**LECTURE NOTES**

For Environmental Health Science Students



# *Water Supply I*

Ethiopia Public Health Training Initiative

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# Preface

There is scarcity of teaching materials on water supply specifically prepared for medium level environmental health and other related health professionals. This holds true for all of the teaching institutions of health sciences in Ethiopia. Because of this, teachers prepare lecture notes using available references in their respective institutions. This contributes to differences in course outlines and contents. Hence, the development of this lecture note will help to maintain the standard of course contents among different institutions of health sciences. It also plays a significant role to solve the shortage of different books and texts on the subject.

This lecture note on Water Supply I contains five chapters. Special emphasis is given to water-associated health problems prevailing in Ethiopia and also on the water source developments. Each chapter is presented in simple language. At the beginning of each chapter the learning objectives are stated.

Books, journals and existing lecture manuscripts were mainly used to develop this lecture note. In addition useful ideas from different instructors were also included.

It is hoped that this material will be of particular use not only to teach medium level environmental health and other related professionals in colleges and universities but also serve as a reference tool for those graduates working in health care service institutions.

## Acknowledgments

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## Abbreviations

| | |
|---|---|
| cm | Centimeter |
| hect | Hectare |
| Kg | Kilogram |
| L/d/c | Liter per day per capita |
| MOH | Ministry of Health |
| PHC | Primary Health Care |
| sq.m. | Square meter |
| WC | Water closet |
| WHO | World Health Organization |

# CHAPTER ONE

# INTRODUCTION

## Learning Objectives

After the completion of this chapter the student will be able to:

- Describe the historical background of water supply
- Describe the public health importance of water
- Identify the global occurrence of water
- List the importance of water

## 1.1 Introduction to the Course

According to WHO survey 80% of all illnesses in developing countries are water-associated. The use of unsafe water causes high prevalence of diarrhoeal diseases among children resulting in high infant and child mortality rates. Water and sanitation have emerged as a primary health care component so that it will be able to alleviate the associated morbidity and mortality. Despite international and local efforts towards improving these conditions, changes are not satisfactory in many African countries. This is because water supply is generally linked with or affected by factors such as:

economy, population growth, educational status, customs, traditions, governmental concern, etc. Hence, the provision of safe and adequate water supply programs requires integrated efforts of different concerned sectors including the community to be benefited for its effective achievements.

In Ethiopia the problems related to water supply are attributed mainly to lack of maintenance of the previously constructed systems, lack of community involvement when the earlier water systems were built, lack of spare parts and local maintenance capabilities, etc. These problems are magnified particularly in the rural parts of the country and greatly hamper the operation even of the minimal water supply systems available in these areas. Because of these facts, the problem still persists and has contributed a lot to the low safe water coverage in the country. For instance, According to the health indicators of MOH, the safe water coverage in 1992 E.C. for urban areas was 83.5%, and 24.7% in the rural parts of the country where the majority of the population is living.

Even though it is the desire of every family and every individual to have adequate and safe water supply, the majority of the population in rural Ethiopia does not have access to this basic requirement.

This course is therefore intended to equip environmental health and other related professionals with basic knowledge, attitude and skills that will enable them to identify water-associated health problems of the community and plan water source development programs. The learner will also be able to work independently in the design, construction, and operation of water supply at small-scale level, thereby solving the health problems associated with unsafe and inadequate water supply in Ethiopia.

## 1.2 Historical Background of Water and Human Progress

Human search for pure water began in prehistoric times. Water was the root of human civilization, which sprang up only where abundant water supply was available. These areas of civilization were those which flourished on the banks of the Nile, the Tigris and Euphrates and in other countries like India and China. Throughout the centuries, the search for safe water kept pace with civilization. Some examples follow:

- **India-2000 B.C**

The Indians boiled and exposed the water to sunlight. They also dipped a piece of hot copper into the water seven times. In addition, they filtered and cooled it in an air vessel.

- **Egypt-1450 B.C**

In ancient Egypt siphons were used to clear water from jars after the Nile water was stored and the impurities settled to the bottom of the jar.

- **Greece-400 B.C**

Hippocrates, the father of medicine, asserted that rainwater should be boiled and strained, otherwise it would smell bad and cause hoarseness.

