Ethiopian TVET-System

Water Supply and Sanitation Supervision

Level-IV

Based on Apr, 2017G.C. Occupational Standard

Module Title: - Selecting Water Treatment Requirements for Waterborne

TTLM Code: EIS WSS4 TTLM 0920v1

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This module includes the following Learning Guides

LG39: Investigate waterborne microorganisms

LG Code: EIS WSS4 M10LO1-LG-39

LG40: Identify processes to remove microorganisms.

LG Code: EIS WSS4 M10LO2-LG-40

LG41: Determine appropriate water treatment processes

LG Code: EIS WSS4 M10LO3-LG-41

Instruction Sheet	**Learning Guide 39:Investigate waterborne microorganisms**

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics:

- Identifying waterborne microorganisms found in water source
- Identifying general characteristics of microorganisms
- Identify water quality and treatment problems of microorganisms
- Identifying water treatment processes for microorganisms' problems
- Identifying characteristics and diseases of pathogenic microorganisms

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, **upon completion of this Learning Guide, you will be able to**:

- Identify the samples of waterborne microorganisms found in water sources
- Identify the general characteristics of different types of microorganisms
- Identify water quality or treatment problems caused by microorganisms
- Identify microorganisms causing problems specific to water treatment processes The Identify characteristics of, and diseases caused by, pathogenic microorganisms

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below
3. Read the information written in the "Information Sheets 1- 6". Try to understand what are being discussed.
4. Accomplish the "Self-checks 1,2,3,4 ,5 and 6 " in each information sheets on pages 4,11,14,19,23 and 26.
5. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to "Operation sheets 1, 2 and 3 on pages 28,29 and 30.and do the LAP Test on page 31". However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity.
7. After You accomplish Operation sheets and LAP Tests, ensure you have a formative assessment and get a satisfactory result; then proceed to the next LG.

Information Sheet-1	**Identifying waterborne microorganisms found in water source**

1.1. Introduction to waterborne microorganisms

Drinking water quality management has been a key pillar of primary prevention for over one-and-a-half centuries and it continues to be the foundation for the prevention and control of waterborne diseases. Water is essential for life, but it can and it does transmit diseases in countries on all continents – from the poorest to the wealthiest. Infectious diseases caused by pathogenic bacteria, viruses and parasites (e.g. protozoa and helminths) are the most common and widespread health risks associated with drinking water. The most predominant waterborne disease, diarrhoea, has an estimated annual incidence of 4.6 billion episodes and causes 2.2 million deaths every year. The sources of most of those pathogens (disease-causing microorganisms) are water contamination with animal or human faecal substances. However, natural and anthropogenic chemical substances in drinking water can also cause different diseases, depending on the geological condition. Furthermore, there are chemical substances without health risks, but due to technical reasons, unwanted by the water supplier in special amount.

The problem of water borne diseases is especially prevalent where general hygiene and environmental sanitation are poor and where there is a shortage of protected water supply. . It is believed that 80% of all diseases in the world are caused by inadequate sanitation, polluted water or unavailability of water (WHO Monica II). Poverty, illiteracy, overcrowding and low health services are contributing factors that directly or indirectly affect the prevalence of water borne diseases. Therefore, an integrated prevention and curative approach with community participation is required in order to tackle this prevalent public health problem.

Waterborne diseases: -

The most common and widespread health risk associated with drinking-water is contamination, either directly or indirectly, by human or animal excreta, particularly faeces. If such contamination is recent, and if those responsible for it include carriers of communicable enteric diseases, some of the pathogenic microorganisms that cause these diseases may be present in the water. Drinking the water, or using it in food preparation, may then result in new cases of infection.

The pathogenic agents involved include bacteria, viruses, and protozoa, which may cause diseases that vary in severity from mild gastroenteritis to severe and sometimes fatal diarrhoea, dysentery, hepatitis, or typhoid fever. Most of them are widely distributed throughout the world.

Faecal contamination of drinking-water is only one of several faeco-oral mechanisms by which they can be transmitted from one person to another or, in some cases, from animals to people.

One ingested waterborne pathogen, namely guinea worm (Dracunculusmedinensis), is not faecalin origin and deserves special mention. Although it is of limited geographical distribution, this helminth is of major public health importance in endemic areas. It is the only human infection that is solely transmitted by the waterborne route, and the World Health Assembly has committed itself to the eradication of dracunculiasis by the end of 1995 (resolution WHA 44.5, 1991).

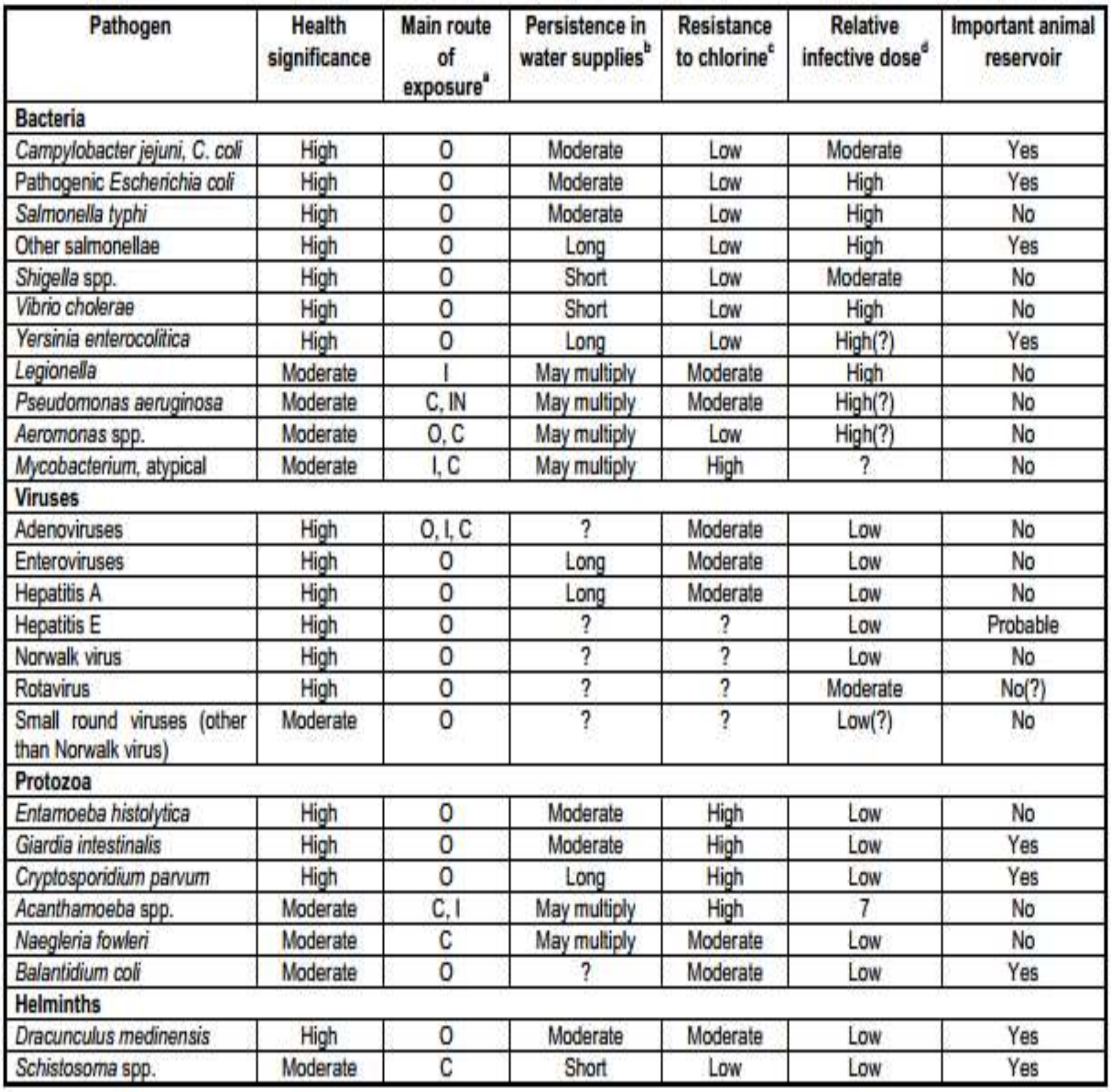
Other pathogens cause infection when water containing them is used for bathing or for recreation involving water contact, rather than by the oral route. Some may also cause infection by inhalation when they are present in large numbers in water droplets, such as those produced by showers and some air-conditioning systems or in the irrigation of agricultural land.

It is not only by causing infection that microorganisms in drinking-water can affect human health. In some circumstances, cyanobacteria can produce toxins that may remain in the water even when the cyanobacteria themselves have been removed. Finally, there are some organisms whose presence in water is a nuisance, but which are of no significance for public health.

1.1 Agents of significance

The human pathogens potentially transmitted in drinking-water are listed in Table 2.1. Some general information on those included in the table is given below.

Table 1.1 Waterborne pathogens and their significance in water supplies



Pathogen	Health significance	Main route of exposure[a]	Persistence in water supplies[b]	Resistance to chlorine[c]	Relative infective dose[d]	Important animal reservoir
Bacteria						
Campylobacter jejuni, C. coli	High	O	Moderate	Low	Moderate	Yes
Pathogenic *Escherichia coli*	High	O	Moderate	Low	High	Yes
Salmonella typhi	High	O	Moderate	Low	High	No
Other salmonellae	High	O	Long	Low	High	Yes
Shigella spp.	High	O	Short	Low	Moderate	No
Vibrio cholerae	High	O	Short	Low	High	No
Yersinia enterocolitica	High	O	Long	Low	High(?)	Yes
Legionella	Moderate	I	May multiply	Moderate	High	No
Pseudomonas aeruginosa	Moderate	C, IN	May multiply	Moderate	High(?)	No
Aeromonas spp.	Moderate	O, C	May multiply	Low	High(?)	No
Mycobacterium, atypical	Moderate	I, C	May multiply	High	?	No
Viruses						
Adenoviruses	High	O, I, C	?	Moderate	Low	No
Enteroviruses	High	O	Long	Moderate	Low	No
Hepatitis A	High	O	Long	Moderate	Low	No
Hepatitis E	High	O	?	?	Low	Probable
Norwalk virus	High	O	?	?	Low	No
Rotavirus	High	O	?	?	Moderate	No(?)
Small round viruses (other than Norwalk virus)	Moderate	O	?	?	Low(?)	No
Protozoa						
Entamoeba histolytica	High	O	Moderate	High	Low	No
Giardia intestinalis	High	O	Moderate	High	Low	Yes
Cryptosporidium parvum	High	O	Long	High	Low	Yes
Acanthamoeba spp.	Moderate	C, I	May multiply	High	7	No
Naegleria fowleri	Moderate	C	May multiply	Moderate	Low	No
Balantidium coli	Moderate	O	?	Moderate	Low	Yes
Helminths						
Dracunculus medinensis	High	O	Moderate	Moderate	Low	Yes
Schistosoma spp.	Moderate	C	Short	Low	Low	Yes

O = oral (ingestion); I = inhalation in aerosol; C = contact with skin; IN = ingestion in immunosuppressed patients.

Detection period for infective stage in water at 20 °C: short = up to 1 week; moderate = 1 week to 1 month; long = over 1 month

When the infective stage is freely suspended in water treated at conventional doses and contact times: resistance moderate, agent may not be completely destroyed; resistance low, agent completely destroyed

Dose required to cause infection in 50% of healthy adult volunteers

1.1.1. Agents of high health significance

Not all potentially waterborne human pathogens are of equal public health significance (Table1.1). Some of them, including most of the ingested pathogens, present a serious risk of disease whenever they are present in drinking-water, and their elimination from it should be given high priority. Examples include strains of Escherichia coli, Salmonella, Shigella, Vibrio cholerae, Yersinia enterocolitica, and Campylobacter jejune, the viruses and the parasites Giardia, Cryptosporidium, Entamoebahistolytica, andDracunculus.

While most of the pathogens of high significance in Table 2.1 are found worldwide, others are a public health problem only in limited regions of the world, e.g. guinea worm is found only in certain countries of Africa and Asia. Historically, pandemics of cholera have spread from well-defined regions where the outbreaks first occurred. Although high priority should be given to control of these pathogens in drinking water, this is of regional significance only

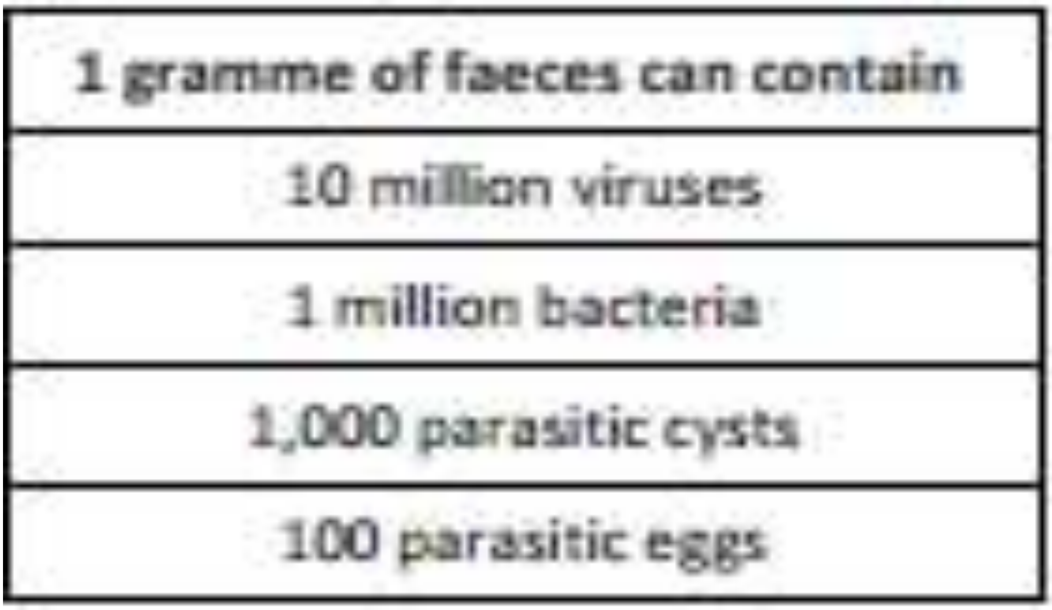
1.1.2. Opportunistic pathogens

Some organisms, naturally present in the environment and not normally regarded as pathogens, may cause disease opportunistically. When such organisms are present in drinking-water, they cause infection predominantly among people whose local or general natural defense mechanisms are impaired. Those most likely to be at risk include the very old, the very young, and patients in hospitals, e.g. those with burns or undergoing immunosuppressive therapy, and those suffering from acquired immunodeficiency syndrome (AIDS). Water used by such patients for drinking or bathing, if it contains excessive numbers of

these agents, may produce a variety of infections involving the skin and mucous membranes of the eye, ear, nose, and throat. Pseudomonas, Flavobacterium, Acinetobacter, Klebsiella, and Serratiaareexamples of such opportunistic pathogens, as is Legionella, which can infect the lungs if inhaled in droplets. Some of these, such as LegionellaandAeromonas, can also cause disease in otherwise healthy individuals when the specific conditions prevailing within a water-supply system have enabled them to multiply to unusually high concentrations. These organisms, while clearly of medical importance, only acquire public health significance under certain conditions. Their removal from drinking-water may therefore be given moderate priority

Most micro-organisms in water are harmless, but disease-causing organisms (called pathogens) may enter water sources as a result of pollution by human and animal wastes and by untreated or poorly treated waste waters discharged into the water source. These organisms may cause diseases such as cholera and dysentery if they are present in water that is consumed without treatment. The water therefore has to be disinfected (i.e. the micro-organisms have to be removed or destroyed) to make the water fit for domestic use. Note Box 1gives a list of disease-causing organisms, the disease each group causes and the typical source (there are also other routes of contamination possible)

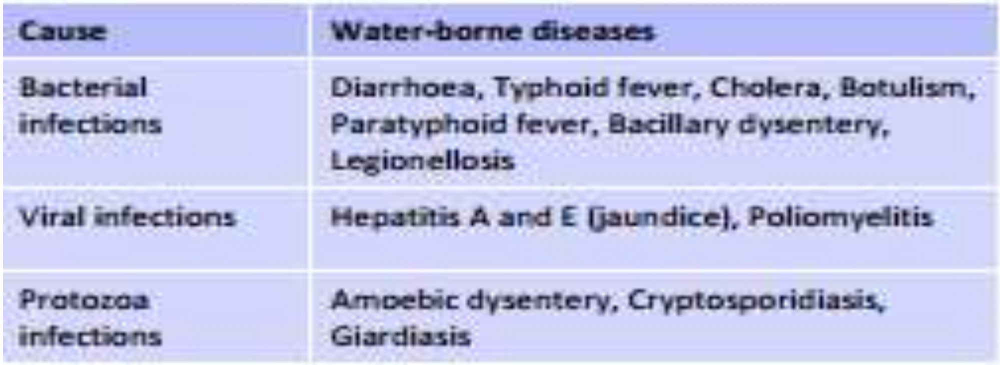
Life would be impossible without microorganisms. Microorganisms, like the group of coliform bacteria, are indispensable for the proper digestive functioning of human beings and animals. However, the bacteria should not appear in drinking water and can cause diseases in vulnerable persons. They can also cause problems if they enter the body via contaminated food or drinks. Particular pathogens that cause diarrhea leave the body via the faeces; and they are then transmitted to humans, who can become ill when they ingest the pathogen. This is called faecal-oral transmission. For pathogens transmitted by the faecal–oral route, drinking water is only one vehicle of transmission. Contamination of food, hands, utensils and clothing can also play a role, particularly when domestic sanitation and hygiene are poor. There are several variants of water borne disease transmission. These include contamination of drinking water catchments (e.g. by human or animal faeces), water within the distribution system (e.g. through leaky pipes or obsolete infrastructure) or stored household water (as a result of unhygienic handling).



1 gramme of faeces can contain
10 million viruses
1 million bacteria
1,000 parasitic cysts
100 parasitic eggs

Table 1.2. Microorganisms in faeces

Table 1 gives an overview of the number of microorganisms that can be present in one gramme of faeces and the causes of water borne diseases. Hence, adequate sanitation measures are required from every step of the drinking water supply system to avoid any drinking water contamination. Hygienic handling of water in all stages of the water supply and personal hygiene (regular hand washing) are essential precautionary measures to minimise water related health risks. Microbial drinking water safety is not only related to faecal contamination. Some organisms live naturally in the water and can become problematic if they grow in large numbers in piped water distribution systems (e.g. Legionella). Whereas the larvae of others occur in the water source, e.g. guinea worm (Dracunculusmedinensis), and may cause individual cases or outbreaks. Improvements in the quality and availability of safe water, adequate excreta disposal and general hygiene are all important in reducing faecal–oral disease transmission.



Cause	Water-borne diseases
Bacterial infections	Diarrhoea, Typhoid fever, Cholera, Botulism, Paratyphoid fever, Bacillary dysentery, Legionellosis
Viral infections	Hepatitis A and E (jaundice), Poliomyelitis
Protozoa infections	Amoebic dysentery, Cryptosporidiasis, Giardiasis

Table 1.3.Causes of water-borne diseases

.1.2. Contamination of drinking water with faecal matter

As illustrated in Table 1, faeces can contain millions of useful microorganisms, but can also harbour pathogens. Laboratory testing for specific disease-causing microorganisms (e.g. Salmonella typhimurium and Vibrio cholerae) can be expensive, and if the bacteria are present only in low numbers, they may not be detected. Instead, more common bacteria are analysed as an indication of faecal pollution of the water, such as coliform bacteria. In many countries, evidence of the faecal coliform bacteria family serves as an indicator for faecal contamination of the drinking water. There are hundreds of coliform bacteria species in the human and animal intestine, and in the environment as well. On the contrary to several other bacteria, viruses and parasites, the bacteria Escherichia coli and faecal streptococci are rather easy to analyse. The presence of those bacteria in water is an indication of recent faecal pollution (see also module 8 and 9). In the following section, some bacteria are presented that are analysed for monitoring the microbiological drinking water quality.

- **Faecal coliforms**

Faecal coliforms are conditionally pathogenic bacteria that are present in the intestinal tract of humans and most mammals. They are called conditionally pathogenic since they can cause diseases only under certain conditions (high concentrations, increased susceptibility and reduced human immune defence). The presence of faecal coliforms in water indicates faecal contamination and most likely the presence of pathogens. The most common health problems that may result from contact with faecal coliform contaminated water are dysentery, typhoid, hepatitis, and gastroenteritis.

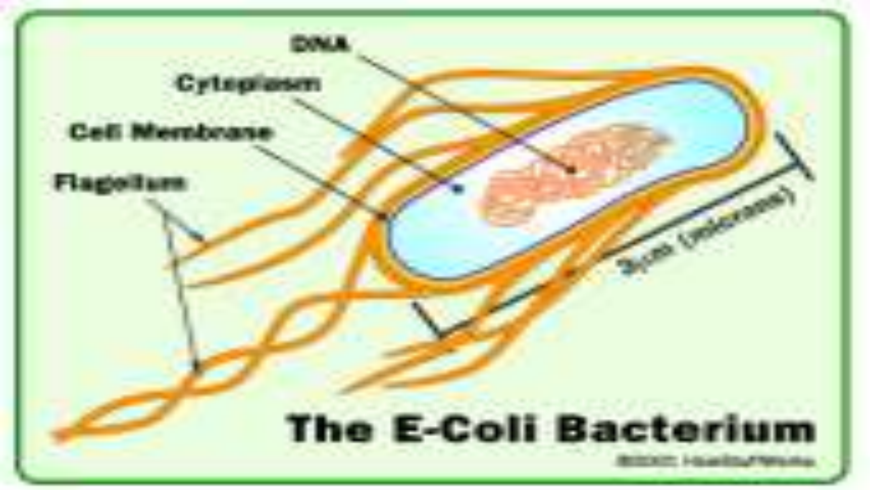


Figure 1: The E-coli Bacterium

- **Escherichia coli (E. coli)**

90% of faecal coliforms are types of Escherichia coli (E. coli). This bacterium lives in the colon of warm-blooded animals and is necessary for proper digestion of food. Yet this bacterium can cause several infections outside of the colonies. coli exists abundantly in nature, but the presence of E. coli in water is a sign of faecal contamination. coli is the most common cause of urinary tract infections, but can also cause many other diseases such as diarrhoea, pneumonia, meningitis. There are many types (serotypes) of the E. coli with different properties. For example, E. coli type O157: H7 releases a powerful toxin, leading to severe and bloody diarrhoea with abdominal cramping's. It can cause HaemolyticUraemic Syndrome (HUS) in children, often with fatal consequences. In Canada, a waterborne epidemic caused by E. coli 0157:H7 infected more than 1.500 persons and resulted in 10 deaths during the year 2000.

Faecal Streptococci / Intestinal Enterococci /

Faecal streptococci and intestinal enterococci bacteria are normally present in the intestinal tract of warm-blooded animals. Outside the intestinal tract, the bacteria cause common clinical diseases, such as urethra infections, bacterial endocarditis, meningitis and diseases of the colon. Enterococci infection may be the reason for bladder infections and health problems with the prostate and male reproductive system. They also develop resistances against antibiotics and are sometimes difficult to treat. Wound infections with faecal streptococci can result in rapid skin damage and sepsis (blood poisoning), sometimes with fatal outcomes (amputation, death). In the environment, faecal streptococci are more resistant than E. coli, and they can survive longer in water.

- **Clostridium perfringens**

perfringens is a Gram-positive, rod-shaped, anaerobic, spore-forming bacterium. It occurs in the soil, and in the intestinal tract of humans and other vertebrates. In contrast to the aforementioned and easy detectable E. coli, C. perfringens is able to survive in a sleeping stage because they form long-lasting spores. These spores can be used as an indicator for faecal contamination too. For the quality control of drinking water derived from surface waters, it is recommended to test on C. perfringens and its spores. They can serve as an indicator for the occurrence of harmful protozoa like Cryptosporidium or Giardia lamblia. C. perfringens effects the nervous system and can cause meningitis, Surface water and water catchment areas with intensively grazing livestock are especially threatened by C. perfringens. The spores of C. perfringens are very resistant to chlorine treatment.

