very young children and seniors. In severe cases, patients may need to be given fluids intravenously, which is usually done in hospital. (Source: Health Canada http://www.hc-sc.gc.ca/hl-vs/iyh-vsv/food-aliment/*salmonella*-eng.php)
***Shigella* spp.** 	Like *Salmonella*, *Shigella* belongs to the same microbiological family as *E. coli*. *Shigella* is a human-specific pathogen and is not expected to be found in the environment. Infected humans are the only significant reservoir of *Shigella*. Transmission is faecal-oral, through drinking water or food that has been contaminated with human faecal wastes. Person-person is also a significant route of exposure for *Shigella*, particularly among children. *Shigella*-associated illness is marked by a watery diarrhoea containing blood and mucus. Once infected, recovering individuals may continue to shed *Shigella* in their faeces for days up to several weeks or months. *Shigella* survival characteristics in water and their susceptibility to disinfection have been demonstrated to be similar to those of coliform bacteria, including *E. coli*. It is generally recognized that well-operated disinfection will be sufficient in controlling *Shigella* in treated drinking water.

Name of Bacteria	Description
Legionella 	*Legionellae* are recognized human pathogens; they are a cause of respiratory illness which can be serious for persons with weakened immune systems (immunocompromised). They are free-living aquatic bacteria that occur widely in water environments. The presence of *Legionella* is more of a concern for water systems outside of municipal water treatment systems, such as cooling towers, hospital and residential plumbing systems. However, the organisms are also capable of colonizing drinking water distribution system biofilms. *Legionella* species exhibit a number of survival properties that make them quite resistant to the effects of chlorination and elevated water temperatures. Plumbing systems outside of public water supply systems (e.g., in residential buildings, hotels, institutional settings) are most commonly implicated in *Legionella* pneumophila infections. Since *Legionella* is a respiratory pathogen, systems that generate aerosols, such as cooling towers, whirlpool baths and shower heads, are the more commonly implicated sources of infection. Although hot water supply systems are a common origin of contamination, cold water supplies at a temperature within the range of *Legionella* multiplication (25°C) can also be implicated. *Legionella* is not transmitted from person to person. There are two distinct illnesses caused by *Legionella*: Legionnaires' disease and Pontiac fever. Collectively, these illnesses are referred to as legionellosis. General recommendations regarding the control of *Legionella* in domestic plumbing systems involve maintaining proper water temperatures. The National Plumbing Code of Canada includes requirements of a minimum of 60°C for water temperature in hot water storage tanks, to address the growth of *Legionella*. Where increased hot water temperatures create an increased risk of scalding for vulnerable groups (e.g., children, the elderly), appropriate safety measures should be applied to limit the temperature to 49°C. Thermostatic or pressure-balanced mixing valves can be installed to control the water temperature at the tap to reduce the risk of scalding.

In conclusion, it is interesting to note that most strains of harmful bacteria reviewed in this chapter reside in the digestive tracts of animals. Faecal contamination from cattle, deer, elk, songbirds, waterfowl, humans, and even pets like dogs and cats have each lead to waterborne disease outbreaks in North America, even within the last several decades. Protecting a watershed from the faeces of animals, and thus bacteria, reaching a drinking water source would be next to impossible. So, it is most important to monitor the water source for the presence of bacteria by testing for the INDICATOR organisms *E. coli*, and Total Coliforms (TC) and then treat the water accordingly. This manual will cover the specifics of water testing (including testing for bacteria) in a later chapter.

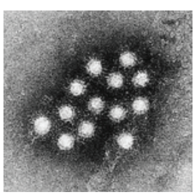
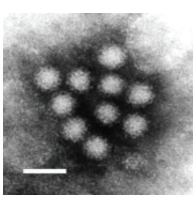
3.3.2 Viruses

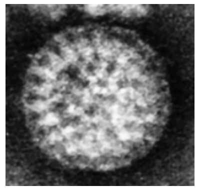
Viruses are the smallest of all of the groups described here. In fact, viruses are the smallest known living organisms. It would take about 100 virus particles stacked end to end to equal the length of a single bacterial cell. Scientists cannot even look at viruses with standard microscopes; they require special multi-million dollar scanning microscopes. Only in the last few decades have scientists begun to understand viruses. One extremely important fact about viruses is that they cannot reproduce on their own like bacteria. Viruses must enter a host (like a human) and essentially take over that host's cellular machinery to make copies of itself. This may not seem all that important at first, but what it means is that most viruses are looking for a very specific host. In other words, a virus that affects deer or elk, is very unlikely to cause illness in humans. For the most part, a human is only affected by viruses from other humans. There are of course exceptions, but most viruses stick to a specific group of hosts.

In order to determine if a water source may be contaminated with viruses that could be harmful, consider this question: "Are there human sources of contamination present?" Of course, there are sources of human contamination that you will not be able to see. Hydrogeologists (experts on groundwater) have recently discovered that viruses can not only reside in aquifers, but they can actually travel through them with the movement of groundwater. It is possible that human contamination from elsewhere could reach your source, even if you are using groundwater. Again, this is a relatively new concept. It was once believed that viruses were only a problem for surface water systems and that deep groundwater was a "secure" source of water.

Numerous waterborne disease outbreaks have been attributed to viruses, though it is sometimes difficult to determine the exact source of contamination or even the specific virus involved. Some of the viruses known to contaminate water are described here.

Table 3.2 Viruses of Concern to Micro-system Operators

Name of Virus	Description
Hepatitis 	To date, six types of hepatitis viruses have been identified, but only hepatitis A (HAV) and hepatitis E (HEV), appear to be transmitted via the faecal–oral route and therefore associated with waterborne transmission. HAV infections, commonly known as infectious hepatitis, result in numerous symptoms, including fever, malaise (fatigue), anorexia, nausea and abdominal discomfort, followed within a few days by jaundice. HAV infection can also cause liver damage, resulting from the host's immune response to the infection of the hepatocytes by HAV. In some cases, the liver damage can result in death. The incubation period of HAV infection is between 10 and 50 days, with an average of approximately 28–30 days, and is shorter at a greater dose.
Norovirus 	Noroviruses are shed in both faecal matter and vomitus from infected individuals and can be transmitted through contaminated water. They are also easily spread by person-to-person contact. Norovirus infections occur in infants, children and adults. The incubation period is short (24–48 h), and health effects are self-limiting, typically lasting 24–48 h. Symptoms include nausea, vomiting, diarrhoea, abdominal pain and fever. In healthy individuals, the symptoms are generally highly unpleasant but are not considered life threatening. In vulnerable groups, such as the elderly, the resulting illness is considered more serious.

Name of Virus	Description
Rotavirus 	In general, rotaviruses cause gastroenteritis, including vomiting and diarrhoea. Vomiting can occur for up to 48 h prior to the onset of diarrhoea. The severity of the gastroenteritis can range from mild, lasting for less than 24 h, to severe. The incubation period is about 4–7 days, and the illness generally lasts between 5 and 8 days. Rotavirus is the leading cause of severe diarrhoea among infants and children and accounts for about half of the cases requiring hospitalization, usually from dehydration.

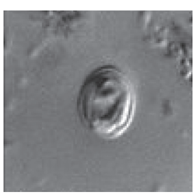
To recap, viruses can be found in both groundwater and surface water sources. They are typically specific to a certain group of animals (like humans for instance), and they are extremely small. All of these factors make testing for viral contamination a lot like finding a needle in a haystack. Instead of testing for viruses, systems typically take measures to ensure that, if the system is contaminated by viruses, appropriate treatment techniques are in place to take care of the problem. To take this one step further, if it is suspected that a water system is contaminated with viruses, the first step is to TREAT rather than TEST. The specific treatment techniques employed to deal with viruses will be covered in other chapters.

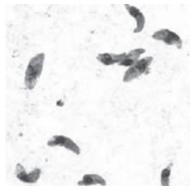
3.3.3 Protozoa

Protozoa are a group of microorganisms that are very difficult to define. In drinking water, most scientists agree that protozoa can be classified as unicellular, heterotrophic organisms that divide (reproduce) within another host organism. What this means is that protozoa are each a single cell (unicellular), that does not make its own food (heterotrophic, as opposed to phototrophic like a plant that can make its own food from sunlight). The final part of the definition is where protozoa become a problem for humans. When they reproduce inside hosts like humans and other animals, they typically cause gastrointestinal problems or worse. For the most part, protozoa are larger than bacteria and viruses. Sizes range from around 2 microns to about 50 microns for a typical protozoa cell. This makes viewing protozoa with a microscope relatively easy, though identifying exactly what you're looking at can be a difficult task that is best left to the experts.

Typically we find these organisms only in surface waters and groundwater that is under the direct influence of surface water (GUDI). Although they are typically not as prevalent as bacteria, protozoa are still a major concern. The enteric protozoa that are most often associated with waterborne disease in Canada are *Cryptosporidium* and Giardia. These protozoa are commonly found in source waters, some strains are highly pathogenic, can survive for long periods of time in the environment and are highly resistant to chemical disinfection.

Table 3.3 Protozoa of Concern to Micro-system Operators

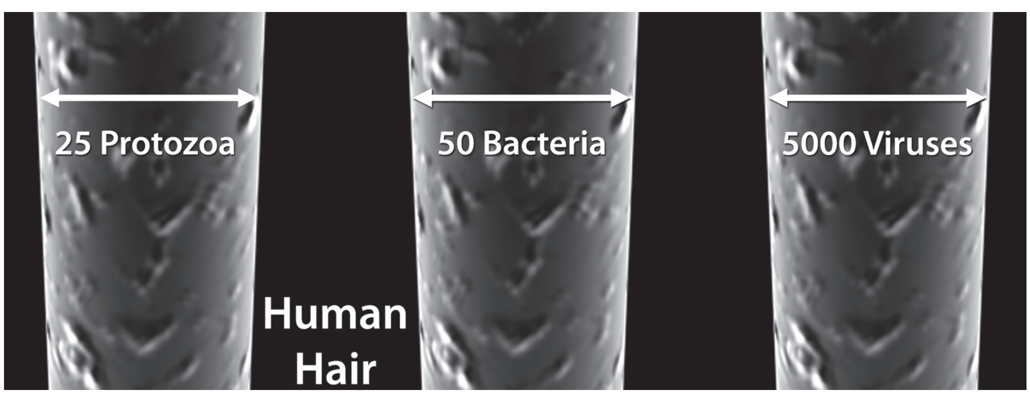
Name of Protozoa	Description
Giardia lamblia 	*Giardia lamblia* is a parasitic protozoa found all over the world. It lives and reproduces in the intestines of mammals. Typically, Giardia is non-invasive (does not invade healthy cells) and results in asymptomatic (without symptoms, showing no subjective evidence of existence) infections. Symptomatic giardiasis can result in nausea, anorexia, uneasiness in the upper intestine, malaise (a general feeling of discomfort or uneasiness) and occasionally low-grade fever or chills. The onset of diarrhoea is usually sudden and explosive, with watery and foul-smelling stools. The acute phase of the infection commonly resolves spontaneously, and organisms generally disappear from the faeces. Human and other animal faeces, especially cattle faeces, are major sources of Giardia. Giardiasis has been shown to be endemic (present or usually prevalent) in humans and in over 40 other species of animals. Person-to-person transmission is by far the most common route of transmission of Giardia. Persons become infected via the faecal–oral route, either directly (i.e., contact with faeces from a contaminated person, such as children in daycare facilities) or indirectly (i.e., ingestion of contaminated drinking water, recreational water and, to a lesser extent, food). Giardia is the most commonly reported intestinal protozoan in North America and worldwide.
Cryptosporidium spp. – most common for human infection: *C. parvum* and *C. hominus* 	Humans and animals, especially cattle, are important reservoirs for *Cryptosporidium*. Individuals infected with *Cryptosporidium* are more likely to develop symptomatic illness than those infected with *Giardia*. The most common symptom associated with cryptosporidiosis is diarrhoea, characterized by very watery, non-bloody stools. The volume of diarrhoea can be extreme, with 3 L/day being common in immunocompetent hosts and with reports of up to 17 L/day in immunocompromised patients. This symptom can be accompanied by cramping, nausea, vomiting (particularly in children), low-grade fever (below 39°C), anorexia and dehydration. Human cryptosporidiosis has been reported in more than 90 countries over six continents. *Cryptosporidium* oocysts (a thick walled structure that allows the protozoa to move to a new host) are easily disseminated in the environment and are transmissible via the faecal–oral route. Common mechanisms of transmission include person-to-person, contact with animals, especially livestock, consumption of contaminated drinking water, recreational water and food. *Cryptosporidium* oocysts are commonly found in sewage and surface waters and occasionally in treated water. *Cryptosporidium* is one of the most commonly reported enteric protozoans in North America and worldwide.

Name of Protozoa	Description
Toxoplasma gondii 	*Toxoplasma gondii* is a parasite that can infect warm-blooded animals, including humans, but the primary host is the cat. It is usually transmitted by ingestion of tissue cysts through consumption of raw or undercooked infected meat, by ingestion of oocysts through consumption of contaminated food or water or after handling contaminated soil or infected cat faeces. Similar to the other protozoa listed above the symptoms are gastrointestinal illness with the most vulnerable more susceptible to severe complications. Although this organism tends to cause mild flu-like symptoms, it can be life-threatening for immunocompromised individuals and pregnant women. Little is known about the distribution of this organism in water sources; however, oocysts have been reported to survive for up to 17 months in tap water. There was an outbreak in British Columbia in 1995, which was thought to be due to contamination of a water reservoir by domestic and wild cat faeces. Water treatment processes in a treatment system for the removal or inactivation of Giardia and *Cryptosporidium* should be effective against this organism.

3.4 Chemical Contamination

Water sources can be contaminated by inorganic or organic chemicals. Although inorganic and organic chemicals can be either man-made or found naturally in the environment, each is more commonly found in their particular environment. Inorganic chemicals tend to be found naturally in the environment, while organic chemicals tend to be more man-made. In the following sections inorganic and organic chemicals will be described in more detail.

Fig 3.3 The Relative Sizes of Micro-organisms



3.4.1 Inorganic Chemical Contaminants

To begin with, the word inorganic refers to any chemical compound that lacks carbon. However, there are numerous exceptions to the "no carbon" rule, even in drinking water discussions. It is perhaps most useful to dispense with the definition of an inorganic contaminant, and focus more on examples.

Inorganics are often naturally occurring contaminants that may be harmful to health, affect treatment processes for a micro-system, or cause aesthetic problems such as stains on bathroom fixtures and laundry. Some inorganics are beneficial to health at low doses. Inorganic contaminants typically leach out of geologic formations like rocks and soil that come into contact with water. For this reason, inorganics are typically found at higher concentrations in groundwaters than surface waters. Groundwater may be in contact with the rocks and soil for a few years, tens of years or even thousands of years before it is pumped to the surface for drinking water. This provides a lot of time for the water to work on the surrounding rocks, dissolving inorganics into solution. But inorganics can also find their way into water from the atmosphere or even from the biological processes of bacteria and plants. Of course, some inorganics may be concentrated in a particular area or water source by humans. Depending on the location of a micro-system, some inorganics may be much more common than others. Systems that are near agricultural areas such as farming operations or animal feed lots may have source waters with elevated levels of nitrate and nitrite. Systems that are close to industrial activities like smelting or mining may see elevated levels of arsenic, lead, or copper. Groundwater in Canada quite often will also contain iron and/or manganese, calcium and magnesium. It is important to understand that drinking water containing low concentrations (i.e., up to the Maximum Acceptable Concentration) of most contaminants will not pose a risk to human health.

There are numerous inorganic substances that are commonly found in surface water and groundwater. The results of a water sample analysis will indicate the inorganic contaminants in the source water. Further information on each substance can be found on the Health Canada website. When looking for information on contaminants, it is important to consider several factors. Firstly, use only credible sources. Secondly, make sure that the information is about the contaminant in water, not just the substance itself. As indicated above, concentrations below the MAC will not pose a human health risk, and in some cases may have a beneficial health aspect. Some inorganic compounds may have operational guidelines; these guidelines may not only be for better system operation but concentrations below the guideline also may improve some treatment operations like membrane filtration or disinfection.

3.4.2 Organic Chemical Contaminants

Organic chemical contaminants are generally those that contain carbon in their atomic structure. These contaminants can occur naturally – oil, natural gas and dissolved organic matter to name just a few. But there are quite a few anthropogenic (man-made) organic chemicals, such as pesticides, gasoline (refined oil) and vinyl chloride. Some organic chemicals can pose a significant risk to the health of individuals exposed to them, especially if the exposure is prolonged. Organic chemical contaminants have been associated with numerous ailments including cancer, gastrointestinal distress, and neurological disorders. When analysing drinking water samples for organic chemicals, tests are conducted on two major groups: **Volatile Organic Contaminants** (VOCs) and **Synthetic Organic Contaminants** (SOCs). VOCs are chemicals that readily volatilize into the air, meaning they turn into a gas that can usually be smelled in a glass of water. SOCs include chemicals such as pesticides, dry cleaning agents and fuels. These are man-made chemicals that have been created to make life easier (at least until they reach a water supply). Many of these chemicals do not fully mix with water, and instead remain in pockets of highly concentrated contamination - called "plumes" which can occur in both surface water and groundwater. Should a micro-system intake pull a plume into the treatment facility, there is unfortunately very little that can be economically done to make that contaminated water safe to drink. Although there are treatment options available, these are often difficult to install and operate in micro-systems.

It is important to monitor organic contamination and try to remedy the problem before it enters a drinking water system in such a concentrated form. Organic contaminants can be found in surface and groundwaters. If they reach a groundwater source, remediation (getting rid of the contaminant) is very difficult and could take years. One common source of organic contamination reaching groundwaters includes underground fuel storage tanks that crack or corrode and begin to slowly leak into the surrounding soil. Eventually, rainwater moves downward through the soils, carrying this contamination with it to aquifers.

Below is a list of some organic contaminants. Clearly, some will be found in the water due to careless handling and accidental spills. However, pesticides are commonly found at trace amounts in surface water and to a lesser extent in groundwater. Pharmaceuticals are also becoming quite commonly found in trace amounts in surface water sources.

Table 3.4 Organic chemical contaminants of concern

Contaminant	Description
Chloroorganics	Chloroorganics are a group of chemicals which are common in many of the solvents we use on a daily basis. For example, dry cleaning solutions are a common source of two chloroorganics that have had a major impact on groundwater sources in all of North America. These chemicals can create plumes (clouds of chemical that do not mix with the water) of contamination that are difficult to remove or even reduce in abundance.
Fuels	Fuels are a prevalent source of drinking water contamination, especially for groundwater sources. These are anthropogenic sources of contamination that can only be stopped by making a conscience effort to keep them from getting into surface and groundwater sources. Underground storage tanks for petrol stations, or even small ones used on farms have broken down over the years. Before the hazards of fuel contamination were clearly understood underground storage tanks were made of materials that did not stand the test of time. Slowly, but deliberately, Health Canada and other government agencies have worked with owners to monitor, remove, and replace leaking underground storage tanks as needed.
Benzene	Benzene is a colourless, odourless chemical that is used in the production of many other products and chemicals such as plastics, rubbers, some drugs, and pesticides. It is a natural by-product of petroleum products and a known carcinogen. Benzene is only expected to be found in water as a result of a spill.
Pesticides	Pesticides are a tricky subject to address. Although many of them are less harmful for the environment than they once were, there are some pesticides that remain a problem for drinking water. The answer is not simple, as a variety of pesticides are used in agricultural operations to ensure that enough food is produced. Working together with farmers, scientists and government, officials believe the answer may lie in a combination of better chemicals and better application techniques. In the past addressing application techniques was not considered helpful, yet many now realize that reducing over-spray and only using enough chemicals to get the job done has significantly reduced the amount of stray pesticide reaching our sources of water.

Contaminant	Description
Pharmaceuticals	Pharmaceuticals have recently emerged as an organic contaminant in drinking water sources. They are being found in extremely low concentrations, but the fact that they are being found in drinking water is significant. It is thought that many of these pharmaceuticals reach water sources through wastewaters. Pharmaceutical products that we take are not entirely used by the body; some of them are excreted in our urine and faeces. Even though our municipal wastewater travels through extensive treatment, these treatment processes have never been designed to remove pharmaceuticals, so some pass through the wastewater treatments processes unaltered. There are also numerous septic systems on the landscape and they offer little to no treatment for pharmaceuticals. Nearly all pharmaceuticals that make it to a septic system are delivered to the surrounding soil and groundwater. Although the effect of pharmaceuticals are known when they are taken as a drug, very little is known about the health effects of these pharmaceuticals when they are taken at the very small concentrations found in source water (environmental exposure) over a period of time.

3.5 Other Water Characteristics

There are many water characteristics that affect drinking water quality, a few of which may be of interest to micro-systems. These include pH, alkalinity, Total Dissolved Solids (TDS), conductivity, and hardness.

3.5.1 pH

pH is a measure of how acidic or basic a water is. This relates directly to the amount of Hydrogen (H+) ions the water has in solution. The more H+ ions, the more acidic the water and the lower the pH number. The pH is typically measured on a scale of 0 to 14, with 0 being extremely acidic and 14 extremely basic. In the middle at 7 is neutral. Each step on the pH scale represents a 10-fold change from the previous step. In other words, a water with a pH of 6 has a concentration of 10 times more H+ ions in solution than a water with a pH of 7. So it may not sound like much, but each step on the pH scale is actually a major leap. Most natural waters range from a pH of 6.5 to a pH of 8.0, so they are very close to neutral. Each treatment process has a specific range of pH where it works best. Keeping the pH within those ranges throughout the treatment process can be challenging. This is where alkalinity comes into the picture. For some, the difference between pH and alkalinity can be the most confusing.

3.5.2 Alkalinity

Alkalinity represents the water's ability to limit changes in pH. In technical terms it is the water's ability to buffer against changes in pH. Alkalinity, contrary to what some may think, does not represent how basic (i.e. opposite of acidic) a water is. This misconception comes from the word "alkaline" and should be disregarded for all discussions of alkalinity. Alkalinity essentially represents a water's ability to neutralize any acid that is added. If the alkalinity of a water is too low, every treatment chemical addition causes a large swing in pH. A stable pH is very important to maintaining treatment processes, water quality and safety. The micro-system operator may need to spend time trying to correct these pH swings so that the treatment processes will work correctly. Increasing the alkalinity may be the answer to reducing the pH swings enough to keep the pH stable within the limits needed for the treatment processes.

3.5.3 TDS

Total Dissolved Solids (TDS) is a catch-all term used to describe any number of dissolved inorganic contaminants and small amounts of organic matter in the water. In general the determining factor of whether a solid is considered a "dissolved" as opposed to a "suspended" solid is whether it will pass through a very fine filter. Depending on the laboratory method being followed, the size of this filter is in the range of 0.45 to 2 microns. If the solid passes through, it is included in the TDS calculation; if not, then it is considered part of the Total Suspended Solids (TSS). Typically, TDS includes calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate and nitrate. TDS is easily measured in the field using conductivity and this value is then converted to a concentration in mg/L using a conversion factor specific to the water type. Generally speaking, these dissolved solids are not considered a health issue.

3.5.4 Conductivity

Conductivity is a measure of how much electricity can pass through a sample of water. Most people are under the assumption that water conducts electricity quite easily, yet this could not be further from the truth. In fact, pure water is an excellent insulator (a substance that does not conduct electricity, rather, it stop electricity from passing through it). But water that has ions in it (resulting from dissolving molecules like table salt for instance) WILL conduct electricity. It is these ions that raise the conductivity of water. In other words, the more dissolved ions in water, the higher the conductivity. Many water treatment system operators measure conductivity as an indirect indicator of the level of TDS. A conductivity measurement can be used to estimate the amount of TDS in water by converting it to a concentration in mg/L using a conversion factor specific to the water type. Although there is no exact relationship between conductivity and TDS, a simple conductivity measurement can give a good approximation of the level of TDS in the water.