- **Ancient Rome**

The ancient Romans built notable water systems, part of which are still in use. Water was brought by gravity from mountain springs through great aqueducts to the cities crossing valleys.

- **Europe 1800 A.D.**

As cities and industries grew, the importance of safe water supply became increasingly apparent. The occurrence of epidemics in different parts of Europe also increased the demand of water purification.

For example, in 1852, the city of London was requested by Parliament to filter its water through sand filters and in 1892, the value of filtration was witnessed, when an epidemic of cholera struck the citizens of Hamburg, Germany. They drank unfiltered water from the Elbe River. Just beyond the Elbe

River, where the water supply was filtered, the residents of Altona remained healthy. In 1912 liquid chlorine was first applied to destroy disease-producing bacteria. Today every large city chlorinates its water.

## 1.3 Terms commonly used in water supply

**Aquifer:** an underground zone or layer, which is a relatively good source of water. It is a rock formation that bears and yields water when penetrated by wells.

**Confined water:** groundwater held between two layers of impermeable rock.

**Eye of the spring:** opening where the water comes out of the earth.

**Free water;** groundwater which can move without hindrance in response to the force of gravity.

**Impermeable:** not allowing passage of, for example, a liquid.

**Infiltrate:** to pass through a permeable substance, usually slowly, as if through a filter.

**Palatable water:** water that is pleasant to drink because its taste is good but it may not be safe to drink.

**Per capita:** literally "by needs" by unit of population by person.

**Permeable:** able to be passed through or penetrated by a fluid.

**Pollution:** the presence of matter whose nature, location, or quantity produces undefined environmental effects.

**Porosity:** the quality of being full of pores and therefore absorbent and permeable.

**Potable:** safe for drinking, free from pathogens which are introduced to the water through feces, dirty containers, etc.

**Raw water:** water that has not been purified.

**Sedimentation:** the action of settling down or depositing matter in a liquid.

**Turbidity:** disturbed, muddy appearance of water.

## 1.4 Public Health Importance of Water

Water is a basic necessity for life. Unfortunately, not all water helps human to survive. Water from contaminated sources causes numerous diseases and untimely deaths. The fact that a human needs water and cannot live without it forces him to use it even for drinking purposes, from any source, whether pure or contaminated, As a result, many people suffer or die from waterborne diseases. Hence, every country has to take preventive measures to avoid pollution and contamination of the available water resources. Therefore, public water supply must be potable, palatable and wholesome. Water must not have disagreeable physical change and must be hygienically safe.

## 1.5 Importance of Water

The following points elaborate the importance of water:

1. It is impossible to have a clean and sanitary environment without water. Water is necessary in promoting personal hygiene and in cleaning the environment. Without an adequate and wholesome water supply, health cannot be maintained.
2. Water is essential for life. Man can live nearly two months without food, but can live only three or four days without water. In general 70% of human body weight is water and a human being needs two liters of water per day as minimum.
3. Most of the foods that man eats contain water.

For example:

- Milk contains about 88% water.
- Egg contains about 66% water.
- Fish are 80% water.
- Potatoes are 75% water.
- Beef is 77% water

4. It is essential to run industries. Nearly all modern industries are thirsty; they need water.

For example:

- It takes about 10 liters of water to produce one litter of petrol.

- It takes about 600 liters of water to produce 1kg of woolen cloth.
- It takes about 3500 liters of water to produce 1kg of dry cement.

5. It's important for the balance in ecology (i.e. the balance in relationship between living things and the environment in which they live). All animal life depends directly or indirectly upon vegetation for food, and vegetation will not grow without water. Vegetable matter, such as leaves and steams, can be converted to soil by bacterial action. Bacteria need water in order to thrive. New plants growing in this soil take up nutrients through their roots in the form of a solution in water. Any break in this ecological chain can mean failure of the whole ecological system.
6. Water is important for agriculture, animal breeding and fishing.
7. Water is a valuable source of energy. It is capable of generating hydroelectric power.
8. Water facilitates transportation and navigation. For example, the Baro River is one of the rivers used for boat transportation in Ethiopia.
9. Water plays an important role in recreation activities. Lake Langano is an attractive lake for recreation.

## 1.6 Global Occurrence of Water

Water is located in all regions of the earth. The problem is that the distribution, quality, quantity and mode of occurrence are highly variable from one locality to another.