1.2. Contamination of water with Legionella bacteria

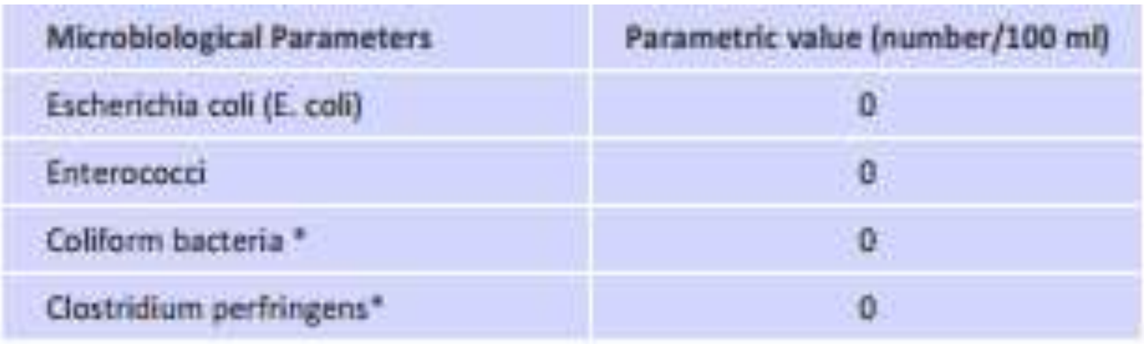
The Legionella pneumophila bacterium was identified in 1977 as the cause of a severe pneumonia outbreak in a convention centre in the USA. This bacterium is associated with outbreaks of Legionellosis (Legionnaires disease) that are linked to poorly maintained artificial water systems; particularly in cooling towers, air conditioners, hot and cold water systems (showers) and whirlpools. Legionella can be spread by aerosols and infections can occur by inhalation of contaminated water sprays or mists. The bacterium is found worldwide in aquatic environments, but artificial water systems sometimes provide environments for growing Legionella bacteria. The bacteria colonize in water systems at temperatures of 20 to 59 degrees Celsius (optimal-35o C

1.3. Microbiological parameters for the quality of drinking water

The EU Drinking Water Directive (90/313/EEC) mentions that member States should take measures to ensure that water intended for human consumption is wholesome and clean. This means that drinking water has to be free of any microorganisms and parasites, and of any substances that causes potential danger to human health! None of the Escherichia coli and enterococci faecal bacteria may appear in 100ml drinking water

- ***.* Frequency of monitoring the quality**

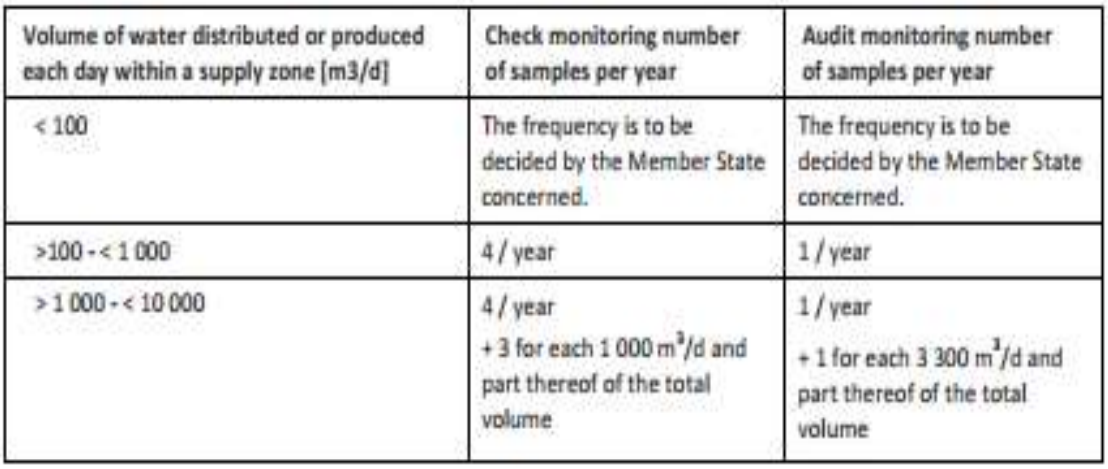
The EU Drinking Water Directive also determines the frequency of water sampling and analyses intended for human consumption (also e.g. used in food-production enterprises), and how water is supplied from a distribution network (e.g. from a tanker). The frequency depends on the volume of water distributed or produced each day within a supply zone.



Microbiological Parameters	Parametric value (number/100 ml)
Escherichia coli (E. coli)	0
Enterococci	0
Coliform bacteria *	0
Clostridium perfringens*	0

Table 3: Microbiological requirements ofdrinking water

* Indicator parameter to be measured if the water originated or Is influenced by surface water



Volume of water distributed or produced each day within a supply zone [m3/d]	Check monitoring number of samples per year	Audit monitoring number of samples per year
< 100	The frequency is to be decided by the Member State concerned.	The frequency is to be decided by the Member State concerned.
>100 - < 1 000	4 / year	1 / year
> 1 000 - < 10 000	4 / year + 3 for each 1 000 m^3/d and part thereof of the total volume	1 / year + 1 for each 3 300 m^3/d and part thereof of the total volume

Table 4:Frequency of sampling and analysing the drinking water quality within the supply zone

Self-Check -1	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. Define water borne diseases

2.The age group most affected by water borne diseases in general is:

A. Children under one year of age

B. Children under 5 years of age

C. Children 5 – 10 years of age

D. Adult above 15 years of age

3.Which of the following water borne diseases is of viral origin.

A. Typhoid fever

B. Poliomyelitis

C. Dracunculiais

D. Shigellosis

4. Name three water borne diseases caused by each of the following pathogenic organisms
   A. Bacteria 1_____________ 2.________ 3.___________
   B. Virus 1.____________ 2.___________ 3.___________
   C. Protozoa &Helminths 1._________ 2.__________ 3.___________
5. Water borne diseases are leading causes of morbidity and mortality in all age groups. (T/F)

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5points**

You can ask you teacher for the copy of the correct answers.

Answers for True or False item

1.___________

Information Sheet-2	**Identifying general characteristics of microorganisms Identify water quality and treatment problems of microorganisms**

2.1. Characteristics of indicator organisms

Total coliforms

The term “total coliforms” refers to a large group of Gram-negative, rod-shaped bacteria that share several characteristics. The group includes thermotolerant coliforms and bacteria of faecal origin, as well as some bacteria that may be isolated from environmental sources. Thus, the presence of total coliforms may or may not indicate faecal contamination. In extreme cases, a high count for the total coliform group may be associated with a low, or even zero, count for thermotolerant coliforms. Such a result would not necessarily indicate the presence of faecal contamination. It might be caused by entry of soil or organic matter into the water or by conditions suitable for the growth of other types of coliform. In the laboratory total coliforms are grown in or on a medium containing lactose, at a temperature of 35 or 37 °C. They are provisionally identified by the production of acid and gas from the fermentation of lactose.

Thermotolerant (faecal) coliforms

The term “faecal coliform” has been used in water microbiology to denote coliform organisms which grow at 44 or 44.5 °C and ferment lactose to produce acid and gas. In practice, some organisms with these characteristics may not be of faecal origin and the term “thermo tolerant coliform” is, therefore, more correct and is becoming more commonly used. Nevertheless, the presence of thermo tolerant coliforms nearly always indicates faecal contamination. Usually, more than 95 per cent of thermo tolerant coliforms isolated from water are the gut organism Escherichia coli, the presence of which is definitive proof of faecal contamination. As a result, it is often unnecessary to undertake further testing to confirm the specific presence of E. coli. In the laboratory thermo tolerant coliforms are grown on media containing lactose, at a temperature of 44 or 44.5 °C. They are provisionally identified by the production of acid and gas from the fermentation of lactose. Nutrient-rich environments may encourage the growth or persistence of some species of thermo tolerant coliform other than E. coli. This possibility should be considered when, for example, an unusually high result is obtained from water that was thought to be relatively clean. In such a case, the advice of a microbiology laboratory should be sought for the determination of the more specific indicator, E. coli.

- **Faecal streptococci**

The presence of faecal streptococci is evidence of faecal contamination. Faecal streptococci tend to persist longer in the environment than thermo tolerant or total coliforms and are highly resistant to drying. It is, therefore, possible to isolate faecal streptococci from water that contains few or no thermo tolerant coliforms as, for example, when the source of contamination is distant in either time or space from the sampling point. Faecal streptococci grow in or on a medium containing sodium azide, at a temperature of 37-44 °C. They are usually detected by the reduction of a dye (generally a tetrazolium-containing compound) or the hydrolysis of aesculin. Routine methods may give “false positives” and additional confirmatory tests may be required.

Information Sheet-3	**Identifying water treatment processes for microorganisms problems**

3 1. Treatment of water supply:

Water for domestic purposes can be treated against contaminants either in small scale or large scale.

3.1.1. Small scale treatment of water supply:

The following treatment methods can be considered as small-scale treatment of water supplies for individuals and families.

- Boiling of water:

It is difficult to practice boiling of water due to fuel and time shortages. Nevertheless, boiling water is an important method to prevent water borne diseases at the household level.

- Filtration:

Homemade sand filters and candle filters are helpful at the household level.

- Storage of water:

Storing water at the household level for 24-72 hours will help settle suspended impurities including pathogens. It creates an unfavourable environment for pathogenic microorganisms. Most pathogens do not survive long in water.

incidental contamination during distribution. Ozone could also be used to treat water supply.

However, • Disinfection:

disinfection of spring or well with chlorine right after construction or when the need arises.

3.1.2. Large scale treatment of water supply

Large scale water treatment involves the municipal treatment of water for
domestic use.

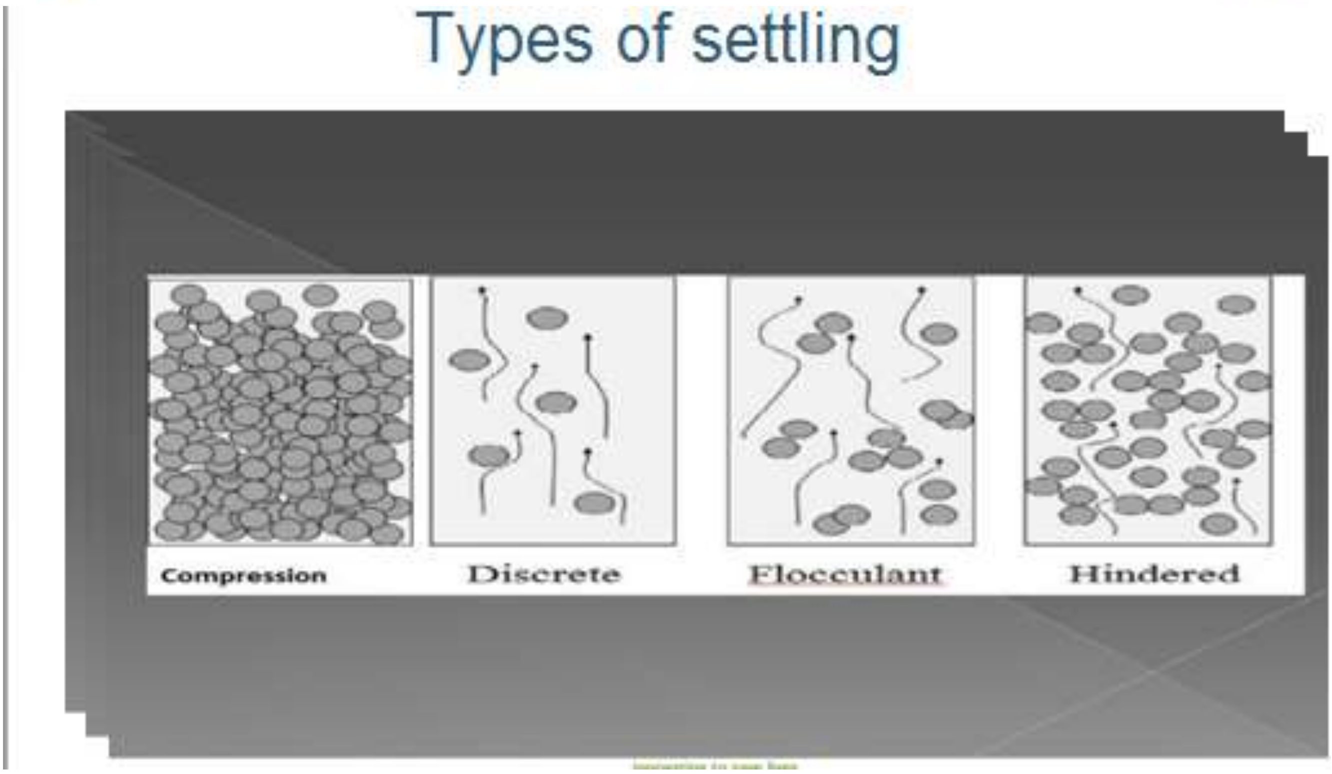
Treatment of surface water involves several stages that include sedimentation assisted with various chemical reagents and the passage of water through sand filters (slow sand filtration or rapid sand filtration processes). Finally the filtered water will be treated with chlorine doses to maintain a residual amount of chlorine throughout the supply lines to avoid any this is expensive and does not have residual effect like to that of chlorine. Whatever chemical is used, administrating the right dose of the disinfectant is vital in the prevention and control of water - borne diseases.

3.2. Coagulation and Flocculation

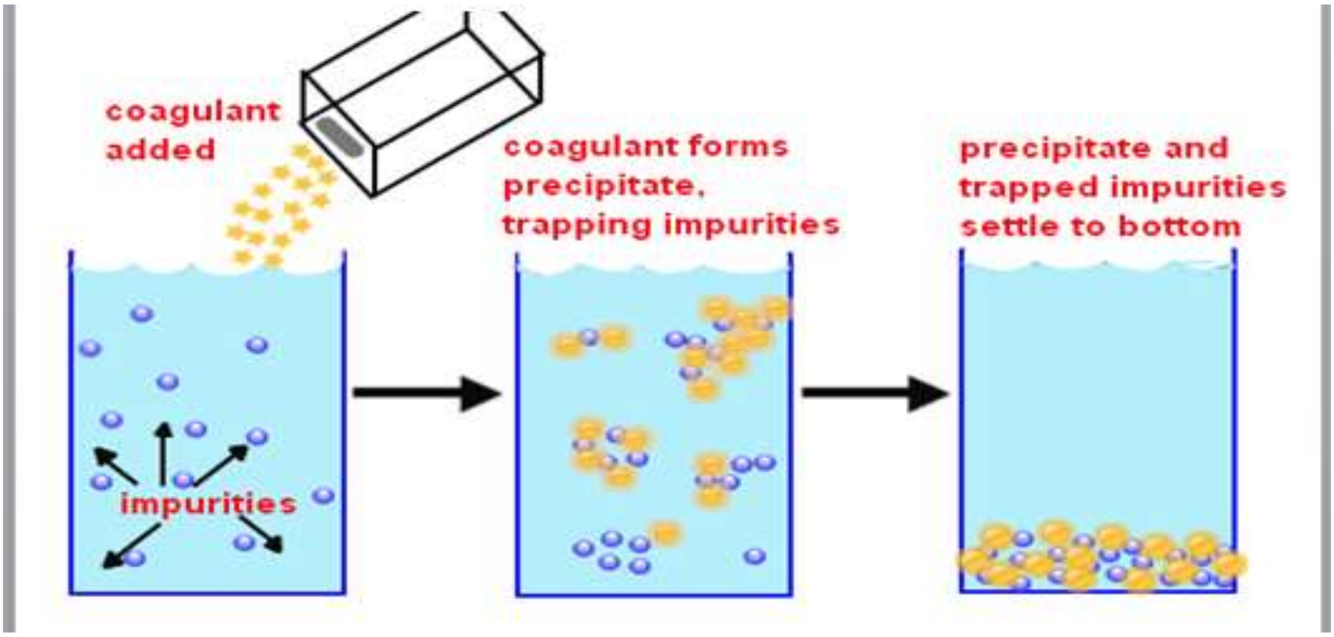
Surface water must be treated to remove turbidity, color, and bacteria. Some particle sizes common to most surface waters are listed in Table 5-1, along with their terminal settling velocity (assuming quiescent conditions and specific gravity of 2.65). From these values it's obvious that plain sedimentation will not be very efficient for the smaller suspended particles. Under conditions normally encountered in settling basins, efficient removal of particles less than 50 µm in diameter cannot be expected.

Table Settling velocities of various size particles

Particle size, mm	**Type**	**Settling velocity**
10	Pebble	0.73 m/s
1	Course sand	0.23 m/s
0.1	Fine sand	0.6 m/min
0.01	Silt	8.3 m/day
0.0001	Large colloids	0.3 m/year
0.000001	Small colloids	3 m/million years



Types of settling



3.2.1. Coagulation

The object of coagulation (subsequently flocculation) is to turn the small particles of color, turbidity, and bacteria into larger flocs, either as precipitates of suspended particles. The term coagulation comes from the Latin word coagulate, meaning to drive together. *Coagulation is a chemical process in which charged particles (colloids) are destabilized.*

Coagulants

A *coagulant* is the substance (chemical) that is added to the water to accomplish coagulation. There are three key properties of a coagulant:

1. Trivalent cation. most efficient cation
2. Nontoxic. For production of safe water
3. Insoluble in neutral pH range. So that coagulants added can precipitate without leaving high concentration of ions in water.

Selection of the proper coagulant depends upon: 1) the characteristics of the coagulant, 2) particulates, 3) water quality, 4) cost, and 5) dewatering characteristics of the solids that are produced. The selected coagulant should be non-toxic and relatively inexpensive. It should also be insoluble in neutral pH range and do not leave high concentrations of metals in the treated water.

Commonly used coagulants are:

- Alum: $Al_2(SO_4)_3.14H_2O$
- Ferric chloride: $FeCl_3$
- Ferric sulfate: $FeSO_4$
- Polyelectrolytes (Polymers)

Aluminum. Aluminum can be purchased as either dry or liquid alum. *Alum* is available either in lump, granular or powdered form (depending on the local supplier). Alum contains a variable amount of water of crystallization, depending on the local method of manufacture ($Al_2(SO_4)_3.nH_2O$ where n is usually in the range 14 to 18. As *liquid alum*, it can be trucked or piped to suitable storages if a treatment plant is near an alum-producing plant. Liquid alum is often cheaper than crystalline alum but it requires acid-proof (stainless steel) tanks and piping for storage and transport.

There is a limited pH range in which the insoluble aluminum hydrates, such as aluminum hydroxide, will form from a dilute alum solution. If the pH is too low, a more soluble compound,

$Al(OH)_2^+$ will form. If it is too high, above pH8, the aluminum becomes complexed into $Al(OH)_4^-$. Optimum pH is 5.5-6.5 and operating pH is 5 – 8.

when alum is added to a water containing alkalinity, the following reaction occurs:

$$Al_2(SO_4)_3.14\,H_2O + 6HCO_3^- \Leftrightarrow 2Al\,(OH)_3\,(s)\downarrow + 6CO_2 + 14H_2O + 3SO_4^{-2}$$

such that each mole of alum added uses six moles of alkalinity and produces six moles of carbon dioxide. The above reaction shifts the carbonate equilibrium and decreases the pH. However, as long as sufficient alkalinity is present and $CO_2(g)$ is allowed to evolve, the pH is not drastically reduced and is generally not an operational problem.

When sufficient alkalinity is not present to neutralize the sulfuric acid production, the pH may be greatly reduced:

$$Al_2(SO_4)_3.14\,H_2O \Leftrightarrow 2Al\,(OH)_3\,.3H_2O(s)\downarrow + 3H_2SO_4 + 2H_2O$$

If the second reaction occurs, lime or sodium carbonate may be added to neutralize the acid.

$$Ca\,(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + 2H_2O$$

$$2Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2NaHCO_3$$

$$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$$

If lime is added the total reaction becomes as follows

$$Al_2(SO_4)_3\cdot 14H_2O + 3Ca\,(OH)_2 \leftrightarrow 2Al\,(OH)_3(s)\downarrow + 3CaSO_4 + 6CO_2 + 14H_2O$$

Example: alkalinity calculation. If 200 mg/L of alum to be added to achieve complete coagulation. How much alkalinity is consumed in mg/L as $CaCO_3$?

Solution:

$$Al_2(SO_4)_3.14\,H_2O + 6HCO_3^- \Leftrightarrow 2Al\,(OH)_3\downarrow + 6CO_2 + 14H_2O + 3SO_4^{-2}$$

594 mg **366 mg**

594 mg alum consumes 366 mg HCO_3^-

200 mg alum will consume (366/594) x 200 mg HCO_3^-

= $\underline{123\text{ mg }HCO_3^-}$

$$\text{Alkas } CaCO_3 = 123 \times \frac{\text{Equivalent weight of } CaCO_3}{\text{Equivalent weight of } HCO_3^-}$$

= 123 x (50/61)

= 101 mg/L as $CaCO_3$

3.2.2. Softening

Sedimentation and plain filtration remove only suspended and colloidal solids from raw water. Still water contains some dissolved mineral matter like calcium, magnesium, iron, manganese, sodium, potassium, and strontium, and so on in association with bicarbonates, carbonates, sulphates, chlorides and nitrates. The minerals in natural water may be of alkaline, neutral and acidic in nature. Alkaline minerals may cause alkalinity or alkalinity and hardness. The removal of such dissolve objectionable substances from water by the addition of some chemicals to convert them into insoluble substances is known **as chemical precipitation.**

Softening is the removal of *hardness* from water. It can be achieved by lime-soda softening or ion exchange. Hard water is usually defined as water which contains a high concentration of calcium and magnesium ions. Measurements of hardness are given in terms of the calcium carbonate equivalent, which is an expression of the concentration of hardness ions in water in terms of their equivalent value of calcium carbonate (Table 8.1).

Table 8.1 Degree of hardness

Mg/L as $CaCO_3$	Degree of hardness
0-75	Soft
75-150	Moderately hard
150-300	Hard
> 300	Very hard

Water softening is needed when hardness is above 150-200 mg/L; Hardness 50-80 is acceptable in treated water.

Hardness is a problem because it interferes with soaps and detergents and leaves a white crusty scale around faucets.

$$Ca^{2+} + (soap)^{-} \longrightarrow Ca(soap)_2$$

Two types of hardness can be identified- carbonate and non-carbonate hardness.

Carbonate hardness	Non-carbonate hardness

compounds	compounds
Calcium carbonate ($CaCO_3$)	Calcium sulfate ($CaSO_4$)
Magnesium carbonate ($MgCO_3$)	Magnesium sulfate ($MgSO_4$)
Calcium bicarbonate ($Ca(HCO_3)_2$)	Calcium chloride ($CaCl_2$)
Magnesium bicarbonate ($Mg(HCO_3)_2$)	Magnesium chloride ($MgCl_2$)
Calcium hydroxide ($Ca(OH)_2$)	
Magnesium hydroxide ($Mg(OH)_2$)	

Carbonate hardness is sometimes called *temporary hardness* because it can be removed by boiling water. Non-carbonate hardness cannot be broken down by boiling the water, so it is also known as *permanent hardness*. In general, it is important to distinguish between the two types of hardness because the removal method differs for the two.

Total Hardness (*TH*) = Sum of $Ca^{2+\ \mathrm{andMg2+}}$ ions measured as mg/L of $CaCO_3$

Total Hardness (as $CaCO_3$) = (eq/L of cation charge) x (50g $CaCO_3$/Charge eq) x 1000mg/g

Example Hardness Calculations:

$$TH(Ca^{2+}) = \left(\frac{1\ mg}{L}\right)\left(\frac{2\ chg\ eq}{mole}\right)\left(\frac{mole}{40{,}000\ mg}\right)\left(\frac{50{,}000mg}{chg\ eq}\right) = 2.50\ {}^{mg}\!/\!_{L}\ asCaCO_3$$

$$TH(Mg^{2+}) = \left(\frac{1\ mg}{L}\right)\left(\frac{2\ chg\ eq}{mole}\right)\left(\frac{mole}{24{,}300\ mg}\right)\left(\frac{50{,}000mg}{chg\ eq}\right) = 4.12\ {}^{mg}\!/\!_{L}\ asCaCO_3$$

Softening methods

1. Boiling
2. Lime treatment
3. Lime-soda process
4. Ion-exchange method

Boiling. Boiling reduces only calcium carbonate hardness but not non-carbonate hardness.

$$Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2 \downarrow$$

Lime treatment. Addition of lime to hardwater converts soluble bicarbonate into insoluble $CaCO_3$. If CO_2 is present in water, some amount of lime is required to neutralize it.

CO_2: $CO_2 + Ca(OH)_2 \leftrightarrow CaCO_3\downarrow + H_20$

Calcium carbonate hardness: $Ca(HCO_3)_2 + Ca(OH)_2 \leftrightarrow 2\ CaCO_3\downarrow + 2\ H_2O$

Magnesium carbonate hardness: $Mg(HCO_3)_2 + Ca(OH)_2 \leftrightarrow CaCO_3\downarrow + MgCO_3 + 2\ H_2O$

Excess lime treeatment: $MgCO_3 + Ca(OH)_2 \leftrightarrow Mg(OH)_2\downarrow + CaCO_3\downarrow$

Noncarbonate hardness: $MgSO_4 + Ca(OH)_2 \leftrightarrow Mg(OH)_2\downarrow + CaSO_4$

$MgCl2 + Ca(OH)_2 \leftrightarrow Mg(OH)_2\downarrow + CaCl_2$

Addition of excess lime raises the pH to 10.5. The excess lime is neutralized by CO_2 to reduce the pH to about 8.0 before filtratration. This is called *re-carbonation*.

$CO_2 + Ca(OH)_2 \leftrightarrow CaCO_3\downarrow + H_20$

Lime-soda process: Used to remove both carbonate and non-carbonate hardness. Lime and soda ash (sodium carbonate) are used to convert calcium and magnasium into insoluble calcium carbonate and magnesium hydroxide flocculated suspensions. These supensions are removed by sedimentation and filtration.

Reaction with soda ash

$CaSO_4 + Na_2CO_3 \leftrightarrow CaCO_3\downarrow + Na_2SO_4$

$CaCl_2 + Na_2CO_3 \leftrightarrow CaCO_3\downarrow + 2NaCl$

Lime and soda-ash requirements are computed as follows:

$$[Ca\ (OH)_2] = [CO_2] + [HCO_3^-] + [Mg^{2+}] + [excess\ lime]$$

$$[Na_2CO_3] = [Ca^{2+}] + [Mg^{2+}] - [Alkalinity]$$

Where,

$[Ca\ (OH)_2]$ = amount of lime required for softening in meq/L

$[Na_2CO_3]$ = amount of soda-ash required for noncarbonate softening in meq/L

$[CO_2]$ = concentration of CO_2 in meq/L

$[HCO_3^-]$ = concentration of HCO_3^- in meq/L

$[Ca^{2+}]$ = concentration of Ca_2^+ in meq/L

$[Mg^{2+}]$ = concentration of Mg_2^+ in meq/L

[Excess lime] = additional lime to maintain elevated pH value (usually 1 or 1.25 meq/L)

[Alkalinity] = concentration of alkalinity in meq/L

Chemical dosing design:

- Softening goals: *TH* = 75 to 120 mg/L Mg^{2+} hardness = 40 mg/L max.