3.5.5 Hardness

Hardness is primarily caused by calcium and magnesium ions in the water. These ions come from natural geologic deposits like limestone and dolomite which are dissolved when they come into contact with water, especially slightly acidic waters. Hard water causes scaling, a build up of white solids that may look a lot like table salt, but are actually made of calcium and magnesium. Scaling can form around heating elements on boilers and water heaters, it can clog pipes and faucets, and it can even negatively affect other drinking water treatment processes. Hard water is very likely the most important and common problem faced by micro-systems using groundwater. It is not as common for surface water systems to have to deal with hard water, primarily because groundwaters are in contact with geologic features for a much longer time and can dissolve more minerals into solution. However, in some cases hardness can also be present in surface water sources.

3.5.6 Colour

Water that is coloured indicates the presence of dissolved matter in the water, which affects the transmission of light. Colour can be a result of dissolved organic matter in the water, such as humic and fulvic acids from soil and peat, and tannins and lignins from decaying vegetation. The orange color of river water can often be attributed to tannins. Lignins also come from the breakdown of organic matter, mainly wood. Although they do not cause health concerns for drinking water, tannins and lignins do pose operational issues. Tannins, for instance, are acids that react easily with metals, causing oxidation (rust is oxidized iron) and staining.

Inorganic iron and manganese in groundwater may impart red or black colour to the water. Microorganisms may also impart colour, for example, iron bacteria or slime-forming bacteria. While colour is an aesthetic parameter, the reduction of colour helps to remove other parameters from water (organic matter, iron, manganese, etc.). Colour is measured in True Colour Units (TCU). Colour is not a health based objective but rather an aesthetic objective.

3.6 Other Contaminants to Consider

Total Suspended Solids (TSS) is the measure of the amount of suspended contaminants in the water. Suspended solids can include a wide variety of natural materials such as silt, soil and decaying plant and animal matter and even industrial waste products. Bacteria, nutrients, pesticides, and metals may attach to suspended solids which could lead to significant water quality problems.

A good way to understand the concept of Total Suspended Solids is to run a simple experiment. Take an ordinary glass of water and stir in a spoon full of soil. After a few minutes, some of the soil settles to the bottom. These are called settleable solids, meaning they do not stay suspended in the water because they are too heavy. These solids are not part of the TSS measurement. Although there is visual confirmation that some solids have settled out, the water still looks murky. The murky appearance comes from those particles in the soil that are not dense enough to settle to the bottom of the glass. These are the Total Suspended Solids and they are typically measured by filtering the particles out, then measuring the total weight of the particles collected. Total Suspended Solids are an important measure of how much physical (not chemical or biological) contamination is present in a water source. A source water with visible suspended solids particles should always be treated. For any system, micro-systems included, removing TSS is an extremely important step in the water treatment process.

But TSS is not the only measure of the cloudiness or murkiness of the water. Turbidity is an important but different measure for drinking water purposes.

Turbidity is caused by very small particles suspended in the water. So small in fact, that they weigh almost nothing and may not be visible. This is why they are considered a separate parameter from TSS even though they are similar. While TSS is a measure of weight, turbidity is a measure of the amount of light scattered by the water. Turbidity particles make the water look cloudy, not by blocking your eyes from peering through it, but by scattering the light that hits the surface of these tiny particles. Perhaps the best way to explain this is by example – driving a car on a foggy night. With the high beams on, every tiny particle of moisture in the air scatters and reflects the light making it difficult to see even a few feet in front of the vehicle. The more microscopic drops of moisture in the air, less light shines down the road and more light gets dispersed and reflected. Turbidity is like measuring how difficult it would be to see through fog with the high beams on. Turbidity particles are so small that they remain suspended in the water and may never settle out without a little help. Turbidity can also be used as an indicator of the quality of drinking water. It is often used to monitor the effectiveness of filtration in removing particles, including microbiological contaminants. Even waters that appear crystal clear to the naked eye may contain turbidity particles. Turbidity must be removed by a micro-system because harmful bacteria can hide behind these particles, which reduces the effectiveness of disinfection. There are a variety of filtration technologies that can be used to remove particles before the disinfection stage.

Radiological contaminants can come from both natural and anthropogenic (man-made) sources. The occurrence of natural radionuclides in drinking water is associated most commonly with groundwater. Natural radionuclides are present at low concentrations in all rocks and soils. In the cases where groundwater has been in contact with rock over hundreds or thousands of years, significant concentrations may build up in the water. These concentrations are highly variable and are determined by the composition of the underlying bedrock as well as the physical and chemical conditions prevailing in the aquifer. Although rare, natural radionuclides have also been known to occur in shallow wells.

Uranium

Most uranium contamination is natural resulting from groundwater being in contact with uranium in the ground though it is possible to find sources of human-caused contamination. Uranium is used in the nuclear power, military or similar industries. Uranium found in groundwater is not very radioactive. The health concerns related to uranium are kidney disease which results from the chemical nature of uranium, not its radioactivity.

Radium

Radium is another radioactive material that is often found in conjunction with uranium. It will usually make its way into drinking water naturally, though it is possible to find sources of human-caused contamination. Radium was once used extensively in the production of phosphorescent paints, like those used on watch dials.

Although the establishment of drinking water guidelines for a contaminant usually takes into consider¬a¬tion the ability to measure the contaminant and remove it from drinking water, the MACs for radionuclides are based solely on health effects. Exposure to radiation from all sources can result in changes to sensitive biological structures, either directly through the transfer of energy to the atoms within the tissue or indirectly by the formation of free radicals. Since the most sensitive structure in the cell is the deoxyribonucleic acid (DNA) molecule, exposure to radiation may damage the DNA, causing the cells to die or to fail to reproduce. This can result in the loss of tissue or organ function or the development of cancer. The likelihood of these events occurring increases with the amount of radiation received. Types of cancer most frequently associated with radiation exposure include leukaemia and tumours of the lung, breast, thyroid, bone, digestive organs, and skin. These cancers can develop between five years and several decades after exposure.

Most radionuclides can be reliably measured to levels below the established MACs. Water samples may be initially analysed for the presence of radioactivity using tech¬niques for gross alpha and gross beta determinations rather than measurements of individual radionuclides. These measurements are generally suitable either as a preliminary screening procedure to determine if further radio¬isotope-specific analysis is necessary or, if radionuclide analyses have been carried out pre¬viously, for detecting changes in the radiological characteristics of the drinking water source.

3.7 Notes on Chapter 3

4 Basic Chemistry and Calculations

4.1 Introduction

This chapter introduces you to the chemistry of water and calculations you will perform in relation to operating a micro-system. The e-Learning tool which accompanies this workbook shows detailed, step-by-step animations which illustrate the calculations you will perform, and so you should view them in conjunction with reading this chapter.

These calculations are just simple math, so don't let them intimidate you. The sections will take you through each calculation one step at a time.

Appendix B contains several reference tables of conversion factors. You will learn how to use these tables in this chapter.

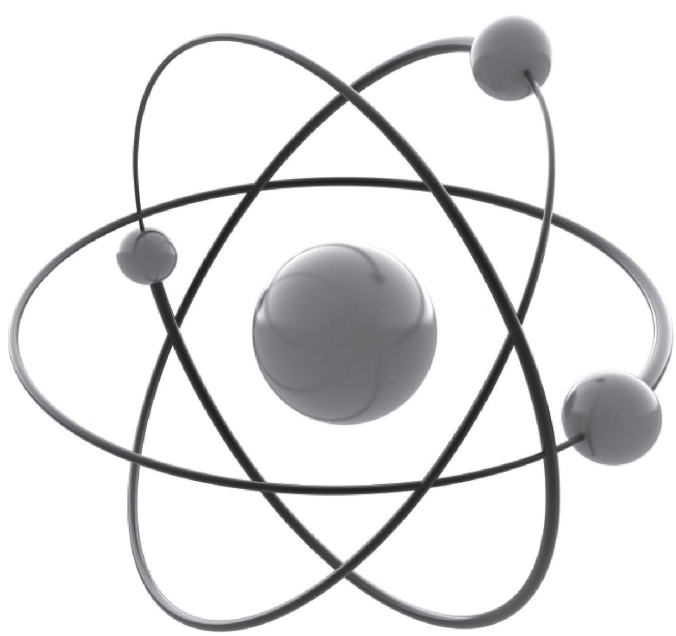
Before you begin to do calculations, you need to understand the chemistry of water.

4.2 Chemical Composition

Water, like all other matter, is made up of atoms. These atoms look like miniature solar systems, with planets orbiting a sun. In this representation, the sun is what is called a nucleus. The nucleus is made up of particles, some of which give the nucleus a positive electric charge. The number of small, positively charged particles in the nucleus determines whether the atom is a hydrogen, calcium or manganese atom, or the atom of some other chemical.

Tiny particles orbit the nucleus. These particles are called electrons and have a negative electric charge. When the number of electrons matches the number of positive charges in the nucleus, the atom is electrically neutral. Electrically neutral atoms are called elements.

Fig. 4.1 An Atom



An element is sometimes defined as a pure chemical substance that is neutrally charged. To date, scientists have discovered 118 elements which make up the periodic table. Elements differ from each other based on the number of protons (positively charged particles) in the nucleus. This number is called the Atomic Number, which is prominently displayed on the periodic table. Elements have a neutral charge, so if they have positively charged protons, then they must also have negatively charged particles to "neutralize" the charges. These negatively charged particles are called electrons. Elements tend to gain and lose electrons all the time. When this happens, they become either positively or negatively charged "ions" depending on whether they have lost or gained electrons.

So, an element is a neutrally charged chemical substance, and an ion is an element with a few extra or less electrons – giving it either a positive or negative charge.

All chemical matter consists of the 118 elements in some form, either alone or in groupings. A group of elements chemically bound to each other is called a molecule. For example, water is a molecule composed of two hydrogen atoms and one oxygen atom – and this gives the molecular name for water – H_2O.

4.3 pH and Alkalinity

The water chemistry parameters of pH and Alkalinity have already been covered in Chapter 3 of this manual. Understanding these two parameters is one of the most important parts of water chemistry. Nearly every chemical reaction from disinfection to corrosion is highly affected by pH and alkalinity. Learning to first monitor and control these two parameters will make chemical additions and adjustments for other treatment processes easier to do and understand.

pH is a measure of how acidic or basic the water is. In drinking water it is important for the treatment process and for potability to ensure that the targeted pH is maintained. In the Guidelines for Canadian Drinking Water Quality, pH is an Aesthetic Objective and the acceptable range is between 6.5 and 8.5. However, for certain disinfectants or processes, a pH above 8.5 is acceptable. The pH for each treatment step or process may differ, depending on the process (e.g., coagulation). The pH may need to be adjusted both before and after a process. A pH less than 6.5 can cause pipes and fixtures to corrode. A pH less than 6.5 is not a health-risk in itself – but it can dissolve metals, such as lead, cadmium, zinc, and copper, that may be present in your water pipes. This will increase the concentrations of these metals in your drinking water, which can cause health concerns. While water with a high pH does not necessarily pose a health risk it can cause water to have a bitter taste. Remember that a pH of 7.0 is neutral – the water is neither acidic nor basic.

Another term used to describe water that has a pH above 7.0, other than basic, is alkaline. This leads to confusion about the chemical property of alkalinity. They are not the same thing. Water that is alkaline has a pH above 7.0. Alkalinity, however, is a measure of the water's capability to buffer (neutralize) an addition of an acid such that the pH does not decrease. Alkalinity is an important water characteristic to consider when adding treatment chemicals, as a water with a low alkalinity may produce unacceptable changes in pH when a chemical is added.

Fig 4.2 The pH Scale

4.4 Concentration

Concentration is simply the measurement of the amount of one substance in another substance – like cream in coffee. When we are talking about water, the substance being dissolved is called the solute, and the water is called the solvent.

A solute's concentration in water can be expressed in weight per volume—as in milligrams per litre, parts per million and percentage. Concentration can also be expressed in volume per volume, as in millilitres per litre. Grains per US gallon is a common unit of measure for hardness—the amount of hardness producing minerals in water.

As a micro-system operator, you need to be familiar with all these units of measure. You must be able to convert one into another as well.

For example if there is 1 gram (a measure of weight) of iron in 1 litre (a measure of volume) of water, then the concentration of iron in that water is 1 g/L. Since there are 1000 milligrams in a gram, this would be an iron concentration of 1000 mg/L. This is a weight by volume concentration, sometimes abbreviated on container labels as w/v. Sometimes this concentration is expressed in another form, called parts per million or ppm. For solutions where water is the solvent, the concentration in mg/L is equivalent to ppm, that is, 1 mg/L = 1 ppm. This is because one litre of water weighs 1,000,000 milligrams. This does not necessarily apply to other solvents (chemicals).

Another common measure of concentration is by the volume of one liquid in another, that is, a volume by volume (v/v) concentration. This is usually measured by the smaller amount of liquid in the larger amount of liquid, for example millilitres per litre – mL/L. For example, if 5 millilitres (a teaspoon) of dye is added to 1 litre of water, then the concentration of that dye is 5 mL/L.

There is one more concentration that is encountered in water quality, and that is concentration expressed as a percent (%). There is no general rule as to whether the concentration is w/v or v/v, but the calculation is quite simple. The percentage is always measured on the basis of parts per hundred – 1 g/100mL = 1% (w/v) and 1mL/100mL = 1% (v/v).

For the first example above, an iron concentration of 1 g/L would be 1g/1000mL. Since we need to get down to 100 ml, we divide both sides by 10, giving 0.1 g/100ml, a concentration of 0.1% (w/v).

The second example is 5mL/L or 5mL/1000mL; again dividing by 10 to get to 100mL of solution gives a concentration of 0.5mL/100mL = 0.5% (v/v).

One common chemical concentration that is expressed as a percent is the amount of sodium hypochlorite in bleach. Sodium hypochlorite is the disinfecting agent in bleach, and it's concentration in household bleach is typically 5% (w/v). That means that there is 5 g of sodium hypochlorite in 100mL of the bleach solution – 5g/100mL. This same concentration – 5% – can be expressed as 50 g/L.

A Handy Number

Since there are 1000 mg in 1g, a concentration of 5%, or 50g/L is the same as 50,000mg/L.

As a micro-system operator, you need to be familiar with all units of measure. You must be able to convert one into another as well. Please see Appendix B for additional sample calculations and conversions.

4.5 Dilution

Dilution is the process of taking a strong solution and making it weaker by adding a solvent (in the case of water treatment –water). Dilution is something that is a daily occurrence that we don't even think about – two simple examples are adding cream to coffee (which dilutes the cream's original concentration) and making orange juice from frozen concentrate (the concentrated juice is diluted by the water added). In these case we know by experience or by following the directions how much to dilute the product by to make the desired final product. But in the area of water treatment, we need to calculate exactly how much concentrated stock to start with and how much solvent (water) to add to end up with the desired result. This isn't too difficult, and is described by this simple formula:

V1 x C1 = V2 x C2 where:

V1 = the volume of the starting (concentrated) solution

C1 = the concentration of the starting solution

V2 = the volume of the final (diluted) solution

C2 = the concentration of the final solution

Both volumes and concentrations must be in the same units. For example if V1 is in mL (millilitres) and C1 is in mg/L, then V2 must be in mL and C2 must be in mg/L.

The easiest way to understand this is to use an example.

Shock chlorination of a well is a process that is used to treat a well if it has tested positive for coliforms. It is also a good process to use as part of a scheduled maintenance program to extend the life of the well. The process requires that the water in the well be shocked with chlorine which means adding chlorine to the water in the well to create a strong chlorine solution.

Well diameter and casing type: 5 inch steel casing (the inside diameter is 5 inches)

Total well depth: 135 feet

Distance to the top of the water in the well from the surface: 87 feet

Volume of water in the well = 6.546 ft^3 (see calculation in 4.6 – Volume)

The chlorine will come from household bleach, which is 5% chlorine, or 5g/100mL. So how much concentrated bleach when added to the well water will be diluted to give a final concentration of 200 mg/L?

V1 = unknown

C1 = 5 g/100 mL = 50 g/L = 50,000 mg/L

V2 = 6.546 ft^3 x 28.317 L / ft^3 = 185. 36 L

Note: the conversion factor of 28.317 which converts cubic feet to litres is found in the table in appendix B.

C2 = 200 mg/L

V1 x C1 = V2 x C2

This formula can be rearranged to solve for V1 as follows:

V1 = V2 x C2 / C1

Therefore V1 = 185.36 L x 200 mg/L / 50,000 mg/L = 0.741 L = 741 mL

Adding 741 mL of 5% bleach solution to the well will dilute the concentrated solution to give a final concentration of 200 mg/L (200 ppm in the well).

4.6 Volume

Volume is the amount of space an object takes up. A micro-system operator will sometimes need to calculate the volumes of two basic shapes: rectangular containers and cylindrical containers. The amount of water in a rectangular container is calculated by multiplying the length of the container times the width times the height. In other words, volume equals length times width times height.

The amount of water in wells and other cylindrical containers, however, is calculated using a different equation. The volume of a cylinder equals pi (π) - a mathematical constant that has a value of 3.1416—times the radius of the base of the container times the radius of the base of the container again times the height of the cylinder. Or, in other words, volume equals pi times the radius of the cylinder's base squared times the height of the cylinder.

When performing these calculations, be mindful that several units of measurement are used to indicate volume—millilitres, litres, cubic feet, cubic metres, fluid ounces, pints, quarts and US gallons, to name a few. Be sure that the units of measure used to indicate a rectangular container's length, width, height, or a cylindrical container's radius and height are all the same.

The formulas are:

V = L x W x H (for a rectangular prism shape) where:

V = volume

L = length

W = width

H = height

L, W and H must all be in the same units; for example if they are all in inches then the resulting volume will be in in3; if they are all in mm then the resulting volume will be in mm3.

$V = \pi \times R^2 \times H$ or $V = \pi \times D^2 / 4 \times H$ (for a cylindrical shape) where:

V = volume

R = radius of base

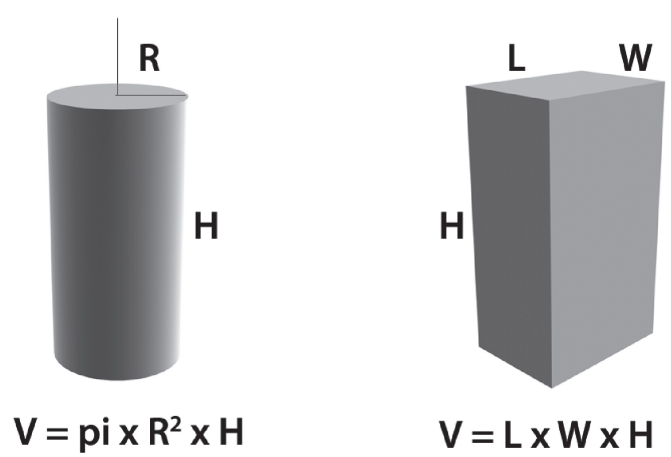
D = diameter of base

H = height of cylinder

π = Pi = 3.1416

As above R (or D) and H must be in the same units, which will give volume in those units.

FIG 4.3 The Volumes of a Cylinder and a Rectangular Prism



Here is a practical example of the calculation for volume.

In Section 4.5 – Dilution, the example of shock chlorination of a well which had tested positive for coliforms was used. The volume of water in the well was given in that example; below is how to calculate the volume.

Well diameter and casing type: 5 inch steel casing (the inside diameter is 5 inches)

Total well depth: 135 feet

Distance to the top of the water in the well from the surface: 87 feet

What is the volume of water in the well?

H = depth of water in the well = 135 feet – 87 feet = 48 feet

D = inside diameter of well = 5 inches x 1 foot / 12 inches = 0.4167 feet

R = radius of well = diameter / 2 = 0.4167 / 2 = 0.20835 feet

$V = \pi \times R^2 \times H = 3.1416 \times 0.20835 \times 0.20835 \times 48 = 6.546\ ft^3$

4.7 Flow Rates

In simplest terms flow rate is a measurement of a volume in a specific amount of time. It is a very common measurement in water treatment, as the physical size of treatment devices limits the amount of water they can treat in a given time. In mathematical terms, flow rate—Q—equals volume divided by time.

Many treatment devices are rated based on this treatment capacity – US gallons per minute (USGPM), cubic feet per second (cfs), gallons per minute (GPM), gallons per day (GPD) and so on.

Here are some common conversions for flow rates in US gallons:

$1\ ft^3/s$ (cfs) = $0.0283\ m^3/s$ = 28.317 L/s = 448.8 USGPM = 646,317 USGPD

and similarly for Imperial gallons:

$1\ ft^3/s$ (cfs) = $0.0283\ m^3/s$ = 28.317 L/s = 373.7 IGPM = 538,171 IGPD

Another area where it is useful to understand flow rates is in calculating how long it will take for certain events to occur. Here is a practical example:

Example of Flow Rate Calculation

There is a 300 (US) gallon tank in the back of a truck. How long will it take to fill the tank with a garden hose that flows at a rate of 1.5 USGPM?

Again, flow is a measure of volume per unit of time, mathematically expressed as:

Q = V / T where:

Q = flow rate

V = volume

T = Time

This formula can be rearranged to be expressed as either in time or volume:

T = V / Q or V = Q x T

The example is looking for a time answer, so the solution would be:

T = V / Q = 300 (US gallons) / 1.5 USGPM = 200 minutes = 3 hours and 20 minutes!!

Avoid the Gotchas!

When performing calculations, remember that several units of measurement are used to indicate volume – millilitres, litres, cubic feet, cubic metres, fluid ounces, pints, quarts and US gallons, to name a few. Be sure that the units of measure used to indicate a rectangular container's length, width, height, or a cylindrical container's radius and height are all the same.

Also, when calculating the volume of a cylinder, make sure to use the RADIUS of the base of the cylinder not the DIAMETER. Radius is equal to half of the diameter.

4.8 Conversion Calculations

Water pressure and temperature are two important water characteristics. Both can be represented with one of several units of measure.

For example, one unit of measure for pressure is pounds per square inch (psi). Another is kilopascals (kPa). As an exercise, convert 50 pounds per square inch to kilopascals.

Again, the key to solve this problem is in the Units and Conversions table in Appendix B. Look under the heading “Pressure”. The table indicates that 1 kPa = .145 psi. However, the problem is to convert the other direction, from psi to kPa. In this case we divide by the conversion factor, rather than multiply:

50 psi x 1 kPa / .145 psi = 344.8 kPa

Now, for a temperature conversion: convert 25˚ Celsius to degrees Fahrenheit. Looking at the conversion information in Appendix B, the conversion is to multiply the number of degrees Celsius by 1.8 and then add 32 to get the number of degrees Fahrenheit.

25˚ C x 1.8 = 45 + 32 = 77˚ F

To convert degrees Fahrenheit to degrees Celsius, the conversion process is simply reversed: subtract 32 from the number of degrees Fahrenheit and divide by 1.8 to get the number of degrees Celsius.

77˚ F – 32 = 45 / 1.8 = 25˚ C

As indicated above, the e-Learning tool provides examples of calculations that are typically used in the field of water quality for micro-systems.

To test your understanding of the training content so far, try answering the questions which appear at the end of appendix B.

4.9 Notes on Chapter 4

5 Treatment Technologies

5.1 Introduction

Numerous treatment technologies exist for drinking water treatment systems but generally speaking only a few are employed regularly in micro-system operations. There may be one or several individual treatment steps in a treatment system – together these steps are commonly referred to as the "treatment train". Every system will have a slightly different treatment train based on the individual parameters and characteristics of each water source.

The primary purpose of all technologies within the treatment train is to make the water safe to drink. Some technologies, like disinfection, directly address the safety of water by killing or inactivating microorganisms that cause disease. For other technologies, it may be more difficult to see the end goal, but each step is important. As an example, the water going into a filter may look just as clean as the water coming out, but remember it is not always the visible contaminants that cause operational and health issues.