Water is the most widely occurring substance in the world. Over 72% of the earth's surface is covered by water. This means that if the body of water were evenly distributed, it would cover the globe to an average depth of over 4 kilometers. Out of the 72% of the earth’s surface water, 97.2% is in the ocean, which is unfit for human consumption, as it is too salty to be used for drinking and irrigation without desalination. Desalination is too expensive to consider as a water purification method. Another 2% of the remaining water lies frozen in glaciers and in icecaps, and is mostly unreachable. The tiny usable portion is about 0.8% of the total, which is neither evenly distributed nor properly used.

## Review Questions

1. Write the public health importance of water.
2. What is the reason that the largest portion of the water is unfit for domestic and agricultural purposes?
3. Explain the global occurrence of water in terms of percentages.
4. Write at least five important reasons for water.

# CHAPTER TWO

# GENERAL CHARACTERSTICS OF WATER AND GEOLOGY

## Learning Objectives

**At the end of this chapter the student will be able to:**

- List the important properties of water.
- Describe the hydrologic cycle.
- Identify impurities of water.
- Describe the geology of the earth.

## 2.1 Some Important Properties of Water

Pure water consists of two atoms of hydrogen and one atom of oxygen chemically combined. The chemical symbol is $H_2O$ and the chemical name is hydrogen monoxide.

Water exists in three states: as a liquid, as a solid (ice and snow), and as a gas (water vapor). It is a very stable chemical substance. Water has a maximum density of one at a temperature of $4^{O}C$. It boils at $100^{O}C$ and freezes at $0^{0}C$ at a barometric pressure of 760 millimeters of mercury. Pure water is practically colorless, odorless and tasteless. Any deviation from these physical characteristics should be considered as an indication of impurity.

Water has the ability to dissolve solids and to absorb gases and other liquids. Hence, it is often referred to as the “universal solvent”. Because of this solvent power, all natural water contains minerals and other substances in solution, which have been picked up from the air, the soil, and rocks through and over which it passes.

Water has very high molecular attraction both for its own molecules (cohesion) and for molecules of other substance (adhesion). Because of this particular characteristic, a large quantity of water is held in rock particles and by plant roots in the soil. The PH of pure water is 7 (neutral).

Upon freezing to ice, water expands in volume by about one tenth and exerts a pressure of 33,000 pounds (15,000 kg) per square inch (6.45 sq. cm). It is this pressure that bursts water pipes in freezing water.

Water in liquid form weighs approximately 62.5 pounds (28.41 kg) per cubic foot. This is 830 times heavier than air. However, in the form of vapor, water is 133 times lighter than air, (volume for volume), which partly explains why water vapor rises in the atmosphere to form clouds.

## 2.2 Hydrologic Cycle

The water on earth, whether as water vapor in the atmosphere as surface water in rivers, streams, lakes seas and oceans or as groundwater in the subsurface ground strata, is for the most part not at rest but in a state of continuous recycling movement. This is called the hydrologic cycle or water cycle. (Fig. 2.1)

This water circulation depends on the temperature and humidity of the environment or atmosphere. The sun's heat acts upon the surface of the earth and bodies of water and as a result, water evaporation takes place from oceans, seas, etc., and water transpiration takes place from leaves of trees and plants.

The process acts continuously to form dense rain clouds in the lower atmosphere. After condensation, the rain clouds precipitate and release water to the surface of earth in the form of rain, snow, dew, etc.

As the rain reaches the ground surface a portion of it evaporates back immediately. Some percolates into the soil to become groundwater.

The remaining portion of the rain flows over the earth's surface as run-off, streams, and rivers and finally joins the oceans, lakes, seas, etc. This cycle repeats again and again. The amount of water involved in water cycle varies from place to place. But the total amount of water in the world is constant. Some raw water called juvenile water is added to the system when water in rocks is released as volcanoes spew out molten rock. Water molecules are dissociated in the upper atmosphere, allowing some hydrogen ions to escape to outer space. Nevertheless, the total amount of water on earth remains the same.