- Practical softening limits: Ca^{2+} = 30 mg/L min.; Mg^{2+} 10 mg/L min.
- Excess chemical requirements: 20 mg/L

3.2.3. Ion-exchange

Softnening by ion-exhange involves passing rhe water through a column containing a special ion-exhange material. Several different types of ion-exchange materials are in use, icluding natural substances called zeolites and synthetic resins. When water containing calcium and magnesium ions is in contact with these materials, an exchange of ions takes place. The calcium and magnesium ions are taken up by the resin, whereas sodium ions, Na+, are released inti the water.

The ion-exchange process is illustrated schematically in Figure 5.12. eventually, the exchange capacity of the zeolite or resin is used up and the ion exchanger must be regenerated for further use. This done by washing the exchanger with a sodium chloride, NaCl, solution.

Softening by ion exchange can produce water with almost zero levels of hardness, but this in not really desirable. Very soft water may be aggressive, or corrosive, causing damage to metal pipes and plumbing. Hardness level of about 100mg/L are considered optimal for drinking water.

Zeolite can be expressed as sodium alumino silicate. Zeolites are either available naturally or prepared artificially (synthetic zeolites). Green sand or gluconite are some of the natural zeolites.

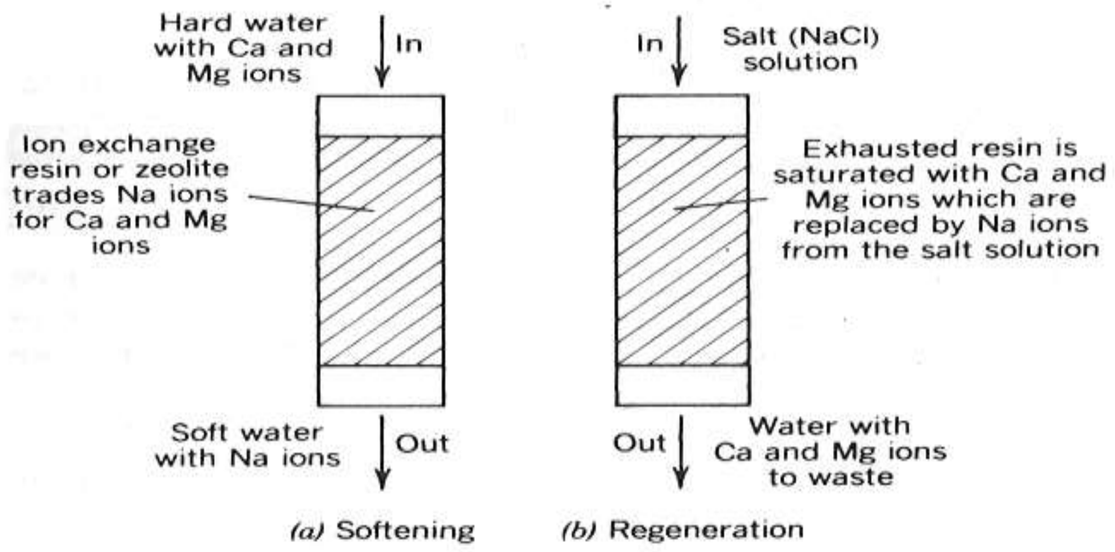


FIGURE 5.12
(a) *An ion-exchange column used for water softening;* (b) *the column may be regenerated and used again after washing with a strong salt solution.*

3.2.4. Filtration

After sedimentation, the water only contains fine solids and soluble material. Filtration is required to remove this residual material. Various filtration processes are used in drinking-water treatment, including granular, rapid and slow sand filters, precoat, and membrane filtration (microfiltration, ultrafiltration, nano filtration and reverse osmosis).

Filtration can act as a consistent and effective barrier for microbial pathogens. Granular media filtration may in some cases be the only barrier (for example for removing Cryptosporidium oocysts by direct filtration when chlorine is used as the sole disinfectant).

Rapid and slow sand filtration

Rapid sand filters contain coarse grades of quartz sand (1 mm diameter) so that the gaps between

the grains are relatively large and the water passes rapidly through the filter. These are used for

water that has previously been treated by coagulation and sedimentation, and are less effective in

removing microorganisms. Turbidity varies through the duration of the run between backwashing's. Immediately after backwashing, performance is poor, until the bed has compacted. Performance will also deteriorate progressively at the stage when backwashing is needed, as floes may escape through the bed into the treated water. These features emphasize the need for proper supervision and control of filtration at the waterworks.

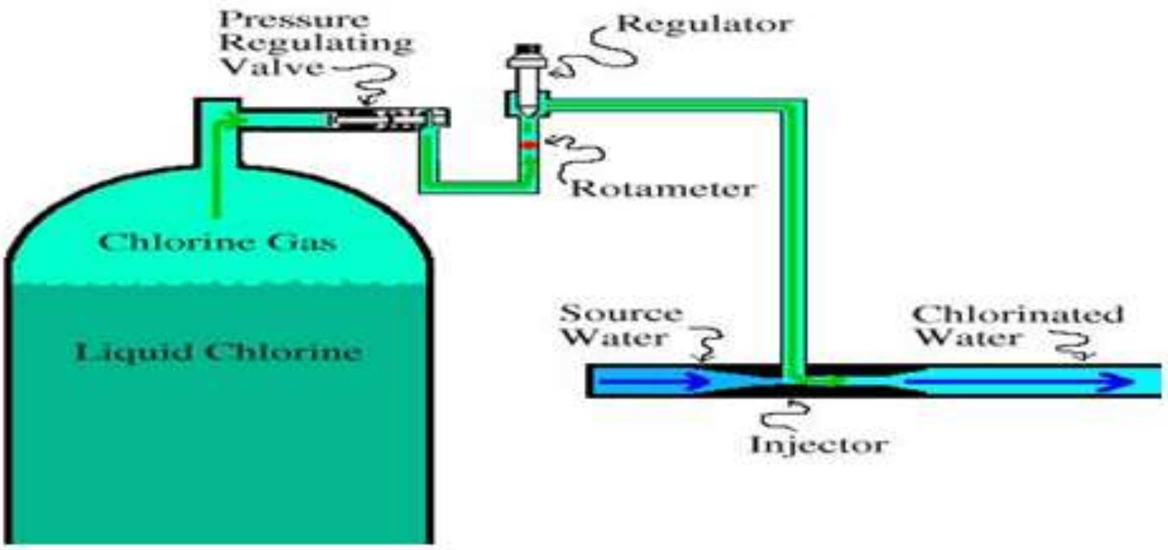
Slow sand filtration is simpler to operate than rapid filtration, as frequent backwashing is not required. It is therefore particularly suitable for developing countries and small rural systems, but it is applicable only if sufficient land is available.

When the slow sand filter is first brought into use, a microbial slime community develops on the sand grains, particularly at the surface of the bed. This consists of bacteria, free-living ciliated protozoa and amoebae, crustaceans, and invertebrate larvae acting in food chains, resulting in the oxidation of organic substances in the water and the conversion of ammoniacal nitrogen to nitrate. Pathogenic bacteria, viruses, and resting stages of parasites are removed, principally by adsorption and by subsequent predation. When correctly loaded, slow sand filtration brings about the greatest improvement in water quality of any single conventional water treatment process. Bacterial removal will be at least 98–99.5% effective, E. coli will be reduced by a factor of 1000, and virus removal will be even greater. A slow sand filter is also very efficient in removing parasites (helminths and protozoa). Nevertheless, the effluent from a slow sand filter might contain a few E. coli and viruses, especially during the early phase of a filter run and with low water temperatures. The disadvantage with this type of filter is that it is operationally expensive and labour intensive because the dirt layer that collects on the surface of the sand impedes drainage and must be removed after the filter have been drained.

The operation of both rapid and slow sand filters is complex, and poor operation can lead to problems. The most serious problem is if the sand bed cracks, allowing unfiltered water to pass though.

3.2.5. Disinfection

Disinfection is the process of killing all pathogens. Safe water means water (a) free from pathogenic bacteria, (b) aesthetically acceptable, and (c) free from excessive minerals, and poisonous matter. Pathogens die away or are destroyed in significant numbers in the course of treatment. The purpose of disinfection is to kill and pathogens remaining after conventional treatment. The substance used for disinfection is called *disinfectant*. When a disinfectant is added to water, it reacts chemically and products are released. They attack the cell of the pathogen and inactivate the cell. Pathogens found in water supplies include ***viruses, bacteria, and protozoa*** (including ***cysts***). Disinfectants must effectively reduce all types of pathogens without being toxic to humans or domestic animals. Additionally, it must not drastically change the taste or color of water and it must be persistent.



<u>Factors affecting the efficiency of disinfection</u>

1. Nature and concentration of organisms
2. Nature and concentration of disinfectant
3. Nature of water to be disinfected (interfering substances like NH_3, iron, Mn, organic matter)
4. Temperature of water
5. Time of contact

<u>Disinfection methods include:</u>

- Heat
- Mechanical (ultrasonic vibration, membrane filtration)
- Radiation (Gamma, Ultraviolet radiation)

- Chemical
    - Halogens (chlorine, bromine, iodine)
    - Chlorine dioxide (ClO_2)
    - Chloramines ($ClNH_2$, Cl_2NH, Cl_3N)
    - Ozone

Disinfection Kinetics

The kinetics of disinfection depends on the following

1. Time of contact
2. Concentration of disinfectant
3. Concentration of organisms
4. Temperature of water

Time of Contact. When a single unit of microorganisms is exposed to a single unit of disinfectant, the reduction in microorganisms follows a first-order reaction. This equation is known as *Chick's Law*, which states that the number of organisms destroyed in a unit time is proportional to the number of organism remaining:

$$-\frac{dN}{dt} = kN \qquad (7-1)$$

$$N = N_o e^{-kt} \qquad (7-2)$$

Where, N = number of microorganism (N_O is initial number)

k = disinfection constant

t = time

Concentration of disinfectant. The disinfection efficiency is generally estimated as,

$$C^n t = Constant \qquad (7-3)$$

where C is the concentration of the disinfectant, t is the time required to affect a constant % kill of the organisms, and n is a coefficient of dilution.

Concentration of organism

$$C^q N_R = constant \qquad (7-4)$$

where C = concentration of the disinfectant, N_R = concentration of organism that reduced by a given percentage in a given time, and q = A coefficient of disinfectant strength.

Temperature. The effect of temperature on disinfection follows the Van Hoff-Arrhenius relationship

$$ln\frac{t_1}{t_2} = \frac{E'(T_2 - T_1)}{R_{T1,T2}} \qquad (7-5)$$

Where t_1,t_2 = time required for a given kills

T_1, T_2 = temperature corresponding to t_1 and t_2, K

R = gas constant, 1.0 cal/K-mol

E' =activation energy, related to pH, cal

Chlorination

Chlorine is the most commonly used disinfectant. The chlorine dosage required is a function of the water's organic content (including the microorganisms) and the water's reduced inorganic content. Reduced inorganics include species such as Fe^{2+}, Mn^{2+}, NH_3, etc. which will be oxidized by chlorine.

Chlorine is added to the water supply in two ways. It is most often added as a gas, Cl_2(g), generated from the vaporization liquid chlorine. However, it also can be added as a salt, such as sodium hypochlorite (NaOCl) or bleach. Chlorine gas dissolves in water following Henry's Law.

$$Cl_{2(g)} \xleftrightarrow{K_H} Cl_{2(aq)} \qquad K_H = 6.2 \times 10^{-2} \frac{moles}{l - atm} \quad (at\ 25°C)$$

When chlorine is added to water, a mixture of hypochlorous acid (HOCl) and hydrochloric acid (HCl) is formed:

$Cl_2(g) + H_2O \quad HOCl + H^+ + Cl^- \quad \rightleftharpoons$

Hypochlorous acid is a weak acid that dissociates to form hypochlorite ion (OCl^-).

$$HOCl \longleftrightarrow OCl^- + H^+ \qquad K_a = 3.2 \times 10^{-8}$$

Hypochlorous acid and hypochlorite ion compose what is called in the water treatment industry the ***free chlorine residual***. These free chlorine compounds can react with many organic and inorganic compounds to form chlorinated compounds. If the products of these reactions possess oxidizing potential, they are considered the combined chlorine residual**.** A common compound in drinking water systems that reacts with chlorine to form combined residual is ammonia. Reactions between ammonia and chlorine form chloramines, which is mainly monochloramine (NH_2Cl), although some dichloramine ($NHCl_2$) and trichloramine (NCl_3) also can form. Many drinking water utilities use monochloramine as a disinfectant. If excess free chlorine exits once all ammonia nitrogen has been converted to monochloramine, chloramine species are oxidized through what is termed the breakpoint reactions. The overall reactions of free chlorine and nitrogen can be represented by two simplified reactions as follows:

Monochloramine Formation Reaction. This reaction occurs rapidly when ammonia nitrogen is combined with free chlorine up to a molar ratio of 1:1.

$$\mathrm{HOCl} + \mathrm{NH_3} \leftrightarrow \mathrm{NH_2Cl} + \mathrm{H_2O}$$

Breakpoint Reaction. When excess free chlorine is added beyond the 1:1 initial molar ratio, monochloramine is removed as follows:

$$\mathrm{2NH_2Cl} + \mathrm{HOCl} \rightarrow \mathrm{N_{2(g)}} + \mathrm{3H^+} + \mathrm{3Cl^-} + \mathrm{H_2O}$$

The formation of chloramines and the breakpoint reaction create a unique relationship between chlorine dose and the amount and form of chlorine as illustrated below.

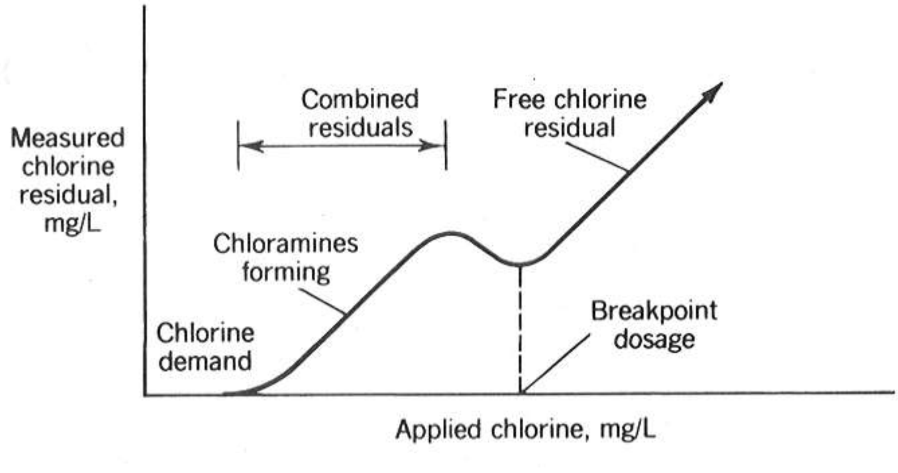


Figure 7.1 Breakpoint chlorination curve.

Chlorine demand: The difference between the amount of chlorine added to water and the amount of residual chlorine after a specified contact period is defined as the chlorine demand.

Chlorination Practice

- Required application rate is site specific.

- Need to establish a combined residual after a reasonable contact time in the plant and with no detectable indicator organism concentration.
- Common dosage range for breakpoint is 4 to 10 mg/L as Cl_2.
- Common contact times 10 to 20 minutes.
- Total combined residual leaving the plant 0.5 to 2.0 mg/L.
- Maintain residual sufficient to ensure 0.2 mg/L free residual available at the farthest points in the distribution system.
- Chlorine to ammonia weight ratios for chloramine formation 3:1 to 4:1.

Points of chlorination

1. Pre-chlorination: It is the application of chlorine to water prior to any unit treatment process.
2. Post chlorination: This is the application of chlorine to treated water before it enter the distribution system.
3. Re-chlorination: This when the distribution system is long and complex, post-chlorination dosages are not sufficient to get required Cl2 residuals at consumers end. So stage wise application of chlorine is distribution system is carried out and is called re-chlorination.

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

TRUE OR FALSE ITEMS

1. Which of the following process is not involved in large scale water vtreatment process?
   - A. Coagulation
   - B. Sedimentation
   - C. Boiling
   - D. Flocculation

2.Which of the following does not affect disinfection process?
   - A. Time of contact
   - B. Nature and concentration of organisms
   - C. Temperature of water
   - D. Color of the water

3. The difference between the amount of chlorine added to water and the amount of residual chlorine after a specified contact period is;-
   - A. Chlorine demand
   - B. combined chlorine residual
   - C. free chlorine
   - D. Consumed Chlorine

4. Which of the following is a liquid disinfectant?
   - A. Calcium Carbonate
   - B. Sodium Chloride
   - C. Sodium Sulfate
   - D. Sodium Hypochlorite

5. The application of chlorine to treated water before it enter the distribution system is called:-
   - A. Re-chlorination
   - B. Post- chlorination
   - C. Pre-chlorination
   - D. Chlorination

Note: **Satisfactory rating - 5 points Unsatisfactory - below 5points**

You can ask you teacher for the copy of the correct answers.

Answers 1.___________ 2._________ 3.___________, 4_____________, 5_____________

Information Sheet-4	Identifying characteristics and diseases of pathogenic microorganisms

4.1. Introduction

Water, although an absolute necessity for life can be a carrier of many diseases. Paradoxically, the ready availability of water makes possible the personal hygiene measures that are essential to prevent the transmission of enteric diseases. Infectious water-related diseases can be categorized as waterborne, water-hygiene, water-contact and water habitat vector diseases. Some water-related diseases, however, may fall into more than one category.

Waterborne infectious diseases are those in which the pathogen, or causative organism, is present in water and ingested when the water is consumed. Most of the pathogens involved are derived from human faeces, and the diseases transmitted by consumption of faecally contaminated water are called “faecal-oral” diseases. All of the fecal oral diseases can also be transmitted through media other than water, for example faecally contaminated food, fingers or utensils. The principal faecal-oral diseases are cholera, typhoid, shigellosis, amoebic dysentery, hepatitis A and various types of diarrhea.

One disease that is exclusively waterborne is dracunculiasis, or Guinea worm disease, which is caused by Ranunculus medinensis. An individual can become infected with Ranunculus only by consuming water contaminated with the microscopic crustaceans (Cyclops) that contain the larvae of the pathogen. Dracunculiasis is not a faecal-oraldisease.

4.2. Bacteriological pathogens

- **Cholera**

Faecalis contamination of drinking-water is still the most significant cause of cholera outbreaks in many parts of the world, especially in critical situations such as natural disasters, mass migration, military actions and refugee camps. Cholera epidemics occur due to insufficient hygiene and sanitation (Exner, 1996).

Vibrio cholera is a Gram-negative bacterium and is the classical causative organism of cholera. To date, 139 different serotypes have been identified of which O1 and O139 are pathogenic types. *V. cholera* 01 is subdivided into the *El TorO1* and the *haemolytic El Tor Vibrio.* These strains are replacing the classical *V. cholerae*. In 1992 the strain O139 was identified for the first time in India and Bangladesh. In 1991, cholera occurred in Latin America after 100 years of absence. Within two years, the cholera spread from Peru to Mexico. These cholera epidemics show the potential for modern societies to disseminate an epidemic pathogen globally.

The organism enters the gut via ingestion, colonizes in the mucosa and produces an enterotoxin, which results in an extreme loss of water and electrolytes. The infectious dose of cholera is relatively high. The incubation period, typically 1–5 days, is rather short. Cholera is an acute infection of the intestine, which begins suddenly with painless watery diarrhoea, nausea and vomiting. The main clinical symptoms include colorless stools, so called rice-water diarrhea. Severe cases start abruptly with endless streams of watery stools. Due to massive loss of body fluids, dehydration and metabolic acidosis leading to death can occur within hours or a few days. Without treatment, mortality is high (50%) in heavy cases. Children at an early age are particularly at risk. With prompt and adequate treatment, mortality can be reduced to 1% of the cases. V. cholerae live attached to a particular kind of algae and zooplankton in aquatic environments, which are its natural reservoir, and can infect foodstuffs grown in contaminated areas.

Cholera remains prevalent in areas with poor hygiene and sanitation, close to surface water, with high population density and a high absolute humidity

- **Typhoid fever**

The causative agent of typhoid fever is Salmonella typhi, which is an enteropathogenic organism among other Salmonellas. They belong to the family Enterobacteriaceae and are Gramnegativefacultatively anaerobic bacteria. Today Salmonellaspp.are classified by DNA serotyping into different serotypes. Common human Salmonella serotypes are S. typhi, S. paratyphoid, S. entertained S. typhimuriumwhich cause enteric fever or gastroenteritis (Miller &Pegues, 2000; Chin, 2000).

Symptoms of infection can be mild or severe and include sustained high fever (as high as 39–40 °C), malaise, anorexia, headache, constipation or diarrhea, rose-colored spots on the chest area and enlarged spleen and liver. Most people show symptoms 1–3 weeks after exposure.

The pathogens can be transmitted from person to person by direct contact to infected individuals or by ingestion of faecal-contaminated food or drinking-water. Important vehicles in some countries include shellfish taken from sewage-contaminated beds, raw fruits, vegetables, contaminated milk and dairy products

Shigella

Shigellosis or bacillary dysenteryis an acute bacterial disease characterized by bloody diarrhea. Shigellaspp.are small Gram-negative bacteria that belong to the Enterobacteriaceae family. The genus Shigellacomprises four species: S. dysenteriae, S. flexneri, S. boydiiand S. sonnei. Bacillary dysentery is the most communicable of the bacterial enteritis. Symptoms are fever, nausea, vomiting, cramps and tenesmus. Mild and asymptomatic cases occur. The illness is usually self-limited and lasts 4–7 days. The incubation time is1–7 days for all Shigellaspp.infectious diseases (Dupont, 2000; Gleeson & Gray, 1997).

Shigellosis is a health problem in developing as well as in developed countries. The infection is recognized to be endemic in the eastern Mediterranean countries and shows a peak of infection predominantly in the warm months. In developing countries, the occurrence is influenced by the availability of water and changes in the hygienic behavior of the population.

Waterborne outbreaks occur more frequently due to faecal-contaminated drinking-water. Epidemics of waterborne shigellosis generally appear in the context of wells contaminated with faecal material and sewage discharge close to water intakes or bathing areas. Because of the low resistance to chlorine, chlorination of water would be an effective prevention measurement

(WHO, 2004; Dupont, 2000). So far, the disease is not known to be often spread by waterborne transmission, but waterborne outbreaks are occurring more frequently due to faecally contaminated drinking-water.

Campylobacter

Campylobacteriosis is a worldwide zoonotic (passed to humans via animals or animal products), enteritic disease which relates to Gram-negative bacteria of different *Campylobacter*species.*Campylobacter* are bacteria which grow under microaerophilic conditions.

Diarrhea (often in the presence of mucus and blood), abdominal cramps, fever, malaise and vomiting are characteristics of acute campylobacteriosis. In some individuals, a reactive arthritis (painful inflammation of the joints) can occur. Rare complications include seizure due to high fever or neurological disorders such as Guillain-Barre syndrome or meningitis. The period from the infection until the occurrence of the first symptoms is about 2–5 days. The infective dose ranges from low to moderate.

The disease can be directly transmitted via the faecal–oral route or indirectly via contaminated foodstuff and drinking-water.

Pathogenic E. coli strains

E. coli strains are present in the normal microbial flora of the gastrointestinal tract of human beings and warm-blooded animals. As they occur in high numbers in all faeces, E. coli are used as an indicator for faecal pollution in drinking-water surveillance (Gleeson & Gray, 1997).

The disease can be transmitted from person to person via direct contact to infected human beings, contact with animals, food and consumption of contaminated water. Person-to-person transmission is particularly prevalent in communities where there is close contact between individuals, such as nursing homes or day-care centers. Infants and old people are at high risk of falling ill (Doyle, 1990).

4.3. Viral diseases – viral hepatitis A

Hepatitis is a broad term for inflammation of the liver. Two viruses that cause hepatitis (hepatitis A and E) can be transmitted through water and food.

The illness starts with an abrupt onset of fever, body weakness, loss of appetite, nausea and Humans are considered to be the only important reservoir of HAV. The main transmission route is ingestion of contaminated faeces. This can occur from person to person via contaminated \hands or by consumption of contaminated water or food. Usually food which is eaten uncooked, such as salads, fruit, vegetables, ice and some dairy products are responsible for foodborne outbreaks. HAV can also be transmitted via food contaminated by infected food handlers, uncooked foods, or foods handled after cooking., The virus can appear in swimming pools and coastal areas used for bathing and swimming. Hepatitis A is particularly frequent in countries with poor sanitary and hygiene conditions

4.4. Protozoan diseases

Giardiasis

Giardia spp. are flagellate protozoan parasites of the genus *Giardia. G. lamblia* (also called *G. duodenalis* or *G. intestinalis*) is believed to be the most frequent cause of diarrheal disease and the most frequent intestinal parasite in humans worldwide. Clinical symptoms after infection with cysts include asymptomatic cyst passage; acute, usually self-limiting diarrheal episodes; and chronic diarrhea syndrome. Further symptoms may be abdominal cramps, malabsorption and weight loss.