A treatment train is designed to address targeted issues and the steps or components are incorporated in a sequence that ensures optimum operation. All systems also require monitoring and regular operation and maintenance procedures, from chemical dosing to backwashing and even replacement of critical components. This chapter contains brief descriptions of common treatment techniques, many of which may be incorporated in the steps of a micro-system treatment train. Note that for each technique, there may be multiple technologies for water treatment. For information on the specific function of system components, consult the manufacturer's information, or talk to a water quality specialist who will be able to explain your system and its limitations.

Fig. 5.1 A sample treatment train

5.2 Clarification

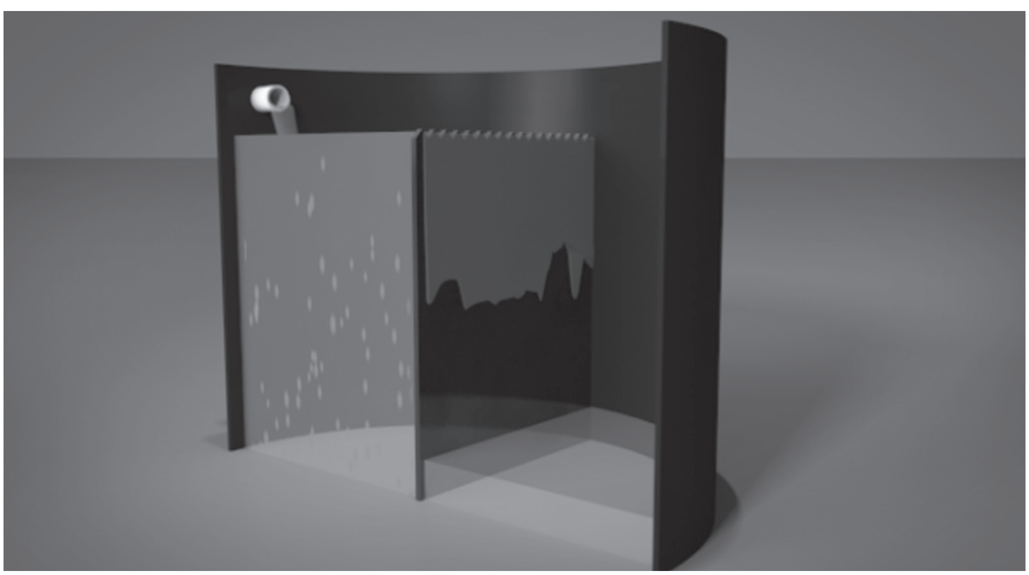
Simply put, clarification is any process that removes solids from water. The various types of solids that can be in raw water have been explained in Chapter 3. Some solids will sink readily to the bottom (settle out), with denser particles settling out quickly while others require more time. However, many particles remain suspended in the water. Suspended particles are almost always found in surface water, and clarification is a conventional and usually an essential step in the treatment of all surface water. Clarification usually involves one of two processes: waiting long enough for the solid particles to settle or changing the water's chemistry to make settling happen a bit quicker. These simple types of clarification which involve mainly settling are considered to be passive, which means they do not require a lot of energy to work. Clarification is a good primary step in a treatment train as it is essential to reduce suspended solids in the water as much as possible. Many other processes such as filtration and disinfection rely heavily on success of the initial clarification process in order to perform effectively.

A weir and other similar devices are commonly used at the source water intake. These devices essentially allow water to be taken from the cleaner top layers of the stored water where the concentration of suspended solids is lowest. It is a simple, yet effective device for reducing larger suspended sediment and solids in the water, but it will not work to remove the very small suspended particles ("colloidal" matter). Also common is a settling tank or basin. Prior to entering the treatment phase of a micro-system, the water is typically allowed to flow through a tank or basin which gives particles time to settle out. These devices are especially common for micro-systems which use moving sources of surface water (streams and rivers) since these sources have a lot of suspended solids stirred up from the sediment by the flowing water. Settling tanks allow time for the larger and heavier suspended solids to settle to the bottom of the basin. Water is drawn from the top of the tank, either directly through a pipe or through the use of a weir as previously described.

Did You Know:

Aluminum can be used in the treatment of potable water and it can occur naturally. It has been has also been suggested that aluminum is a cause of Alzheimers disease, Lou Gehrig's disease and other forms of senile dementia. It is still unclear if aluminum leads to these diseases or if it is that the diseases cause brain tissues to retain aluminum secondarily.

Fig 5.2 The concept for a Weir



With regular monitoring and maintenance, a simple settling basin or weir setup can vastly reduce the level of treatment required in subsequent steps of the treatment train. This is especially true if the treatment train includes filtration - any removal of suspended solids by clarification improves the effectiveness and operation of filters.

In order to remove more of the suspended particle, the water chemistry may be adjusted by adding chemicals called coagulants (aluminium or iron based chemicals). Coagulants are added to help suspended solids clump together (resulting in larger particles called "floc") and settle quickly. This is a common practice for systems using surface water sources with high concentrations of suspended soil particles (such as silt) and other suspended solids.

The use of coagulation chemicals requires proper dosing, testing and monitoring and the process may be too complicated for micro-systems. However, some unique approaches for chemical coagulation have been adapted for use by micro-systems and are now commercially available. These generally rely on a basic understanding of the chemical dose needed and a water supply that is not widely variable in its chemical dosing requirements. The chemical is injected into the water, and the resulting floc is allowed to settle in a specially designed settling tank, before the water is filtered. These micro-system style coagulation and clarification systems have been functioning well for micro-system operators and are even in use at some small rural communities.

5.3 Filtration

Filtration is a process by which particles are removed from the water. Most commonly this is achieved by straining them through a porous filter media such as sand where the spaces between particle (voids or pores) are too small for the particles to pass through. A filter's primary purpose is to remove suspended solids such as particles that cause turbidity. The selection of a filter and the design of the filter media considers the type and size of particles to be removed from the source water. Grain size distribution, filter media depth, volume and surface area and the water flow rate through the filter media are all critical design features of filters. Sometimes a sequence of filters can be used where initial coarse filters remove larger particles and subsequent finer filters are designed for removal of smaller particles. Filtration rates are a key design feature. Slower filtration rates trap more particles than faster filtration rates. Filters are limited by the amount of material that is removed, and eventually need to be cleaned (backwashed) on a regular schedule.

Filters come in all shapes, sizes, and types. The simplest contain a single type of media such as sand. More complex filters have multiple layers of sand, gravel and other filter media of specific grain size distributions. Some filters may include layers of a material called granular activated carbon (GAC - similar to charcoal). Other filters such as steel sieves, canisters, and cartridges rely on physical straining. Cartridge filters may use synthetic material in a cartridge composed of tightly wound paper or fabric; some cartridges of compressed stone-like materials are designed for even more effective removal of very small particles.

The first filtration step in a micro-system usually employs is a coarse filter or intake screen. If your micro-system uses surface water, the intake is normally surrounded by a screen. Though it may not look like it, this intake screen is indeed a filter. Water flows through a restriction (the screen), which is designed to keep large debris like sticks, rocks, and other things such as animals from entering your system. Following this coarse filter, components in a conventional filtration system may include a settling tank, followed by sand and gravel filters, and subsequent treatment components. These filters are continuously reusable by proper operation, which includes scheduled backwash cycles.

Some systems may only have cartridge type filters, or may have a combination of conventional and cartridge filters. Cartridge filter systems usually employ several filters progressing from coarse to fine. The first filter is generally one that pre-filters the water. Often, these filters remove particles in the neighbourhood of 5 to 50 microns in size. This may sound pretty small, but in the microbial world of water, even 5 microns is large. Most microorganisms and all dissolved solids will pass right through this filter. Sediments and suspended solids larger than 5 microns will be removed. Depending on the characteristics of the source water, the system may have one or several more filters following the pre-filter. All of these filters function in essentially the same fashion, they allow water to flow through, while restricting the passage of particles of specific sizes. Most cartridge filters are designed to be replaced with a new cartridge on a scheduled basis.

5.4 Sand and multi-media filters

Sand filtration is a technology that has been used for centuries. In this filter water is delivered on top of the bed of sand and the water flows by gravity through the sand where it is collected by a system called the underdrain, commonly a group of connected perforated pipes. The interlocking grains of sand form the filter, allowing only very fine particles to pass through. In addition to the physical restrictions presented to contaminants by the interlocking particles, sand filters also remove particles through a process called electrostatic adsorption. Electrostatic forces refer to the fact that the grains of sand naturally have slightly positive electrical charges on their surface. The small suspended sediment and colloidal particles in the water have natural negative charges. As water passes by the grains of sand, contaminants adsorb (stick to the outside) of the grains through these “electrostatic forces.” This type of “chemical process” is somewhat similar to chemical coagulation but at a much weaker strength. This common type of sand filter is often referred to as a “rapid sand filter”.

Fig 5.3 A Slow Sand Filter

When the sand filter gets full of the particles it was designed to remove, it is cleaned by backwashing. Backwashing involves forcing clean water backwards through the filter at a high flow rate, which dislodges the particles trapped in the sand. The backwash water will need to be disposed of properly, following directions provided by a water quality specialist. If maintained properly, a rapid sand filter will have a very long service life.

A sand filter is effective at removing suspended material, and over time improvements to this simple filter technique have been made using various sizes of sand and other materials, resulting in multi-media filters. These filters, as the name implies, include several filter media types of different densities and sizes such as sand, garnet, anthracite (a hard type of coal) and gravel. They are designed to be as effective as a sand filter, but can treat more water in the same size of filter. The layers of media material are designed to stay in place during backwashing due to their different densities, so that as the backwash cycle ends the heavier materials settle to the bottom first, with the lighter ones on top.

As noted earlier the water flow rate through a filter is critical. With sand or multi-media filters, a general rule is that the slower the flow rate, the better the filter performance. Gravity filtration is the most common, and the most practical to manage particle removal in balance with filter backwash frequency. However, gravity filters require substantial floor space, which is generally at a premium for a micro-system. Many micro-systems utilize pressure filters which are much smaller than gravity filters but tend to be less effective than gravity filtration. Properly-designed pressure filters and backwashing frequencies must always be suited to the characteristics of the water source, and operated to cope with any varying changes in water quality, particularly when sediment loads or algae loads increase.

One of the best particle removal filters is a slow sand filter, operated at very slow flow rates where water passes through layers of fine to coarse sand and then through the gravel. These filters rely on the development of a biologically active layer on the top of the sand. This coating is called the schmutzdecke—a German word meaning "dirty skin". In addition to the physical filtration provided by the sand, the naturally occurring organisms in the schmutzdecke consume or convert various contaminants thereby increasing their removal from the water. For example, some organisms remove iron or arsenic, while others will remove other microscopic organisms. Be aware that the water flow through a slow sand filter may stop completely if the schmutzdecke is allowed to become too dense. When flow is reduced, scrape away the schmutzdecke and the top several centimetres of sand.

Slow sand filters have been adapted to micro-systems for use on individual households and have been quite successful on groundwater supplies. They may have limited application on surface water supplies which normally have larger loading from particulate matter and algae, causing the filters to plug prematurely. As with any type of primary treatment, when these type of filtration systems are in the treatment train it is essential to have disinfection before using the water.

Make sure to follow the manufacturer's recommendations for the operation and maintenance of rapid sand, multi-media, pressure and slow sand filters.

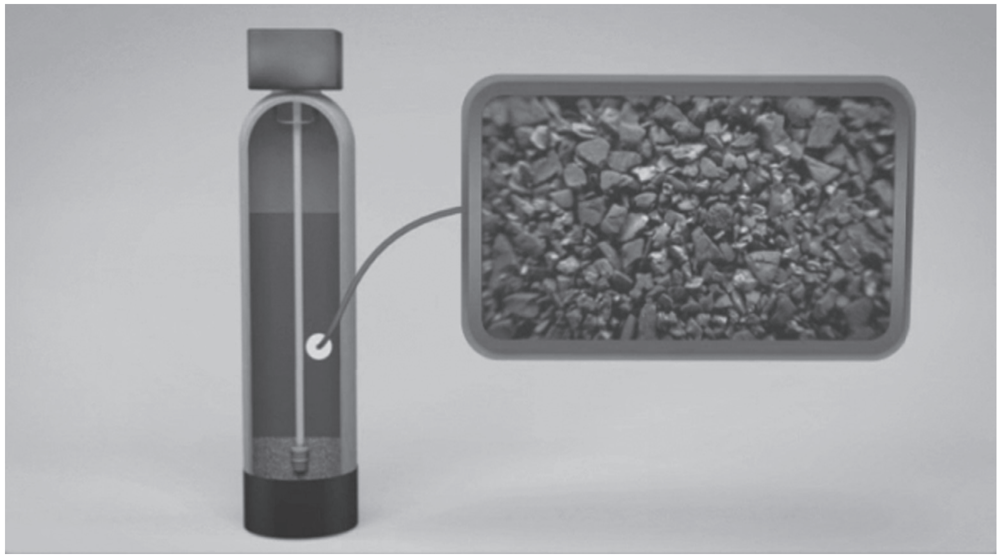
5.5 Granular Activated Carbon Filters

Granular Activated Carbon filters (GAC) are another common option for micro-systems, and are used for removal of organic matter, colour, taste and odour problems. The word "Activated" comes from the fact that during the manufacturing process, grains of carbon are fed into an oven at a very specific temperature. This heat puffs the grains of carbon up like puffed rice cereal. The process creates numerous grooves and ridges on the carbon grains resulting in a very large surface area for adsorption to occur. Adsorption is a chemical processes that removes dissolved organic matter, colour, taste and odour compounds. GAC filters use large volumes (or beds) of carbon, and require sufficient contact time between the water and the carbon media. The dissolved organic matter chemically adsorbs or sticks to the large surface area of granular activated carbon. Eventually, the GAC filter's ability to adsorb contaminants is exhausted, and the media is "spent" and requires replacement.

Did You Know:

Drinking water fountains should be disinfected a minimum of once every two months and at an increased frequency if heavily used.

Fig 5.4 A Granular Activated Carbon Filter



Recent advances in GAC filters have resulted in the design of biological GAC filters. Biological GAC filters have been successfully adapted to micro-systems and achieve removal of dissolved organic matter in micro-systems. This type of system relies on a combination of biological removal of the organic matter, and possibly biological regeneration of the ability of the carbon to adsorb the organic matter. The system has been successfully adapted for use on micro-systems by using a gravity sand filter ahead of a biological GAC filter. The design is commercially available for individual systems and small communities.

Note that both regular and biological GAC filters will eventually need to be replaced or reactivated. Once the filter is spent, replace the media in the filter or return it to the manufacturer to have it reactivated.

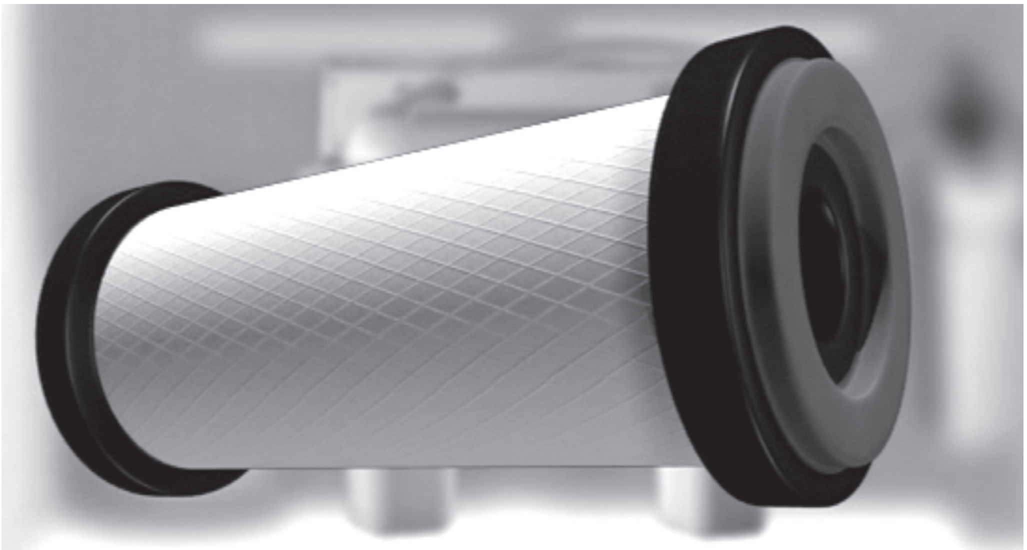
5.6 Cartridge Filters

Did You Know:

Kitchen sink RO units produce "reject" water in volumes anywhere from seven to twenty times the volume of treated water. This means that for every litre of drinking water produced, the RO unit will generate seven to 20 litres of reject or waste water.

Cartridge filters are yet another type of filter used in micro-systems. The advantage to all cartridge filters is that they are easy to change out and can be arranged in a limitless combination of different sizes to accommodate almost any water source. There are two basic types of cartridge filters – pleated (or surface) filters and depth filters. Both are named by where particles are trapped – either on the outside surface, in case of pleated filters or across the entire depth of the cartridge in the case of depth filters. Pleated filters may be cleaned by backwashing, and are therefore reusable to a certain extent. Depth cartridges become plugged and must be replaced on a regular basis. They are contained in housings of plastic or metal, 0.5 metres long to several meters in length. Some cartridges may contain carbon and work a lot like GAC filters. Many restrict contamination solely based on size, either by tightly winding string, rolling paper or fabric, or compressing powders into a solid block that is permeable only to water and perhaps some very small contaminants. These systems are useful only on relatively clean water, and can be expensive due the cost of continual cartridge replacement.

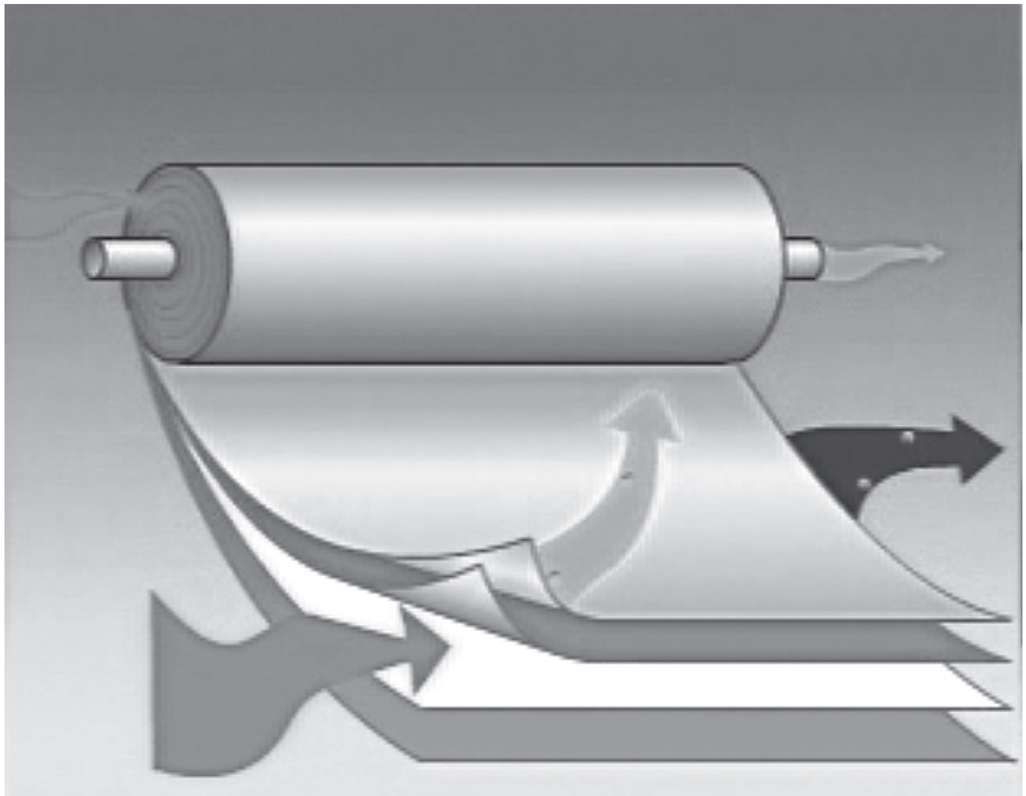
Fig 5.5 A Cartridge Filter



5.7 Membrane Filters

At the finest end of the spectrum of filters is the membrane filter. Media bed (sand, carbon, etc.) filtration and cartridge filters rely on a physical process where the solid particles are separated from the liquid water. Membrane filters work on much the same principle; however, they are designed to remove very small particles and some membrane filters can even remove particles that are dissolved in the water. This family of filters includes (from coarsest to finest) Microfiltration, Ultrafiltration, Nanofiltration and Reverse Osmosis (RO) membranes. Membrane filters are a common choice for micro-systems. Nanofiltration and reverse osmosis membranes can typically filter out particles 10 times smaller than an average sized virus. In general, membrane filters require high pressure to move the water through the membrane which will remove all contaminants larger than the opening size of the membrane. Only a portion of the water supplied to the membrane is filtered; from 50% to 85% of the water is rejected, and this reject water will contain the filtered contaminants of the treated water, increasing the concentration of contaminants in the reject water stream. The disposal of the concentrated reject water can be very costly and must consider the impact on the environment Normally, properly designed pre-treatment is required before a membrane filter to ensure it will not be plugged by larger particles or fouled by other constituents (such as hardness, iron, and the numerous chemical and biological contaminants found in all groundwater supplies). In addition, due to the very small pore size of membrane filters treating water with this type of filter is a much slower process than any other type of filtration process.

Fig 5.6 A Membrane Filter



It is important to monitor the performance of membrane filters regularly. Pay particular attention to any changes in the quality or quantity of the treated water. Poor filter performance may be a sign that the water has not been adequately pre-treated, or that the upstream components in the treatment train are not operating properly. It may also be a sign that the membrane filter is dirty.

Sometimes, filters degrade enough to allow untreated water to pass through. At this point, the problem must be recognized and the filter either fixed or replaced. Many manufacturers offer recommendations regarding the replacement of filtration units. Check the product brochure or manual that came with the filtration unit, and monitor the quality of the treated water to detect signs of filter degradation early.

Like all filters, membrane filters will eventually become too clogged with contaminants to let water pass through. Membrane filters can be cleaned with chemical washes, or they can be sent to the supplier for cleaning. Follow the manufacturer's instructions to reinstall, operate and maintain membrane filters.

For more information on filtration and reverse osmosis systems, please take the time to review the DVD modules entitled

"Filtration and Ion Exchange for Micro-systems" and

"Ultraviolet and Reverse Osmosis for Micro-systems"

5.8 Oxidation

Oxidation, although not necessarily a treatment technology by itself, is a chemical process that can improve filtration by converting a portion of the dissolved particles into insoluble suspended particles. This process is commonly used to convert dissolved contaminants such as iron or manganese into particulate form.

Oxidation involves the addition of an oxidant – such as air or a stronger oxidizing chemical like potassium permanganate, chlorine or ozone - into the water converting a portion of the dissolved particles into insoluble suspended particles which can then be removed by physical filtering.

Oxidation and chemical oxidation are commonly used to convert iron or manganese into suspended particles that can then be filtered out. Iron at low concentrations is usually easy to remove by oxidation with the addition of air. But manganese does not oxidize so readily. Manganese that is not removed will stain appliances and kitchen and bathroom fixtures black, and impair laundry activities. Manganese will also give a bad taste to prepared beverages and cooked foods. A manganese greensand filter uses oxidation and physical filtration to remove manganese. Potassium permanganate, an oxidant, is added before the greensand filter, causing oxidation of the manganese. The oxidized manganese is physically filtered out by the sand. The sand in the filter is specially treated to attract and adsorb manganese as well. Manganese greensand filters are also capable of removing high concentrations of iron and treating hydrogen sulphide—a compound that causes water to smell like rotten eggs.

Oxidation treatment systems rely on precisely adjusting the amount of oxidant added, based on the water chemistry, sufficient contact time, and appropriate filter maintenance. Ozone, a very strong oxidant, may also be used to oxidize and break down organic matter, which can more readily be removed by granular activated carbon filtration. However there are safety concerns when using ozone so this feature is not often incorporated in a micro-system.