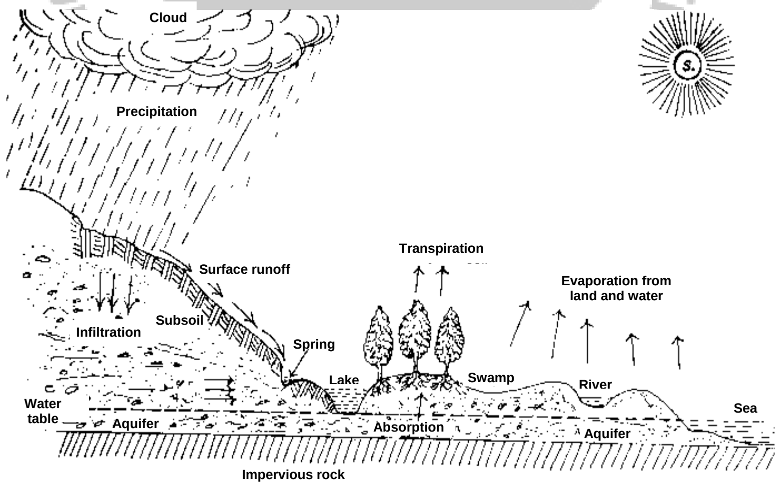


Fig.2.1. The hydrologic cycle

Source: Gebre Amanuel Teka, Water supply in Ethiopia, 1973

## 2.3 Impurities of Water

Water is not absolutely pure in nature. Impurities vary from dissolved gases, chemicals, minerals, to suspended matter and disease-causing micro-organisms. Some can be seen with the naked eye, while others that cannot be seen are detected by taste or smell or other laboratory methods.

**Sources of Impurities**: Water gathers impurities as it goes through its natural cycle. First it may pick up micro-organisms, dust, smoke, and gases from the atmosphere as it comes down as rain, hail, etc. As rain touches the earth's surface, it becomes surface water. As it flows over the earth's surface, it may pick up dirt, micro-organisms, chemicals and anything else in its path which can be moved or dissolved.

Water which percolates into the ground loses many of its suspended impurities as it filters through the earth.

**Impurities of water may be divided into two classes:**

**1. Suspended Impurities**

**a. Micro-organisms**: they may get into water from the air with dust, etc., as rain falls, or commonly when soil polluted with human and animal wastes is washed into the water source. The latter type of impurity in water is the most dangerous one because a good number of micro-organisms are pathogenic and cause disease.

**b. Suspended solids**: Minute particles of soil, clay, silt, soot particles, dead leaves and other insoluble material get into water because of erosion from higher ground, drainage from swamps, ponds, top soil, etc. Toxic chemicals such as insecticides and pesticides are also included in this category.

They are introduced to streams either as industrial wastes or drained in after rain from land treated with these chemicals. Generally, suspended solids cause taste, color or turbidity.

**c. Algae**: Algae are minute plants that grow in still or stagnant water. Some algae are green, brown or red, and their presence in water causes taste, color and turbidity. Some species of algae could be poisonous both for aquatic animals and humans.

**There are different types of algae found in water:**

i. Asterionell – Gives water an unpleasant odor.

ii. Spirogyra – Is a green scum found in small ponds and polluted water. It grows in thread like groups. It is slippery and non-toxic.

iii. Anabaena – Is blue- green and occurs in fishponds, pools, reservoir, and clogs filters.

**2. Dissolved Impurities**

**a. Gases:** Oxygen ($0_2$), carbon dioxide ($C0_2$), hydrogen sulphide ($H_2S$), etc, find their way into water as it falls as rain or, in the case of the latter two, from the soil as water percolates through the ground. All natural water contains dissolved oxygen, and in certain circumstances carbon dioxide. The presence of $C0_2$ and $H_2S$ (but not $0_2$) causes acidity in water. In addition, $H_2S$ imparts a bad odor to the water.

**b. Minerals**: minerals get into water as it percolates downward though the earth layers. The type of minerals dissolved will depend on the nature of the specific rock formation of an area.

Most common dissolved minerals in water are salts of calcium, magnesium, sodium, potassium, etc. Salts of the first two elements cause hardness in water, while salts of the latter two elements cause alkalinity. Salts of toxic elements, such as lead, arsenic, chromium, etc, get into water mainly as industrial wastes dumped into streams.