Water plays a major role in the transmission of Giardia. Most waterborne outbreaks occur due to inadequate chlorination or/and insufficient filtration methods of drinking-water. Like C. parvum, the parasite is relatively resistant to chlorine and has a high tenacity.

4.5. Helminthic diseases

Helminths are generally known as parasitic worms. They usually invade their hosts in a larval stage and migrate through the body before maturing in the gut. They can cause serious tissue and organic damage, as well as malnutrition.

The major helminth infections of humans are caused by nematodes (roundworm), trematodes (flukes) and cestodes (tapeworms). The transmission route is through the ingestion of eggs and contact with faecally contaminated soil and food (Mahmoud, 2000b). A problem is the use of inadequately treated wastewater in irrigation and faecal sludge in soil fertilization.

Infections with nematodes comprise ascariasis, trichiasis and hookworm. Trichiasis is among the most prevalent human helminthiasis. About800 million cases occur worldwide, mostly in

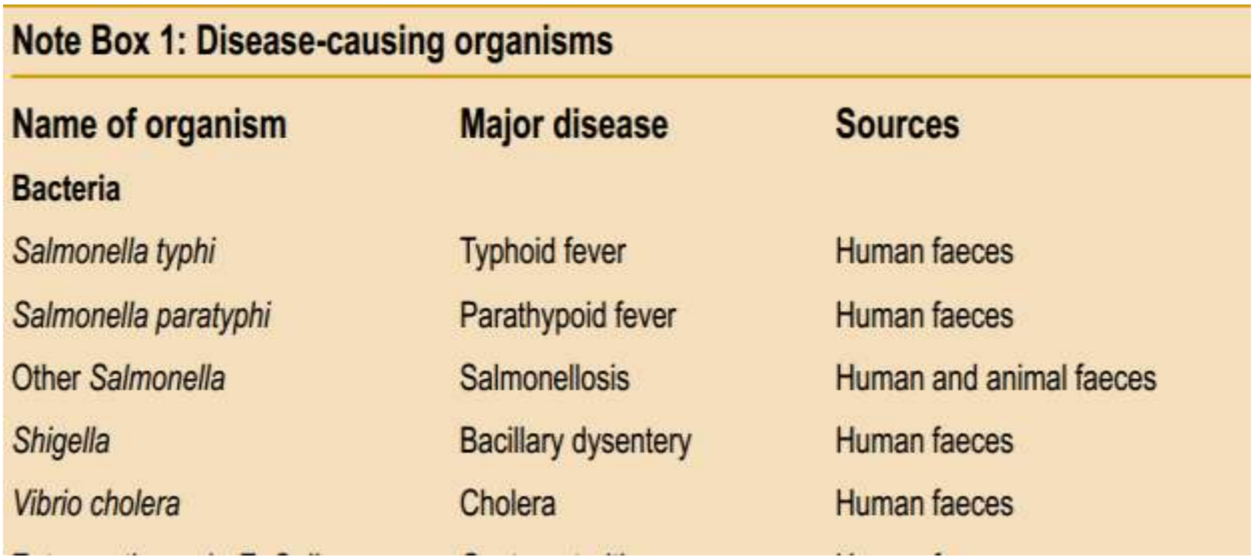
warm and moist regions (Mahmoud, 2000a). In humans the infection may manifest as mild anemias, bloody diarrhea or chronic gastrointestinal diseases. Malnutrition and growth retardation can also occur. Flukes are parasitic worms which cause schistosomiasis, Clonorchis's and fasciolosis. Humans are the definitive host for five schistosome species.

4.6. Cyanobacteria in drinking-water

Cyanobacteria are ubiquitous prokaryotic microorganisms that occur in particular in inland and coastal surface waters. In favorable conditions they reach high densities and may form blooms and scums. As secondary metabolites, most cyanobacteria produce cyanotoxins, which can be grouped according to their biological effects (Codd, Morrison & Metcalf, 2005) into:

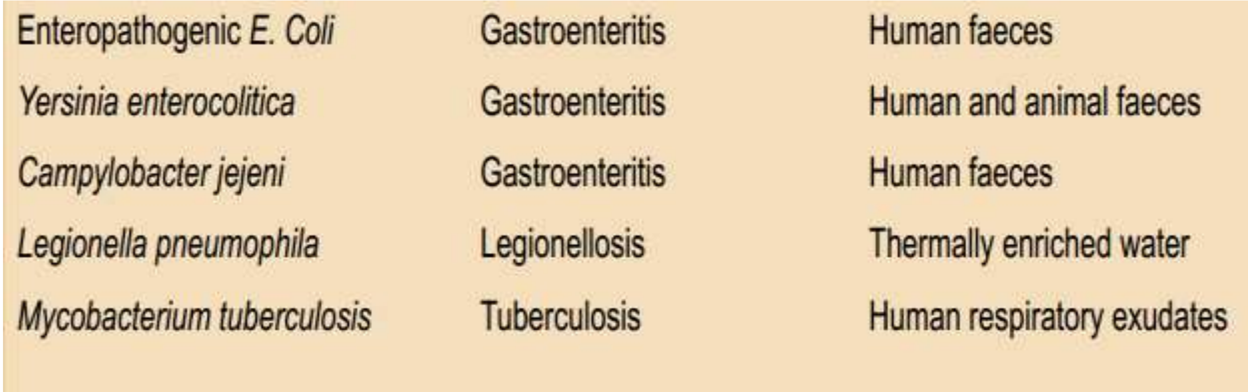
- hepatotoxins
- neurotoxins
- cytotoxins
- irritants and gastrointestinal toxins: (produced by marine cyanobacteria);
- lipopolysaccharide (LPS) endotoxins;
- other cyanotoxins, the toxicological or Eco toxicological profile of which is still only partially known, such as microviridin J and β-N-methylamino-L-alanine (BMAA).

Humans may be exposed to cyanotoxins via several routes: orally is by far the most significant, occurring through consumption of contaminated drinking-water or food (including dietary supplements) or by ingesting water during recreational activities. Dermal and inhalation exposure may also occur due to recreational, sports and professional activities (such as fishery) in infested waters, or to the domestic use of water containing cyanotoxins, for example through showering.



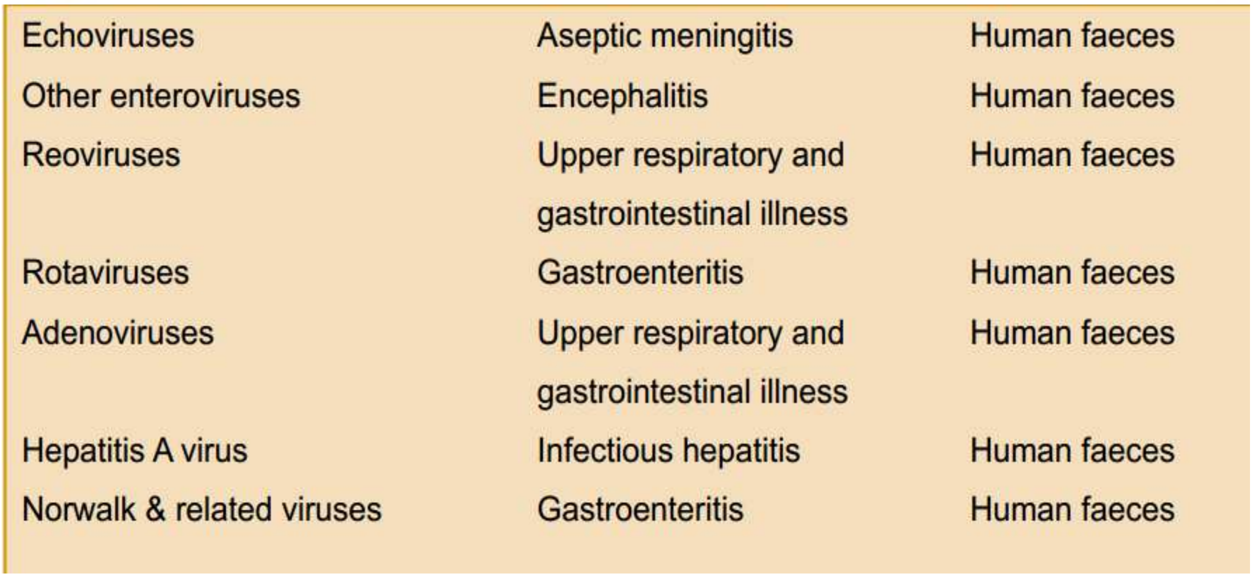
Note Box 1: Disease-causing organisms

Name of organism	Major disease	Sources
Bacteria		
Salmonella typhi	Typhoid fever	Human faeces
Salmonella paratyphi	Parathypoid fever	Human faeces
Other *Salmonella*	Salmonellosis	Human and animal faeces
Shigella	Bacillary dysentery	Human faeces
Vibrio cholera	Cholera	Human faeces

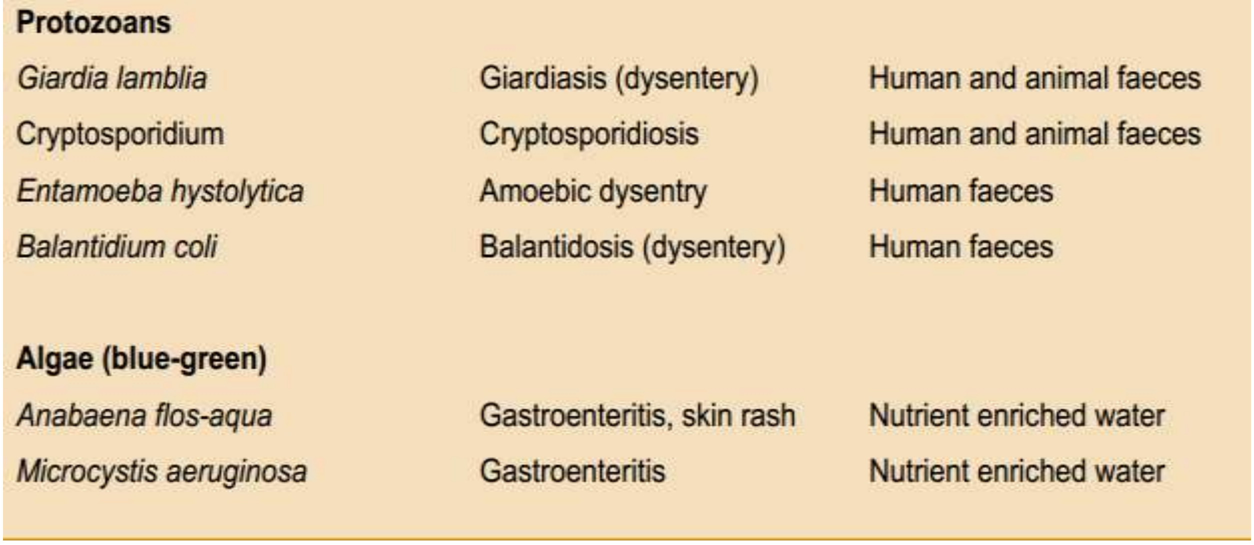


Enteropathogenic *E. Coli*	Gastroenteritis	Human faeces
Yersinia enterocolitica	Gastroenteritis	Human and animal faeces
Campylobacter jejeni	Gastroenteritis	Human faeces
Legionella pneumophila	Legionellosis	Thermally enriched water
Mycobacterium tuberculosis	Tuberculosis	Human respiratory exudates

Enteric viruses		
Polioviruses	Poliomyelitis	Human faeces
Coxsackie viruses A & B	Aseptic meningitis	Human faeces



Echoviruses	Aseptic meningitis	Human faeces
Other enteroviruses	Encephalitis	Human faeces
Reoviruses	Upper respiratory and gastrointestinal illness	Human faeces
Rotaviruses	Gastroenteritis	Human faeces
Adenoviruses	Upper respiratory and gastrointestinal illness	Human faeces
Hepatitis A virus	Infectious hepatitis	Human faeces
Norwalk & related viruses	Gastroenteritis	Human faeces



Protozoans		
Giardia lamblia	Giardiasis (dysentery)	Human and animal faeces
Cryptosporidium	Cryptosporidiosis	Human and animal faeces
Entamoeba hystolytica	Amoebic dysentry	Human faeces
Balantidium coli	Balantidosis (dysentery)	Human faeces
Algae (blue-green)		
Anabaena flos-aqua	Gastroenteritis, skin rash	Nutrient enriched water
Microcystis aeruginosa	Gastroenteritis	Nutrient enriched water

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

TRUE OR FALSE ITEMS

1. Which of the following disease is Bacterial?

A.schistosomiasis,

B. fasciolosis.

Cholera

D.Poleo

2.Cyanotoxins in water are formed by:-

A. Algae

B. Protozoa

C. Viruses

D. Bacteria

3. Ascariasis is ……………disease.

A. Helimentic

B. Bacterial

C. Viral

D. Protozoan

***Note:* Satisfactory rating - 5 points** **Unsatisfactory - below 5points**

You can ask you teacher for the copy of the correct answers.

Answers 1.___________ 2._________ 3.___________,

Instruction Sheet	Learning Guide40: Identify processes to remove microorganisms.

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Assessing effectiveness of filtration processes for removing pathogenic microorganisms
- Assessing effectiveness of disinfection processes for inactivating pathogenic microorganisms
- Identifying by product formation from disinfection processes
- Assessing metabolic. nuisance and toxicity problem of pre or post treatment Processes

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:

- Assess the effectiveness of a range of *filtration processes* for physically removing pathogenic microorganisms according to *organizational and legislative requirements*.
- Assess the effectiveness of a range of disinfection processes for inactivating pathogenic microorganisms according to organizational and legislative requirements
- Identify and assess the implications of by-product formation resulting from disinfection processes
- Assess the effectiveness of various pre- or post-treatment processes for removing microorganisms, or their metabolites, causing nuisance and toxicity problem.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below
3. Read the information written in the “Information Sheets 1- 6”. Try to understand what are being discussed. Accomplish the “Self-checks 1,2,3,4, 5 &6” in each information sheets on pages 36,38, 41, 45, 47, & 55.

4. If you earned a satisfactory evaluation proceed to “Operation sheets 1, 2,3, 4, 5, 6, 7, 8. on pages56,58,59,60, 61,62,63 64. and do the LAP Test on page 65”. However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity.

5.AfterYouaccomplish Operation sheets and LAP Tests, ensure you have a formative assessment and get a satisfactory result; then proceed to the next LG.

Information Sheet-1	Assessing effectiveness of filtration processes for removing pathogenic microorganisms

1.1. FILTRATION

Various filtration processes are used in drinking-water treatment. Filtration can act as a consistent and effective barrier for microbial pathogens. the most commonly used filtration processes in potable water treatment, the pore size of the filter media and the sizes of different microbial particles. These size spectra are useful for understanding removal mechanisms and efficiencies, and for developing strategies to remove microbes by different filtration processes.

1.1.1. GRANULAR HIGH-RATE FILTRATION

Granular media filtration is the most widely used filtration process in drinking water treatment. Under optimal conditions, a combination of coagulation, flocculation, sedimentation and granular media filtration can result in 4 logs or better removal of protozoan pathogens with chlorine-resistant cysts.

Design of granular filtration

In granular filtration, water passes through a filter consisting of a packed bed of granular materials. Microbes or microbe-associated particles are removed as they deposit on the filter medium. The removal occurs within the granular medium (depth filtration) rather than on the top layer only (cake filtration). After a period of operation, the head loss increases (i.e. the pressure increases) or the effluent quality deteriorates to an unacceptable level. The filter then has to be cleaned by backwashing, after which it performs poorly during a ‘ripening period’ before achieving a stable level of performance. Passage of microbial pathogens during the ripening period can be very high. Various strategies are used to minimize this effect, including:

- filter to waste— wasting the initial filtered water;

- Slow start— limiting the initial filtration rate until the filtrate quality is acceptable;

- delayed start— leaving the filter inactive for a time following backwash, before bringing it into operation;

- filter aid— adding a filter aid to the wash water supply.

Granular filters can be constructed as monomedium (e.g. silica sand), dual media (e.g. anthracite coal and sand) and trimedia (e.g. coal, sand and garnet). Granular activated carbon is used when both filtration of particles and adsorption of organic compounds are desired. Depending on raw water quality, granular filtration can be operated in three different modes:

- Conventional, which includes addition of coagulants (rapid mixing), flocculation (slow mixing), sedimentation and filtration;
- Direct filtration, in which the sedimentation step is omitted;
- In-line filtration, in which both flocculation and sedimentation steps are omitted.

Conventional treatment is appropriate for most source waters, whereas direct and in-line filtration is used for raw waters with a consistently good quality (low turbidity and colour).

Importance of filter backwash

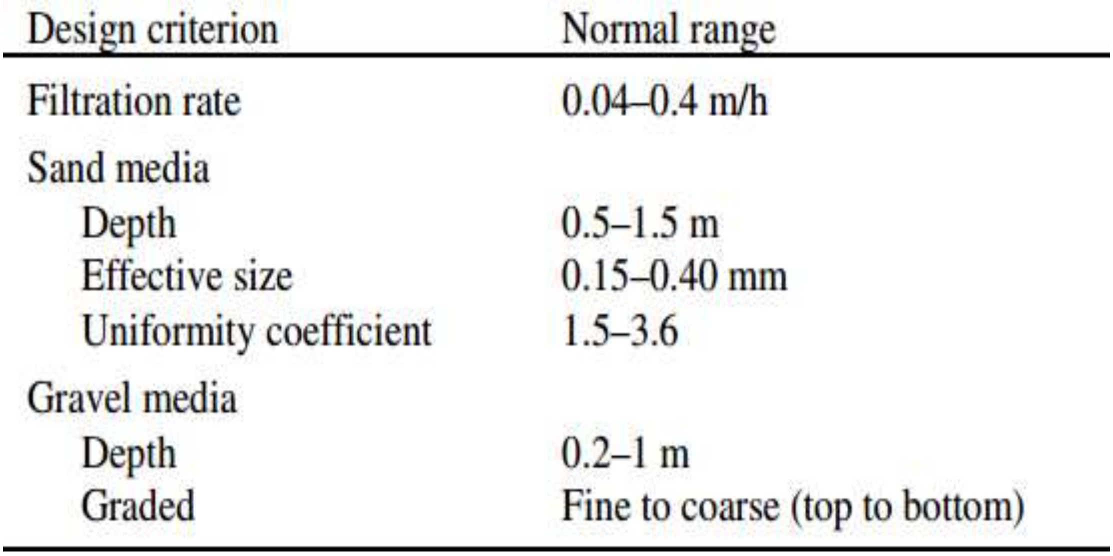
When solids accumulate within a filter bed, they create a resistance to flow. This resistance is measured as loss of head (pressure increase) for the filter bed. The filter is backwashed, usually with finished water, to remove the accumulated particles. The need for backwashing may be determined using various criteria — a terminal head loss, a fixed time interval, or a breakthrough of solids (measured as turbidity or particle counts). Options for disposal of the spent filter backwash water may include discharge to a sewer or a receiving stream. Because backwash water may contain disinfectants and other chemicals that may be harmful to the biological life of a stream, direct discharge to streams may be restricted. Similarly, discharge to sewers may be restricted, based on the constituents and total quantity of the backwash water.

SLOW SAND FILTRATION

The use of slow sand filtration to protect drinking-water consumers from microbial risk was well established more than 100 years ago. Numerous disease outbreaks due to chlorine-resistant protozoan pathogens in the past two decades have increased interest in slow sand filtration because of its ability to remove parasites. Slow sand filtration involves passing water through a sand filter by gravity at a very low filtration rate, without the use of coagulation pretreatment. The filter typically consists of a layer of sand supported on a layer of graded gravel.

Typical design criteria for slow sand filtration are given in Table 1.1

Table 1.1 Typical design criteria for slow sand filtration



Design criterion	Normal range
Filtration rate	0.04–0.4 m/h
Sand media	
Depth	0.5–1.5 m
Effective size	0.15–0.40 mm
Uniformity coefficient	1.5–3.6
Gravel media	
Depth	0.2–1 m
Graded	Fine to coarse (top to bottom)

Removal of particles by slow sand filtration occurs predominantly, if not entirely, in a thin layer on the top of the sand bed. This biologically active layer, composed of living and dead microorganisms and microorganisms, is termed *schmutzdecke*. As operation progresses, deposited materials and biological growth on the sand medium increase the head loss across the filter. When the head loss reaches the operational limit (normally 1–2 m), the filter is removed from service. It is then usually cleaned by scraping about 2 cm of accumulated material and sand from the top layer of the sand bed, before being returned to service. A typical filter run is from one to six months, depending on the raw water quality and filtration rate. After the sand bed is reduced to a lowest acceptable depth by repeated scrapings, it is necessary to replace the sand down to the gravel support level.

Protection provided by slow sand filtration

Slow sand filtration can provide some degree of protection against microbial pathogens. As coagulation pretreatment is not required, slow sand filtration has little maintenance or chemical cost. If the raw water has a high concentration of suspended particles or algae, physical pretreatment processes (e.g. roughing filter or micro strainers) can be used to prevent clogging of the filter and maintain a reasonable filter run period

Removal of microbes

In a review by Ellis (1985), virus removal ranging from about 1 to 5 logs was reported for bench and full-scale slow sand filters. Various studies have reported the effective removal of bacteria and protozoa by slow sand filtration in pilot and full-scale systems.

Information Sheet-2	**Assessing effectiveness of Disinfection processes for removing pathogenic microorganisms**

2.1. Disinfection

2.1.1. Introduction

Disinfection should be regarded as obligatory for all piped supplies using surface water, even those derived from high-quality, unpolluted sources, as there should always be more than one barrier against the transmission of infection in a water supply. In large, properly run waterworks, regulatory standards can then be met with a very high degree of probability of success.

Although slow sand filters are extremely efficient at removing bacteria, and the coagulation process is good at removing viruses, the finished water may still contain pathogenic viruses and bacteria that need to be removed or destroyed. In practice it is impossible to sterilize water without using a very high concentration of chemicals that would make the water unpleasant and probably dangerous to drink. Terminal disinfection of piped drinking-water supplies is therefore of paramount importance and is almost universal, as it is the final barrier to the transmission of waterborne bacterial and viral diseases. Although chlorine and hypochlorite are most often used, water may also be disinfected with chloramines, chlorine dioxide, ozone, and ultraviolet irradiation.

The efficacy of any disinfection process depends upon the water being treated beforehand to a high degree of purity, as disinfectants will be neutralized to a greater or lesser extent by organic matter and readily oxidizable compounds in water. Microorganisms that are aggregated or are adsorbed into particulate matter will also be partly protected from disinfection, and there have been many instances of disinfection failing to destroy waterborne pathogens and faecal bacteria when the turbidity was greater than 5 nephelometric turbidity units (NTU). It is therefore essential that the treatment processes preceding terminal disinfection are always operated to produce water with a median turbidity not exceeding 1 NTU and not exceeding 5 NTU in any single sample. Values well below these levels will regularly be attained with a properly managed plant.

Disinfection is the process of killing all pathogens. Safe water means water (a) free from pathogenic bacteria, (b) aesthetically acceptable, and (c) free from excessive minerals, and poisonous matter. Pathogens die away or are destroyed in significant numbers in the course of treatment. The purpose of disinfection is to kill and pathogens remaining after conventional treatment. The substance used for disinfection is called *disinfectant*. When a disinfectant is added to water, it reacts chemically and products are released. They attack the cell of the pathogen and inactivate the cell. Pathogens found in water supplies include **viruses, bacteria, and protozoa** (including **cysts**). Disinfectants must effectively reduce all types of pathogens without being toxic to humans or domestic animals. Additionally, it must not drastically change the taste or color of water and it must be persistent.

- Factors affecting the efficiency of disinfection
  - ✓ Nature and concentration of organisms
  - ✓ Nature and concentration of disinfectant
  - ✓ Nature of water to be disinfected (interfering substances like NH3, iron, Mn, organic matter)
  - ✓ Temperature of water
  - ✓ Time of contact
- Disinfection methods include:

✓Heat
✓Mechanical (ultrasonic vibration, membrane filtration)
✓Radiation (Gamma, Ultraviolet radiation)
✓Chemical
  - o Halogens (chlorine, bromine, iodine)
  - o Chlorine dioxide (ClO_2)
  - o Chloramines ($ClNH_2$, Cl_2NH, Cl_3N)
  - o Ozone

2.1.2. Disinfection Kinetics

The kinetics of disinfection depends on the following

- Time of contact
- Concentration of disinfectant
- Concentration of organisms
- Temperature of water

- **Time of Contact**. When a single unit of microorganisms is exposed to a single unit of disinfectant, the reduction in microorganisms follows a first-order reaction. This equation is known as *Chick's Law*, which states that the number of organisms destroyed in a unit time is proportional to the number of organisms remaining:

$$-\frac{dN}{dt} = kN \qquad (7-1)$$

$$N = N_o e^{-kt} \qquad (7-2)$$

Where, N = number of microorganism (N_O is initial number)

k = disinfection constant

t = time

- **Concentration of disinfectant**. The disinfection efficiency is generally estimated as,

$$C^n t = Constant \qquad (7-3)$$

where C is the concentration of the disinfectant, t is the time required to affect a constant % kill of the organisms, and n is a coefficient of dilution.

- **Concentration of organism**

$$C^q N_R = constant \qquad (7-4)$$

where C = concentration of the disinfectant, N_R = concentration of organism that reduced by a given percentage in a given time, and q = A coefficient of disinfectant strength.