5.9 Ion Exchange

As discussed in Chapter 4, electrically charged atoms or molecules are called ions. Ion exchange is a chemical process for "exchanging" one ion in the water for another. Commonly, micro-systems use ion exchange to trade calcium and magnesium ions in the water for either sodium or potassium ions. Water that contains high levels of calcium and magnesium is often called hard water. While not a health risk hard water can harm distribution systems, disrupt water-treatment processes, damage water heaters, dishwashers and washing machines, and keep soap from producing suds. Many treatment trains therefore involve an ion exchange process, called a water softener, to replace the calcium and magnesium with sodium or potassium.

Water is brought into a vessel containing resin filter media (specially designed synthetic plastic beads). The negatively charged (anionic) resins used for softening purposes are attracted to positively charged (cationic) calcium and magnesium ions. As water passes through the resin, calcium and magnesium hardness ions are drawn out of solution as they bind to the resin, exchanging themselves for the weaker cations on the resin which are released into the water (principally sodium or potassium depending on the system used). Eventually, enough hardness causing calcium and magnesium ions are bound onto the resin that the resin bed is exhausted and cannot remove any more ions. It has

Did You Know:

In a water softener, one (1) cubic foot of a typical high capacity resin can remove 30,000 grains or about 500,000 milligrams of hardness. This means that if water is 500 mg/L hard, one cubic foot of resin would soften 1,000 L of water before requiring regeneration.

reached its loading capacity for removing calcium and magnesium and the bed needs to be "regenerated". Regeneration is accomplished by flooding (saturating) the resin bed with a sodium chloride (or potassium chloride) brine solution with a chemical energy strong enough to break the calcium and magnesium bonds. The regeneration brine solution therefore "re-generates" the design feature of the media to continue exchanging sodium or potassium for calcium and magnesium as water is passed through the media. After the regeneration step, the ion exchange backwash solution is discarded to a waste water stream before the component is put back into its operational mode. Water softeners are programmed to regenerate automatically. To conserve water the regeneration process should be initiated based on the total amount of water treated and not time.

Water softeners come with a brine tank that holds the salt solution used in the regeneration process. Be sure to check the level of salt in the tank regularly and add salt as required. Also, monitor the hardness of treated water regularly. Use a field test kit to determine the hardness or send a sample of the treated water to a certified lab.

Fig 5.7 A water softener

While the beneficial aspects of softening are a good enough reason to use it, the process must be managed for its impact on water. Ion exchange softening will add either sodium or potassium to the water, each of which can be problematic if their concentrations are too high in the distributed water. Sodium, for instance, can be a problem for those drinking the water that may be on sodium-restricted diets. High sodium content in the backwash water can also have an impact in certain septic fields. In clay soils, sodium mixed in the water can cause the clay itself to expand, thus making it impermeable to water and useless as a septic drain field. These impacts of course depend on the amount of softening needed, and the quantities of brine solution discharged.

Although "softening" ion exchange units are a fairly common and familiar component in a treatment train, the ion exchange principle can be applied to design a component that removes other contaminants from the water, such as iron, manganese, fluoride, sulphate, nitrate, and magnesium or virtually any other targeted cation or anion that does not foul the resin bed. When ion exchange is used for purposes other than "softening", it is possible that it can make water aggressive. The ions that contribute to alkalinity (a water's buffering ability to absorb acids without a pH change) can also be removed when using certain types of resins. When this happens, the pH will be lowered and the water becomes aggressive, oxidizing metal components and pipes in the system.

For more information on filtration, ion exchange, please take the time to review the DVD modules entitled

"Filtration and Ion Exchange for Micro-systems"

5.10 Disinfection

Disinfection is the process of killing or inactivating disease-causing microorganisms in order to make the water safe to drink. Disinfection is not sterilization, which is impractical and unnecessary for drinking water.

Once inside your body, microorganisms may find it an ideal location to replicate themselves. This replication increases the number of microorganisms and in the case of disease-causing pathogens in water it may cause human health issues. Most traditional disinfection methods are designed to kill the pathogens in the water however this isn't always simple to do. Other disinfection processes inactivate the pathogens, which doesn't kill them but prevents the microorganism from reproducing thereby reducing the likelihood of illness from the pathogens. Many different disinfection processes exist, but the addition of chlorination chemicals and the use of Ultraviolet (UV) light disinfection are the two that predominate for micro-systems.

The type of disinfection used in a micro-system will depend on the microorganisms found in the water. For example, some microorganisms are resistant to chlorine including the protozoa *Cryptosporidium*. Talk to a water quality specialist to learn more about the disinfection process most suited to the water supply.

Chlorination has been effectively used to produce safe drinking water for nearly a century. Chlorine was first introduced to water treatment as a disinfectant in the early 1900's. It is easy to apply, measure and control and it is relatively inexpensive.

Chlorination relies on adding a sufficient dose of chlorine chemical to the water to kill microorganisms. The targeted concentration of chlorine must be large enough to react with chlorine-consuming substances in the water and remain at a concentration that is of sufficient strength to kill the targeted disease-causing organisms. Chlorination dose and contact time are two critical factors in disinfection.

Determining the proper amount of chlorine to add is important. If not enough chlorine is added, or the chlorine does not have enough contact time with the water, all of the chlorine-sensitive, disease-causing microorganisms may not be killed. If too much is added the drinking water will taste and smell strongly of chlorine. A water quality specialist can help to determine the correct amount of chlorine to be added to the treatment system for your primary disinfection.

When applied properly, the primary chlorine disinfection process will kill the targeted organisms. If chlorine is also used for secondary disinfection, there should be a small residual concentration of chlorine left as the water makes its way to the consumer. This residual chlorine is called free chlorine residual and it and helps protect the distributed water from microbiological regrowth. This is an operational advantage because it helps protect the distributed water and also allows operators to test for the free chlorine residual at the tap to ensure the water is safe.

Occasionally chloramine (chlorine and ammonia) is used as the secondary disinfectant instead of chlorine. In this case there will be a total chlorine residual instead of a free chlorine residual.

While there are different ways to chlorinate water, the most common is to feed a specific dose of chlorine into the water for a sufficient contact time. The treated water is then tested for free chlorine residual concentration immediately after the chlorination point. If chlorine or chloramines is used for secondary disinfection, the water is also tested for free chlorine or total chlorine residual concentrations at points in the plumbing (distribution system) where water is available, such as taps and drinking fountains. The concentration of disinfectant residual in potable water should be not less than 0.2 mg/L of free chlorine (when using chlorine) or 1.0 mg/L of total chlorine (when using chloramine). Although both measurements are important to determining correct operation, the free chlorine residual is the most important value to indicate that the water is initially disinfected.

If naturally-occurring ammonia is present in the water (sometimes present in groundwater), sufficient chlorine dosing is necessary to consume all of the ammonia to achieve the targeted free chlorine residual. If this is done incorrectly, the water may not be safely disinfected.

Chlorine reacts with organic matter naturally present in water such as that from decaying leaves. This chemical reaction forms a group of chemicals known as chlorinated disinfection by-products, or CDBPs. The most common of these by-products are trihalomethanes, or THMs, and haloacetic acids, or HAAs. Together, the concentrations of THMSs and HAAs can be used as indicators of the total loading of all CDBPs that may be found in the drinking water supply. Several studies have found a link between long-term exposure to high levels of CDBPs and a higher risk of cancer. Generally, rivers or other surface waters contain more organic matter than wells.

Pre-treating the source water before chlorination reduces the natural organic matter that reacts with chlorine and will help reduce the level of CDBPs in the drinking water. Treatment processes like clarification and filtration that occur before chlorination will help reduce the formation of CDPBS. If CDBPs such as THMs and HAAs are a concern for the drinking water system, speak to a water quality specialist and have the water analyzed for chlorinated disinfection by-products.

5.11 Types of Chlorine

Chlorine can come in one of three forms: gas, liquid, and solid. Chlorine that is used in micro-systems is typically in the liquid form. Regardless of the form of chlorine used only chlorine that meets NSF/ANSI Standard 60 should be used as a drinking water disinfectant

Gaseous chlorine, though the least expensive of the three, is not a common form for micro-systems due to the hazards involved. Gaseous chlorine can be extremely dangerous if used improperly or leaks occur due to an accident. Chlorine gas, heavier than air, will sink to the bottom of a room and can be deadly with only a few breaths. If your system is using chlorine gas for disinfection, you should have a dedicated chlorine room with proper ventilation, secured chlorine cylinders, and emergency equipment in case of a leak.

Liquid and solid chlorine forms are much less dangerous than gas chlorine, though precautions must still be taken. Liquid chlorine is commonly available in concentrations of 5 - 15% chlorine by volume. A typical chlorine concentration from a chemical supplier supplying a micro-system is 5 - 12%. One disadvantage to using liquid chlorine is that it is primarily water, meaning it can freeze in the winter if not stored properly. Liquid chlorine will also lose it effectiveness if left unused for long periods of time and can form undesirable by-products. In order to minimize these effects follow the manufacturer's recommendation regarding storage. A form of liquid chlorine with which you may be familiar with is household bleach, though most bleach is only around 5 or 6% chlorine. Some forms of this household chemical are actually approved for drinking water use (if applied properly) so they may be of use in situations when no other disinfectant is available. Be sure, however, that the household bleach to be used is unscented and is not past its expiry date.

Solid chlorine is commonly used for swimming pools, yet it is also sometimes used for micro-systems, providing it is packaged and labelled for use in potable water supplies. This form of chlorine comes in concentrations of 50-70% by weight and must be mixed with water before being delivered as a disinfectant. Because it must first be mixed with water, additional equipment is needed for a solid chlorine system. One problem often associated with the use of solid chlorine is clogging of tubes and pipes during the initial dissolving phase.

Both liquid and solid chlorine (after dissolving in water of course) are fed into the water supply using a chemical feed pump. These pumps must be calibrated for a particular flow so that precisely the right amount of chlorine is delivered to disinfect the water. In some cases, this calibration process may be automated, but not always. Finding the right amount of chlorine involves knowing a bit about how chlorine works to disinfect the water and monitoring the amount of free chlorine residual in the system following the treatment cycle. For any system that includes chlorine disinfection there should be testing procedures in place for monitoring this parameter. For more information on chlorine residual, please review section 6.2 of this workbook.

Did You Know:

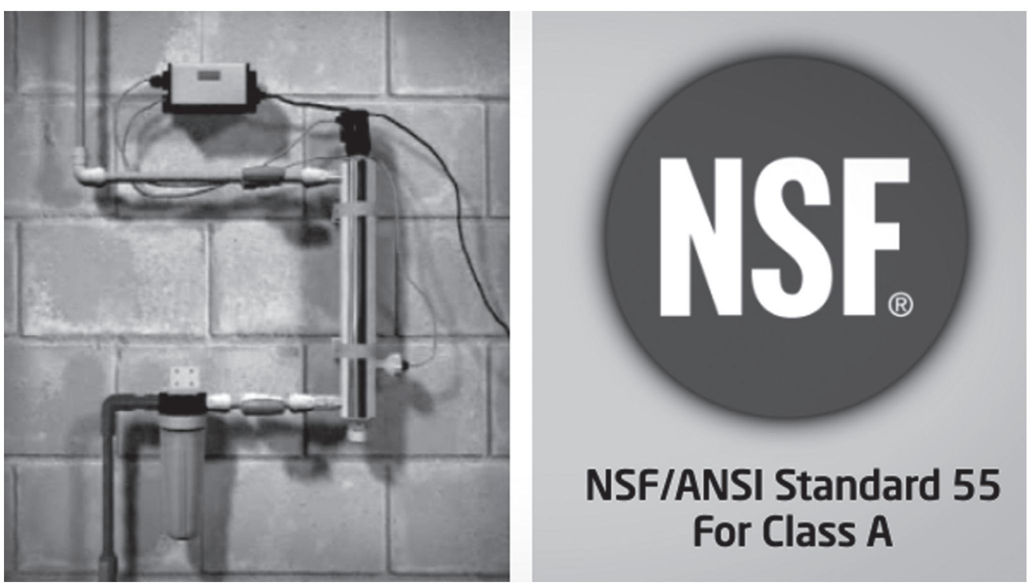
A water softener can readily remove up to 3 mg/L of iron with a five cycle fully automatic softener.

5.12 Ultraviolet Light

Many systems, especially those using groundwater, are opting for a chemical-free disinfection option. Ultraviolet (UV) light has become an extremely popular primary disinfection method in recent years, especially for micro-systems. UV light produces radiation powerful enough to inactivate bacteria, viruses, and protozoa in water by disrupting their genetic material so they cannot reproduce inside our bodies. Similar to a chlorination system concentration (strength of the UV light) and contact time are important - UV light disinfection relies on generating a correct dose of UV light for a sufficient length of time in contact with the targeted disease-causing organism. A small UV system requires little energy to run and can be an extremely efficient and effective system for treating water, providing the water is clean enough (proper treatment before the UV light unit). The water must be low in suspended solids, turbidity particles, calcium, magnesium, iron, manganese, organic matter and colour. The light has to reach the microorganism in order to inactivate it – having particles in the water that will get in the way of the light will reduce the effectiveness of the UV system. A parameter known as Ultraviolet Transmittance – a measurement of the ability of UV light to pass through the water will help determine if additional pre-treatment is required before the UV device.

A UV light disinfection system should meet NSF/ANSI Standard 55 for Class A systems and be fitted with lights or alarms to warn when the UV doses drop too low. If the light or alarm built into the UV light system triggers, be aware that this indicates that safe drinking water can no longer be ensured until proper maintenance is performed.

Fig 5.8 A typical UV disinfection system



As with any part of a treatment system, there are maintenance tasks associated with UV disinfection. The water is passed through a vessel with a quartz sleeve which protects the UV bulb in the centre of the device. The quartz sleeve requires regular cleaning and may need eventual replacement. The UV bulb will lose its strength over time, and should be replaced on a regular basis. Warning systems (a light and/or alarm) should be built into the UV system to indicate when the UV dose is too low, indicating that maintenance is required in order to continue to provide safe drinking water. A disadvantage of a UV system is that it is not possible to measure a treatment residual like a chlorination system. The only way to know if it is working is to measure microbiological contaminants in the treated drinking water.

For more information on disinfection and UV light systems, please take the time to review the DVD modules entitled

"Disinfection Processes for Micro-systems" and

"Ultraviolet and Reverse Osmosis for Micro-systems"

5.13 Design of a Treatment System

The intent of this course is to provide introductory information on water quality as it relates to micro-systems and not to provide in depth scientific information in order to design treatment trains. However, throughout this chapter information has been presented on various treatment processes and an indication of what contaminants they are capable of removing. The focus was on the treatment process, so this section takes that information and provides it from the perspective of contaminants in the water and in general what treatment processes could be used to remove these contaminants.

Each treatment train is designed to meet the specific requirements of the source water. Most likely, it is arranged to initially remove large suspended particles and then finer suspended particles in the following step. Any remaining suspended particles and dissolved contaminants are then removed. The last step in the treatment train is the disinfection of the water.

The treatment train may start out with a clarification process, which would include some combination of a settling tank, coagulant addition and mixing to remove the larger suspended particles. This could be followed by a sand or multimedia filter. Then it might have a finer cartridge filter. Depending on the dissolved contaminants it may have an ion exchange unit or a membrane filter, such as a reverse osmosis filter. At some point in the filtration process oxidation might be used to bring dissolved particles out of the water so they can be filtered and removed. Also, a Granular Activated Carbon filter might also be used to take out dissolved organic matter, colour, taste and odour. After the water has been sufficiently filtered it will be disinfected, typically by chlorination (especially if there is a distribution system) or with ultraviolet light.

This is a classic treatment train. However, not all treatment trains will contain all of these components, and the components may not be in the order listed above. Each treatment train is designed specifically for the characteristics of the source water.

Did You Know:

There are no known beneficial or harmful health effects associated with the ingestion of demineralized or distilled water.

TABLE 5.1 Treatment technologies for typical contaminants

Treatment Technology	Targeted Contaminants	Special Requirements and Conditions
Clarification	Suspended solids	- Requires the installation of a settling tank - Coagulants may be added to aid settling
Sand and multi-media filters	Various size particles (depending on pre-treatment), Oxidized metals	- Rapid and slow sand filters are available - Slow sand filters require a large amount of floor space - Various medias are available for different contaminants
Activated carbon Filters - Granular activated carbon filters	Removes tastes, odours, many Volatile Organic Contaminants (VOCs) and lead	- Carbon particles have large surface area to absorb contaminants - Carbon eventually has to be replaced or regenerated
Cartridge filters	Removes particles of various sizes	- Depth or pleated filters are available - Must be replaced periodically
Ion exchange (Water Softener)	Calcium, Magnesium, low concentrations of Iron (<2 mg/L)	- Requires addition of sodium or potassium to regenerate resin beads
Membrane Filtration - Reverse osmosis	Wide range of inorganic substances (TDS, Hardness, Arsenic, Sulphates, Manganese, Iron, etc.), Microorganisms (Protozoa)	- Requires significant pretreatment - Produces large amounts of reject or waste water, approximately 50% of treated water - High % removal of many contaminants in water
Ultraviolet (UV) disinfection	Microorganisms (Bacteria, Viruses, Protozoa)	- Chemical free method of disinfection - Pre-treatment required - Only primary disinfection, no secondary disinfection
Chlorination	Microorganisms (Bacteria, Viruses), Oxidizes metals	- Requires adequate pre-treatment - Ongoing monitoring of free chlorine residual required - Provides primary and secondary disinfection

The source of the raw water will have an affect on the design of the treatment train. Water that comes from properly installed deep wells which are operated according to designed flow rates has already been filtered by the aquifer, so it doesn't generally need as much filtration as surface water. So a groundwater treatment system may have less filtration than a surface water treatment system.

Groundwater spends a lot of time in contact with natural minerals, and so may be quite hard and contain dissolved minerals such as iron, manganese and even arsenic. These are less prevalent in surface water – so a groundwater system might have the addition of oxidants with filtration and an ion exchange unit, whereas these are less typical on surface water systems.

Regardless of the source of the water it must be disinfected. Microorganisms are found in both surface water and groundwater, and must be killed or inactivated before the water is safe to drink.

It is important to not only monitor the effectiveness of the disinfection process but to also monitor the quality of the source water on a regular basis. A qualified specialist should evaluate the tests of the source water to determine if there are adjustments needed in the design and operation of the water treatment train.

5.14 Operation and Maintenance of a Treatment System

Your system may have been designed by a water treatment specialist, but its operation and maintenance are likely up to you. Your first task is to become familiar with all the equipment and processes in the treatment train. Take the time to review the manufacturer's recommendation for operation and maintenance and capacity of each component of your system. Using the flow meter, periodically check the flow rate to make sure your system is not treating more water than it is rated for.

If there are any questions, contact your water quality specialist for clarification. Never hesitate to call a professional if an operation or maintenance task is over your head.

> Part of being a good operator is knowing when the help of others is needed. You may be responsible for the health of others, so the operation and maintenance of your treatment systems is nothing to take lightly

Did You Know:

The minimum treatment requirement for systems on groundwater, is disinfection to ensure greater than 99.99 per cent (4 log) reduction of viruses, at or before the first consumer.

Periodically, intake screens for surface water systems will need to be cleaned off. This is an easy, but potentially time-consuming task. In the winter, it is also possible that the water surrounding the intake becomes frozen. It may be necessary to manually keep ice from forming in this area and clogging the intake.

Chemical injection systems must dose the correct amount of chemical. If water quality varies, the doses need to be adjusted. Contact times in mixing chambers or contact tanks also need to be correct and flow rates may need to be varied if the dosage is changed.

Sand, and multi-media filters require water (and sometimes air scour) backwashing on a regular frequency. After the filter traps enough particles the backwash of this particulate matter needs to be performed to re-establish the capacity of the filter. The dirty backwash water is flushed to waste. Filter backwashing must occur well before the filter is plugged or an internal channel develops which allows contaminated water to "break through" into the treatment process. Filter backwashing must be done properly so that the filter media is not damaged as it is uplifted and cleaned by the backwash water.

Granular activated carbon media requires replacement once it loses its capacity to remove the targeted organic compounds. The exception to this is biological activated carbon filters that are continuously regenerated by biological activity in the carbon media; however, even these filters require regular water backwashing and may even require intermittent cleaning or even replacement.

Cartridge filters require maintenance. Pleated and surface cartridges might be able to be backwashed and put back into service so the manufacturer's recommendation should be followed closely. Depth cartridges will need to be replaced at the end of their useful life. Consult the owner's manual that came with the filter unit or contact a water quality specialist for more information.

Membrane filters might be able to be cleaned using clean-in-place procedures (usually with chemical washes containing acids and bases) to manage or reduce the extent of membrane plugging by inorganic and organic foulants and biological organisms which secrete wastes that foul membranes. Oftentimes, membranes may be sent to a supplier for cleaning.

Eventually, all filters will reach a point where they become too clogged with contaminants to let water pass through, or they degrade enough to let both water and contaminants through. It is at this point that the problem must be recognized and either fix the filter, or replace it all together. Many manufacturers will have recommendations regarding the replacement of filtration units.

Ion exchange filters required appropriate brine regeneration at appropriate times. The regeneration cycle is usually automatically controlled either based on time or a physical characteristic of the treatment process such as flow. The level in the brine tank must be monitored and additional regenerant such as sodium or potassium (usually in a solid form – salt) should be added as required.

Chlorine disinfection systems require regular addition of chlorine, correct dose adjustments and monitoring of free residual chlorine. They will also require periodic cleaning, as chlorine is an oxidant and will cause some build-up on metal parts.

UV light disinfection systems required regular cleaning of the quartz sleeve and also regular replacement of the UV lamp. Scheduled sampling and testing for microbiological contaminants is also required for this type of disinfection process.

Keep a record of all maintenance for all treatment components. Follow manufacturer's recommended maintenance schedules, and modify as necessary to suit the water being treated.

For more information on operation and maintenance of treatment system components, please take the time to review the DVD modules entitled:

"Ultraviolet and Reverse Osmosis for Micro-systems"

"Filtration and Ion Exchange Processes for Micro-systems"

"Disinfection Processes for Micro-systems"

5.15 Notes on Chapter 5

6 Distribution Systems

6.1 Introduction

Once water has passed through the treatment train and the contaminants removed or reduced to acceptable levels and it has been disinfected it is safe to drink and use for other purposes such as washing and food preparation. The water now has to get from the treatment location to where it will be used. The pipes and valves that control and carry the water are called the distribution system. This may only be the plumbing in the building, or if the treatment system is in a separate location it may also include underground piping from the treatment system to the building. It is important that proper operation and maintenance procedures be followed in order to prevent the contamination of the potable water as it makes its way through the distribution system from the treatment location to the point of use. Although each micro-system will have some unique characteristics, this chapter highlights some of the common elements that need to be considered for the proper operation and maintenance of a distribution system.

6.2 Chlorine Residual

Chlorine is the eleventh most abundant element in nature. Probably the most familiar form is in the salt (sodium chloride) naturally present in sea water and salt deposits in the ground. As a drinking water disinfectant, chlorine plays a critical role in protecting people from waterborne illnesses.

Chlorine has many uses and application in today's world – and of particular interest to water quality and micro-systems is the use of chlorine to disinfect the water and ensure it remains potable. The use of chlorine as a disinfection agent for water dates back more than 150 years. Today chlorination plays a critical role in protecting drinking water supplies from waterborne infectious diseases and it continue to be used extensively by municipal water treatment plants and micro-systems to disinfect water. There are two reasons for the use of chlorine in the treatment train – the first is to disinfect the water – this is called primary disinfection. The second reason is to ensure that a small concentration of chlorine remains in the water after it is disinfected to ensure that it remains potable as it goes through the distribution system to the end user – this is called secondary disinfection.

The addition of chlorine is a very complex chemical process. When chlorine is used as the primary disinfectant and fed into water, it is first consumed by any organic contaminants present. This is called chlorine demand. The more contaminants in the water, the higher the chlorine demand and therefore, more chlorine must be added to satisfy this demand. In other words, the cleaner the water is when it gets to the disinfection stage, the less chlorine will be required for disinfection.