**c. Plant dyes**: These originate from plants, which grow in or around water and cause acidity and color.

## 2.4 Introduction to the Physical Geology

The earth is one of the planets, and has nearly spherical shape slightly flattened at the poles and at the equator. The three zones of earth corresponding to the three states of matter (solid, liquid and gas) are:

1. Lithosphere- solid central zone
2. Hydrosphere- The zone of water – cradled in the ocean basins and distributed across the surface of the land.
3. Atmosphere – gaseous envelope surrounding them.

The earth was originally a molten mass. Through the ages its upper portions have cooled and solidified gradually to form an earth crust. The interior of the earth is variable, consisting of concentric shells which differ in composition, density and elasticity.

**Classification and characteristics of formations:** Rocks are divided into three major classes.

1. **Igneous rocks**: are those formed by the cooling and hardening of molten rock masses. The rocks are crystalline and contain quartz, feldspar, mica, hornblende, pyroxene, and olivine. Igneous rocks are not usually good sources of water, although basalts are exceptions. Small quantities of water are available in cracks and fissures.

2. **Sedimentary rocks**: are those resulting from the deposition and accumulation of materials. Weathered and eroded remains of plants, animals, or material precipitated limestone, fossils, gypsum, peat, shale, loess, and sandstone are examples of sedimentary formations. Deposits of sand and gravel generally yield large quantities of water. Sandstones, shale, and certain limestone may yield abundant groundwater, although results may be erratic.

3. **Metamorphic rocks**: are produced by the alterations of other rocks, generally by means of heat and pressure. Gneisses and schist, quartzite, slates, marble, serpentines, and soapstones are metamorphic rocks. A small quantity of water is available in joints, crevices, and cleavage planes.

**The rock cycle**: This shows how the three major classes of rocks are formed (Fig 2.2).

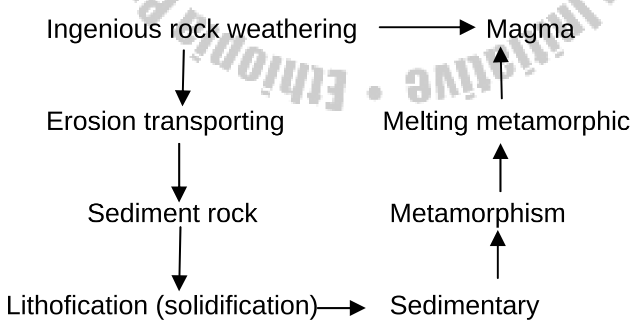


Fig. 2.2 The rock cycle

**Porosity and texture of rocks**

**Porosity**: Openings in rocks may contain water between individual mineral or sediment grains called pores. The porosity of rocks or soils is the ratio of volume of the pore space to the total volume of the material including its pores. Porosity varies with type of rock that makes up the water-bearing stratum. Porosity varies from 1% in unfractured granite to more than 40% in a poorly cemented sand stone. Examples of porosity percentages of common rocks are depicted in Table 2.1.

**Table 2.1:** Porosity of common soils and rocks

| | Type of rocks | Porosity (%) | Grading pore space in rock |
|---|---|---|---|
| 1 | Top soil | 37-65 | Very high |
| 2 | Clay | 44-47 | Very high |
| 3 | Sand and gravel compacted | 35-40 | Very high |
| 4 | Chalk | 14-45 | High |
| 5 | Sand stone | 4-30 | High |
| 6 | Lime stone | 0.5-17 | Fairly high |
| 7 | Granites Schist (Igneous and metamorphic) | 0.02-2 | Very low |

The size and addition of the openings exerts a strong influence upon rate of flow. The course sands and gravel permit rapid flow of water and these are referred to as highly permeable materials. But the clay form will obstruct the flow of water because of their microscopic openings, thus their formation is impermeable.

- **Specific yield**: is the quantity of water that a formation will yield in proportion to the total volume it holds. If a sandstone has a porosity of 20% but will yield only half of this water, then the rock is said to have a specific yield of 10%. A specific yield of 10%, however, represents a great volume of available water in storage. Topsoil with 50% porosity will have yield of 25%.

**Movement of water within the soil**

In the process of water movement underground or in the soil, two forces are involved: capillary and gravity.

**Capillary**: is the tendency of a liquid to cling to the surface of a solid material and draw the liquid up against the pull of gravity.