- **Temperature.** The effect of temperature on disinfection follows the Van Hoff-Arrhenius relationship

$$ln\frac{t_1}{t_2} = \frac{E'(T_2 - T_1)}{R_{T1,T2}} \qquad (7-5)$$

Where t_1,t_2 = time required for a given kills

T_1, T_2 = temperature corresponding to t_1 and t_2, K

R = gas constant, 1.0 cal/K-mol

E' =activation energy, related to pH, cal

2.2. Sources of Contamination

There are three phases associated with water main construction or repair activities where contamination may occur:

- ✓ prior to construction/repair,
- ✓ during construction/repair, and
- ✓ after construction/repair.

2.3. Contamination Sources Prior to Construction or Repair

- ✓ Accumulation of soils, sediments, and trash which can carry and/or harbor
- ✓ microbial contaminants.
- ✓ Exposure to storm water runoff and other waters that can carry microbial and chemical contaminants.
- ✓ Exposure to harmful chemicals.
- ✓ Exposure to chemically contaminated soils and sediments.
- ✓ Exposure to animals and humans and their wastes.

2.4. Contamination Sources during Construction or Repair

Water main construction or repairs are most commonly done in open trenches or excavations, during which the interiors of pipes and fittings can come into contact with soil and water in the trench. The chance of soil and water contacting piping materials during construction or repair activities is potentially much greater than it is during storage and handling prior to construction/repair.

2.5. Contamination Sources after Construction or Repair

Contamination of water mains after their construction or repair has been completed can occur through these pathways:

- ✓ Leaking pipe joints
- ✓ Stagnant, unsanitary water from adjacent piping sections
- ✓ Cross-connections
- ✓ Transitory pressures

Requirement

Materials shall comply with the requirements of the Safe Drinking Water Act and other federal regulations for potable water, waste water, and reclaimed water systems as applicable.

2.9. Forms of Chlorine for Disinfection

The forms of chlorine that may be used in the water main disinfection operations are liquid chlorine (gas), sodium hypochlorite solution, and calcium hypochlorite granules or tablets

- **Liquid chlorine (gas).**

Liquid chlorine (gas) contains 100 percent available chlorine and is packaged in steel containers usually of 100-lb, 150-lb, or 1-ton (45.4-kg, 68.0-kg, or 907.2-kg) net chlorine weight. Liquid chlorine (gas) shall be used only

- ✓ in combination with appropriate gas-flow chlorinators and ejectors to provide a controlled high-concentration solution feed to the water to be chlorinated;
- ✓ under the direct supervision of someone familiar with the biological, chemical, and physical properties of liquid chlorine (gas) and who is trained and equipped to handle any emergency that may arise; and
- ✓ when appropriate safety practices are observed to protect working personnel and the public. Makeshift equipment is not acceptable when liquid chlorine (gas) cylinders are used.

- **Sodium hypochlorite.**

Sodium hypochlorite is available in liquid form in glass, rubber-lined, or plastic containers typically ranging in size from 1 qt (0.95 L) to 5 gal (18.92 L). Containers of 30 gal (113.6 L) or larger may be available in some areas. Sodium hypochlorite contains approximately 5 percent to 15 percent available chlorine, and the storage conditions and time must be controlled to minimize its deterioration.

(Available chlorine is expressed as a percent of weight when the concentration is 5 percent or less, and usually as a percent of volume for higher concentrations. Percent × 10 = grams of available chlorine per liter of hypochlorite.)

- **Calcium hypochlorite.**

Calcium hypochlorite is available in granular form or in 5-g tablets and must contain approximately 65 percent available chlorine by weight. The material should be stored in a cool, dry, and dark environment to minimize its deterioration.

Caution: Tablets dissolve in approximately 7 hr and must be given adequate contact time. Do not use calcium hypochlorite intended for swimming pool disinfection, as this material has been sequestered and is extremely difficult to eliminate from the pipe after the desired contact time has been achieved.

2.9. General Considerations for All Methods of Chlorination

General.

Four methods of chlorination are explained in this section: tablet, continuous feed, slug, and spray. The tablet method gives an initial chlorine dose of 25 mg/L; the continuous-feed method gives a 24-hr chlorine residual of not less than 10 mg/L; the slug method gives a 3-hr exposure of not less than 50 mg/L free chlorine; and the spray method gives a 30-min exposure of not less than 200 mg/L free chlorine. Caution should be used with highly chlorinated water when conducting hydrostatic pressure testing and with high volume flushing of water.

- **Flushing.**

Potable water shall be used for disinfection, hydrostatic pressure testing, and flushing. Drainage should take place away from the construction or work area. Adequate drainage must be provided during flushing. If applicable, the valve(s) isolating the main from existing system should be locked out and tagged out to prevent unintentional release of the elevated chlorine residual water used for disinfection.

- **De chlorination**

When dichlorination is required, it is recommended that any high-velocity flushing be completed prior to disinfection. De chlorination equipment may not be capable of handling high flows with high levels of chlorine.

Conduct risk assessment for environment, safety and water quality factors.

Care must be taken when disposing of all liquids used for cleaning and disinfectionon. Sudden discharge of water will cause localized erosion or flooding. Make sure the water follows a channel to its final disposal point

Liquid waste should not be disposed of in rivers and ponds as the organic materials and high chlorine levels may kill fish and plant life. Waste water should be disposed of to a sewer network, carried in tankers to a sewage treatment plant or placed in a septic tank that overflows into an underground soakage system.

3.2.1. Select and check equipment and personal protective equipment to meet safety requirements of task and site.

MATERIALS AND EQUIPMENT

- Furnish liquid chlorine and/or calcium hypochondria and injection equipment as needed to disinfect all pipelines and appurtenances.
- Liquid chlorinegas contains 100% available chlorine and is packaged in steel containers, usually of 100 lb, 150 lb, or 1-ton net chlorine weight.
- Calcium hypochlorite is available in granular form or in approximately 5-g tablets, and contains approximately 65% available chlorine by weight. The material should be stored in a cool, dry, and dark environment to minimize its deterioration. Do not use calcium

hypochlorite intend for swimming pool disinfection, as this material (containingtrichloroisocyanuricacid) has been sequestered and is extremely difficult to eliminate from the pipe after the desired contact time had been achieved.

- ✓ personal protective equipment
  - headwear
  - gloves
  - safety shoes and work boots
  - Over coats
  - Mouth and nose cover (Mask)
  - Eye glass

3.2.2. Determine size of area to be disinfected.

The size of area should be determined by the operational period limitation.

Perform calculations to establish dose rate and target residual and contact time of disinfectants

Read well lo 2 and discuss with your trainer

Conduct disinfection

Tablet/Granule Method of Chlorination

Tablet method. The tablet method consists of placing calcium hypochlorite granules or tablets in the water main during installation and then filling the main with potable water to create a chlorine solution. This method may be used only if the pipes and appurtenances are kept clean and dry during construction.

Warning: This procedure must not be used on solvent-welded plastic or unscrewed-joint steel pipe because of the danger of fire or explosion from the reaction of the joint compounds with the calcium hypochlorite.

Placement of calcium hypochlorite granules during construction. Calcium hypochlorite granules shall be placed at the upstream end of the first section of pipe, at the upstream end of each branch main, and at 500-ft (150-m) intervals.

Placement of calcium hypochlorite tablets during construction. Calcium hypochlorite tablets (5-grams) shall be placed in the upstream end of each section of pipe to be disinfected, including branch lines. Also, at least one tablet

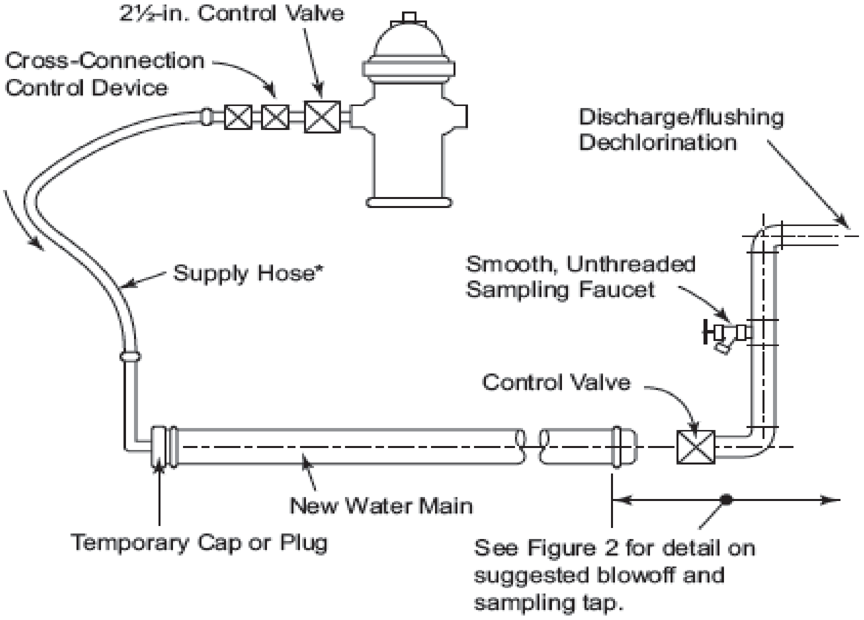
shall be placed in each hydrant branch and in other appurtenances. The number of5-g tablets required for each pipe section shall be 0.0012 d 2L rounded to the next higher integer, where d is the inside pipe diameter, in inches, and L is the length of the pipe section, in feet. Calcium hypochlorite tablets shall be attached by an adhesive meeting the requirements. There shall be adhesive only on the broadside of the tablet attached to the surface of the pipe. Attach tablets inside and at the top of the main. If the tablets are attached before the pipe section is placed in the trench, their positions shall be marked on the pipe exterior to indicate that the pipe has been installed with the tablets at the top.

Filling and contact time. When installation has been completed, the main shall be filled with water such that the full pipe velocity is no greater than1 ft/sec (0.3 m/sec). Fill rate must be carefully controlled to ensure tablets do not come loose from pipe. Precautions shall be taken to ensure that air pockets are eliminated. As an optional procedure, if required by the purchaser, water used to fill the new main shall be supplied through a temporary connection that shall include an appropriate cross-connection control device, consistent with the degree of hazard, for back flow protection of the active distribution system (see Figure).The chlorinated water shall remain in the pipe for at least 24 hr. If the water temperature is less than 41°F (5°C), the water shall remain in the pipe for at least48 hr. A detectable free chlorine residual (≥0.2 mg/L) shall be found at each sampling point after the 24- or 48-hr period

3.3. Continuous-Feed Method of Chlorination

Continuous-feed method. The continuous-feed method consists of completely filling the main with potable water, removing air pockets, then flushing the completed main to remove particulates, and refilling the main with potable water that has been chlorinated to 25 mg/L. After a 24-hr holding period in the main there shall be a free chlorine residual of not less than 10 mg/L.

Preliminary flushing. Before the main is chlorinated, it shall be filled with potable water to eliminate air pockets and flushed to remove particulates. The flushing velocity in the main shall not be less than 3.0 ft/sec (0.91 m/sec) unless



Note: Figure 1 applies to pipes with diameters 4 in. (100 mm) through 12 in. (300 mm). Larger sizes must be handled on a case-by-case basis.

* Clean potable-water hose only. Size and number of taps per Table . This hose must be removed during

the hydrostatic pressure test.

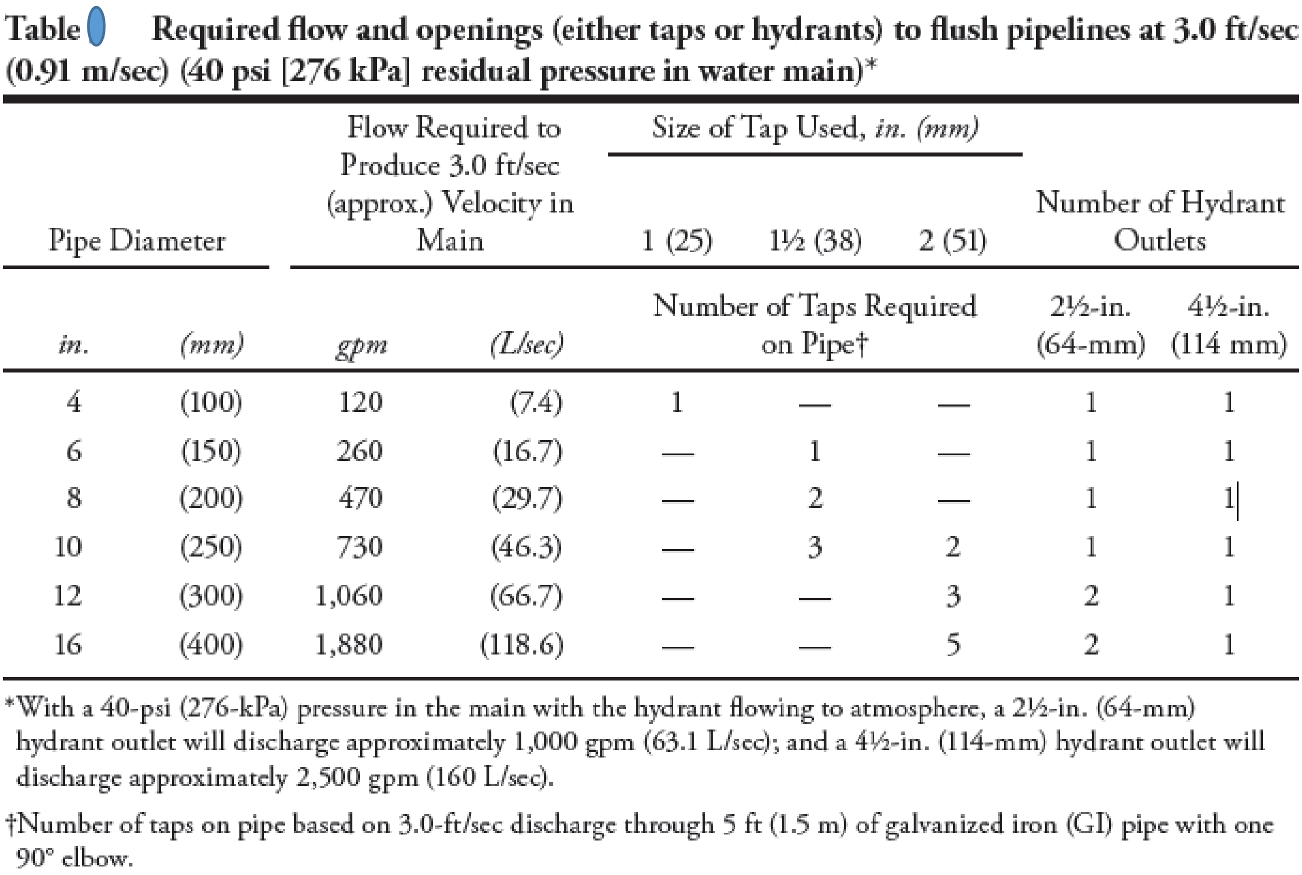


Table Required flow and openings (either taps or hydrants) to flush pipelines at 3.0 ft/sec (0.91 m/sec) (40 psi [276 kPa] residual pressure in water main)*

Pipe Diameter		Flow Required to Produce 3.0 ft/sec (approx.) Velocity in Main		Size of Tap Used, *in. (mm)* 1 (25)	1½ (38)	2 (51)	Number of Hydrant Outlets	
in.	*(mm)*	*gpm*	*(L/sec)*	Number of Taps Required on Pipe†			2½-in. (64-mm)	4½-in. (114 mm)
4	(100)	120	(7.4)	1	—	—	1	1
6	(150)	260	(16.7)	—	1	—	1	1
8	(200)	470	(29.7)	—	2	—	1	1
10	(250)	730	(46.3)	—	3	2	1	1
12	(300)	1,060	(66.7)	—	—	3	2	1
16	(400)	1,880	(118.6)	—	—	5	2	1

*With a 40-psi (276-kPa) pressure in the main with the hydrant flowing to atmosphere, a 2½-in. (64-mm) hydrant outlet will discharge approximately 1,000 gpm (63.1 L/sec); and a 4½-in. (114-mm) hydrant outlet will discharge approximately 2,500 gpm (160 L/sec).

†Number of taps on pipe based on 3.0-ft/sec discharge through 5 ft (1.5 m) of galvanized iron (GI) pipe with one 90° elbow.

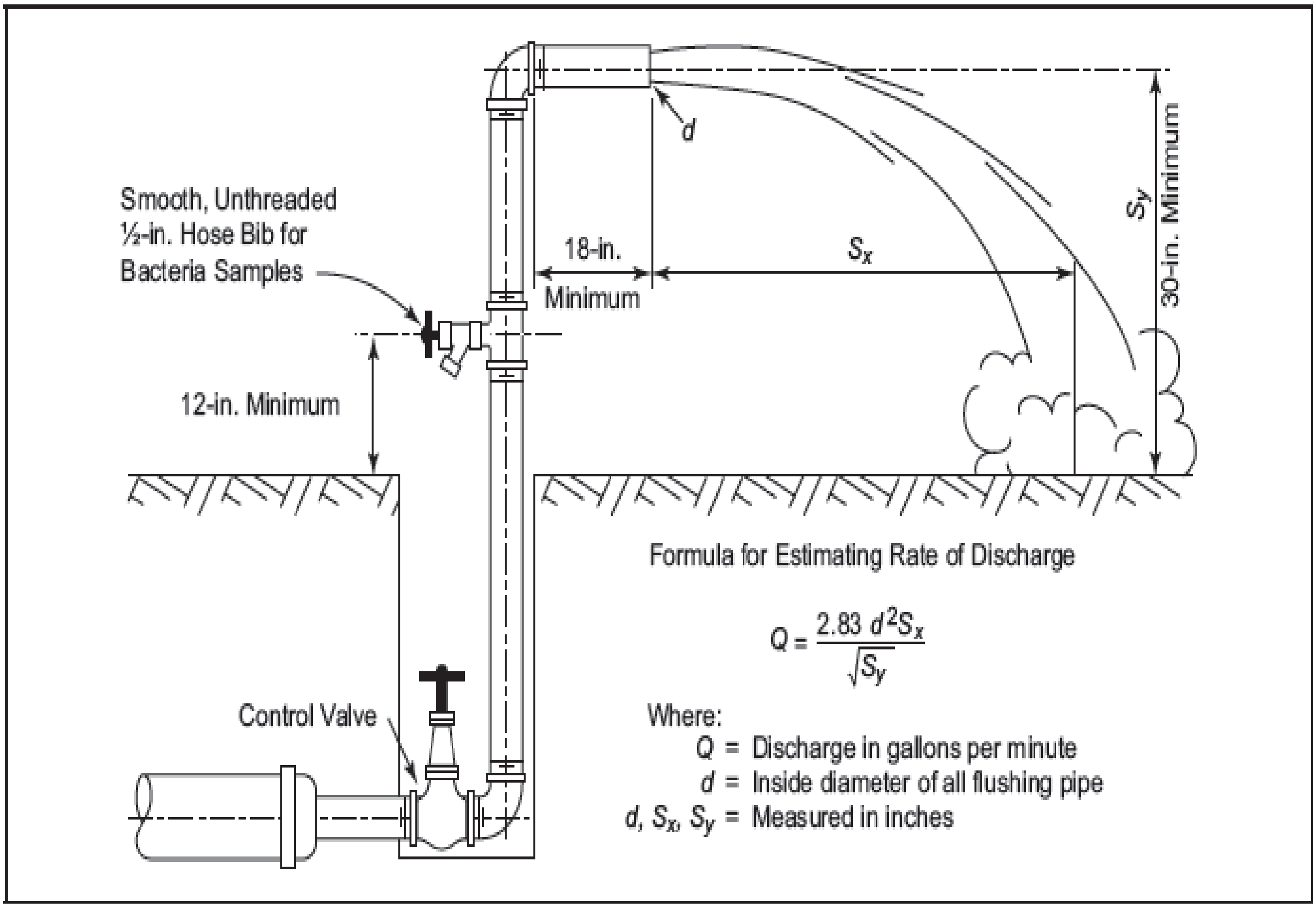
Procedure for chlorinating the main.

1. Potable water may be supplied from a temporary backflow-protected connection to the existing distribution system or other supply source approved by the purchaser. The cross-connection control device shall be consistent with the degree of hazard for backflow protection of the active distribution system (see Figure 1). The flow shall be at a constant, measured rate into the newly installed water main. In the absence of a meter, the rate may be approximated using a Pitot gauge in the discharge, measuring the time to fill a container of known volume, or measuring

the trajectory of the discharge and using the formula shown in Figure 2. The main should undergo hydrostatic testing prior to disinfection.

2. At a point not more than 10 ft (3 m) downstream from the beginning of the new main, water entering the new main shall receive a dose of chlorine fed at a constant rate such that the water will have not less than 25 mg/L free chlorine. To ensure that an appropriate concentration is achieved, the free chlorine concentration shall be measured at regular time intervals by using appropriate chlorine test kit. the Table gives the amount of chlorine required for each 100 ft (30.5 m) of pipe for various pipe diameters. Solutions with a minimum 1 percent chlorine

concentration may be prepared with sodium hypochlorite or calcium hypochlorite. The latter solution requires 1 lb (454 g) of calcium hypochlorite in 8 gal (30.3 L) of water.



Note: This figure applies to pipes up to and including 8-in. (200-mm) diameter.

Table Chlorine required to produce an initial 25-mg/L concentration in 100 ft (30.5 m) of pipe by diameter

Pipe Diameter		100% Chlorine		1% Chlorine Solution	
in.	*(mm)*	*lb*	*(g)*	*gal*	*(L)*
4	(100)	0.013	(5.9)	0.16	(0.6)
6	(150)	0.030	(13.6)	0.36	(1.4)
8	(200)	0.054	(24.5)	0.65	(2.5)
10	(250)	0.085	(38.6)	1.02	(3.9)
12	(300)	0.120	(54.4)	1.44	(5.4)
16	(400)	0.217	(98.4)	2.60	(9.8)

3. Chlorine application shall not cease until the entire main is filled with chlorinated water. The chlorinated water shall be retained in the main for at least 24 hr, during which time valves and

hydrants in the treated section shall be operated to ensure disinfection of the appurtenances. At the end of this 24-hr period, the treated water in all portions of the main shall have a residual of not less than 10 mg/L of free chlorine.

4. Direct-feed chlorinators, which operate solely from gas pressure in a chlorine cylinder, shall not be used for the application of liquid chlorine (gas). (The danger of using direct-feed chlorinators is that water pressure in the main can exceed gas pressure in the chlorine cylinder. This allows backflow of water into the cylinder, resulting in severe cylinder corrosion and the escape of chlorine gas.)

The preferred equipment for applying liquid chlorine (gas) is a solution-feed, vacuum-operated chlorinator and a booster pump. The vacuum-operated chlorinator mixes the chlorine gas in solution water; the booster pump then injects the chlorine solution into the main to be disinfected. Hypochlorite solutions may be

applied to the water main with a chemical-feed pump designed for feeding chlorine solutions. Feed lines shall be made of material capable of withstanding the corrosion caused by the concentrated chlorine solutions and the maximum pressures that may be created by the pumps. All connections shall be checked for tightness before the solution is applied to the main.

2.10. Slug Method of Chlorination

Slug method. The slug method consists of completely filling the main to eliminate air pockets; flushing the main to remove particulates; then slowly flowing through the main a slug of water dosed with chlorine to a concentration of 100 mg/L. The slow rate of flow ensures that all parts of the main and its appurtenances will be exposed to the highly chlorinated water for a period of not less than 3 hr.

Preliminary flushing.

Procedure for chlorinating the main.

1. Potable water may be supplied from a temporary backflow-protected connection to the existing distribution system or other supply source approved by the purchaser. The cross-connection control device shall be consistent with the degree of hazard for backflow protection of the active distribution system (see Figure 1). The flow shall be at a constant, measured rate into the newly installed water main. In the absence of a meter, the rate may be approximated using a Pitot gauge in the discharge, measuring the time to fill a container of known volume, or measuring the trajectory of the discharge and using the formula shown in Figure 2. The main should undergo hydrostatic testing prior to disinfection.

2. At a point not more than 10 ft (3 m) downstream from the beginning of the new main, water entering the new main shall receive a dose of chlorine fed at a constant rate such that the water will have not less than 100 mg/L free chlorine. To ensure that this concentration is achieved, the free chlorine concentration shall be measured at regular time intervals sufficient to guide the completion of the successful loading of the target chlorine concentration. The chlorine shall be applied continuously and for a sufficient period to develop a solid column, or slug, of chlorinated water that will, as it moves through the main, expose all interior surfaces to a concentration of approximately 100 mg/L for at least 3 hr.

3.**The free chlorine residual** shall be measured in the slug as it moves through the main. If at any time it drops below 50 mg/L, the flow shall be stopped; chlorination equipment shall be relocated at the head of the slug; and, as flow resumes, chlorine shall be applied to restore the free chlorine in the slug to not less than 100 mg/L.

4**.As chlorinated water flows** past fittings and valves; related valves and hydrants shall be operated so as to disinfect appurtenances and pipe branches.

Spray Disinfection for Large Transmission Lines

For very large transmission mains (where personnel or equipment may safely enter the pipe), spray disinfection may be an appropriate and efficient means of achieving disinfection. In general, once pipe is cleaned, spray a 200-mg/L free chlorine solution on all surfaces. After 30 min, fill line and sample as described.

Basic Disinfection Procedure for New Mains

The basic disinfection procedure consists of

- Inspecting materials to be used to ensure their integrity.
- Preventing contaminating materials from entering the water main during storage, construction, or repair and noting potential contamination at the construction site.
- Removing, by flushing or other means, those materials that may have entered the water main or appurtenances.
- Preventing contamination of existing mains from cross-connection during flushing, pressure testing, and disinfection.
- Pressure testing the water main to ensure the main meets the purchaser’s allowable leakage rate. Hydrostatic pressure tests should be conducted with potable water.
- Chlorinating and adequately documenting the process used for disinfection.
- Flushing the chlorinated water from the main. FieldDechlorination for dichlorination procedures, if dichlorination is required.
- Determining the bacteriological quality of water samples collected from the pipe by laboratory test after disinfection.