Once the chlorine demand is met, if chlorine is added to the water as a secondary disinfectant, it will start to form what is called a free chlorine residual. The free chlorine residual is what keeps the water disinfected all the way to the tap, even if it is stored in a tank or cistern for a length of time. But even this chlorine will decrease over time. It is important to know how much water is used in the system on a daily basis, and add (dose) chlorine appropriately so that a free chlorine residual is maintained all the way to the tap. If the residual drops to zero, there is a risk that the water may not be microbiologically safe to drink.

After primary disinfection if the water is not immediately used or travels through a distribution system then it needs to have a secondary disinfectant as described above. Typically this secondary disinfection is achieved by dosing with chlorine. However, sometimes chloramine (chlorine and ammonia) is used as the secondary disinfectant instead of chlorine. In this case the total chlorine residual is measured to ensure adequate protection, rather than the free chlorine residual when chlorine is used. . Chloramines are typically used in municipal treatment systems or in micro-systems that have large distribution systems.

Free chlorine is the amount of all forms of chlorine present in water (i.e., gas (CL2), hypochlorous acid (HOCL) and/or hypochlorite (OCL-)) that is not combined with ammonia or other compounds. Combined chlorine is what results from the reaction of free chlorine with ammonia (i.e., chloramines).Total chlorine is the sum of both combined chlorine and free chlorine. In other words:

Total chlorine = free chlorine + combined chlorine

The concentration of disinfectant residual in potable water should be not less than 0.2 mg/l of free chlorine when using chlorine or 1.0 mg/l of total chlorine when using chloramine.

Chlorine can be measured in a number of different ways. In general, if the chlorine demand for the water is 2.0 mg/L and you dose with chlorine at 5.0 mg/L, the initial free chlorine residual will be 3.0 mg/L. Of course this is just on paper - in the real world, the process is much more complex and will require some form of testing to ensure you have an appropriate residual.

The most common test is the DPD (Diethyl-paraphenylenediamine) colour comparator method. This test is the quickest and simplest method of testing for chlorine residual. The kit used will specify that it will measure either free chlorine residual or total chlorine so read the instructions carefully. With this test, a reagent is added to a water sample in a small vial or bottle. This will result in a reaction with the chlorine turning the sample to a pink or red colour. The intensity of the colour is compared against standard colours on a chart which relate to a known level of chlorine. The stronger the colour, the higher the concentration of chlorine in the water. If the kit is used to determine total chlorine, be sure to follow the instructions carefully and attentively to avoid false or incorrect readings.

Fig 6.1 A DPD Colour Comparator Kit

Did You Know:

It is extremely important for all new or repaired watermains to be disinfected. Disinfection may be done in accordance with the American Water Works Association (AWWA) Standard for Disinfecting Water Mains.

A variation of the DPD method uses a device called a colorimeter to measure the intensity of the sample color directly. This device passes a light through the sample of dyed water and measures the amount of and type of light that cannot pass through. This gives a direct measure of the sample color without having to compare it to a chart by eye.

The second and more sophisticated technique for measuring chlorine levels is the amperometric method. This method uses an electronic meter with a probe that contains a solution of potassium chloride (KCl). As the water travels past the probe, the chlorine reacts with the potassium chloride resulting in an electric current. The probe measures this current to determine the chlorine concentration in the water.

As mentioned in Chapter 5 chlorine reacts with organic matter naturally present in water such as decaying leaves and forms a group of chemicals known as chlorinated disinfection by-products, or CDBPs. The most common of these by-products are trihalomethanes, or THMs, and haloacetic acids, or HAAs. Several studies have found a link between long-term exposure to high levels of chlorination by-products and a higher risk of cancer. Generally, rivers or other surface waters contain more organic matter than wells.

Filtering the source water before chlorination reduces the natural organic matter that reacts with chlorine and will help reduce the level of DBPs in the drinking water. If DBPs such as THMs are a concern for the drinking water system, speak to a water quality specialist and have the water analyzed for disinfection by-products.

For more information on disinfection, please take the time to review the DVD module entitled "Disinfection Processes for Micro-systems"

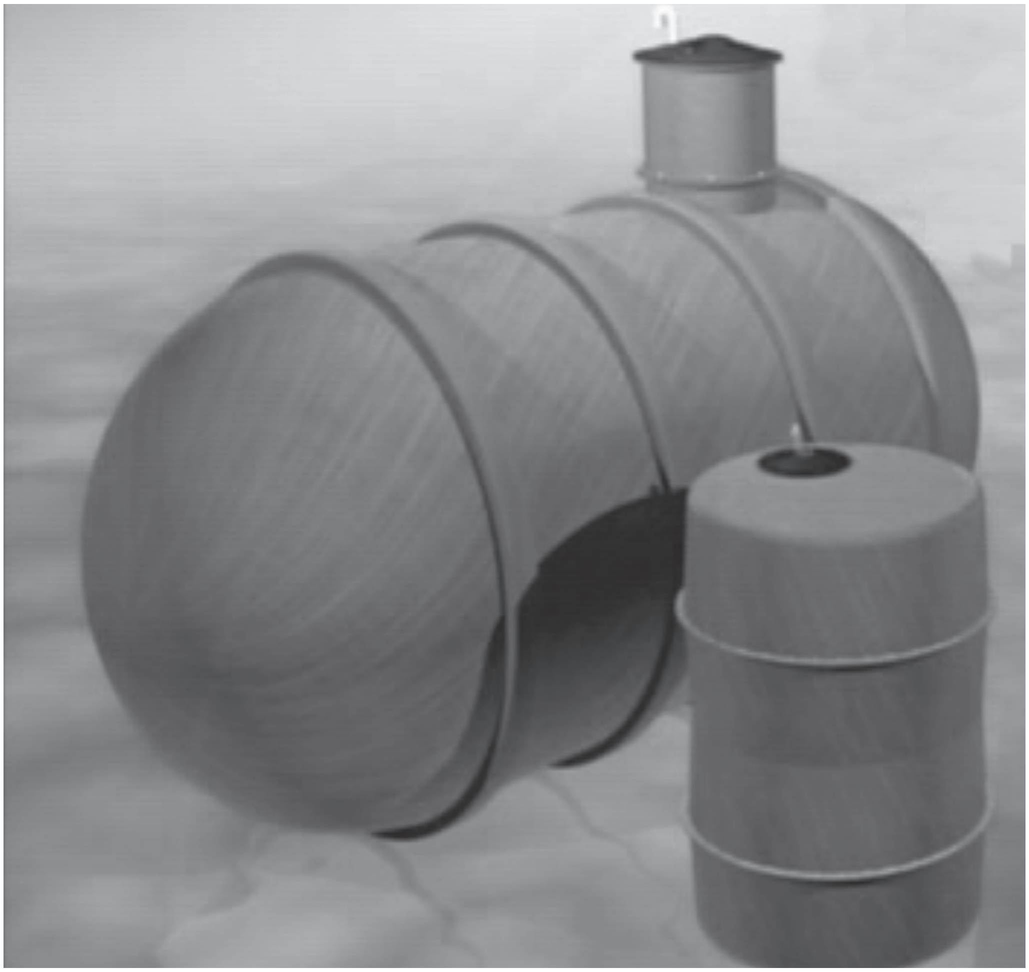
"Disinfection Processes for Micro-systems"

6.3 Drinking Water Storage Tanks

Drinking water storage tanks are commonly used in remote or rural communities (e.g. small isolated locations, First Nations) to store treated water where municipal or on-site sources like wells are not available. Storage tanks are used to store treated water which is supplied via water trucks or in some cases, small diameter low-pressure rural water pipelines. They may also be found in a micro-system that treats water at a rate lower than the supply needed by the system to meet the demand. Drinking water storage tanks are also used on ships in order to provide passengers and crew with drinking water. When used on ships, storage tanks are used to store potable water which is either produced on board, or supplied in bulk while at port.

There are various types and sizes of drinking water storage tanks. The choice of size and type will depend on various factors, including siting (on land, on ship), climatic conditions (indoor or outdoor storage tanks), topographical conditions (above ground, buried) and other factors. All drinking water storage tanks should be constructed with materials that meet NSF/ANSI Standard 61, be watertight, have an access hatch with a watertight lid, a fill pipe and a vent pipe. Storage tanks should be installed in accordance with the manufacturer's instructions. All pertinent codes, legislation and acts (public health protection, construction, plumbing, environmental considerations, etc.) must also be followed.

Fig 6.2 Drinking water storage tanks



For buried storage tanks, it is particularly important to ensure that the access hatch cannot be damaged. Installing some type of barrier protection around the storage tank's access hatch, to prevent damage from vehicles, is one method of increasing their lifespan. All storage tanks should be locked and protected from access by individuals other than qualified persons such as water delivery personnel.

All pipes and plumbing fittings connecting the storage tank to the point-of-use should be constructed in accordance with the National Plumbing Code of Canada. The distribution pipe leaving the tank should have a sampling port or sampling valve to allow for monitoring of water quality.

Proper operation and maintenance of storage tanks is important to ensure continuous delivery of safe drinking water. Storage tanks should only store water that meets the Guidelines for Canadian Drinking Water Quality, and that has been disinfected with chlorine. After storage a sufficient chlorine residual should be maintained to ensure microbiological safety. If the tank remains unused for any period of time throughout the year, the tank may need to be emptied and flushed with chlorinated water before it is put into operation.

Regular inspection, cleaning, disinfection of and repair to the drinking water storage tank is required to avert any serious health and safety risks. Tanks are considered confined spaces – areas whose enclosed conditions and limited access make them dangerous. This means that proper safety procedures must always be used when entering a storage tank. Follow the operation and maintenance procedures provided by your water quality specialist and the manufacturer.

For tanks that are not pressurized, there will always be an opportunity for exposure to air which could encourage microbiological growth on the inside of the tank. One of the recommended practices to prevent microbial contamination is a thorough cleaning using a strong chlorine solution (shock chlorination). Inspect the tank on a regular basis. Vents should be screened to keep pests like birds and rodents from entering the tank. These vents should be clean because a clogged vent could create a vacuum within the tank from normal water use that can collapse the tank. Look inside the tank to make sure nothing is floating on the surface of the water. The bottom of the tank should be visible and it should look clean. Make sure the tank is not rusty, does not have holes, or is cracking. Remember, a leaking tank is a potential source of contamination for the water. Be sure to follow all standard operating procedures for working around and in a confined space. It is also considered a best practice to keep records on storage tank operation, condition and regular water quality monitoring.

For more information on storage tanks, please take the time to review the DVD module entitled

"Drinking Water Storage Tanks"

6.4 Valves and Piping

A micro-system may be rather simple, or it may be a complex system of pipes and valves. Knowing how the system operates in this case can be a challenge. It is important to take the time to learn what each valve in the system does, how it operates and to exercise it (close and open it) on a regular basis to ensure it works when it is needed. Take note of any changes in condition of the pipes and valves in the system. If a valve becomes corroded or starts to leak, do not wait until it fails completely before repairing or replacing it. This might be a "do it yourself" task or one that can be done by a qualified plumber. The same goes for pipes in the micro-system. Pipes do not last forever, and catching a corroded pipe before it ruptures can save time, money, and a lot of headaches. Note that all plumbing work must be done in accordance with the National Plumbing Code of Canada.

When a piece of pipe or a valve is replaced due to breakage or periodic maintenance, it is important to understand what to do before placing the system back in operation. It is wrong to assume that new components are clean components. After changing a system component, especially after an unexpected break or any replacement of underground pipes, the system will need to be cleaned and disinfected. If the section of pipe being worked on was isolated by valves, only that section will need to be disinfected. If this was not possible then the entire system will need to be disinfected. Typically, this process involves first flushing the system with water until it "looks clean" and then disinfecting the system by a process called shock chlorination (sometimes also referred to as hyperchlorination).

Shock chlorination involves adding chlorine to a system at a much higher than normal dose. Shock chlorinating at levels of 20, or even 50 mg of chlorine per litre of water (mg/L) is common practice, depending on the level of contamination in the system. Although it is safest error on the side of higher chlorine concentrations, always keep in mind that any chlorine put into the system will eventually need to be flushed out into the environment. Chlorine can be harmful to surrounding plant and animal life, so use only what is needed. In some cases the water flushed out should be de-chlorinated – a water quality specialist will be able to provide instructions on how to do this. Check with a water quality specialist or local waste water authority before sending a large quality of chlorine down the drain or to a septic field (in the case of a septic tank), as the chlorine may cause harm to the system or the environment.

To shock chlorinate, the first step is to calculate the required dosage. For this example, assume the desired chlorine concentration is 20 mg/L. Suppose that the section of pipe that needs to be disinfected holds 100 litres of water. For a concentration of 20 mg/L pure chlorine needs to be added at the rate of 20 mg for every litre of water. Therefore this will require the addition of 20 X 100 or 2,000 mg or 2 g of chlorine to that section of pipe. But chlorine is not supplied pure – it is generally supplied in a liquid (hypochlorite) solution which may be only 5% (0.05) or 10% (or 0.1) chlorine by volume. Assuming that 1 gram of liquid chlorine is about equal to 1 ml, then 2 ml (2 g) of pure chlorine is requires, or 2/0.1 = 20 ml of 10% hypochlorite solution (a review of Chapter 4 may be beneficial in order to understand this example).

Once the correct dosage has been determined, add it to the system and let the water dosed with chlorine sit. Chlorination takes time to work. Depending on the dose, the chlorine and water mixture may need to stand in the system for 2 - 24 hours (the higher the dose, the shorter the wait). After about 2 hours, take a sample to see how much chlorine residual remains in the system. If the residual has dropped below 10 mg/L at this time, the system will need to be flushed and the chlorination cycle started again – the repaired section was too dirty and the chlorine demand was therefore too high. If at the end of 2 hours the chlorine residual is 10 mg/L or greater, let the system sit another 2 hours and then flush the lines until there is no longer any smell of chlorine. Before bringing the system back on line, take a water sample and test it for the presence of coliform bacteria. See Chapter 8 on Monitoring and Testing for more information about how to take a sample and Chapter 9 on Analysis and Reporting for information about how to interpret the results. If the test is negative, the system can be returned to service.

Did You Know:

Nearly 80% of Canada's population is classified as "urban," and the distribution of water to this group of users is a major task.

6.5 Cross Connection and Backflow Prevention

The water treated in a micro-system must remain potable. Even in the smallest micro-systems the possibility of a cross-connection or backflow event is always there.

A cross-connection is any direct connection of the treated water supply to any source of pollution or contamination. This can include direct connections to irrigation systems, storm sewer lines, septic system lines, or even a garden hose left sitting in a bucket of water, a pond or a puddle. Note the use of the word "direct" in each of these statements. Obviously irrigation systems and garden hoses need to be connected to the water supply, but there must also be measures in place to prevent potentially contaminated water from these systems from entering the drinking water supply. Such a flow of contaminated water into the potable supply is called a backflow event. Backflow events can be divided into two categories: backpressure and back-siphoning.

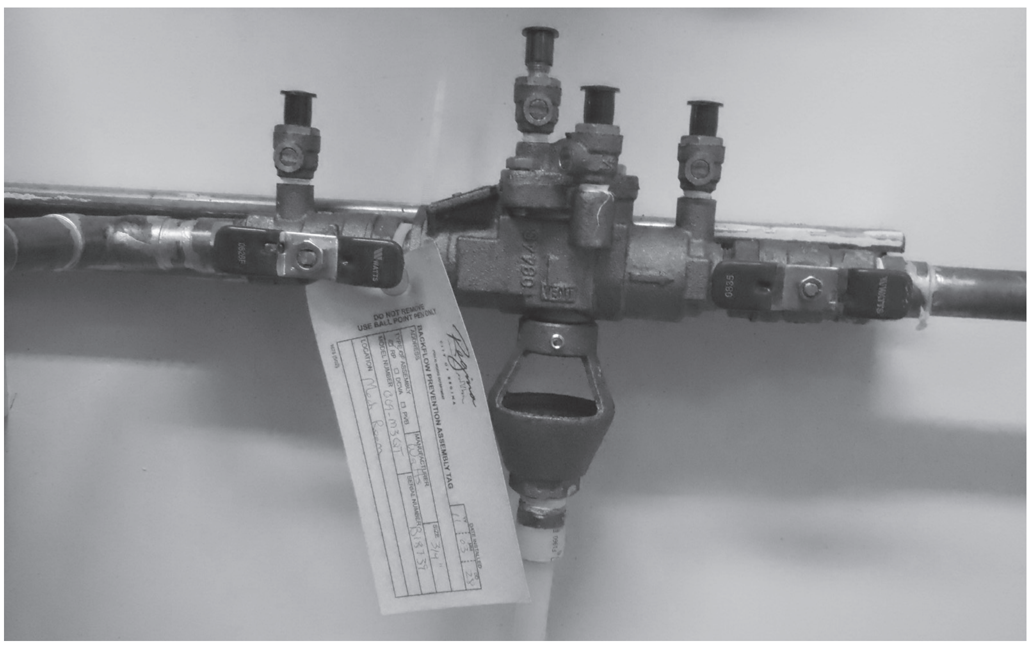
Backpressure takes place when something connected to the water system overcomes the pressure in the system and pushes water through the pipes in a reverse direction. An example of this might be an improperly plumbed boiler that builds up too much pressure and contaminates the system with water from the boiler tank.

Back-siphoning takes place when the system experiences a sudden loss of pressure and water from a contamination source is sucked in a reverse direction by the vacuum created. An example of this might be a garden hose left submerged in basin of water that contains water and soap or in a puddle. A sudden pressure drop in the system will draw water up through the hose that is submerged in the basin or puddle and into the potable water piping.

Backflow prevention involves any step that is taken to prevent a backflow event from taking place. This can be broken down into two sets of prevention activities: avoiding cross-connections in the first place, and installing protection devices where cross-connections are possible.

Avoiding cross-connections is usually as easy as making sure that all plumbing for the system is done by a licensed professional. These individuals are trained to recognize cross-connections and can help evaluate the system for potential hazards. Additionally, making sure that the end of any pipe (including hoses) connected to the system is NOT submerged in ANY source of water. As described in the back-siphoning example, submerging the end of a pipe or hose is creating the potential for a backflow event to happen.

Fig 6.3 A Backflow Prevention Device



Many devices exist to help prevent backflow evts. By far the most effective of the backflow prevention devices is an air gap. Simply stated this involves placing a physical separation between the end of a potable piping system and the fixture or device receiving the water supply (e.g. sink) . A kitchen faucet is a good example. The end of the faucet is far from the rim of the sink. Even if you filled the sink to the top, it would still be far from reaching the potable piping itself. But now imagine connecting a hose onto the end of the faucet and letting it hang into the basin of water. Now, the “gap of air” is no longer there, and all the ingredients for a backflow event are in place.

It isn’t always possible to use an air gap to prevent cross-connections and in these cases mechanical devices are used to ensure cross-connection does not occur. These devices must be designed and installed according to the National Plumbing Code of Canada. Some devices are testable and others are not testable. Testable devices are easily identified by the presence of test ports. They must be tested every year by a cross-connection control specialist. Non-testable devices must be installed by a licensed plumber and must be maintained as part of the distribution system. A water quality specialist or a cross-connection control specialist can provide more information.

Hiring a licensed cross-connection control specialist is the best way to ensure the water supply system is protected from cross-connections that can lead to backflows. They are trained to recognize cross-connections and can evaluate the system for potential hazards.

6.6 Trucked Water

In some situations a micro-system may not have access to municipal water or an on-site source like a well. In these situations the water is delivered on a regular basis by a commercial water hauler. For trucked water, the sanitary condition of the transportation equipment is critical since all of the water hauling equipment essentially becomes a part of the distribution system. The tank or container (called a water tank hereafter) used to carry potable water including the pumps, hoses and other equipment used to deliver the potable water must be maintained and operated under clean and sanitary conditions to reduce the potential of contamination. The water tank must not be used to transport other liquids or material that could contaminate that water. The water tank must not have been used previously to transport a noxious, hazardous or toxic substance.

> **Did You Know:**
>
> Lead can be leached into the drinking water supply from lead service lines (water pipes that link the house to the main water supply), lead solder in plumbing, or brass fittings such as faucets.

The water tank should be constructed of materials that meet NSF/ANSI Standard 61 (which covers materials acceptable for use in potable water systems) and should allow easy access for cleaning. Any visual inspection inside of the water hauling tank should follow all standard operating procedures for working around and in a confined space. It should be disinfected on a weekly basis. When the water tank is filled or emptied, precautions must be in place to prevent backflow or back-siphoning as discussed in Section 6.5 (e.g., through an air gap or double-check valve assembly).

The water tank connections must be constructed and protected so that contaminants cannot enter the water supply and so their nozzles are kept free of ice build-up during the winter. They should be closed except when filling or cleaning the tank.

The water being delivered should be tested to ensure that a minimum of 0.2 mg/L free chlorine is present.

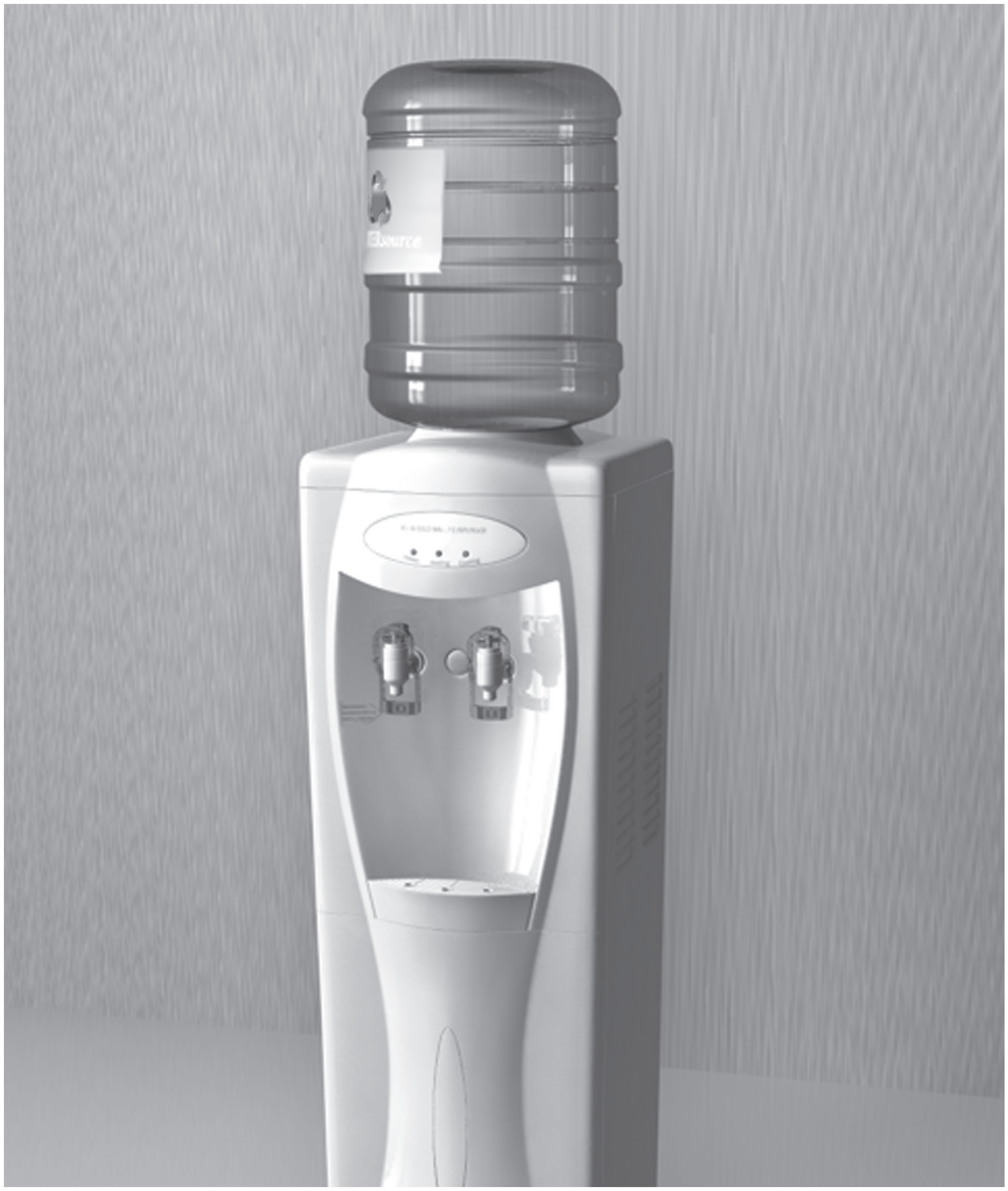
As discussed in Section 6.3 (drinking water storage tanks), it's important to carefully maintain and clean the receiving tank. Ensure that it is never used for any purpose other than potable water storage. Clean and disinfect it regularly, before its first use, and after any repair or maintenance. Finally, ensure to regularly monitor the water quality in the storage tank for *E. coli* and total coliforms as outlined by Health Canada.

> **For more information on trucked water, please take the time to review the DVD module entitled**
>
> "Drinking Water Storage Tanks"

6.7 Bottled Water and Dispensers

Regulations governing bottled water are different from the guidelines governing production of treated water in a micro-system. For an overview of the regulations associated with distributing bottled water as a source of drinking water, turn to Section 2.7 of this manual.

Fig 6.4 A typical water dispenser



Even if bottled water is delivered to a facility free from contamination, the process of distributing that water requires that steps are taken to ensure it is potable when it is dispensed. It is necessary to clean and disinfect dispensers with a chlorine based solution on a regular basis. Regular household bleach (unscented) can be used to do this, as it is cheap, handy, and effective. Cleaning and disinfecting the dispenser by chlorinating at a concentration of 10 mg/L is a good way to keep the dispenser clean and the water safe. Step by step instructions on how to clean a bottled water dispenser are available from Health Canada and have been included in Appendix C.

For more information on bottled water and dispensers, please take the time to review the DVD module entitled

"Bottled Water: Selection and Application in Federal Facilities"

6.8 Notes on Chapter 6

7.0 Knowing Your System from Source to Tap

7.1 Introduction

As mentioned in Chapter 1, Canada supports the multi-barrier approach to providing safe drinking water. This includes barriers such as those physical barriers found in the treatment process, training to understand the treatment process and, the operation and maintenance of the treatment train and the distribution system. Another important barrier is knowledge – knowledge of the complete system from the source of the raw water right to the point where the treated water is used at the tap – source to tap. This chapter discusses three important tools used to develop that knowledge: a vulnerabilities assessment, a sanitary survey and a baseline chemical analysis. In addition, the importance of knowing your source and how to protect it is discussed.

A vulnerabilities assessment, sanitary survey and baseline chemical analysis should be conducted every 5 years, or when there are significant changes to the treatment system, land use, or other conditions which may adversely affect water quality. This will help to determine if changes are required to the monitoring program.

It is recognized that, in the case of unique facilities or situations such as systems in remote locations that serve very few individuals, it may not be physically or economically feasible to conduct each of the assessment/survey/analysis components every 5 years once the first ones have been completed. In these cases, every effort should be made to, at a minimum, do the vulnerabilities assessment and sanitary survey every 5 years, to determine if any changes have occurred that might require changes to the ongoing monitoring program.

Although the assessment/survey/analysis may only be done every five years, departments should endeavour to be aware on an ongoing basis of any changes at a site that could impact on water quality.

7.2 Vulnerabilities Assessment and Risk Management

A vulnerabilities assessment has three major components. These are:

1. Learning where your source water comes from.
2. Identifying potential hazards.
3. Determining your source's susceptibility to these hazards.

In the following sections, we'll look at these three components in more detail.

7.2.1. Knowing Your Source

The land area that contributes the source water and potential contaminants to the water supply must be defined and mapped (delineated). This will allow the team responsible for managing the facilities' drinking water to focus their efforts within a defined area and respond appropriately to incidents or emergencies. This is true for both surface water and groundwater supplies. For a surface water supply, the delineated area is known as a watershed. For a groundwater supply, the area where water enters from the surface, called the recharge area, may be in the watershed where the well is, or it may be quite distant from the well.

This component of the vulnerabilities assessment should include identifying the characteristics of the water source, geology, and features of the surrounding area to determine what may be in the water and what could become a concern in the treated drinking water. For example, dissolved organic material in surface water may lead to harmful disinfection by-products when the water is chlorinated.

Many methods exist to delineate watersheds and aquifers, ranging from simplistic terrain mapping to complex mathematical models requiring significant amounts of field data. The decision about which method is required will depend on source water characteristics and the relative risk of contamination.

7.2.2. Identifying Hazards

The next step is to identify the potential hazards to the water source within the delineated area. Hazards can be identified in a number of ways such as inventories of land uses and contaminant sources, evaluations of watershed and/or aquifer characteristics, and monitoring data related to source water quality and quantity.

In the vulnerabilities assessment, it is essential to identify hazards, as they influence the type of treatment required as well as any response required in the watershed/aquifer. For instance, a watershed where the primary hazards come from industrial effluent will be managed differently than one where the main threat to water quality is high nutrient levels due to agricultural activities.

Did You Know:

In First Nations communities located south of 60°N, the responsibilities for drinking water are shared between First Nation Band Councils, Health Canada, and Indian and Northern Affairs Canada (INAC). In First Nations communities located north of 60°N, responsibilities for drinking water generally rest with the territorial governments.

7.2.3. Determining Susceptibility to Hazards

Once the hazards have been identified within a delineated area, the vulnerability of the source to the hazards needs to be determined. The potential impact of the hazards on human health also needs to be determined. The results of these assessments influence the treatment required to ensure the water is safe and aesthetically-pleasing for human consumption. They also guide best management practices on the land affecting the watershed / recharge areas by identifying the quantity and quality of the water, and its potential vulnerability to degradation. Assessment results may be extremely useful to other agencies, local industry and community water users who share common interests.

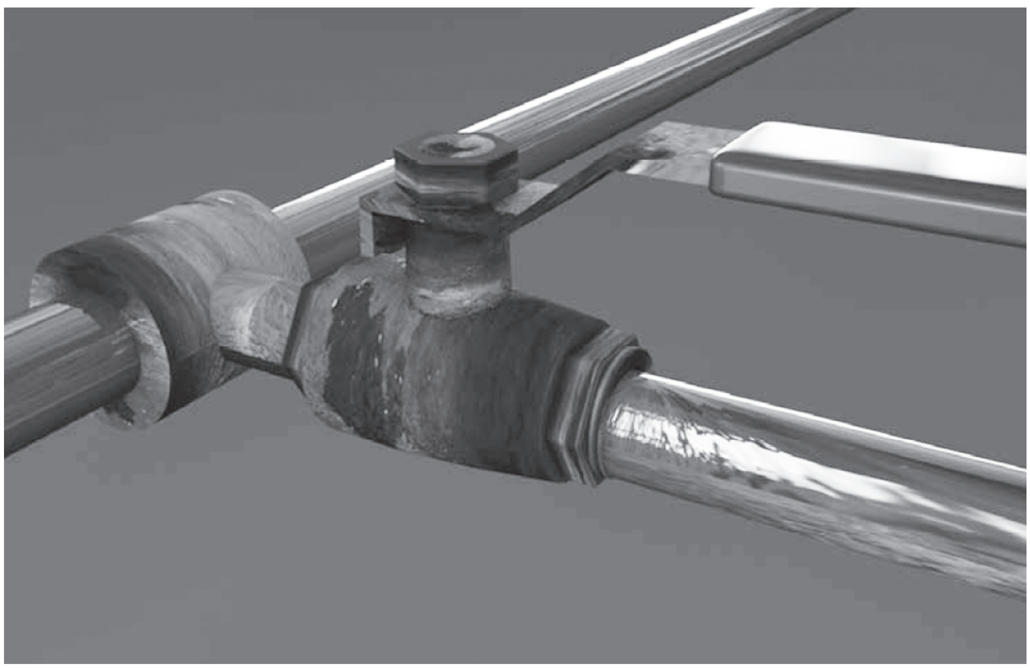
In assessing vulnerability or risk, the data from the identification of hazards needs to be complemented with monitoring data to get an idea of the concentration at which the contaminant is found in the source water and whether this concentration fluctuates over time. Fluctuations in physical parameters such as pH and turbidity should be noted. These types of data are gathered through long-term monitoring programs. While concentrations can be modeled, it is preferable to obtain real-time, site-specific monitoring data.

7.3 Sanitary Survey

A sanitary survey is an on-site review, from intake to tap, of the water system's raw water quality, the source water intake facilities, treatment equipment and distribution system, operational procedures in place and maintenance records. The purpose of the survey is to evaluate the system's ability to adequately treat the source water in order to produce and deliver safe drinking water. The extent of the sanitary survey will vary depending upon the type and complexity of the system.

Monitoring of the quality of a water supply source can identify changes in the water quality over time, which can help in detecting contamination problems and in determining whether they have happened at the source, during water treatment, or in the distribution system. However, it may not be possible to take more than a few samples, and consequently the results of any analysis may not be representative of the water supply system as a whole. A sanitary survey is an essential complement to water quality monitoring. Together they allow for an overall appraisal of the many factors associated with a water supply system, including the treatment and distribution systems. Combined with water quality monitoring, a sanitary survey provides a range of information which will help to locate potential problems. This information may identify failures, issues that should not normally occur, operator errors, and any deviations from normal that may affect the production and distribution of safe drinking water.

Fig 7.1 Monitoring for corroded pipes and fixtures



7.4 Baseline Chemical Analysis

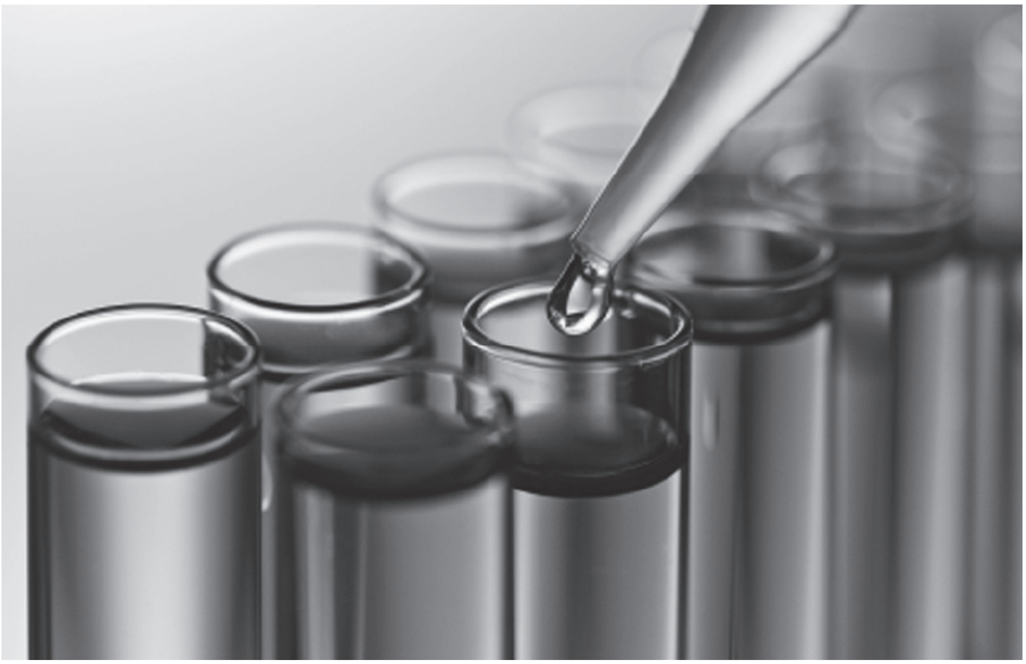
The baseline chemical analysis, in combination with the vulnerabilities assessment and sanitary survey, should be the basis for the monitoring program (i.e. a list of substances that should be routinely monitored). Based on the monitoring program, departments should be able to develop an appropriate process to treat the water to meet the needs of the facility.

The monitoring program for chemical contaminants specifically identified by the baseline analysis should include, at a minimum, annual monitoring for surface water sources and monitoring every 2 years for groundwater sources, unless otherwise specified in the Guidelines for Canadian Drinking Water Quality.

As a safeguard, it is also recommended that a baseline chemical analysis be conducted every five years, unless a sanitary survey or vulnerabilities assessment indicates that this type of analysis should be done more or less frequently.

If particular substances are consistently absent from a water system, the frequency of sampling of those substances can be reduced. As well, where water supplies are obtained from sources that are not likely to be contaminated by human activities (industrial and agricultural wastes, municipal waste water), a baseline chemical analysis may be needed only to identify potential new drinking water sources and only occasionally thereafter.

Fig 7.2 Baseline chemical analysis provides input to the monitoring program



For drinking water supplied by a municipality, the baseline chemical analysis would include an analysis of the water received to determine if there are any concerns with the supply that require further treatment or whether an alternative source should be used. Federal departments and First Nations communities should request water quality testing results from the municipality. This information will indicate which substances are being tested for and analyzed.

7.5 Source Protection

The vulnerabilities assessment will have identified the water source and the watershed area (for a surface water source) or the recharge area (for a groundwater sources). Identifying recharge areas for shallow groundwater may be easy whereas identifying those areas for deep wells may be extremely difficult. Once recharge areas have been identified it is important to protect the area to reduce the potential for contamination of the groundwater. The vulnerabilities assessment will also have identified potential risks of contamination to the source water. As a result, your water quality specialist may have developed a water source protection program.

Did You Know:

The purpose of a watershed/aquifer management plan is to implement management actions that serve to maintain or improve the quality of source waters.

Water source protection is a critical component of the multi-barrier approach to safe drinking water. It is an important activity for surface water sources and shallow well sources. Deep wells may have recharge areas very distant from the well, and it may be very difficult to determine where the surface recharge area for the aquifer is located and be a part of protecting the surface source of the water. But even deep aquifers can become contaminated so it is still important to monitor the source water quality.

There are four elements to source water protection: establishing objectives, monitoring source water quality, developing and maintaining partnerships with other same source users, and public awareness.

- Establishing guidelines provides targets to meet.
- Monitoring helps to determine if the targets are being achieved.
- Creating and maintaining partnerships and improving public awareness develops the support needed to manage the difficult task of source water protection.

One of the easiest methods to provide potable water is to start with a water source that has very few contaminants. Source water protection (SWP) is a method to ensure everyone in the watershed works together to reduce the contaminants introduced into the water source. It is a large task requiring the cooperation of many different people and agencies, and requiring compromises based on the assessment of the risks involved.

Fig 7.3 Source protection includes getting other interested parties involved

Developing a source water protection plan is not usually the responsibility of the micro-system operator. A water quality specialist, water quality engineer, or environmental health officer will normally lead a team to develop a protection plan. The leader of the team will look for input and participation from a variety of sources, which usually includes but not limited to the facility manager, departmental experts, the micro-system operator and resources from the community if required.

Source water protection depends on knowledge of the water supply system, from source to tap. The SWP plan brings together elements from the vulnerabilities assessment, the sanitary survey and the baseline chemical analysis. It's a complicated task that often seems daunting, but it's critical as one of the multiple barriers that helps to provide safe drinking water.

7.6 Using Municipally Supplied Water

Often the source of potable water for facilities owned and operated by the federal government is the local municipality. The quality of this water is the responsibility of the owner of the water system, not the local municipality.

In order to ensure the water received is of acceptable quality, federal water quality managers and, in the case of First Nations communities, water treatment plant operators and technical support staff, should be in regular contact with the municipality. Maintaining solid relationships with key contacts in the municipality's drinking water program is important in order to be kept informed of any water quality or quantity issues that could affect the health of consumers. The municipality's reports describing water sampling results should be periodically reviewed in order to keep informed of the water's changing characteristics and to understand the quality of drinking water entering the facility's distribution system or building plumbing.

In cases where water is received from a municipality, it may be possible to negotiate to have the federal building designated as a routine municipal water sampling location. If this is not possible, water samples should be collected at the point closest to the intake of municipal water to the building in order to establish a baseline understanding of the water quality.

Did You Know:

The watershed/aquifer plan is an innovative management process that examines all factors affecting the entire watershed (such as air, land, and water resources) while focusing on the highest priority problems.

7.7 Notes on Chapter 7

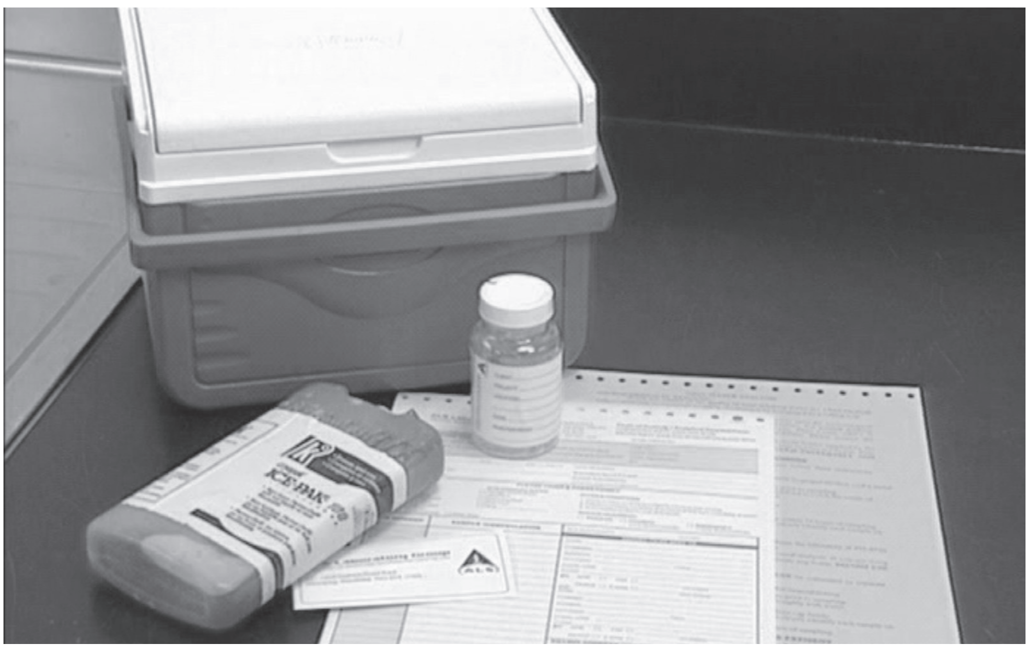
8 Monitoring and Testing

8.1 Introduction

The multi-barrier approach to providing safe drinking water is based on ensuring that several barriers are in place to prevent contaminants from ending up in the water that is consumed. These barriers include familiar physical barriers such as source protection and treatment processes. Another important barrier is the regular monitoring and testing of the water. A scheduled program of monitoring will provide test results to indicate the physical processes are working and the water is potable. Without monitoring and testing, there is no way of knowing whether or not the system is producing water that meets the federal guidelines for safe drinking water.

The *Guidance for Providing Safe Drinking Water in Areas of Federal Jurisdiction* document provides the framework for the responsibilities and duties of those involved with the provision of safe drinking water. Based on this guidance, a water quality expert will develop a monitoring program for the micro-system. As this monitoring program is one of the protective barriers, it is important to follow both the schedule and the procedures for monitoring the water quality.

Fig 8.1 A Sampling Kit



8.2 When You Should Sample

All federal facilities require some kind of monitoring plan. The monitoring program for all federal drinking water systems, regardless of their size, should be developed based on the information provided by a vulnerabilities assessment, a sanitary survey and a baseline chemical analysis. Each of these components should be conducted by a competent expert in the appropriate field. This information will be used, along with the *Guidance for Providing Safe Drinking Water in Areas of Federal Jurisdiction* to develop a monitoring plan. This plan will specify when and how often samples will need to be taken.

The monitoring plan should be reviewed every 5 years, or when there are significant changes to the treatment system, land use, or other conditions which may adversely affect water quality. The vulnerabilities assessment, sanitary survey and baseline chemical analysis should be re-visited to determine if changes are required to the monitoring program.

For very small systems which serve very few individuals, and where the supply has a history of producing water of high bacteriological quality, it may be possible to reduce the number of sampling events. In such cases, samples should be collected and analyzed when the risk of contamination is highest and correspondingly there is potential health risk. This would include spring thaw, heavy rains or dry periods, when changes are made to the plumbing system or when a noticeable deterioration in water quality occurs. It is important to consult with a water quality specialist when reducing the frequency of sampling.

8.3 What to Sample

Did You Know:

Tests for operational monitoring do not need to go to an accredited lab.

The most significant parameters to be monitored relate to the microbiological quality of drinking water. The presence of biological activity can result in serious health hazards. Indeed, ensuring the microbiological quality of drinking water is the highest priority for protecting public health. The indicator organisms total coliforms and *E. coli* are the microbiological parameters that need to be monitored. The presence of *E. coli* in the water indicates that there has been faecal contamination of the water. The presence of total coliforms in the water indicates that in the case of a non-disinfected system there is microbiological contamination and in the case of a disinfected system the disinfection system is not properly treating the water.

Micro-system operators, water quality specials, Environmental health officers or those responsible for providing safe drinking water may also choose to test for Heterotrophic Plate Count (HPC) bacteria in order to better understand the overall quality of the drinking water. If the HPC increases over baseline conditions, this indicates an increase in microbiological activity in the system. Note that unlike total coliforms and *E. coli*, HPC is not a suitable indicator of the microbiological safety of the water.

Federal facilities and facilities in First Nations communities that treat and supply their own drinking water must monitor their water for turbidity as it is a strong indicator of water quality. It is also an important indicator of treatment efficiency and filter performance. Turbidity can be measured by on-line turbidity meters or by using a test kit. Turbidity samples must be tested on-site by a trained person. Turbidity is measured in Nephelometric Turbidity Units (NTU), and the allowable value for turbidity will be established by your water quality specialist.

Turbidity in water is caused by suspended and colloidal matter such as clay, silt, fine organic and inorganic matter, plankton and other microscopic organisms. Control of turbidity in water supplies is important for both health and aesthetic reasons. Water that has high levels of turbidity is not only unappealing to the consumer, but the particles that cause turbidity can also interfere with disinfection and can be a source of disease-causing organisms.

If the micro-system incorporates chlorine as either a primary or secondary disinfection, it is important to monitor the free chlorine residual. Like turbidity, chlorine residual in a micro-system is a strong indicator of the safety of the water or potential problems relating to microbiological integrity. The chlorine residual should always be within the range specified for the system, at all points in the system.

The initial baseline chemical analysis may have identified certain specific parameters that are present in the source water that are health concerns, such as arsenic. Or it may have identified parameters that are operational or aesthetic concerns, such as iron and colour. These parameters should be analyzed in every sample to ensure that the treatment system is performing properly.

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The initial baseline chemical analysis may have identified certain specific parameters that are present in the source water that are health concerns, such as arsenic. Or it may have identified parameters that are operational or aesthetic concerns, such as iron and colour. These parameters should be analyzed in every sample to ensure that the treatment system is performing properly.

8.4 Where to Sample

Samples should be taken at the point where the water enters the system (to monitor the quality of the untreated source water) and from representative points throughout the potable water distribution system, although not necessarily the same points on each occasion. For very small systems where there is little or no distribution system, samples should be taken as the water leaves the treatment system.

If the water supply is obtained from more than one source, the location of sampling points in the distribution system should ensure that water from each source is periodically sampled. The majority of samples should be taken in potential problem areas: low-pressure zones, reservoirs, dead ends, areas at the side of the system farthest from the treatment plant and areas with a poor previous record. Facilities that receive municipal water should collect samples at the water main or point of entry to the building, in the building's plumbing system, and in other locations identified in the vulnerabilities assessment and sanitary survey.

Sampling locations within the building's plumbing system could be randomly selected at first, to find "hot spots" – locations where water quality is not as good as it is leaving the treatment system. Over time, these "hot spots" could become regular sampling locations. Samples should occasionally be collected from other locations in the building. The sampling for chemical analyses will differ from the microbiological sampling with respect to location, frequency and how to sample. Check with a water quality specialist to ensure that sampling is done correctly for each type of analysis.