- Final connecting of the newly disinfected water main to the active distribution system without sacrificing sanitary practices and conditions

Disinfection Procedures When Cutting into or Repairing Existing Pipe

General. The planned, unplanned, or emergency repair of a water main or appurtenance (e.g., valve) is time sensitive—an important goal is to minimize the disruption of water service to customers. Nonetheless, the repair work needs to be accomplished using sanitary and safe procedures by well-trained crews with proper supervision and guidance. Refer to preventive and corrective measures. Follow all personal protection precautions when working with chlorine solutions.

Basic disinfection*.* Work should follow basic disinfection and contamination prevention procedures:

- **Preventing contaminants** from entering the existing pipe during the repair such as by maintaining positive pressure in the leaking pipe until the repair site on the pipe is fully exposed, by maintaining a dewatered trench, and by keeping all pipe materials being used in the repair in a clean and sanitary condition.
- **Inspecting and cleaning**, followed by disinfection of spraying or swabbing with a minimum 1 percent chlorine solution:
  - ✓ Exposed portions of existing pipe interior surfaces
  - ✓ Pipe materials used in the repair
  - ✓ Handheld materials and tools used to make the repair
- **As appropriate**, advising affected customers to adequately flush their service lines upon return to service.

Selection of disinfection procedure*.* The disinfection procedure selected should be determined by the conditions and severity of the main break. Many leaks or breaks can be repaired under controlled conditions without depressurizing the water main, such as when applying a clamp to a small crack or hole, thus preventing contaminants from entering the water system. In most other situations, the water main can be maintained pressurized until the break site is secured and the pipe is fully exposed. Some circumstances (e.g., severe erosion of the local environment or icing of the roadway) that impact public safety may require that water pressure be substantially reduced prior to exposing the pipe in the area of the leak. In some cases, situations become catastrophic where there is a pipe blowout and a loss of water pressure prior to shut down, requiring disinfection procedures equivalent to those of a new main installation.

distribution mains may need to be modified for large transmission mains. Large mains may need additional work (such as having a valve replaced or requiring a special order on a connection), may be out of service for more than a day, or may not be able to accommodate a scour flush. These modifications need to be made on a case-by-case basis but should still take into account the procedures outlined.

Controlled pipe repair without depressurization. In this situation, activities are well controlled and a full shutdown is not needed, thus maintaining positive pressure to the area of shutdown and around the break site at all times. The repair site is exposed and the trench is adequately dewatered so that the repair site can be cleaned and disinfected by spraying or swabbing with a minimum

1 percent chlorine solution. The water main is then returned to service with flushing to obtain three volumes of water turnover, making sure that the flushed water is visually clear. No bacteriological testing is necessary. It is advisable to check for a typical system chlorine residual, and if not found, to continue flushing until residuals are restored to levels maintained in the distribution system by the water utility—if the system operates with a disinfectant residual.

Controlled pipe repair with depressurization after shutdown. In this situation, after the repair site has been exposed and secured from trench soil water contamination, the water main is depressurized by a shutdown to complete the repair. The repair site should be cleaned and disinfected by spraying or swabbing with a minimum 1 percent chlorine solution. The water main is then returned to service with flushing to scour the pipe and obtain three volumes of water turn-over, making sure that the flushed water is visually clear. It is advisable to check for a typical system chlorine residual, and if not found, to continue flushing until residuals are restored to levels maintained in the distribution system by the water utility—if the system operates with a disinfectant residual. When the existing pipe has to be opened and the interior surfaces of the water system exposed to the environment, additional procedures need to be followed. The existing pipe should be inspected and cleaned with the help of flushing water into the trench, where possible, until the flush water runs visually clear. The repair site should be accessible and the trench adequately dewatered so that the repair site can be cleaned and disinfected by spraying or swabbing with a minimum 1 percent chlorine solution. Additionally, any accessible upstream and downstream interior of the existing pipe should be disinfected by swabbing or spraying with a minimum 1 percent chlorine solution. If the repair requires a full pipe section replacement, the new pipe should be inspected, cleaned, and disinfected from both ends by swabbing with a minimum 1 percent chlorine solution. The water main may then be returned to service after flushing to scour the pipe and obtain three volumes of water turnover. The flushed water should run visually clear, have a measurable chlorine residual if the system operates with a residual, and be checked with bacteriological testing. The pipeline may be returned to service prior to obtaining bacteriological results.

Uncontrolled pipe break with a likelihood of water contamination or loss of sanitary conditions during repair. In situations in which the existing main to be repaired could not be protected and kept free of contamination and there are obvious signs of contamination (e.g., muddy trench water flowing into the broken pipe and a leaking sewer pipe in the trench, or catastrophic pipe failure where pipe is open and there is a likelihood that contamination was drawn into the active system) or when a controlled repair situation turns into a situation in which the internal pipe and water have become contaminated, the preferred procedures should be followed where practical.

These methods specify chlorine doses of 25–300 mg/L; however, such levels may present greater harm if the line or services cannot be reliably isolated or shut down and exposure of customers to high concentrations of chlorine cannot be controlled.

water regulations; therefore, this level is suggested as a minimum to be maintained for at least 16 hr in conjunction with flushing, coliform sampling, and associated customer education. Such situations require careful review and need to balance the public health risks of the pipeline failure as well as the repair process. Where practical and appropriate considering the risks of public exposure to high concentrations of chlorine, in addition to the procedures previously described in this standard, the section of pipe in which the break is located shall be isolated, all service connections shut off, and the section flushed and disinfected. If the slug chlorination method is employed, the dose may be increased to as much as 300 mg/L and the contact time reduced to as little as 15 min. After chlorination and repair, perform scour flushing at 3.0 ft/sec (0.91 m/sec) or greater for a minimum of three pipe volumes and continue until discolored water is not observed and the chlorine residual is restored to the levels maintained in the distribution system by the water utility. For larger-diameter pipe (12 in. and greater), if a water velocity of 3.0 ft/sec (0.91 m/sec) cannot be achieved, it is desirable to flush at the maximum flow for the main until three pipe volumes have been displaced before returning the main to service. The flushed water should run visually clear, and have typical system chlorine residual (if the system operates with a disinfectant residual). For very-large-diameter pipe (where personnel may safely enter the pipe), in lieu of flushing following disinfection, the interior of the pipe at the repair site may be cleaned by sweeping or high pressure wash using potable water before disinfection. Standing water and debris from the cleaning must be removed from the pipe prior to disinfection. The affected pipe shall be disinfected by swabbing or spraying with a minimum 1 percent chlorine solution. After following the appropriate methods above, prior to returning the pipe to service, the efficacy of the disinfection procedure shall be verified by testing for the absence of coliform bacteria. If allowed by local regulations, the pipeline may be returned to limited service prior to obtaining bacteriological results with proper notification of the affected customers.

Temporary service lines. Temporary water service lines to customers during main repair activities shall be disinfected prior to use. Materials shall meet the requirement for potable water use. Disinfection should

be accomplished by the procedures as described before and by scour flushing at 3.0 ft/sec (0.91 m/sec) or greater for a minimum of three pipe volumes, or until the water runs visually clear and preferably a measurable chlorine residual is restored.

Information Sheet-4	**Assessing metabolic. nuisance and toxicity problem of pre or post treatment Processes**

4.1. Nuisance organisms

Nuisance organisms constitute a morphologically and physiologically diverse group, including planktonic and benthic cyanobacteria (blue-green algae), actinomycetes, iron, manganese, and sulfur bacteria, Crustacea, and protozoa. These organisms cause problems when the conditions in reservoirs or distribution systems are such as to support their growth. Thus, organic matter in drinking-water supports the growth of bacteria and fungi, which in turn will help to maintain populations of protozoa and Crustacea. Many invertebrate animals can feed on bacteria, fungi, and protozoa. The content of organic compounds in treated water should therefore ideally be so low as to inhibit the growth of bacteria and to prevent that of other organisms during distribution.

4.2. Microbiological problems

Although the raw water itself does not usually contain large numbers of nuisance organisms, problems may develop during the water-treatment process. Nuisance organisms become concentrated on the surfaces and inside the beds of filters, where they autolyze and release cellular compounds that cause color, turbidity, tastes, and odors. Activated carbon filters will, after a while, contain large amounts of organic matter, thus providing an excellent substrate for bacteria, which can create problems in the water supply, either by causing taste, odor, and turbidity, or microbiologically by increasing the colony counts of aerobic heterotrophic bacteria. Significant amounts of organic carbon can cause the growth of Aeromonas. in the distribution system during the warmer months of the year (see section 3.2.2). Large numbers of aerobic, heterotrophic bacteria in treated water can interfere with the interpretation of the tests for the coliform group by masking their presence or giving false positive reactions. A particular problem exists with some strains of Aeromonas., which produce acid and gas with coliform media, even at 44 °C.

Most of these nuisance organisms can be controlled relatively easily by care in operating water-treatment processes. Nutrient-rich raw water should be avoided if proper water treatment cannot be applied.

The compounds produced by nuisance organisms have low taste and odour thresholds, e.g. the earthy taints of geosmin (trans-1,10-dimethyl-trans-9-decadole) and MIB (2-methylisoborneol) produced by actinomycetes and cyanobacteria. These compounds cause problems in drinking-water at threshold values of 10 and 25 ng/litre respectively, and are therefore often the cause of complaints by consumers before they are detected by analytical methods. It is therefore advisable to use panels of trained judges of taste and odour so that the compounds can be detected and the necessary measures taken before they become a problem in the drinking-water supply. Another way to prevent nuisance organisms from causing taste and odor problems is by means of regular microscopic examination of the organisms present in the water. As soon as a group of organisms known to cause these problems becomes dominant, appropriate measures should be taken to deal with them.

Some of these organisms can also produce color in drinking-water. Pigmented organisms, such as cyanobacteria and algae, can be crushed on filters, resulting in the release of pigments, while microalgae can pass through the filters and cause both coloration and turbidity.

If water contains ferrous or manganous salts, these can be oxidized by iron or manganese bacteria, resulting in rust-colored or black deposits in storage tanks and on the walls of pipes in parts of the distribution system where the flow rate is low. If the flow rate is subsequently increased, however, these deposits can be loosened and transported to consumers. Rust-coloureddeposits can stain laundry. The slurry will also contain organic deposits which can decompose to produce tastes and odors. Manganese oxidizing microorganisms (bacteria, fungi, and, very rarely, protozoa) produce deposits in aquifers, wells, and water conduits, the problems caused by such deposits including reduced yield, clogging of slots in well pipes, increased turbulence in pipes resulting in reduced flow velocity, damage to equipment for measuring water flow, black-colored water, stains on laundry, and problems with food-handling establishments. The deposits can contain heavy metals such as arsenic, lead, zinc, and copper. Bacteria can become attached to them, so that, if they are disturbed, the colony count of the water will be increased. Prevention is based on the removal of Mn(II) from raw water, if a value of about 0.1 mg/liter is exceeded.

Iron and sulfur bacteria may contribute to the corrosion of iron and steel well pipes and drinking-water mains. Such microbially mediated corrosion can occur as a consequence of:

- the adsorption of nutrients and the depletion of dissolved oxygen by the colonies of microorganisms that have accumulated at the metal surface;
- the liberation of corrosive metabolites, such as organic acids and other complex-forming compounds;
- the production of sulfuric acid from sulfides or elemental sulfur; and
- the inclusion of sulfate-reducing bacteria in the cathodic process under anaerobic conditions

The presence of certain organisms in water may be an indication either of the corrosion of cast iron or of the biodeterioration of construction materials to form substances that support the growth of microorganisms. The latter include non-metallic materials, such as plastics, rubber-jointing compounds, and pipe-lining materials, which can provide organic nutrients and thus encourage the growth of microorganisms, sometimes including coliform organisms other than Escherichia coliand Pseudomonas aeruginosa. Deterioration can occur in pipelines carrying groundwater or surface water. Unchlorinated waters, or water in which the chlorine residual has disappeared, appear to support higher rates of attack than those in which a residual can be detected.

Nuisance organisms may also cause problems in groundwater sources by encrusting well screens, thus reducing yield and impairing the aesthetic quality of the supply. Their presence may also indicate organic pollution of the aquifer.

Routine monitoring of such nuisance organisms cannot be recommended because of their diverse nature and unpredictable occurrence, although bacteriologists should be aware that they can impair water quality. It is not practicable to specify any quantitative guideline values for nuisance microorganisms.

Instruction Sheet	Learning Guide 41: Determine appropriate water treatment processes

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Identifying optimum treatment processes for microorganisms in water sources
- Maintaining water quality by appropriate sampling and testing

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:

- Identifying optimum treatment processes for the range of microorganisms found in water sources
- Reporting effective treatment processes and associated sampling and testing requirements required to maintain water quality

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below
3. Read the information written in the “Information Sheets 1- 6”. Try to understand what are being discussed. Accomplish the “Self-checks 1,2,3,4, 5 &6” in each information sheets on pages 36,38, 41, 45, 47, & 55.
4. If you earned a satisfactory evaluation proceed to “Operation sheets 1, 2,3, 4, 5, 6, 7, 8. on pages56,58,59,60, 61,62,63 64. and do the LAP Test on page 65”. However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity.
5. AfterYouaccomplish Operation sheets and LAP Tests, ensure you have a formative assessment and get a satisfactory result; then proceed to the next LG.

Information Sheet-1	**Identifying optimum treatment processes for microorganisms in water sources**

1.1. WATER TREATMENT

1.1.1. SOURCES AND CHARACTERISTICS

It is important to know where the water entering a plant comes from as the source often affects the quality of the water, the amount available, and the treatment required.

Groundwater is water that lies below the surface of the ground. Wells are often used to draw groundwater. Some groundwater can be free of turbidity and microorganisms because the water has been naturally filtered as it travelled through the soil. Other groundwater sources can be influenced by surface conditions and porous soils. As a result, the bacteriological and chemical quality of these sources can fluctuate.

Groundwater is often high in mineral content and can contain dissolved gases such as methane and hydrogen sulphide.

Surface water comes from two very different sources: rivers, and lakes. Surface waters in their natural state are potentially unsafe for human consumption because they are constantly exposed to contamination from human, animal, industrial wastes, and from natural sources such as soil, vegetation, and algae.

Rivers can be a difficult source of water to treat as the turbidity can change rapidly and dramatically. Lakes are less prone to changes in turbidity as suspended matter tends to settle to the bottom, however, ice cover can cause degradation along with taste and odor problems in water quality. All-natural waters contain some turbidity and color. Turbidity is caused by very finely divided particles held in suspension. This gives the water a cloudy appearance. Color is caused by dissolved and colloidal particles, a result of organic or inorganic material in the water.

1.2 PRE-TREATMENT

1.2.1 pH ADJUSTMENT

The pH of water may need to be adjusted to:

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

The pH is usually adjusted with lime, or soda ash.

1.2.2. WATER STABILIZATION

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

1.2.2 HYDROGEN SULPHIDE REMOVAL

Hydrogen sulphide (H2S) s not a constituent of surface water and is only found in ground water that has not been exposed to the atmosphere. Where H2S is a problem, it can be removed by:

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

1.2.3. Pre-Sedimentation

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

Settling of larger-sized particles occurs naturally when surface water is stored for a sufficient period of time in a reservoir or a natural lake. Gravitational forces acting in the lake accomplish the same purpose as sedimentation in the water treatment plants; larger particles such as sand and heavy silts settle to the bottom. Debris dams, grit basins or sand traps can also be used to remove some of the heavier particles from source water. The facilities may be located upstream from the reservoir, treatment plant intake or diversion facilities, and serve to protect the municipal intake pipeline from siltation. Grit basins may be located between the intake structure and the coagulation flocculation facilities. Thus, pre-sedimentation facilities such as debris dams, impoundments and grit basins reduce the solids removal load at the water treatment plant. At the same time, they provide an equalizing basin, which evens out fluctuations in the concentration of suspended solids in the source water. Water with more suspended solids is mixed with water with less suspended solids

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

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

1.3. COAGULATION & FLOCCULATION

Coagulation and flocculation are two of several steps to purify raw water to acceptable standards.

1.3.1. COAGULATION

In the coagulation process, coagulant chemicals are added to the water as it passes through the static or flash mixer. (A static or flash mixer is used to mix chemicals into the water quickly. It does this by the turbulence created by the mixer.) Primary coagulants are chemicals that are responsible for the main coagulation reactions, being the formation of floc and the neutralization of particle charges. Of all the coagulants, aluminiumsulphate (alum) is the most commonly used. It is relatively inexpensive; easy to handle, store, and apply; and when used properly, very effective.

Figure 1-1 Static Mixer and Alum Injection

All particles carry an electrical charge on their surface, which is usually negative, and thus, the particles tend to repel each other. Coagulation chemicals neutralize this charge so the particles can combine into large accumulations if they touch each other.

The chemistry of alum flocculation is complex, but can be simplified to the equations which follow. The pH of the water is very important as it determines the charge of the chemicals in the reaction, and determines the solubility of aluminum. The greater the solubility of aluminum is, the higher the amounts of aluminum present in the finished water. A high amount of aluminum in drinking water is undesirable.

$$Al^{3+} + H_2O <=> Al(OH)^{2+} + H^+$$

$$Al\,(OH)^{2+} + H_2O <=> Al(OH)_2^+ + H^+$$

$$Al(OH)_2^+ + H_2O <=> Al(OH)_3 \downarrow + H^+$$

$$Al(OH)_3 + H_2O <=> Al(OH)_4^- + H^+$$

These equations are written in “chemical shorthand” and show the progressive reaction of the aluminum ion to produce a molecule with a negative charge. An important reaction is the fourth reaction which yields aluminum hydroxide, which forms as a precipitate, denoted by ↓and is the aluminum that is seen.

Note how in each of the reactions a H^+ion is formed. Recall that pH is a measure of the hydrogen ion concentration. If the water has a high alkalinity it will tend to resist pH changes when hydrogen ions are added or removed. The effect on pH of adding aluminum will depend on the properties of the water, but alum will always decrease the pH, the alkalinity, or both.

With most waters the best pH for coagulation and flocculation is treatment plant specific though it is generally between 5 and 7. In the NWT, the natural alkalinity in the water may not be enough to support typical alum dosages without affecting pH. Spring freshet and associated high turbidity may cause a further demand on alkalinity as alum doses increase. Alkalinity needs to be assessed throughout the year and varying conditions, and appropriate adjustments made to keep pH in the optimum range for both flocculation and corrosion control.

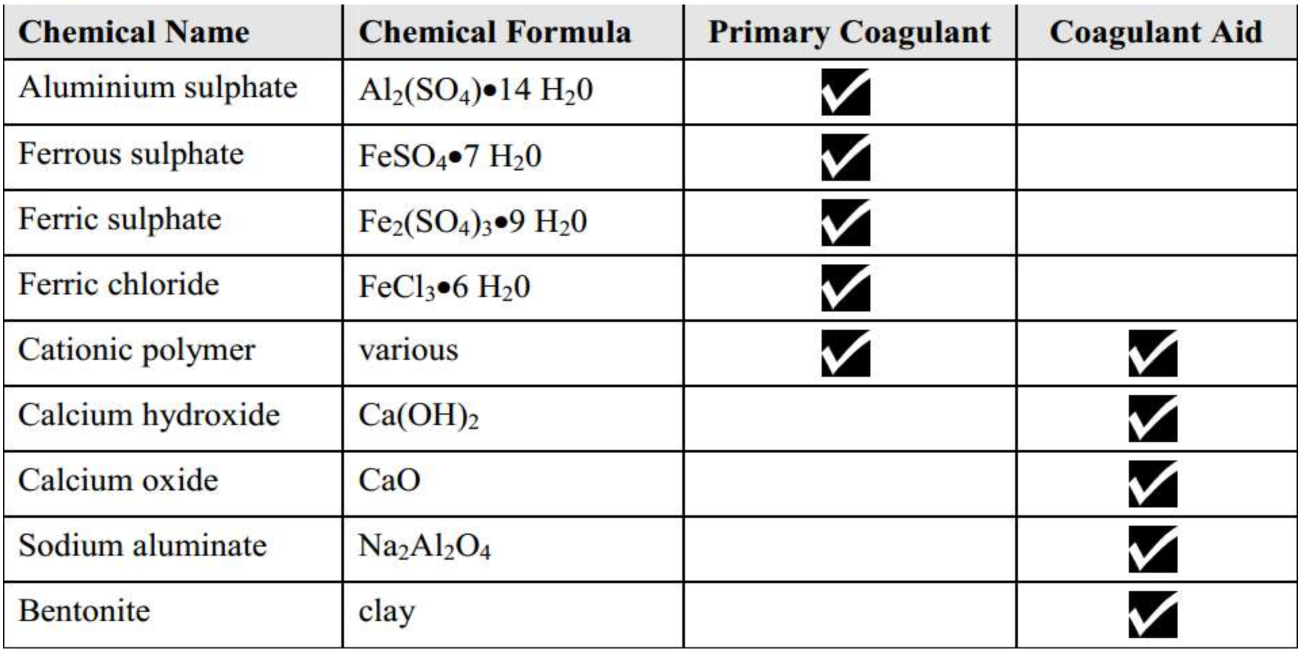
Residual aluminum in finished waters has become a great concern. Residual aluminum comes from two sources: floc carryover and soluble aluminum. High soluble concentrations result when the pH is less than 6.0. In order to minimize the amount of soluble aluminum the pH should be maintained in the range of 6.0 to 6.8. Floc carryover can be reduced through the use of coagulant aids, sedimentation and filtration.

Coagulant aids (also called flocculant aids) are used to increase the density of slow settling floc particles, or to strengthen them so they do not break up during settling and filtration.

Polymers are a popular coagulant aid. There are many different polymers on the market classified into three groups:

- Cationic -- having a negative charge
- Anionic -- having a positive charge
- Non-ionic -- having no charge

Table 1-2 Coagulant Chemicals Used in Water Treatment



Chemical Name	Chemical Formula	Primary Coagulant	Coagulant Aid
Aluminium sulphate	$Al_2(SO_4)\bullet 14\ H_20$	✓	
Ferrous sulphate	$FeSO_4\bullet 7\ H_20$	✓	
Ferric sulphate	$Fe_2(SO_4)_3\bullet 9\ H_20$	✓	
Ferric chloride	$FeCl_3\bullet 6\ H_20$	✓	
Cationic polymer	various	✓	✓
Calcium hydroxide	$Ca(OH)_2$		✓
Calcium oxide	CaO		✓
Sodium aluminate	$Na_2Al_2O_4$		✓
Bentonite	clay		✓

Most NWT plants use alum and a polymer.

1.3.2. FLOCCULATION

Following the flash mixer, flocculation is the slow stirring process that causes the flocs to grow and to come in contact with particles of turbidity to form larger particles that will readily settle.

The purpose is to produce a floc of the proper size, density, and toughness for effective removal by sedimentation and filtration.

Floc formation depends on the rate at which collisions between flocs and particles occur, and how the flocs stick together after collision.

In a conventional system using separate tanks for flocculation and sedimentation, detention time is usually about 30 minutes. Detention times shorter than 20 minutes may result in incomplete floc formation especially during cold-water conditions. Cold water conditions reduce collisions in between molecules, resulting in lower floc formation rates, necessitating longer detention times to achieve the proper amount of floc formation. Longer detention times may break up large floc particles, and result in wasted capacity.

It takes very little excessive mixing intensity to cause floc break up. A variable speed motor on the flocculator is a must. How fast the water is mixed is very important. If it istoo slow, there will be relatively few collisions between particles; if it is too fast the flocs could be broken up. Flocs are very delicate. Floc break up is a real problem in many plants and can go unnoticed. There is an easy demonstration.

Take a sample of effluent from the flocculator in a large container such as a pail by letting the water flow gently into the pail. Stir the contents gently and dip a sample from the pail into a 1-litre flask. Take another sample in the same manner into a stoppered bottle. Shake the bottle vigorously for a few seconds and pour the contents into a second 1-litre flask. Observe the contents of each for about an hour. The second flask should have much smaller flocs that settle poorly, and leave a turbid supernatant.

Unfortunately, there are no simple tests to see if the coagulation/flocculation process is working well and it is impossible to provide guidelines or instructions. Experience, careful observation, proper records, and good judgement are the only ways to determine the best operating conditions.

OPERATIONAL PROBLEMS

The most common operational problem is a sudden change in raw water quality, usually a result of changing turbidity. The causes are many. In the North, some of the most common causes are:

- Spring break up on rivers and lakes;
- Heavy rainstorms;
- High wind;
- Turnover in lakes and reservoirs; and
- Algae blooms or insect hatches.

A significant change in raw water quality means that adjustments may be needed including:

- Changing coagulants;
- Adjusting coagulant dosages;
- Adjusting flash mixer and/or flocculator mixing intensity (speed);
- Adding a coagulant aid; and
- Adjusting alkalinity or pH.

In cases where such a change in raw water quality occurs, jar tests may only provide some of the answers. Final adjustments should be based on careful plant observations and measurements.

Accurate records are essential in preparing for, and responding to, raw water quality changes. Often, events occur at similar times and with similar intensity. Records should include what worked and how well, and what didn't work so mistakes are not repeated.