8.5 How to Sample

> **Did You Know:**
>
> Symptoms from drinking water that has been contaminated from *E.coli* can appear as soon as a few hours or as long as a month, after ingesting the *E.coli* contaminated water.

When testing for contamination, it's critical that the sample taken is representative of the water in the distribution system. Following the procedures below will help ensure that the samples taken and sent to the lab are free from any introduced contaminants. Samples will usually be taken from an accessible water tap.

As sampling procedures may change over time, check with a water quality specialist to ensure the procedure that is being followed to collect a sample is correct.

When testing for contamination, it's critical that the sample taken is representative of the water in the distribution system. Following the procedures below will help ensure that the samples taken and sent to the lab are free from any introduced contaminants. Samples will usually be taken from an accessible water tap.

As sampling procedures may change over time, check with a water quality specialist to ensure the procedure that is being followed to collect a sample is correct.

Microbiological Sampling.

1. Remove aerators, hoses, screens, or treatment devices attached to the faucet (they can harbour bacteria).

   If the environment is dirty, you may want to dip the faucet in a solution of unscented household bleach to ensure that live microbiological material from the faucet doesn't accidentally fall into the sample. Make this solution from 2ml bleach per litre of water. Note that sterilizing the faucet is not a mandatory part of the sampling procedure, but might be advisable if the faucet is quite dirty.
2. Wash your hands or use single-use sterile gloves.
3. Read and follow exactly the instructions that come with the sampling kit supplied by a laboratory. Select the appropriate sampling bottle. Some kits come with a powder in the sample bottle. This powder is Sodium Thiosulphate. Do not rinse or pour this powder out as it is needed to neutralize the chlorine in the water.
4. Sample using the cold-water tap only. Open the tap fully and allow the water to run for two minutes before taking sample.
5. After the water has run for 2 minutes, reduce the flow to the diameter of a pen.
6. Remove the cap from the bottle, but don't put it down. Fill bottle to the fill line marking, taking care not to touch the inside of the cap or bottle threads and don't let the bottle touch the tap.
7. Replace the cap on the sample bottle, and tighten it firmly so that the sample is sealed in the bottle.
8. Immediately wipe the outside of the bottle dry and fill out all the required information on the bottle's label. Then complete the laboratory's chain of custody form, including signing it where necessary. Keep one signed copy of the form.
9. Place sample and the chain of custody forms in the re-sealable plastic bag provided by the laboratory. Place the bag in the shipping container, usually a cooler, along with an ice pack to keep the sample cool.
10. In order for the sample to be tested, it needs to be kept cool until it reaches the testing laboratory. The sample needs to arrive at the laboratory within 24 to 48 hours.

For more information on how to take a water sample, please take the time to review the DVD module entitled

"Procedures for Conducting Water Sampling in Federal Facilities"

8.6 Where to Send Samples

When testing and analysing water samples (with some exceptions, such as *E. coli* and total coliforms, under the conditions outlined below), federal departments or, in the case of First Nations communities, managers and operators of facilities and technical support personnel, must use a laboratory accredited by one of the following:

Canadian Association for Laboratory Accreditation Inc. (CALA),

Standards Council of Canada (SCC), or,

Programme d'accréditation de laboratoires d'analyse environnementale (PALAE) (Quebec).

SCC/CALA defines accreditation as "the formal recognition of the competence of a laboratory to carry out specific tests." Accreditation is awarded to a laboratory for each individual test, for example, the analysis of pesticides in drinking water.

Canadian missions in other countries should use laboratory services accredited as meeting the International Organization for Standardization (ISO) standard IEC17025-1999, General Requirements for Competence of Calibration and Testing Laboratories.

A list of accredited laboratories worldwide can be found at the website of the International Laboratory Accreditation Cooperation (ILAC). The list of laboratories by country can be found in the Membership area.

In the case of sampling and testing for some microbiological parameters (*E. coli* and total coliforms), managers and/or operators of facilities may allow trained personnel to use portable test kits rather than an accredited laboratory. However, in order to ensure quality control, a minimum of 10% of all samples must be sent to an accredited lab for analysis or, if this is not physically possible, additional samples should be analyzed using the kit for quality control purposes.

Portable test kits can be used to sample a variety of parameters, such as the microbiological parameters mentioned above or other parameters like turbidity, pH or chlorine. The supplies that are used with portable test kits may have an expiry date, so it is important to ensure that all supplies being used are not past their expiry date. All instruments used should be calibrated for accuracy, and if single use type test kits are being used each batch of new kits should be tested for accuracy.

Test kits should meet minimum requirements for accuracy and detection (sensitivity) for the contaminant of interest.

Note: Test kits are not as reliable as laboratory testing and should only be used as an indicator of problems and not as a means to fully diagnose them. If a test kit indicates a possible contamination, further laboratory testing is required.

Did You Know:

Beaver fever is caused by *giardia*, a instetinal parasite that can affect mammals and humans.

8.7 Notes on Chapter 8

9 Analysis and Reporting

9.1 Introduction

The results of a laboratory analysis of a water sample will indicate what is in the water. However, it is up to the water quality team to interpret these results and decide what actions, if any, are needed. Who interprets the results and who takes any action required will vary – in some cases the water quality specialist will interpret the results and advise the person responsible for operating and maintaining the system what action to take. In other situations the micro-system operator may receive the laboratory report and use operating manuals to help with the interpretation of the analysis and standard operating procedures to determine what action to take.

9.2 Reading a Laboratory Report

A laboratory report contains not only the results of the water sample analysis, but also all the information that was recorded on the sample bottle and the chain of custody form that was sent in with the sample. It's important to take the time to review this information to ensure that it was transferred accurately onto the laboratory report.

At the top of the report is the laboratory's name and contact information. The lab may also list its accreditations. As indicated in Chapter 8, laboratories are accredited not by their name, but by the tests they have been accredited to carry out.

Also near the top appears all the information about the sample. This will include the name of the person who sent in the sample, the location of where the sample was taken, the date it was taken and the date the lab received the sample. It will also contain the name of the sample that was provided, for example, "kitchen sink". If a sample number was written on the sample bottle then that information should also appear on the report.

The main body of the report will contain a number of columns, which will usually include Parameter (Analyte), Units, Result, Detection Limit (DL) and Method.

The Parameter column indicates what the sample was analysed for. This will include the list of parameters that was specifically requested. In some cases, laboratories have standard test suites for potable water, so the list will include all the parameters in that test suite if that is the way the analysis of the sample was requested.

The Units column indicates the units that the test results and the detection limit are expressed in. The most common units are milligrams per litre (mg/L) or sometimes micrograms per litre (μg/L). As discussed in Chapter 4, 1 mg/L is equivalent to 1 part per million (ppm). So the units may also be expressed in ppm. In the case of tests for microorganisms, such as total coliforms or *E. coli*, the units are the number of Colony Forming Units per 100 ml (which is abbreviated to CFU/100mL). If the laboratory uses a presence / absence method to analyse for a particular parameter, the units will indicate P/A.

The Result may indicate an exact number – this is the result of the analysis showing the actual concentration of the substance in the water sample. If the result indicates "<" and then a number, this indicates that the concentration of the substance in the water was below the detection limit of the equipment the laboratory uses to test for the substance in accordance with the standard method for the test. The Detection Limit column indicates the detection limit of the equipment used by the laboratory for each individual parameter.

The Method column indicates the standard method that the laboratory used to analyze the sample for each specific parameter.

9.3 Test Results

Did You Know:

At elevations greater than 2,000 m water boils at slightly loxer temperatures. Therefore water should be boiled for two minutes to kill disease causing organisms.

As mentioned above, the analysis of the test results may be done by the water quality specialist or in some cases it may be done by the micro-system operator. The first step is also described above – to review the sample information to verify that the test results that have been provided are for the micro-system. The next step is to carefully compare the results of the sample analysis against the Maximum Acceptable Concentration (MAC) in the current Guidelines for Canadian Drinking Water Quality. This information can be found on the Health Canada website. It can also be obtained by contacting a water quality specialist. As the parameters that are tested for will remain the same over time, the operation and maintenance manual prepared by a water quality specialist for the micro-system should also indicate what parameters are to be analyzed and their corresponding MACs.

The first parameters to consider are the microbiological parameters – total coliforms and E. coli. The guideline for both these parameters is 0 CFU/100mL.

For very small systems with little or no distribution system, the following guidance could apply:

No sample should contain E. coli. As discussed in Chapter 8, 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.

No sample should contain total coliforms. The presence of total coliforms does not necessarily mean a boil water advisory must immediately be issued; however, re-sampling and/or other corrective actions should be taken.

In non-disinfected well water, the presence of total coliform bacteria in the absence of E. coli indicates the well may be prone to surface water infiltration and is therefore at risk of faecal contamination. In disinfected water systems, the presence of total coliform bacteria indicates a potential failure in the disinfection process. In both disinfected and non-disinfected systems, total coliform detection may also indicate the presence of a biofilm in the well or plumbing system. A biofilm is a community of micro-organisms attached to a solid surface, for example the inside wall of a pipe, in an aquatic environment.

Even though the biofilm itself is not a health concern, it could interfere with analytical testing. Also, it could eventually impede water flow, potentially leading to deterioration of aesthetic water quality and ultimately taste and odour problems.

Boil Water Advisories

As discussed above, when considering microbiological contamination, boil water advisories should be issued - or an alternative safe source of drinking water used - in the following cases:

- If the water supply is not disinfected and is contaminated with either total coliforms or *E. coli*.
- If the water supply is disinfected and water leaving the treatment system has no chlorine residual or is contaminated with either total coliforms or *E. coli*.

A boil water advisory tells people to boil the water before they use it to drink, prepare food and beverages, make ice cubes, wash fruits and vegetables or brush their teeth. People must understand that, until further notice, they cannot drink or use water unless it has been boiled.

It is recommended that a boil water advisory be used only as a temporary measure while problems are being identified and corrected.

If total coliforms are present with no E. coli present, re-sampling and corrective action should be taken. These corrective actions could include shock chlorination (the addition of a strong solution of liquid chlorine into a drinking water system to reduce the presence of microbiological contaminants) and flushing of the well and/or distribution system.

If there is no evidence to suggest faecal contamination, a boil water advisory may not be necessary.

9.4 Accountability and Record Keeping

Monitoring all operational and compliance aspects of a drinking water system is an important part of establishing on-going verification that the water is safe to drink and the operational plan is being followed. Equally important is being accountable for the records of all these activities. This includes a system of document management which ensures that documents are properly maintained and easily accessible.

Documentation is equally important as a tool for verifying that training activities are taking place and that corrective actions have been taken as required. It also helps track the continuous improvement of operations and/or policies. Comprehensive documentation is also a fundamental requirement in the event that any operator or manager should be required to show that they have been taking all due diligence in using the system to produce and provide potable water.

Finally, well-maintained documentation allows for a more effective and meaningful audit process. Audits that are based on good records can lead to improvements of both the management and operational strategies being used to provide safe drinking water.

Accurate and accessible records of monitoring and testing are important, but they're not the only records that should be kept. Documentation should be in place to keep track of the location and condition of the treatment equipment, distribution system, and the associated treatment/cleaning chemicals and spare parts. Examples of common record types are listed below:

- Water quality testing results – baseline testing, and all ongoing bacterial and chemical analyses, all recorded chlorine residual and turbidity levels.

- A summary of analytical results obtained during the year, in table format
- Reports on the quality of drinking water from the municipal system (if the facility receives municipally supplied water)
- Correspondence and reports of any incidents, including remedial and emergency measures, boil water advisories, shock chlorination, etc. A record of corrective actions taken as part of operational controls, or in the event of a sample analysis that indicated the water exceeded any of the MACs.
- Assessment reports (such as vulnerabilities assessment, sanitary survey, cross-connection control survey/program, potable/drinking water management plans, etc.)
- Reports of in-house operational procedures, tests, protocols (communication, storage of on-site chemicals, etc.)
- Infrastructure and maintenance reports including:
    - "As-built" drawings
    - Plumbing drawings
    - "Life history cards" (these files should contain data about each piece of equipment in the water system, including the date and conditions of installation, types of material, record of service problems and/or performance and costs of operation and maintenance)
    - Schedule of routine O&M for distribution system and treatment equipment
    - Operational and maintenance manuals
    - Manufacturer's information and specifications for each piece of equipment
- Training records, including exam results, relevance of training, and validation of the source of training
- Auditor's reports (internal/external auditing)

9.5 Notes on Chapter 9

10 Where to Get Help

10.1 Introduction

This course has covered a lot of information – sources of water, contaminants that might be found in those water sources, the various methods of treating water to remove contaminants, various tools to use to completely understand the system from source to the tap, monitoring, sampling, analysis and reporting. In addition, basic mathematics and chemistry for water systems. That is a tremendous amount of information to memorize, and even more to put into practice and truly learn. There are several ways of putting all this knowledge into practice, but perhaps one of the best ways is to take a close look at the water system, and understand how the water gets from it's source to the tap that will fill the glass of water. Not only will this help to put some of the new knowledge into practice, but it will help to identify locations and situations where risks to the safety of the water might be encountered and what can be done to manage those risks.

Providing safe drinking water is a complex job that can easily exceed the capabilities of any one person. For this reason, it's important to know your limitations. While nothing will guarantee that every decision you make will be a correct one, using the tools and information at your disposal will help you with one critical skill: the ability to know when a situation exceeds your skill level. Understanding the limits of your knowledge means you will be willing to ask for help when you need it, and this will give you the confidence to declare the water unsafe if you have any doubts about its potability.

One of the most important tools to consider is preparation – being ready for most situations. This can be as easy as looking at one of the devices in the treatment train and asking questions like "What should be done if that indicator light comes on?", "What do the readings on the pressure gauge mean?" or, from a monitoring perspective, "What should be done if a test analysis reports a parameter is above it's Maximum Acceptable Concentration?". If you don't know the answer to the question, don't guess at the answer. There is a team of people that can be asked for help – the water quality specialist, other micro-system operators, health and safety officers, provincial water quality partners, manufacturer's representatives and others. It's good not only to ask these people for help and instruction, but also to ask them if they can be contacted in an emergency for advice, and to keep their contact information up to date.

The following sections provide some ideas on where to look or who to contact to find the answers to some of these questions.

10.2 Equipment

All micro-systems have equipment that at the minimum will include a pump and a series of pipes and valves. In many cases the system will include some type of treatment equipment to remove contaminants from the water. Both the possible contaminants and the treatment devices have been discussed in this course. It is critically important that the equipment be properly operated and maintained to ensure the production and delivery of safe drinking water.

There are several sources of information that are valuable in operating and maintaining this equipment. The first is the operator's manual that came with the equipment. Read this manual to understand the operation and maintenance of the equipment. If there are instructions that are not clear, call the manufacturer or the installer for clarification. Also, this work book explains the general principles for various types of treatment equipment which should help in understanding how they operate and their limitations. There may be also other micro-system operators who are familiar with the same types of equipment that can provide operation and maintenance advice. Make notes on routine maintenance and operation procedures for all the equipment in the micro-system. This will not only help to understand the information by writing it down in familiar terms and language, but it will also provide a list that can be used to verify scheduled maintenance.

Some equipment problems are easy to solve. For example, it may simply require the addition of salt to the water softener (an ion exchange device) when the brine tank is low or replacing the bulb in the Ultraviolet (UV) disinfection system when the indicator light flashes.

Other problems are more complex. For example, the chlorinator may stop working, or the controls on the equipment may stop responding. Preparing a plan in advance to address some of these common problems is a good idea. Part of the plan may be to call in the experts. Don't hesitate to do so. Their job is to support micro-system operators with their task of providing potable water.

There will inevitably be problems with the equipment in the micro-system as it wears out over time. The first thing to do is to identify the cause of the problem. The operator's manual and other sources of information may be of assistance. But sometimes all the information available won't immediately identify the problem. When this happens, contact a water quality specialist or the professional who installed the equipment for help in determining the cause of the problem. Once the problem is identified, the solution might be obvious or the advice of a specialist might be required to help devise a solution.

As indicated in the introduction above, it is useful to think of operational and emergency situations that might arise. For each situation, develop and write down a solution. Then identify the names and contact information of people who could help, verify that they would be willing to help, and write down their contact information. Review this list of potential problems, solutions and contacts periodically to keep it up to date.

10.3 Distribution System

Most micro-systems have a simple water distribution system, consisting of a combination of pipes and valves. There may also be some other devices in the distribution system such as drinking water fountains and janitorial style sinks. Most of these devices are easy to maintain, but problems can arise.

Contact a water quality specialist immediately if there are any irregularities such as pressure changes or leaks in the distribution system or changes in the quality of the water. A qualified professional should be hired to do any repairs or changes to the distribution system that are required.

10.4 Monitoring

Monitoring the water quality is an important part of providing safe drinking water. This might be a team effort where the person on site is responsible for taking samples and implementing corrective actions while a water quality specialist is responsible for analyzing the test results and indicating what corrective actions need to be taken. In other cases, the person on site might be responsible for all these actions. In any case, the *Guidelines for Canadian Drinking Water Quality* form the basis for determining the safety of the water. These guidelines are updated periodically, based on new scientific findings, so always check Health Canada's website for the latest version.

One of the most important roles in protecting public health is to monitor the treated water for the presence of microorganisms, as they can be a serious health hazard. This is done by monitoring for the presence of indicator organisms – total coliforms and *E. coli*.

Fig 10.1 Microorganisms pose the greatest risk to health

Chemical parameters are generally a concern only when they are above the Maximum Acceptable Concentrations specified in the Guidelines for Canadian Drinking Water Quality. Some of these chemical parameters may not be health-based, but are important to ensure the proper operation of the micro-system. To learn more, talk to a water quality specialist and consult Health Canada's website for technical documents published for the different parameters.

This work book provides information about how a monitoring program is developed and how to take samples in Chapter 8. Chapter 9 provides information on analysis and reporting, which should also be discussed with the water quality specialist sharing the responsibility for the micro-system. As indicated in Chapter 8, more information on sampling can be found on the DVD training module entitled "Procedures for Conducting Water Sampling in Federal Facilities".

Water samples must be sent to an accredited laboratory for analysis. If this is not possible and a portable test kit is being used, ensure that an appropriate quality assurance or quality control protocol is in place. If there are any questions about the results of the sample testing, contact the responsible water quality specialist or the facility's health and safety personnel right away. If the micro-system is located in a First Nations community, call the environmental health officer.

Never assume that laboratory results are wrong or that any contaminants found in the water are safe to drink. Microorganisms can be especially harmful to human health and must be dealt with immediately. In the event of an emergency or when the water is considered unsafe to drink, the appropriate water advisory should be issued immediately.

Never assume that laboratory results are wrong or that any contaminants found in the water are safe to drink. Microorganisms can be especially harmful to human health and must be dealt with immediately. In the event of an emergency or when the water is considered unsafe to drink, the appropriate water advisory should be issued immediately.

10.5 Standard Operating Procedures

Standard Operating Procedures (SOPs) may have been prepared to guide all activities related to the operation and maintenance of the micro-system. The SOPs are basically a list of instructions to be followed to address a specific topic or issue. For example, there may be an SOP on how often samples must be taken and where they are to be sent. There should also be an SOP on how to issue a boil water advisory. There may also be SOP on record keeping management. The number and extent of the SOPs will depend on where the micro-system is located and who is responsible for that location. These requirements will vary because the location could be a coast guard vessel, a border crossing, a diplomatic mission abroad, an RCMP detachment, an Agriculture and Agri-Food Canada site or a First Nations community. If available, follow the SOPs specific to the department, facility or community.

10.6 Continuing Education

This training course provides the information essential to understand and operate a micro-system. But taking the course does not make the student an expert. The information from the course needs to be combined with hands on experience in order to apply the knowledge. That combination of learning through doing, as well as learning from taking this course, is an important part to any educational process. It is especially important in the area of water quality where there are many interactive components to consider.

As you gain more confidence in the area of micro-systems, it may be easy to think that you have learned all you need to know, and are capable of dealing with any situation that might arise. But part of being prepared is continuing education – ensuring that your knowledge and skills are fresh and up to date. Here are some ideas to do just that.

- Stay up to date on the Guidelines for Canadian Drinking Water Quality, and the operation and maintenance of water treatment systems.
- Familiarize yourself with the Health Canada website on water quality. Here you will find many helpful resource documents and lots of ready-to-use information.
- Develop partnerships with other facilities and communities that use micro-systems, and find tools to help you implement sound drinking water management practices.
- Find out who provides training for Provincial water treatment system operators near you, and see if there are courses that are interesting and useful.
- Provincial health agencies generally provide information on water quality and may be a useful resource in learning more about contaminants in water.
- Provincial health agencies generally provide information on water quality and may be a useful resource in learning more about contaminants in water.

Don't take chances. Don't take risks. The health of the people at your facility or in your community is on the line. Ask questions. Get answers. And operate your micro-system with confidence.

10.7 Notes on Chapter 10

Appendix A:

Guidelines for Canadian Drinking Water Quality - Summary Table

(From the Health Canada web site March 2011)

The Guidelines for Canadian Drinking Water Quality are updated regularly by the Federal-Provincial-Territorial Committee on Drinking Water. Please consult the following URL for the most recent version of the guidelines: http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/2010-sum_guide-res_recom/index-eng.php (link verified March 2011)

Table 1: New and Revised guidelines

Parameter	Guideline (mg/L)	Previous Guideline (mg/L)	CHE Approval
Microbiological parameters[a]			
Bacteriological		0 coliforms/ 100 mL	
E.coli	0 per 100 mL		2006
Total coliforms	0 per 100 mL		2006
Heterotrophic plate count	No numerical guideline required		2006
Emerging pathogens	No numerical guideline required		2006
Protozoa	No numerical guideline required	None	2004
Enteric viruses	No numerical guideline required	None	2004
Turbidity	0.3/1.0/0.1 NTU[b]	1.0 NTU	2004
Chemical and physical parameters			
Aluminum	0.1/0.2[c]	None	1999
Antimony	0.006	None	1997
Arsenic	0.01	0.025	2006
Benzene	0.005	0.005	2009
Bromate	0.01	None	1999
Chlorate	1	None	2008
Chlorine	No numerical guideline required	None	2009
Chlorite	1	None	2008
Cyanobacterial toxins—microcystin-LR	0.0015	None	2002
Fluoride	1.5	1.5	1996

Parameter	Guideline (mg/L)	Previous Guideline (mg/L)	CHE Approval
Formaldehyde	No numerical guideline required	None	1998
Haloacetic Acids--Total (HAAs)	0.08	None	2008
2-Methyl-4-chlorophenoxyacetic acid (MCPA)	0.1	None	2010
Methyl tertiary-butyl ether (MTBE)	0.015	None	2006
Trichloroethylene (TCE)	0.005	0.05	2005
Trihalomethanes--Total (THMs)[d]	0.1	0.1	2006
Uranium	0.02	0.1	2000
Radiological parameters			
Cesium-137 (^{137}Cs)	10 Bq/L	10 Bq/L	2009
Iodine-131 (^{131}I)	6 Bq/L	6 Bq/L	2009
Lead-210 (^{210}Pb)	0.2 Bq/L	0.1 Bq/L	2009
Radium-226 (^{226}Ra)	0.5 Bq/L	0.6 Bq/L	2009
Strontium-90 (^{90}Sr)	5 Bq/L	5 Bq/L	2009
Tritium (^{3}H)	7000 Bq/L	7000 Bq/L	2009

[a] Refer to section on Guidelines for microbiological parameters.

[b] Based on conventional treatment/slow sand or diatomaceous earth filtration/membrane filtration.

[c] This is an operational guidance value, designed to apply only to drinking water treatment plants using aluminum-based coagulants. The operational guidance values of 0.1 mg/L applies to conventional treatment plants, and 0.2 mg/L applies to other types of treatment systems.

[d] The separate guideline for BDCM was rescinded based on new science. See addendum to the THM document. In certain situations, the Federal-Provincial-Territorial Committee on Drinking Water may choose to develop guidance documents: for contaminants that do not meet the criteria for guideline development, and for specific issues for which operational or management guidance is warranted.