1.4. Sedimentation

1.4.1. Definition

Sedimentation is the separation of suspended material from the water by gravity. In water treatment the main purpose is to reduce solids loading on the filters. Sedimentation is carried out in a sedimentation tank, a settling tank, or clarifier-- different words for the same process. Clarification of the water is the direct result of the sedimentation of particles. The words sedimentation and clarification are used interchangeably and refer to the same process.

1.4.2. Principles

The settling velocity of particles in water follows a fundamental theoretical equation known as Stokes Law where:

$$V_{at} = \frac{g}{18} * \frac{D^2}{v} * (S_s - S_W)$$

where: V_{at} = Settling velocity of the particle

g = Gravitational constant

D = Diameter of the particle

v = Viscosity of water

S_s = Specific gravity of the particle

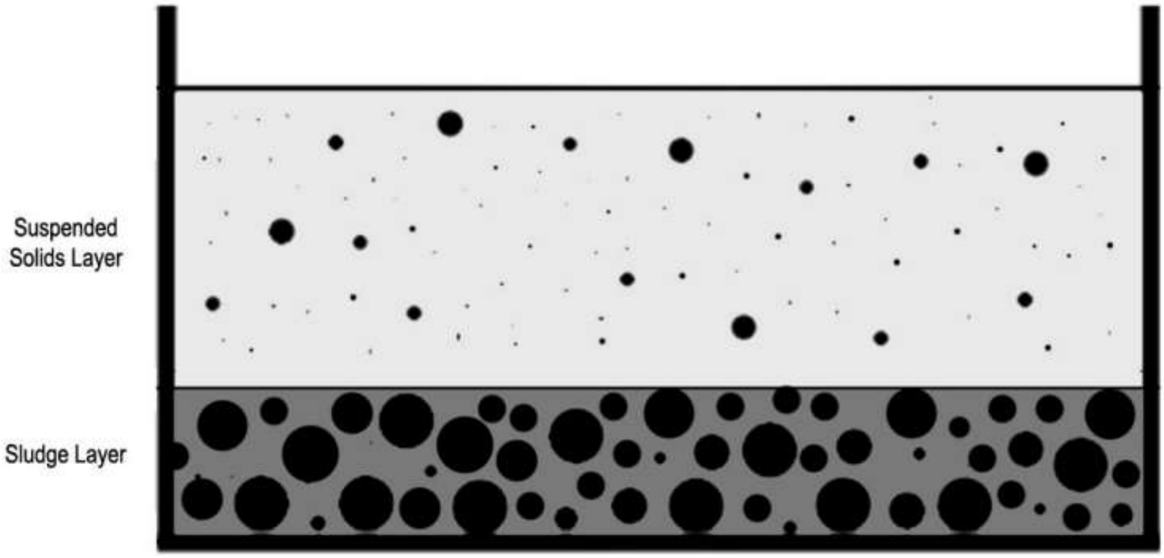
S_W = Specific gravity of water (= 1)

Table 1-3 Settling time of various particles

Diameter of Particle (microns)	**Order of Size**	**Approximate Time Required to Settle (Relative)**
100	Fine Sand	12.4 seconds
10	Silt	10.7 min
1	Bacteria	17.9 hr
0.1	Colloidal Particle	74.7 days

The most important concept to note from Stokes Law is that larger particle sizes will increase settling velocities and hence reduce settling times, exponentially. This is the rational for having the coagulation/flocculation process. The coagulation/flocculation process increases the size of the particles to reduce to amount of time to settle the particles during sedimentation.

Figure 1.2. Settling tank demonstrating settleability of various particle sizes



1.5. Filtration

Various filtration processes are used in drinking-water treatment. Filtration can act as a consistent and effective barrier for microbial pathogens. Figure 1.3. shows the most commonly used filtration processes in potable water treatment, the pore size of the filter media and the sizes of different microbial particles. These size spectra are useful for understanding removal mechanisms and efficiencies, and for developing strategies to remove microbes by different filtration processes.

After sedimentation, the water only contains fine solids and soluble material. Filtration is required to remove this residual material. Various filtration processes are used in drinking-water treatment, including granular, rapid and slow sand filters, precoat, and membrane filtration (microfiltration, ultrafiltration, Nano filtration and reverse osmosis). With proper design and operation, filtration can act as a consistent and effective barrier for microbial pathogens. Granular media filtration may in some cases be the only barrier (for example for removing Cryptosporidium oocytes by direct filtration when chlorines used as the sole disinfectant).

1.5.1. Rapid and slow sand filtration

Rapid sand filters contain coarse grades of quartz sand (1 mm diameter) so that the gaps between the grains are relatively large and the water passes rapidly through the filter. These are used for water that has previously been treated by coagulation and sedimentation, and are less effective in removing microorganisms. Turbidity varies through the duration of the run between backwashing's. Immediately after backwashing, performance is poor, until the bed has compacted. Performance will also deteriorate progressively at the stage when backwashing is needed, as floes may escape through the bed into the treated water. These features emphasize the need for proper supervision and control of filtration at the waterworks.

Slow sand filtration is simpler to operate than rapid filtration, as frequent backwashing is not required. It is therefore particularly suitable for developing countries and small rural systems, but it is applicable only if sufficient land is available.

When the slow sand filter is first brought into use, a microbial slime community develops on the sand grains, particularly at the surface of the bed. This consists of bacteria, free-living ciliated protozoa and amoebae, crustaceans, and invertebrate larvae acting in food chains, resulting in the oxidation of organic substances in the water and the conversion of ammoniacal nitrogen to nitrate. Pathogenic bacteria, viruses, and resting stages of parasites are removed, principally by adsorption and by subsequent predation. When correctly loaded, slow sand filtration brings about the greatest improvement in water quality of any single conventional water treatment process. Bacterial removal will be at least 98–99.5% effective, E. coli will be reduced by a factor of 1000, and virus removal will be even greater. A slow sand filter is also very efficient in removing parasites (helminths and protozoa). Nevertheless, the effluent from a slow sand filter might contain a few E. coli and viruses, especially during the early phase of a filter run and with low water temperatures. The disadvantage with this type of filter is that it is operationally expensive and labour intensive because the dirt layer that collects on the surface of the sand impedes drainage and must be removed after the filter has been drained.

The operation of both rapid and slow sand filter sis complex, and poor operation can lead to problems. The most serious problem is if the sand bed cracks, allowing unfiltered water to pass though.

1.6. Disinfection

Disinfection should be regarded as obligatory for all piped supplies using surface water, even those derived from high-quality, unpolluted sources, as there should always be more than one barrier against the transmission of infection in a water supply. In large, properly run waterworks, regulatory standards can then be met with a very high degree of probability of success. Although slow sand filters are extremely efficient at removing bacteria, and the coagulation process is good at removing viruses, the finished water may still contain pathogenic viruses and bacteria that need to be removed or destroyed. In practice it is impossible to sterilize water without using a very high concentration of chemicals that would make the water unpleasant and probably dangerous to drink. Terminal disinfection of piped drinking-water supplies is therefore of paramount importance and is almost universal, as it is the final barrier to the transmission of waterborne bacterial and viral diseases. Although chlorine and hypochlorite are most often used, water may also be disinfected with chloramines, chlorine dioxide, ozone, and ultraviolet irradiation.

The efficacy of any disinfection process depends upon the water being treated beforehand to a high degree of purity, as disinfectants will be neutralized to a greater or lesser extent by organic matter and readily oxidizable compounds in water. Microorganisms that are aggregated or are adsorbed into particulate matter will also be partly protected from disinfection, and there have been many instances of disinfection failing to destroy waterborne pathogens and faecal bacteria when the turbidity was greater than 5 nephelometric turbidity units (NTU). It is therefore essential that the treatment processes preceding terminal disinfection are always operated to produce water with a median turbidity not exceeding 1 NTU and not exceeding 5 NTU in any single sample. Values well below these levels willregularlybe attained with a properly managed plant.

In many countries, much of the unit operations that together form a drinking-water production plant do not work at the designed level of efficiency. Poor design, bad execution of the design, and faulty installation of design components aggravate the problem. A comprehensive hazard assessment and risk analysis program will need to identify the vulnerable points within the production plant, and will become one of the key components of a WSP.

The importance of plant maintenance is obvious, yet maintenance may be often poor so that continued emphasis on operation and management from the management side is required to ensure that the importance of this is understood by the workers. This is a large subject field and covering it in depth is beyond the scope of these guidelines. Maintenance includes the use and care of plant structures and equipment, in a way that will extend their useful life and will avoid breakdowns and emergencies. General rules can be set out which cover the broad maintenance picture, as listed here.

- Provide good housekeeping – everything clean, orderly, and organized.

- Develop a plan of daily operation and follow it.
- Modify the daily plan as experience and conditions indicate.
- Follow manufacturers' recommendations for operation and maintenance of equipment.
- Establish and follow an inspection and lubrication routine for each piece of equipment.
- Keep records of maintenance and repair for each piece of equipment.

Information Sheet-2	Maintaining water quality by appropriate sampling and testing

2.1. INTRODUCTION

The course Water Quality describes the concepts and principles that affect water quality and the engineering sy stems that can be used to improve water quality. However, before water quality can be improved, it is important to understand how water quality is measured and how to interpret the results. Consequently, an important part of Water Quality is the laboratory portion of the course, where students conduct basic water quality tests. The labs have been developed to give students experience in analyzing for a variety of physical, chemical and biological parameters.

2.1.1. Sampling and water quality testing

Introduction to developing sampling plan documents

A sampling plan is a detailed outline of which measurements will be taken at what times, on which material, in what manner, and by whom. Sampling plans should be designed in such a way that the resulting data will contain a representative sample of the parameters of interest and allow for all questions, as stated in the goals, to be answered.

The accuracy of water quality results obtained in the laboratory is just as dependent on the correctness of the sampling technique as it is dependent on the accuracy of the analytical procedures. Therefore, the sampling exercise requires careful planning beforehand.

Before any sampling program is started, it is important to define clearly the objectives of the sampling program as this will dictate issues such as:

- The substances to be sampled and analyzed
- The frequency of sampling
- The choice of preparatory steps prior to analyses
- The appropriate guidelines to evaluate the results.
- Which substances in the water are of interest
- Where and when are samples to be taken
- how are samples to be taken
- Which analytical methods are to be used

- How results are to be reported; and
- What is to be done with the reported results.

2.2. Types and purpose of water samples

The two types of water samples typically to be taken are grab samples and composite samples. Grab samples are usually taken when you want information specific to a particular sampling location, time or distinct areas within a sampling location.

Composite samples are usually taken when we want an average representation of a sampling location or time. For example, if we want to know how water chemistry varies within a lake, then we will take a number of grab samples. If we don't care how the chemistry varies within the lake, but just want to know the "average" water quality of the lake, we can take a composite sample from several locations.

A properly taken grab sample is a snap shot of the quality of the water at the exact time and place the sample was taken. Depending on the water body, grab samples may be taken by simply dipping a sample bottle in the water body, or they may require the use of specific sampling devices.

- **Grab Samples**

The simplest, a “grab” sample, is taken at a selected location, depth and time. Normally, the quantity of water taken is sufficient for all the physical and chemical analyses that will be done on the sample. Sometimes, if the sampler is small and many analyses are to be done, two grab samples will be taken at the station and will be mixed in the same transport container. Grab samples are also known as “spot” or “snap” samples.

There are two types of grab samples that are used for sampling water matrices: discrete and depth-integrated.

The ***discreet*** grab sample is one that is taken at a selected location, depth, and time and then analyzed for the constituents of interest.

A **depth-Integrated** grab Sample is collected over a predetermined part or the entire depth of the water column, at a selected location and time, in a given body of water, and then analyzed for the constituents of interest.

The primary advantage of grab samples is that sometimes very little equipment is required for sample collection and there is flexibility in sampling location selection. However, this method sacrifices data resolution because of the smaller number of samples that are usually collected

- **Composite samples**

A composite sample is a mixture of grab samples taken at different times or locations and pooled together to provide one sample. Composite samples may be of the following types:

- ✓ **Area-integrated**: made by combining a series of samples taken at various sampling points spatially distributed in the water body (but usually all at one depth or at predetermined depth intervals).
- ✓ **Time-integrated**: made by mixing equal volumes of water collected at a sampling station at regular time intervals.
- ✓ **Discharge-integrated**: It is first necessary to collect samples and to measure the rate of discharge at regular intervals over the period of interest. A common arrangement is to sample every 2 hours over a 24-hour period. The composite sample is then made by mixing portions of the individual sample that are proportional to the rate of discharge at the time the sample was taken
- ✓ **Depth-integrated**: most commonly made up of two or more equal parts collected at predetermined depth intervals between the surface and the bottom. A piece of flexible plastic piping of several meters in length, and which is weighted at the bottom, provides a simple mechanism for collecting and integrating a water sample from the surface to the required depth in a lake.

2.3. Advantages and Disadvantages of Composite Samples

Advantages of composite samples include reduced costs of analyzing a large number of samples, more representative samples of heterogeneous matrices, and larger sample sizes when amounts of test samples are limited.

It also gives you an idea of the average condition of a water body over time, (samples taken at different times and mixed together) or space, (samples taken at different locations within the water body). This is particularly useful in water bodies that have a lot of chemical variability either over space or over short time periods. Composite samples are often used to reduce the cost of analyzing a large number of samples

Disadvantages of composite samples include loss of analyte relationships in individual samples, potential dilution of analytes below detection levels, increased potential analytical interferences, and increased possibility of analyte interaction.

2.4. Methods of Sampling

- **Manual Sampling**: Manual sampling involves minimal equipment but may be unduly costly and time-consuming for routine or large-scale sampling programs. It requires trained field technicians and is often necessary for regulatory and research investigations for which critical appraisal of field conditions and complex sample collection techniques are essential.
- **Automatic sampling**: Automatic samplers can eliminate human errors in manual sampling, can reduce labor costs, may provide the means for more frequent sampling and are used increasingly. Be sure that the automatic sampler does not contaminate the sample.

2.5. Sampling Locations

Water samples are collected from locations which are representative of the water source.
Locations for collecting water sampling can be described as:

- **Raw water supply** which includes surface water and ground *water* supply.
  - ✓ **Surface Water supply**: Surface water sources are divided into flowing and standing water. The sampling frequency at these two types of water resources differs. Rivers and streams are more susceptible to sudden water quality changes than lakes and dams. Thus, more frequent samples are needed from a river or stream than from a lake or dam. Surface water supply sources include rivers, streams and lakes.
  - ✓ **Groundwater supply**:

    Ground water is a type of water found in the ground seeps down through the soil until it reaches rock material that is saturated with water. Water in the ground is stored in the spaces between rock particles. This type of water can be used for taking water samples.

- **Water distribution and treatment systems.**

Are ways of controlling the flow and direction of both surface and ground water**.** They are the link between the water supply source and the consumer.

Water samples are taken at the outlet of treatment works to check the treatment processes and/or the quality of the water supplied to the consumer.

Water within a distribution system is normally sampled to evaluate and check whether the distribution system performs correctly. If overall performance of the distribution system needs to be evaluated it is better to take the sample from a pipe with significant flow, rather than from a stagnant section of the distribution system. For contamination, monitoring samples must be collected down-flow of the (suspected) point of contamination in the distribution system.

2.6. Safety Precautions for Water Sampling

While safety is often not considered an integral part of the sampling program, the sampler must be aware of possible unsafe working conditions, hazards associated with the operation of sampling gear, and other risks.

Basic good practice should be followed in the field. Always keep the following points in mind –

- Wear appropriate PPE
- Never drink the water you are about to sample unless you are very sure about the quality and safety of the water.
- Many hazards lie out of sight on the bottom of dams, rivers and streams. Broken glass or sharp pieces of metal embedded into the substrate can cause serious injury if care is not exercised when working in such environments**.**
- A clean pair of new, non-powdered, disposable gloves will be worn each time a different location is sampled and the gloves should be donned immediately prior to sampling.
- The gloves should not come in contact with the media being sampled and should be changed any time during sample collection when their cleanliness is compromised.
- Sample containers for samples suspected of containing high concentrations of contaminants shall be stored separately.
- Samplers must use new, verified and certified-clean disposable or non-disposable equipment cleaned according to work operating procedures
- Maintain decontamination and contamination free zones properly
- Contain all contaminated PPE and sampling equipment for disposal or decontamination.

2.7. General Rules of Sampling

In taking water samples from different sources take extra care to avoid contaminating the sample container and water sample.

Do not:

- Contaminate the bottle by touching the inside of the bottle.
- Contaminate the bottle lid by touching the inside rim.
- Put the bottle lid on the ground while sampling.
- Transport aquatic facility water samples with other water samples, e.g. effluent or drinking water.

Always:

- Collect microbiological samples before collecting other samples.
- Label the bottle before sampling.
- Discard damaged or contaminated bottles. If in doubt throw it out and take sample in a new bottle.
- Wash your hands thoroughly before and collecting samples.

Self-Check -2	Written Test

Direction I: Choose the best answer for the following questions. Use the Answer sheet provided in the next page: Each question worth one point

1. Which step is considered developing sampling plan?

A/ Selecting sampling size B/Identifying of parameters

C/ Design of sampling scheme D/ All

2. Which one of these is **not** a disadvantage of composite samples?

A/ Loss of analyte relationships in individual samples

B/ Reduced costs of analyzing of samples

C/potential dilution of analytes below detection levels

D/ Increase the possibility of analyte interaction.

3-------------- is a type of sample usually taken when you want information specific to a particular sampling location, time or distinct areas within a sampling location:

A/ Composite sample B/ Grab sample C/ Analyte D/ All

4. Types of samples usually taken when we want an average representation of a sampling location or time are-------. A/Grab sample B/ Composite sample C/Discreet grab sample D/ None

5. A properly taken grab sample is a snap shot of the quality of the water at the exact time and place the sample was taken.

A/ True B/ False

***Note:* Satisfactory rating - 5 points** **Unsatisfactory - below 5points**

Answer Sheet-1

Name: ___________________________ Date: ________________

Choice Questions

Score = ___________

1________ 4.___________

2._______ 5.___________

3_______

Information Sheet-3	Selecting and Checking appropriate Sampling Equipment

3.1. Introduction

Water sampling equipment is used to collect water samples from different water supply sources. The type of sampling equipment used for groundwater depends on the type of well, depth to water from ground surface, physical characteristics of the well, groundwater chemistry, and the analytes targeted for study.

Selecting the appropriate equipment for collecting of water samples from various sources is important in order to obtain data that will meet study objectives and data-quality requirements.

3.2. Selection of Sample Containers:

Sample containers must be thoroughly clean so that they do not contaminate the samples placed in them.

Containers for the transportation of samples are best provided by the laboratory. This ensures that large enough samples are obtained for the planned analyses and that sample bottles have been properly prepared, including the addition of stabilizing preservatives when necessary. It is essential to have enough containers to hold the samples collected during a sampling expedition.

Sample containers should be used only for water samples and never for the storage of chemicals or other liquids.

3.3. Types of Sampling Equipment's

Sampling equipment's used to collect samples from different sources should be with the proper design and quality. Equipment's which are required for collecting raw water sample from the surface, ground or other sources are listed below.

- **Buckets or wide-mouthed containers**: A plastic bucket can be used to collect samples for measurement of water quality parameters such as pH, temperature, and conductivity.

Typically, a bucket is used to collect a sample when the water depth is too great for wading, it is not possible to deploy a boat, or access is not possible and the water column is well mixed.

- **Submersible pumps** can be used to collect surface water samples directly into a sample container. The constituents of interest should be taken into consideration when choosing the type of submersible pump and tubing to be used
- **Open-mouth samplers;** Are used for the collection of water samplesinclude the hand-held bottle, the weighted-bottle sampler, the biochemical oxygen demand (BOD) sampler, and the volatile organic compound (VOC) sampler.
- **Depth samplers:** The depth sampler, which is sometimes called a grab sampler, is designed in such a way that it can retrieve a sample from any predetermined depth.
  It consists of a tube, approximately 10 cm in diameter and 30 cm in length, fastened to a frame along which it can slide.

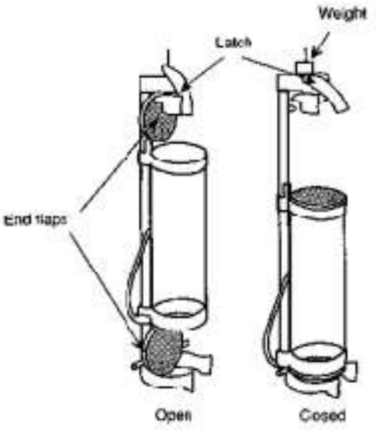


Fig.2.1. Depth sampler

- **Sample dippers**: Are small and long handled dippers for easy water samplingof hard to reach areas.
- **Sterile sample containers**: Are sample containers designed for collecting samples for microbiological testing. These are free from microorganisms contamination.
- **Weighted sample bottles:** is available in stainless steel or polyvinyl chloride. An open bottle is inserted into a weighted holder that is attached to a hand line for lowering.
- **Dip tubes:** A glass or plastic device used for collecting samples.
- **Sludge Sampler:** A sludge sampler is used to sample a profile of sludge in a basin. The tube is inserted into the sludge blanket. The tube then fills with sludge. The top of the tube is sealed and withdrawn from the basin.

Self-Check -2	**Written Test**

Direction I: Choose the best answer for the following questions. Use the Answer sheet provided in the next page:

1. Water sampling equipment's:

A**.** Should be with proper design

B. Should hold proper volume

C. Should be easily manageable

D. All

2. Water samples can be collected from sample source using:

A. Refrigerators

B. Sampling equipment

C. Handling tools

D. All

3. ________ is used to collect a sample when the water depth is too great for wading.

A. Dip tubes B. Bucket C. Submersible samplers D. Sample dippers

Note: **Satisfactory rating – 3 points** **Unsatisfactory - below 3 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet-1

Name: ___________________________ Date: ________________

Choice answer sheet

Score = ____________

1________

2._______

3_______

Information Sheet-4	Collecting Samples according to Sample Plan

4.1. Introduction

In order to ensure the high quality and reliability of water quality results, a water quality sample must be collected in a manner that follows a standard procedure. Preparation and training are required to collect samples to accurately reflect the water quality at a particular site and to preserve the sample during handling and transportation to the laboratory. Subtle deviations may influence results that will be used in making decisions regarding public health.

4.2. Water Samples Collection

It is important to collect water samples under normal, everyday conditions in order to gain a representative sample. Proper procedures for collecting samples must also be observed. Technicians should be properly trained since the way in which samples are collected has an important bearing on the tests results.

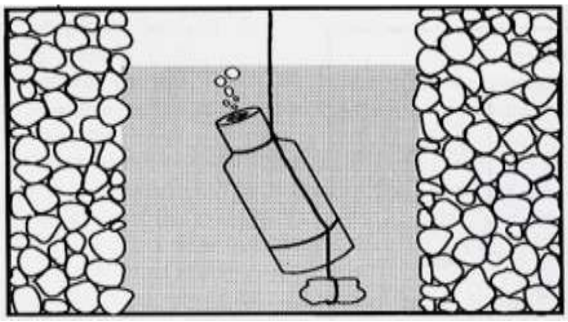


Fig.3.1 Lowering a weighted bottle in to a well

In obtaining water samples we have to be careful in selecting in choice the type of bottles.
It is important when undertaking sampling, particularly for trace analytes, that the sampling equipment is inert, that is, it does not cause contamination or interference with the sample.
For example, if the water sample is being collected to determine the presence of trace metals (e.g. copper or zinc) in the water, do not use sample bottles with metal components (e.g. metal caps).
When sampling for organics, avoid using sample bottles with plastic components, as the Plasticizers may leach and contaminate the samples.

Samples should be collected in a non-reactive borosilicate glass, plastic bottle or plastic bag that has been cleaned, rinsed and sterilized. A sample container is usually provided as part of portable field kits. Disposable Whirl-pak® sample bags are another option to collect water samples.

Fig3.2. Sample bag Fig.3.3.Sample bottles

.

- **Sampling a Surface Water Source**

When the waterbody is shallow and well mixed, sub-surface water sampling is generally adequate. Sub-surface samples should be taken from approximately 30 cm depth, with caretaken to ensure no floating films or organic material are collected unless they are of specific interest.

You should try to obtain samples that are representative of the source of the drinking water supply. Do not take samples that are too near the bank, too far from the point of draw off, or at a depth above/below the point of draw off. Water quality can change depending on the time of day or season.

It is important to sample at the same time of day and record the weather conditions when you are taking your sample. It may be possible to take samples by hand if it is easy to get the water. In many cases it may be inconvenient or dangerous to enter the water source such as river, pond or canal. In these cases, you may need to tie your container to a piece of wire or rope and throw it into the water.

When sampling by hand, surface films can be avoided by removing the cap, inserting the container into the water vertically with the neck facing down. Once at the required depth, the container can then be inverted, allowing the sample to flow in.

The mouth of the container should be faced into the current while keeping the hands, sampler and any other equipment downstream to minimize the chance of contamination.

Fig.3.4. Locating and Identifying correct sample site

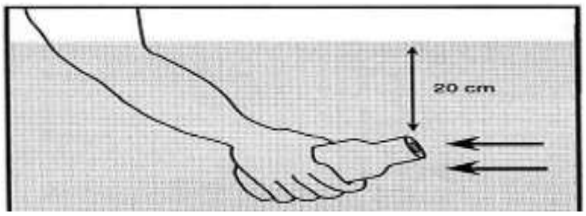


Fig.3.5..Collecting a sample from surface water

Sample handling and sample transport are important aspects of water quality sampling that are often neglected.

As soon as the water sample has been collected some of the chemical characteristics of the water start to change. For this reason, some samples must be preserved to keep the quality of the water sample as stable as possible until the analysis can be carried out. It must, however, be kept in mind that the preservation technique only retards chemical and biological changes that continue after sample collection and will not stop quality changes altogether.

- **Sample Handling and Preservation Requirements**
  - ✓ To minimize water quality changes between sampling and analysis it is important to keep the samples as cool as possible, without freezing them.
  - ✓ Chemical samples will be kept cool and analyzed at a laboratory within 7 days of sampling. This technique excludes the physical measurements that are taken on site, and microbiological samples that must be analyzed within 6 hours of sampling if not cooled, and within 24 hours if cooled.

- ✓ During sample collection, if transferring the sample from a collection device, make sure that the device does not come in contact with the sample containers.
- ✓ Place the sample into appropriate, labeled containers.
- ✓ All samples requiring preservation must be preserved as soon as practically possible, ideally immediately at the time of sample collection.

Self-Check -4	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

TRUE OR FALSE ITEMS

1. For microbiological testing 100 ml is the minimum volume of sample to be taken as a sample to obtain reliable results.
2. Ensure that you don't touch any part of your face while doing the tests
3. Washing hands before and after doing any bacteriological testing is not necessary.
4. Any type of plastic bottles can serve for sampling purposes.
5. Preparation and training are required to collect samples to accurately reflect the water quality at a particular site.

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5points**

You can ask you teacher for the copy of the correct answers.

Answers for True or False item

1.___________ 2._________ 3.___________, 4_____________, 5_____________

Information Sheet-5	Maintaining Integrity of samples

5.1. Introduction to maintaining Integrity of samples

Ensuring sample integrity is critical in laboratory and pharmaceutical research, microbiology, food technology, forensics, water quality testing and many other scientific applications.

To ensure that sampling is consistent, and of good quality and traceability, samples need to be representative of the body from which they were taken. If the sample integrity is altered, the information gained from analysis could be misleading and ultimately result in mismanagement of water resources and/or polluting of the resource.

Collecting integrated samples is a complicated and specialized process that must be described adequately in a sampling plan.

Fundamental to water-quality sampling is the fact that the quality of the analytical results can be no better than the quality of the sample on which the analyses were performed. The sample collector has primary responsibility for the quality and integrity of the sample up to the time that the sample is delivered to the analyzing laboratory or office. Data quality is determined from analysis of quality-control data.

5.2. Requirement for maintaining integrity of samples

In order to maintain sample integrity, the sample should be with:

- ✓ Adequate volume
- ✓ Correct handling procedure.
- ✓ Free from contamination
- ✓ Good labeling.
- ✓ Correct holding time
- ✓ Storage procedures
- ✓ sub-sampling procedure

- **Correct holding Times**

The integrity of the sample is dependent on strict adherence to standard operating procedures in place in the laboratory. Sample holding times are determined by the analytical method.

Samples received after the holding time has expired are analyzed only under direct request from the client.

Appropriate sample and/or data qualifiers are noted on the final report, as while preservation techniques can reduce degradation rates, they may not completely halt such changes. All analytes therefore have a holding time, which is the maximum time that can elapse between sampling and analysis, and where the sample is unlikely to be significantly modified under the recommended preservation conditions. Samples must be delivered to the laboratory within the required holding times.

- **Sample Storage Prior to Analysis**

All samples are properly stored from the time they arrive at the laboratory to disposal. Samples are refrigerated at 4ºC prior to analysis unless method of standard operating procedures indicates other storage conditions.

- **Nature of Sample Changes**: Some analyses are more likely than others to be affected by storage before analysis. Certain cations are subject to loss by absorption or ion exchange with the walls of glass containers. These include aluminum, cadmium, chromium, copper, iron, lead, manganese, silver, and zinc, which are best collected in a separate clean bottle and acidified with nitric acid to a pH below 2.0. This minimizes precipitation and absorption to container walls.

Temperature, pH, and dissolved oxygen are best determined in the field. Temperature changes quickly and pH may change significantly in a matter of minutes.

Dissolved gases (oxygen, carbon dioxide) may be lost very quickly. With the changes in the pH-alkalinity-carbon dioxide balance, calcium carbonate may precipitate and cause a decrease in the values for calcium and total hardness

Biological changes taking place in a sample may change the oxidation state of some constituents. Soluble constituents may be converted to organic bound material in cell structures, or cell lysis may result in release of cellular material into solution.

- **Sample Disposal:** All samples are disposed in an environmentally sound manner or returned to the client upon request. Samples may also be returned to the client if they contain hazardous wastes.

Samples that contain solvents are evaporated in a fume hood unless the vapors create an environmental concern. Samples that contain hazardous materials, such as mercury and silver, are sent to a hazardous waste collection facility.

The remaining samples are stored in a holding tank that is transferred to a Wastewater Treatment Facility for proper disposal. Samples are typically stored for 30 days following the report date unless otherwise instructed by the. client.

Self-Check 5	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part I. True or False items

1. All samples should be collected with enough time for analysis within the holding time of desired analysis.
2. Sample containers can be used for sampling before they are inspected for cleanliness and integrity.
3. Biological changes taking place in a sample may change the oxidation state of some constituents.
4. All samples should be properly stored from the time they arrive at the laboratory to disposal.

Part II. Multiple choice items

5. If the sample integrity is altered:

A/ the information gained from analysis could be misleading

B/ ultimately result is deceptive

C/ Will not be representative of the sample source

D/ All

6. Which one of these is incorrect to maintain the integrity sample?

A/Correct handling procedure	C/Free from contamination
B/Inadequate volume	D/Good labeling

Note: **Satisfactory rating – 9 and above points Unsatisfactory - below 9 points**

You can ask you teacher for the copy of the correct answers.

Name: ___________________________ Date: ________________

PART I. True or True items

I.______

2._____

3._____

4.______

Score = ____________

Rating: _____________

II. Multiple Choice items

5.______ **6.**_______

Information Sheet-6	Checking and Recording Sample Information

6.1. Introduction to Checking and Recording Sample Information

It is crucial for each sample bottle to have a clearly identifiable label when arriving at the laboratory. Labels printed on special water-resistant paper should preferably be used. The label should be completed with a waterproof pen immediately after the sample is taken and tied to the neck of the bottle with a piece of string with the following information written on the labela unique sample number and description.

- The date and time of sampling (Remember day/month/year).
- The name of the sampler.

Collected water samples for study or analysis purposes should be labeled with proper information prior to use**.** The sample information should be recorded correctly and precisely on prepared recording formats such as field sheet details, log books or chains of custody

- **Field sheets:**
  - ✓ Reminder of where and what need to sampled/measured
  - ✓ Permanent record of sample details
  - ✓ Record of field measurements
  - ✓ Observations
  - ✓ Deviations
- **Information to be filled in a field Sheet**
  - ✓ Sampling location (name and/or code)
  - ✓ Sampling date and time
  - ✓ Name & signature of sample collector
  - ✓ Results of field measurements e.g. Temp, pH
  - ✓ Types of samples taken (general chemical, metals,)
  - ✓ Details of any preservative used
  - ✓ GPS readings – if new location or non-routine site
  - ✓ Observations – weather, visual inspection
  - ✓ Deviations

Table 1.Sample recording and reporting formats

LOCATION: ______________________SAMPLES TAKEN BY: _______________

DATE OF SAMPLING: _____________Day____Month________Year________

TIME OF SAMPLING:_______________Hour______Minute_________

SAMPLE TESTED BY: ______________

Purpose of Sampling________________

Sample Description	Sample ID #	Color	Temp.	Turbidity	P^H	TDS	EC	Fecal Coliform (CFU/100ml)	Total Coliform (CFU/100ml

DATE OF REPORT: ____

COMMENTS:____

- **Data sheets:** Data sheets make provision for recording the physical and environmental information of the sampling point. This information is needed to interpret water quality at a site especially if the water quality results obtained from the laboratory indicate a sudden change.

Self-Check -6	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

TRUE OR FALSE ITEMS

1. Water samples for analysis purposes should be labeled with appropriate information after it is tested.

2. The labeling of samples be completed with a waterproof pen immediately before the sample is taken.

3. Data sheets make provision for recording the physical and environmental information of the sampling point.

Note: **Satisfactory rating – 3 and above points** **Unsatisfactory - below 3 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet-5

Name: ___________________________ Date: ________________

Part:-Short answer

1.__________

2.__________

3.__________

Information Sheet-7	Recording Results of Repeated Sampling

7.1. Introduction to recording repeated Sample results

It is important to take accurate records of analyzed water sampling results properly.

After analyzing the testing values of repeated sample water results, the data which is obtained should be recorded on log books, recording formats or other data recording forms. It is imperative to store sample results in a computer or filled in printed paper forms to make reports and logs. The records of results are containing valuable information which can serve for further decision making and quality improvisation of the system. It also helps in creating conducive communication environment between clients, regulating bodies and decision makers.

7.2. Sample Records information

Sample records, field detail sheets or chain of custody forms, include information such as:

- ✓ time sample was taken
- ✓ Person collecting sample
- ✓ sample point location
- ✓ volume of sample collected
- ✓ data gathered at time of collection
- ✓ preservation methods employed
- ✓ instructions to transporters
- ✓ time and logging of sample receipt and testing
- ✓ equipment identification
- ✓ atypical test results

Self-Check -7	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I.TRUE OR FALSE ITEMS

1. The results of sample data can be recorded in a field detail sheets.
2. No need of recording sample point location in a chain of custody forms
3. Sample observations should be included as well and describes anything unusual about the water.

Answer Sheet-6

Name: ___________________________ Date: ________________

Short Answer Questions

1.__________

2.__________

3.__________

Score = ___________

Rating: ____________

Note: **Satisfactory rating – 2 points Unsatisfactory - below 2 points**

You can ask you teacher for the copy of the correct answers.

Operation Sheet 1	Sampling Preparation

Procedures for Sample plan preparation

Step1.Determine the purpose of your sampling

Step 2. Identify the site location for sampling

Step3.Select tools enduements

Step4.Select required safety equipment

Operation Sheet 2	Surface water sampling

Procedures for collecting water sample from River, Stream or lake.

Step1. At the sampling point remove cap of sample bottle but do not contaminate inner surface of cap and neck of sample bottle with hands

Step2.Take samples by holding bottle with hand near base and plunge the sample bottle, neck downward, below the water surface (wear gloves to protect your hands from contact with the water).

Step.3.Turn bottle until neck points slightly upward and mouth is directed toward the current (can also be created artificially by pushing bottle forward horizontally in a direction away from the hand)

Step 4.Fill sample bottle without rinsing and

replace cap immediately.

- Before closing the sample bottle leave ample air space in the bottle (at least 2.5 cm) to facilitate mixing by shaking before examination.

Step 5. Complete label and sample sheet

Operation Sheet 3	Sampling from an Open Well

Procedures for collecting samples from an open wall

Step1. Prepare the appropriate sample container

Step 2. Fasten a cable, rope or string to the sample container.

Step 3. Lower the sample container into the well or tank, taking care not to allow the container to touch the walls of the structure where it may pick up dirt.

Step 4. Submerge the container to a depth of 30 cm.

Step 5. Lift the sample container carefully and place on a clean surface.

Step 6. Proper sample labeling.

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LAP Test	**Practical Demonstration**

Name: ________________________________ Date: _________________

Time started: __________________________ Time finished: ____________

Instructions: Giving the necessary equipment and PPEs you are required to perform the following tasks within 3 hours.

Task1. Prepare Sample planning

Task2. Sampling from an Open Well

Task3.Sampling from a river or lake

Task4. Sample labeling

Task5. Sample Reporting

Microbiological sampling

Following tap preparation and all relevant chemistry samples, carry out the following procedures: NB. For purposes of best practice this method employs a double disinfection pro

- ✓ Inject or spray a pre-prepared chlorine solution over and into the tap nozzle using a suitable vessel/container (the make shall be named in the equipment list appended in this manual). Leave the solution for a contact time of 1 minute. (N.B. the make and model of the vessel or container used must be listed in the equipment list provided in the appendix of this document and added to the local version of this manual).
- ✓ Turn on the tap and adjust the flow to a steady stream.
- ✓ Run for 1 minute.
- ✓ Re-apply the disinfectant and leave for 1 minute
- ✓ Turn on the tap and adjust flow to steady stream
- ✓ Run the tap for a minimum of 2 minutes.
- ✓ Where the supply has been treated with a chlorine disinfectant, take a free chlorine residual reading to ensure they match the readings obtained taken at the stage. If the reading is higher flush the tap for a further 2 minutes and repeat the test. I

Bacteriological sampling procedure:

Usually a pre-prepared 500ml sterilized clear plastic bottle with added sodium thiosulphate):

- Using the bacterial bottle type shown in the appendix of this manual, hold it near its base and unscrew cap.
- Do not put the cap down. Hold it open end downwards.
- Do NOT rinse the bottle.
- Fill the bottle by holding it under the water stream a slight angle ensuring the top of the
- bottle does not come into contact with the tap.
- Avoid splashing and fill to the line where the cap meets the bottle so as to leave an air space to allow for expansion during transportation.
- Replace the cap taking care not to touch the inside of the cap or it to come into cont. act with anything.

- Tighten the cap and invert.
- Transfer to and transport in a refrigerated unit or cool box.

Procedure for sampling raw water from an open water source:

This procedure is applicable for taking investigational samples from any open water facility. This includes from rivers and streams, chambers, channels and storage reservoirs (and tanks) where sampling can only be achieved by standing over open water from height. This method is not appropriate for bacteriological sampling as it poses contamination risks and health and safety hazards. When sampling from height, all appropriate local health and safety procedures must be adhered to. Disposable gloves must be worn when taking microbiological samples (e.g. large volume samples). Where a risk of falling into open water is a risk always wear a life jacket. Raw water is defined as water that has not been treated for human consumption and other domestic purposes and includes any point that is prior to the regulatory sampling point.

- When working from height, direct filling of sample bottles, other than samples for pathogens and viruses is not to be used. It requires the use of a dipping jug – a jug on a chain or rope.
- First find a suitably safe place to take the sample without causing risk of injury. This may be a bridge, platform or jetty.
- Check that the jug is clean and dry. Disinfection of the jug at this stage shall be considered where appropriate. Methods of disinfection should observe all necessary health and safety procedures
- Throw the jug out and allow it to sink well below the surface. Do not allow the jug to hit the bottom of the tank, channel etc.
- Draw the jug back using the attached rope.
- Fill sample bottles by pouring from the jug, observing any specific requirements of the bottle type.

Procedure for visual appearance

N.B. vessel types for this test may vary and the method should be checked by the laboratory supplier. The procedure should be amended locally as required.

- Take an untreated 1-liter taste and odor bottle and rinse the bottle and stopper under the tap twice.

- By holding under a running tap half fill the taste and odor bottle and replace the stopper
- Invert the bottle and shake vigorously
- Hold the bottle up to the light and inspect the contents for any particulates, turbidity/cloudiness or color.

- Note the appearance of the water.
- Record the results of your observations. Procedure for odor test
- After completing the visual test remove the stopper immediately and smell the sample.
- Note and record any abnormal odor.
- Discard the sample unless carrying out a taste test Procedure for taste test (optional)
- Pour a small portion of the original odor sample into a beaker and rinse.
- Discard the water in the beaker
- Pour approximately 125ml of the original odor sample into the beaker. Taste the sample.
- Note and record any abnormal taste

Residual Chlorine-Using Comparator

After chlorinating a water source or container one of the simplest ways to test if the right chlorine dose is given is to measure the Free Residual Chlorine (FRC). The presence of FRC in water proves that enough chlorine has been added to treat the water o r in other terms to react on all matter present in the water, including microorganisms, and leaving some extra chlorine (residual) in the water to deal with possible recontamination (such as during handling etc.) The measurement of Free Residual Chlorine is most easily done using a comparator also commonly called a « Pool tester » and tablets (called DPD1) that will be added to the water in the comparator, and that will react and change the color of the water if residual chlorine is present.

Procedures

1. Rinse the Pool tester 3 times with the water to be tested, including the cover. If a syringe is used to fill the pool tester, it should be rinsed inside and outside thoroughly with the water to be tested.
2. Fill the 3 compartments to the top with the water to be tested.

a. 

3. Put one DPD 1 tablet in the right hand or pink colored compartment (measurement of Free Residual Chlorine) Prevent touching the tablet with dirty hands!
4. Replace the cover tightly (it is normal that some liquid is pressed out) with the arrows pointing towards the colored reference scale.
5. Shake until the tablets are completely dissolved (about 20 seconds).

6. Read the results in natural day light, comparing the colors in the outside compartments (sample) with those in the central compartment (reference). The residual chlorine level is the level at which the sample color is similar to the central compartment. A darker pink indicates a higher residual chlorine level no color change indicates the water is not chlorinated or not sufficiently chlorinated to have a residual chlorine level
7. After testing empty pool tester and rinse again

Important

- ✓ Chlorine takes time to kill all the organisms so the chlorine should be in contact with the water for at least 30 minutes

- ✓ For step 1 and 2 always make sure that you the quality of the water you’d like to test does not change: let water flow for a few moments before taking it from a tap. Be careful whenpouring water out of a container: let it flow before taking your sample. If using jerry cans, fitted with a tap, do not use the tap to fill the pool tester, as the taps being placed next to the ground are often soiled (leading to false results).
- ✓ Never touch the tablets with, the inside of the pool tester or the inside part of the cover with dirty your fingers: this could affect the results. Never use tablets that have fallen on the ground.
- ✓ DPD3 cannot be used to determine free residual chlorine.
- ✓ Only whole DPD1 tablet must be used. Do not use broken tablets (while opening packaging or because of bad storage).
- ✓ Tablets have a shelf life of 5 years. The expiry date is written on the outside of the 500 tablets cardboard boxes.

Condition of water	**Contact time**	**Recommended Free Residual Chlorine**	**Acceptable chlorine level**
pH< 8	30 minutes	0.5 mg/l	0.2-1.5 mg/l
pH > 8	60 minutes	1.0 mg/l	0.5-1.5mg/l

- **Important**

- ✓ In most waters the required free residual chlorine should be 0.5mg/l. In water with a pH of more than 8, chlorine is less efficient and a residual chlorine level of 1.0 mg/l is recommended.
- ✓ If chlorine level in the water is source is below 0.2mg/l it is recommended to increase the chlorine doses at the water source.
- ✓ If chlorine levels are too high one has to reduce the chlorine doses at the water source when treating again the same water source. Water with a high chlorine dose (eg 2mg/l) is still safe for consumption but the taste will be affected.
- ✓ Residual chlorine levels in water will reduce over time retreatment might be needewhen
- ✓ water is stored over longer periods (eg in a bladder)
- ✓ To find the right chlorine doses to treat water one has to do bucket testing (see separate guidance sheet)

- **Residual Chlorine-Using Photometer**

The Palin test Chlorine/Chloramines test uses the DPD method. This method is internationally recognized as the standard method of testing for chlorine and other residuals. In the Palin test method, the reagents are provided in tablet form for maximum convenience and simplicity of use.

- **Reagents and Equipment**

  - ✓ Palin test DPD No 1 Tablets
  - ✓ Palin test DPD No 2 Tablets
  - ✓ Palin test DPD No 3 Tablets
  - ✓ Palin test Automatic Wavelength Selection Photometer
  - ✓ Round Test Tubes, 10 ml glass (PT 595)

- **Separation of Chlorine Residuals**

The photometer is programmed for free chlorine and for the chloramine stages. Use program Phot71 Free Chlorine then select ‘Follow On’ from screen options to continue test for program 72 Monochloramine and again for program 73 Dichloramine.

- **Procedures**

1. Rinse test tube with sample leaving a few drops in the tube.
2. Add and then crush the DPD No 1 tablet in the few drops of the water sample until the tablet is thoroughly crushed.
3. Add the 10 ml test solution, mix and seal the tube with the cap.
4. Gently invert the tube to remove any bubbles from the inner walls of the tube.
5. Select Phot 7 on photometer.
6. Take photometer reading in usual manner - see photometer instructions.
7. The result represents the free chlorine residual as mg/l CI2.
8. To measure monochloramine, continue the test on the same test sample. Select ‘Follow On’ from screen options to continue the test program.
9. Add one DPD No 2 tablets, crush and mix to dissolve.

10. Gently invert the tube to remove any bubbles from the inner walls of the tube.
11. Take the photometer reading. The result displayed is the mono-chloramine concentration as mg/l Cl2.
12. To measure dichloramine, continue the test on the same test portion. Select ‘Follow On’ option from screen options to continue the test program.
13. Add one DPD No 3 tablets, crush and mix to dissolve. Stand for two minutes to allow full color development.
14. Take the photometer reading. The photometer displays the dichloramine concentration as mg/l Cl2.

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

TRUE OR FALSE ITEMS

1. For microbiological testing 100 ml is the minimum volume of sample to be taken as a sample to obtain reliable results.
2. Ensure that you don't touch any part of your face while doing the tests
3. Washing hands before and after doing any bacteriological testing is not necessary.
4. Any type of plastic bottles can serve for sampling purposes.
5. Preparation and training are required to collect samples to accurately reflect the water quality at a particular site.

***Note:* Satisfactory rating - 5 points** **Unsatisfactory - below 5points**

You can ask you teacher for the copy of the correct answers.

Answers for True or False item

1.___________ 2._________ 3.___________, 4_____________, 5_____________

Membrane Filter Technique

The Membrane Filter (MF) Technique was introduced in the late 1950s as an alternative to the Most Probable Number (MPN) procedure for microbiological analysis of water samples. Them Technique offers the advantage of isolating discrete colonies of bacteria, whereas the MPN procedure only indicates the presence or absence of an approximate number or organisms (indicated by turbidity in test tubes).

Principle

The membrane filter method gives a direct count of total coliforms and faecal coliforms present In a given sample of water. A measured volume of water is filtered, under vacuum, through a cellulose acetate membrane of uniform pore diameter, usually 0.45 µm. Bacteria are retained on the surface of the membrane which is placed on a suitable selective medium in a sterile container and incubated at an appropriate temperature. If coliforms and/or faecal coliforms are present in the water sample, characteristic colonies form that can be counted directly.

Apparatus

- Incubator(s) or water-bath(s) capable of maintaining a temperature to within ± 0.5 °C of 35 and 37 °C and to within ± 0.25 °C of 44 and 44.5 °C. Choice of temperature depends on the indicator bacteria and the medium.
- Membrane filtration apparatus, complete with vacuum source (electrically operated pump, hand-pump or aspirator) and suction flask.
- Autoclave for sterilizing prepared culture media. A pressure-cooker, heated on a hot-plate or over a Bunsen burner, may be substituted in some circumstances.
- Boiling-pan or bath (if filtration apparatus is to be disinfected in boiling water between uses).
- Laboratory balance, accurate to ± 0.05 g, and with weighing scoop. This may be omitted if media and potassium dihydrogen phosphate are available in pre-weighed packages of the correct size.
- Racks for bottles of prepared culture media and dilution water. These must fit into the autoclave or pressure-cooker.
- Distilling apparatus with storage capacity for at least 5 litres of distilled water.
- Refrigerator for storage of prepared culture media.

- Hot-air sterilizer for sterilizing pipettes and glass or metal Petri dishes.
- Thermometer for checking calibration of incubator or water-bath.
- Pipette cans for sterilizing pipettes.
- Boxes for Petri dishes for use in hot-air sterilizer.
- Reusable bottles for culture media.
- Measuring cylinders, capacity 100 ml and 250 ml.
- Reusable pipettes, glass, capacity 1 ml and 10 ml.
- Bottles to contain 9-ml volumes of buffered dilution water.
- Flasks for preparation of culture media.
- Wash-bottle.
- Blunt-edged forceps.
- Pipette bulbs.
- Spatula.
- Container for used pipettes.
- Brushes for cleaning glassware (several sizes).
- Fire extinguisher and first-aid kit.
- Miscellaneous tools.
- Waste bin.

Consumables

- Methanol for disinfecting filtration apparatus using formaldehyde gas (unnecessary in the laboratory, but essential if analyses are done in the field). It is essential to use methanol. Ethanol or methylated spirits cannot be substituted.
- Membrane filters, 0.45 µm pore size and of diameter appropriate for the filtration apparatus
- being used and complete with absorbent pads.
- Disinfectant for cleaning laboratory surfaces and a container for discarded pipettes.
- Culture media (options are listed in the section on media).
- Phosphate-buffered dilution water.
- Petri dishes, glass or aluminium (reusable) or plastic (disposable).
- Polyethylene bags for wrapping Petri dishes if dry incubator is used.
- Magnifying lens (as an aid to counting colonies after filters are incubated).
- Wax pencils for labelling Petri dishes.
- Autoclave tape.
- Detergent for cleaning glassware and equipment

Procedures

1. Collect the sample and make any necessary dilutions.
2. Select the appropriate nutrient or culture medium. Dispense the broth into a sterile Petri dish, evenly saturating the absorbent pad.
3. Flame the forceps, and remove the membrane from the sterile package.
4. Place the membrane filter into the funnel assembly.
5. Flame the pouring lip of the sample container and pour the sample into the funnel.
6. Turn on the vacuum and allow the sample to draw completely through the filter.

7. Rinse funnel with sterile buffered water. Turn on vacuum and allow the liquid to draw completely through the filter.
8. Flame the forceps and remove the membrane filter from the funnel.
9. Place the membrane filter into the prepared Petri dish. 10. Incubate at the proper temperature and for the appropriate time period.

10. Count the colonies under 10 - 15 X magnification.

11. Confirm the colonies and report the results.

1. Note: Observe aseptic technique throughout the procedure.

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