Table 2: Health-based and aesthetic guidelines for chemical/physical parameters

Parameter	MAC (mg/L)	AO [or OG] (mg/L)	Year of Approval (or reaffirmation)
Aldicarb	0.009		1994
Aldrin + dieldrin	0.0007		1994
Aluminum[a]		[0.1/0.2]	1998
*Antimony[b]	0.006		1997
Arsenic	0.01		2006
*Atrazine + metabolites	0.005		1993
Azinphos-methyl	0.02		1989 (2005)
Barium	1		1990
Bendiocarb	0.04		1990 (2005)

Parameter	MAC (mg/L)	AO [or OG] (mg/L)	Year of Approval (or reaffirmation)
Benzene	0.005		2009
Benzo[a]pyrene	0.00001		1988 (2005)
*Boron	5		1990
*Bromate	0.01		1998
*Bromoxynil	0.005		1989 (2005)
Cadmium	0.005		1986 (2005)
Carbaryl	0.09		1991 (2005)
Carbofuran	0.09		1991 (2005)
Carbon tetrachloride	0.005		1986
Chloramines—total	3		1995
Chlorate	1		2008
Chloride		≤250	1979 (2005)
Chlorite	1		2008
Chlorpyrifos	0.09		1986
Chromium	0.05		1986
Colour[d]		≤15 TCU	1979 (2005)
Copper[b]		≤1.0	1992
*Cyanazine	0.01		1986 (2005)
Cyanide	0.2		1991
Cyanobacterial toxins-Microcystin-LR[c]	0.0015		2002
Diazinon	0.02		1986 (2005)
Dicamba	0.12		1987 (2005)
1,2-Dichlorobenzene[e]	0.2	≤0.003	1987
1,4-Dichlorobenzene[e]	0.005	≤0.001	1987
*1,2-Dichloroethane	0.005		1987
1,1-Dichloroethylene	0.014		1994
Dichloromethane	0.05		1987
2,4-Dichlorophenol,	0.9	≤0.0003	1987 (2005)
*2,4-Dichlorophenoxyacetic acid (2,4 -D)	0.1		1991
Diclofop-methyl	0.009		1987 (2005)
*Dimethoate	0.02		1986 (2005)
Dinoseb	0.01		1991
Diquat	0.07		1986 (2005)
Diuron	0.15		1987 (2005)
Ethylbenzene		≤0.0024	1986 (2005)
Fluoride	1.5		1996
*Glyphosate	0.28		1987 (2005)
Haloacetic Acids-Total (HAAs)	0.08		2008
Iron		≤0.3	1978 (2005)
Lead[b]	0.01		1992
Malathion	0.19		1986 (2005)

Parameter	MAC (mg/L)	AO [or OG] (mg/L)	Year of Approval (or reaffirmation)
Manganese		≤0.05	1987
Mercury	0.001		1986
Methoxychlor	0.9		1986 (2005)
2-Methyl-4-chlorophenoxyacetic acid (MCPA)	0.1		2010
Methyl tertiary-butyl ether (MTBE)		0.015	2006
*Metolachlor	0.05		1986
Metribuzin	0.08		1986 (2005)
Monochlorobenzene	0.08	≤0.03	1987
Nitrate[f]	45		1987
Nitrilotriacetic acid (NTA)	0.4		1990
Odour		Inoffensive	1979 (2005)
*Paraquat (as dichloride)[g]	0.01		1986 (2005)
Parathion	0.05		1986
Pentachlorophenol	0.06	≤0.030	1987 (2005)
pH[h]		6.5-8.5	1995
Phorate	0.002		1986 (2005)
*Picloram	0.19		1988 (2005)
Selenium	0.01		1992
*Simazine	0.01		1986
Sodium[i]		≤200	1992
Sulphate[j]		≤500	1994
Sulphide (as H_2S)		≤0.05	1992
Taste		Inoffensive	1979 (2005)
Temperature		≤15°C	1979 (2005)
*Terbufos	0.001		1987 (2005)
Tetrachloroethylene	0.03		1995
2,3,4,6-Tetrachlorophenol	0.1	≤0.001	1987 (2005)
Toluene		≤0.024	1986 (2005)
Total dissolved solids (TDS)		≤500	1991
Trichloroethylene	0.005		2005
2,4,6-Trichlorophenol	0.005	≤0.002	1987 (2005)
*Trifluralin	0.045		1989 (2005)
Trihalomethanes-total (THMs)[k]	0.1		2006
Turbidityl			2004
*Uranium	0.02		1999
Vinyl chloride	0.002		1992
Xylenes—total		≤0.3	1986 (2005)
Zinc[b]		≤5.0	1979 (2005)

[a] This is an operational guidance value, designed to apply only to drinking water treatment plants using aluminium-based coagulants. The operational guidance values of 0.1 mg/L applies to conventional treatment plants, and 0.2 mg/L applies to other types of treatment systems.

[b] Faucets should be thoroughly flushed before water is taken for consumption or analysis.

[c] The guideline is considered protective of human health against exposure to all microcystins that may be present.

[d] TCU = true colour unit.

[e] 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.

[f] 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.

[g] Equivalent to 0.007 mg/L for paraquat ion.

[h] No units.

[i] 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.

[j] There may be a laxative effect in some individuals when sulphate levels exceed 500 mg/L.

[k] Expressed as a running annual average. The guideline is based on the risk associated with chloroform, the trihalomethane most often present and in greatest concentration in drinking water.

[l] Refer to section on Guidelines for microbiological parameters for information related to various treatment processes.

Appendix B:

Units, Conversions and Sample Calculations

SI Unit:		Multiply By:	To Get:	
Length				
mm	millimetre	0.04	inch	in
cm	centimetre	0.394	inch	in
m	metre	3.28	feet	ft
m	metre	1.1	yard	yds
km	kilometre	0.62	mile	mi
Area				
cm^2	square centimetre	0.16	square inch	in^2
m^2	square metre	1.2	square yard	yd^2
km^2	square kilometre	0.4	square mile	mi^2
ha	hectare (10,000m^2)	2.5	acre	acrs
Volume				
mL	millilitre	0.03	fluid ounce	fl oz
l, L	litre	2.1	pint	pt
l, L	litre	1.06	quart	qt
l, L	litre	0.26	gallon	gal
m^3	cubic metre	35.0	cubic feet	ft^3
m^3	cubic metre	1.3	cubic yard	yd^3
Flow				
L/s	litre/second	15.85	gallons/minutes	gpm (US)
Weight				
g	gram	0.035	ounce oz	
kg	kilogram	2.2	pound lbs	
Temperature				
°C	Celsius	1.8 and then add 32	Fahrenheit	°F
Pressure				
kPa	kilopascals	0.145	pounds/in^2	psi
B	Bar (at sea level)	14.5	pounds/ in^2	psi
B	Bar (at 1000 feet above sea level)	14.1	pounds/ in^2	psi
B	Bar (at 2000 feet above sea level)	13.67	pounds/ in^2	psi

Conversion Factors

1 ft^3 water =	62.4 lbs
1 ft^3 water =	28.317 L
1 L water =	1 kg **
1 yd^3 =	27ft^3
1 acre =	43,560 ft^2
1 psi =	2.31 feet of water
1 mg/L =	1 ppm
1% =	10,000 mg/L ***
1 grain/US gallon =	17.118 mg/l
1 HP =	550 ft-lbs/sec
1 HP =	0.746 kilowatts
1 kilowatt =	1.34 HP
π(Pi) =	3.1416

** Note that this converts volume of water to weight of water

*** e.g. 5% bleach solution = 50,000 mg/L

Conversion Factors

	US Gallons	Imperial Gallons
1 ft^3 water =	7.48 gal	6.23 gal
1 litre =	0.264 gal	0.22 gal
1 gal water =	8.34 lbs	10.0 lbs
1 MGD* =	694.4 gpm	694.4 gpm
1 MGD =	1.547 cfs	1.858 cfs
1 gpm =	0.00223 cfs	0.00268 cfs
1 cfs =	448.83 gpm	373.8 gpm

* MGD = million gallons per day

* gpm = gallons per minute

* cfs = cubic foot per second

Power of 10	E notation	Decimal Equivalent	Prefix/Symbol	
10^{12}	E+12	1,000,000,000,000	tera	T
10^{9}	E+09	1,000,000,000	giga	G
10^{6}	E+06	1,000,000	mega	M
10^{3}	E+03	1,000	kilo	k
10^{2}	E+02	100	hecto	h
10	E+01	10	deka	da
10^{-1}	E-01	0.1	deci	d
10^{-2}	E-02	0.01	centi	c
10^{-3}	E-03	0.001	milli	m
10^{-6}	E-06	0.000,001	micro	u
10^{-9}	E-09	0.000,000,001	nano	n
10^{-12}	E-12	0.000,000,000,001	pico	p
10^{-15}	E-15	0.000,000,000,000,001	femto	f
10^{-18}	E-18	0.000,000,000,000,000,001	atto	a

Sample Calculations

Example Conversions:

Using the conversion tables above, here are a few examples of typical conversions.

Problem: Convert 4 L/s (litres per second) to USGPM (US gallons per minute)

Solution: 4 L/s x 0.264 US gallons / L x 60 seconds / minute = 63.4 USGPM

Problem: Convert 10 grains / US gallon hardness to ppm

Solution: 10 grains/US gallon x 17.118 mg/L / 1 grain/US Gallon
= 172 mg/L = 172 ppm

Problem: Convert ¾ (0.75) HP (motor rating) to kilowatts

Solution: 0.75 HP x 0.746 kilowatts / HP = 0.56 kilowatts (560 watts)

Problem: Convert 10 ft^3 to litres and weight in kilograms

Solution: 10 ft^3 x 28.317 L / ft^3 = 283.2 L

283.2 L x 1 kg / 1 L = 283.2 kg

Dilution:

Preparing a disinfecting solution for cleaning.

Assuming that 200 mg/L is a good concentration for cleaning surfaces, and you wanted to make 4 litres of this solution in a pail, how much 5% bleach solution would you need to add?

Again, this question uses the dilution formula:

V1 x C1=V2 x C2

Which can be rearranged to solve for the unknown, V1:

V1 = V2 x C2/ C1

Therefore V1 = 4 L x 200 mg/L / 50,000 mg/L = 0.016 L = 16 ml (roughly 3 teaspoons)

Adding 16 ml of 5% bleach solution to 4 litres of water will dilute the concentrated solution to give a final concentration of 200 mg/L (200 ppm).

Flow Rate:

The manufacturer's recommended treatment capacity for a multimedia filter in the micro-system treatment train is 5,000 US gallons. After the filter has treated that volume, it must be cleaned by a simple backwash, a process where the flow in the filter is reversed. If the average flow rate through the filter is 1.2 USGPM, what would be the setting for the electric timer that controls the start of each backwash cycle?

Flow is a measure of volume per unit of time, mathematically expressed as:

Q = V / T where:

Q = flow rate

V = Volume

T = Time

This formula can be rearranged to be expressed as either in time or volume:

T = V / Q or V = Q x T

The example is looking for a time answer, so the solution would be:

T = V / Q = 5,000 (US) gallons / 1.2 USGPM = 4,167 minutes = 69 hours 27 minutes or about 2 days 21 ½ hours.

Sample General Questions

Question 1

Which source of water would be the most likely to contain potentially harmful micro-organisms?

a. Lakes and streams
b. Water from deep wells
c. Bottled water
d. Municipal distribution.

Question 2

In the Hydrological Cycle, the process where water soaks into the ground is called.

a. Evaporation
b. Infiltration
c. Run-off
d. Condensation.

Question 3

What are the main sources of harmful waterborne bacteria that can cause health issues in humans?

a. Plants
b. The digestive tracts of humans and animals
c. Deep aquifers
d. Run-off water.

Question 4

Viruses can travel long distances in aquifers.

a. True
b. False

Question 5

Hardness in water is caused by:

a. Calcium or Magnesium ions
b. Manganese or Iron ions
c. A low pH value
d. A high turbidity value.

Question 6

Alkalinity is a measure of:

a. The number of Hydrogen ions in the water
b. The ability of water to buffer against changes in pH
c. The percentage of alkaline ions in the water
d. The presence of dissolved alkaline salts.

Question 7

A settling tank is a device to provide:

a. Chlorination
b. Clarification
c. UV Disinfection
d. Monitoring capability.

Question 8

Shock chlorination is intended to:

a. Remove suspended solids
b. Kill microorganisms
c. Remove calcium ions
d. Reduce turbidity.

Answers to Sample General Questions

Answer to Question 1

The correct answer is a: Lakes and streams. Surface water bodies can potentially be contaminated by animal waste, decaying plants, and industrial and agricultural operations.

Answer to Question 2

The correct answer is b: Infiltration.

Answer to Question 3

The correct answer is b: In the digestive tracts of animals.

The digestive tracts of humans and animals are the main source of bacteria that cause waterborne illnesses, and these bacteria can be found in feces

Answer to Question 4

The correct answer is a: Viruses in aquifers can be transported far from the original site of contamination.

Answer to Question 5

The correct answer is a: Calcium and Magnesium ions from natural geologic deposits like limestone or dolomite are dissolved into the water and increase the hardness.

Answer to Question 6

The correct answer is b: Adding chemicals to water can cause large swings in pH. A higher alkalinity suppresses these large swings, and makes water pH control easier for you.

Answer to Question 7

The correct answer is b: Clarification. A settling tank allows heavier suspended solids to settle out.

Answer to Question 8

The correct answer is b: Kill or inactivate microorganisms. With the appropriate contact time this should adequately kill any biological activity in the water line.

Appendix C:

Cleaning a Bottled Water Dispenser

The following instructions are for cleaning a cold water cooler with an exposed reservoir or no-spill device. They are from the Health Canada web site. Check the web site periodically to see if changes have been made to these instructions.

To clean the reservoir:

Unplug cord from electrical outlet of cooler. Remove empty bottle.

Drain water from stainless steel reservoir(s) through faucet(s).

If there is a removable baffle and/or no-spill device, remove it. You should be able to see into the reservoir.

Prepare a disinfecting solution by adding one tablespoon (15 mL) household bleach to one Imperial gallon (4.5 L) of water solution. Use a "food grade" bleach. Some commercially available household chlorine bleaches contain fragrances, thickeners or other additives not approved for food use. Do not use scented or colour-safe bleaches.

Bleach decreases in effectiveness with age, so it is recommended to use bleach purchased less than four months ago. Older bleach may not be strong enough to achieve disinfection.

Some companies suggest using one part vinegar to three parts water solution to clean the reservoir of scale before cleaning with bleach. Check your manual. Other disinfecting solutions may be suitable. Please check with your water cooler supplier/manual.

Pour the bleach/other disinfection solution into the reservoir.

Wash reservoir thoroughly with bleach solution and let stand for not less than two minutes (to be an effective sanitizer) and not more than five minutes (to prevent corrosion). Use a clean dish-type scrub brush to clean the inside of the reservoir. Do not use steel wool, Brillo, or other abrasives on the reservoir as it will scratch the finish and make it easier for bacteria to grow.

Drain bleach/disinfection solution from reservoir through faucet(s). Rinse reservoir thoroughly with clean tap water, draining water through faucets, to remove traces of the bleach/disinfection solution. Rinse and dry the baffle / no spill device and replace. You may need to rinse the reservoir more than once to remove the taste and odour of chlorine.

To clean the drip tray (located under faucets):

Lift off drip tray.

Remove the screen and wash both tray and screen in mild detergent.

Rinse well in clean tap water and replace on cooler.

To replace bottle:

Wash hands with soap and warm water before handling. If you choose to use clean protective gloves (ex. latex), discard or disinfect after each use and prior to reuse.

Note : Protective gloves should never replace proper hand washing and hygiene.

Wipe the top and neck of the new bottle with a paper towel dipped in household bleach solution (1 tablespoon (15 ml) of bleach, 1 gallon (4.5 L) of water). Rubbing alcohol may also be used, but must be completely evaporated before placing the bottle in the cooler

Remove cap from new bottle without touching the surface of the opening to avoid any contamination.

Place new bottle on cooler.

Appendix D:

Frequently Asked Questions

Will a water filter disinfect my water?

No, filters can remove a lot of the microbial organism that can cause illness but it will not disinfect your water. Disinfection can only be achieved when you use technologies like ozone, chlorination and UV. For more information on disinfection see Module 5 or the DVD on disinfection.

How often should we be sampling for microbiological parameters?

There are many factors to consider when putting a sampling program in place. The source of the water, number of people being served, and the type of disinfection used all need to be considered before putting a sampling program in place. For additional information on monitoring consult the following document *"Guidance for Providing Safe Drinking Water in Areas of Federal Jurisdiction"*.

Is it necessary to boil all water during an advisory or order?

During boil water advisories or boil water orders, you should boil all water used for drinking, preparing food , beverages, ice cubes, washing fruits and vegetables, or brushing teeth. Severely immunocompromised individuals should always boil their tap water for the purposes noted above. Infant formulas should be prepared using boiled tap water at all times. In the event that boiling is not practical, your local public health authority or other responsible authority may direct you to disinfect the water using household bleach, or to use an alternative supply known to be safe.

It is not necessary to boil tap water used for other household purposes, such as showering, laundry, bathing, or washing dishes. Adults, teens, and older children can wash, bathe, or shower; however, they should avoid swallowing the water. Toddlers and infants should be sponge bathed.

(Health Canada - http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/boil-ebullition-eng.php)

My chlorine reading is low at some locations – what should I do?

If the building is supplied with municipal water, assuming chlorine residual is acceptable at other locations, retest the site in question. If results are low at the location where the water enters the building contact the water supplier (city/municipality).

If residual disinfectant is added on site – check disinfection equipment.

If disinfectant residual is repeatedly low, flushing lines may be in order and review the water use patterns(ie stagnating water due to low water use)

The water at our facility normally tastes fine, this morning the water tasted bad. What should we do?

In the case of municipally supplied water you should contact your water authority immediately. If you produce your own water on site there may be an issue with your source water or perhaps your treatment system is not working properly. You should contact your water quality specialist and investigate the cause of the problem. If the problem can not be repaired quickly an alternate source of drinking water should be provided.

The water looks cloudy when I fill my glass and then clears as it sits – is this safe to drink?

The cloudy water is caused by tiny air bubbles in the water. The pressure in the pipes causes the air to dissolve into the water. When the water comes out of the tap, it is no longer under pressure and the air that was dissolved in the water, comes out of solution forming very tiny bubbles. When poured into a glass, the cloudy water will start to clear from the bottom up - with the clear water slowly moving upward.

This type of cloudiness occurs most often in the winter when the drinking water is cold, if there is an aerator on the tap or if service has been done to a line. The water is still safe to drink.

My building is very old, does that mean there is lead in my drinking water?

Not necessarily. A water analysis can determine if there is lead in your water. The presence of lead in drinking water depends on several factors:

- Age of the distribution system - Older systems may have lead service lines (not typical in buildings), solder or fittings (taps, valves) that contain lead.
- Water chemistry – how aggressive the water is will determine if lead will leach out of the plumbing.
- The length of time water sits in the pipes – Lead levels in the water will increase as it sits, or stagnates, in the pipes when the water is not used for several hours, such as overnight or during working hours. Taps that are used frequently will be less likely to contain lead in the water.
- Whether your water supplier has a corrosion control program in place.

I requested a total coliform test from a lab but I received the results that atypical bacteria overgrowth and *E. coli* as zero. Why wasn't total coliform reported?

Some labs use a membrane filtration procedure to test the water for total coliform but when this procedure is used the overgrowth of atypical bacteria can block the detection of total coliform however another media is used for *E. coli* therefore it can be reported. Below are the suggested actions:

1. Resample but request an absence/presence test for total coliform.
2. If the sample results in reported exceedances (presence) of total coliform, the next step is to shock chlorinate the system, resample and request a total coliform count or a P/A test.

Who samples bottled water?

As part of its enforcement role, the Canadian Food Inspection Agency can inspect bottled water products, labels and establishments (conveyances, equipment etc.) involved in the sale, manufacture and distribution of bottled water. In addition, some provincial and municipal ministries and agencies may inspect bottled water. If your facility relies on bottled water as its main source of drinking water you should ensure it meets the requirements of the Guidelines for Canadian Drinking Water Quality.

I have a new UV system and it is operating as required by the manufacturer but I still have total coliform in the water sample from the sample port immediately after the UV. What should I do?

1. Resample but ensure that you disinfect the sample spigot as outlined in the water sampling video.
2. Check the Ultraviolet Transmittance (UVT) of the water. This is the ability for the water to allow the UV to work effectively. The testing for this parameter is usually done by a lab.
3. Make sure that there is a 5 micron pre-filter to the UV.
4. Contact your water quality specialist.

The indicator light on my UV unit is on, what do I do?

The bulb in your UV unit may need replacement. The bulb gradually loses its disinfecting capabilities over time. If you are not familiar with the procedure you need to follow to replace the UV bulb contact the manufacturer or your water quality specialist.

Note that not all UV units have an indicator light or alarm. In these situations you should be changing your bulb at least once a year. When you change the bulb you should also clean the quartz sleeve surrounding the bulb.

How long do Granular Activated Carbon (GAC) or carbon based filters last?

Depending on the quality of water coming into a GAC, it could effectively do it's intended job for two months, one year, two years or longer. Typically the filter is located near the end of the treatment train to deal with odour, taste, pesticides and dissolved organic matter issues. Treating raw surface water without any pre-treatment will use up the carbon filter in a short amount of time, as a result the carbon will have to be replaced.

In a well designed treatment train the carbon filter should last a long time. Regular sampling and analysis or when there is a noticeable change in taste or smell can indicate that a carbon filter should be inspected or replaced. If the carbon filter is located near the beginning of the treatment train and is removing more concentrations of organic material, constant inspection of the filter is required to ensure it is not all used up.

A carbon filter, where the carbon is spent and is not operating according to manufacturer's specifications or a carbon filter that was improperly sized can negatively impact the water quality. Microbiological growth will form on the carbon and will be passed on to the end-user of the water.

What is cross connection control?

This is an existing or potential connection between a potable water system and any other environment that under any circumstance can enter the potable water system.

How often are testable backflow devices checked?

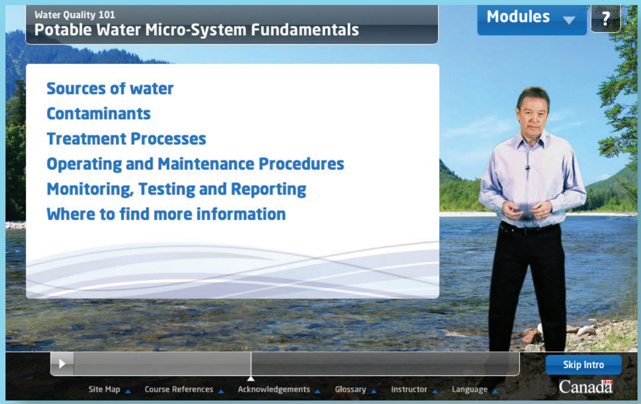
Testable backflow devices such as a Reduced Pressure Principle Backflow (RP), Double Check Valve Assembly (DCVA), Pressure Vacuum Breaker (PVB) or Spill Resistant Pressure Vacuum Breaker must be tested:

- Upon installation
- Annually
- If relocated
- If plumbing in the area of the backflow device is undertaken
- After routine maintenance

I have a very small water distribution system (micro-system) and the facility is a single story building with just a few employees. Do I need to know about cross connection control?

Most municipalities will require a form of cross connection control for even a low risk (minor) water system. It is important to understand what is needed to meet the local bylaws and the applicable plumbing codes. Contact your municipality and a local certified cross connection control specialist for more information.

This product was created as a training tool by the federal Interdepartmental Water Quality Training Board to provide information on water quality management methods for potable water systems that serve up to and including 25 people. These are called “micro-systems”, and are in place at a variety of locations including remote federal facilities, ships, embassies, and First Nation communities.



This Workbook is also available in French and Spanish.

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