**Gravity:** is the movement of water towards the pull of gravity.

- **Water table**: is the top (upper) limit of the zone of saturation in the groundwater formation (See Fig.2.3). Rain and run-off water filters into the soil, passes through the margin of water table and reaches the lower zone called the zone of saturation.

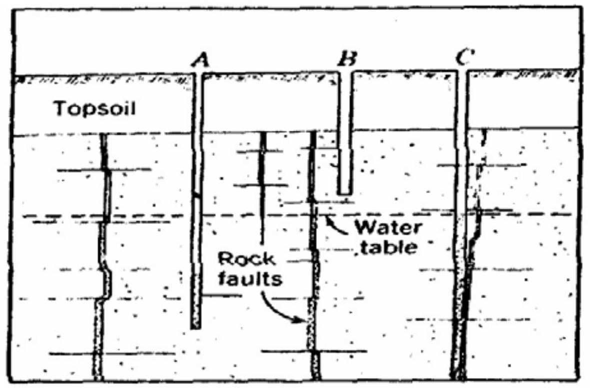


Fig. 2.3 water table in bedrock

Source: Wright F.B, Rural Water Supply and Sanitation, 1977

If the rock is faulted as shown in Fig 2.3 the water may collect in the faults and flow in quantity for long distances. Wells drilled between faults, as at “A”, may have a very weak flow because the water moves slowly through the rock. A shallow well, as at “B”, may go dry in dry weather. A well which strikes faults with flowing water, as at “C”, may have a very strong flow, but is more likely to be contaminated than water which filters through soil or rock.

## Review Questions

1. Write about the important physical and chemical properties of water.
2. Draw the hydrologic cycle and show the important phenomenon that is taking place.
3. What are the differences between suspended impurities and dissolved impurities?
4. Identify the forces which are involved in the process of water movement underground or in the soil.

# CHAPTER THREE

# WATER SUPPLY AND HUMAN HEALTH

## Learning Objectives

At the end of this chapter the student will be able to:

- Describe the relation between water and diseases.
- Identify waterborne, water-washed, water-based and water-related diseases.
- Describe the prevention and control of waterborne, water-washed, water-based and water-related diseases.

## 3.1 Water, Health and Disease

The saying "water is life" is found in many cultures around the world. It underscores the fact that clean water is an absolute prerequisite for healthy living. The importance of water in human welfare cannot be over-emphasized. The normal functioning of the human body depends entirely upon an adequate quantity and quality of water. But if the water is from contaminated sources, it causes numerous water-associated diseases.

In the developed world, water-associated disease are rare, due essentially to the presence of efficient water supply and waste water disposal systems. However, in the developing world, the majority of people are without a safe water supply and adequate sanitation.

A WHO survey has highlighted the following facts:

- Each day, 30,000 people die from water-associated diseases.
- In developing countries, 80% of all illnesses are water-associated.

Safe, adequate and accessible supplies of water, combined with proper sanitation, are basic needs. Therefore, water supply is taken as an essential component of primary health care (PHC). Safe, adequate and accessible water supply can help to reduce many of the disease affecting under-privileged populations especially those who live in rural and urban fringe areas.

A wide range of natural and human influences affects water quality. The most important of the natural influence are geological, hydrological and climatic conditions, since these affect the quantity and the quality of water available.

The effect of human activities on water quality are both widespread and varied in the degree to which they disrupt the ecosystem and/or restrict water use.

There are two main types of water pollution:

**1. Chemical pollution of water and diseases**

Almost every known element existing normally in the environment can become poisonous when introduced into the human system in larger than normal quantities. One major way of introducing these elements into the environment and later into the human system is through the discharge of industrial effluents into water sources such as rivers.

These pollutants include detergents, solvents, nitrogenous substances, dyes, ammonia, etc. This can affect human health directly or indirectly by accumulating in aquatic life.

Some elements or chemicals maybe found in water in excessive or inadequate amounts. For instance, excess fluorine in water causes dental flourosis or mottled enamels while lack of fluorine in water causes dental cavities (decay).Therefore, maintaining the optimal level (1mg/l) is essential.

It has been observed that surface water is often low in fluoride content but the concentration is high in underground water sources.

A concentration of 10 PPM of nitrate nitrogen is thought to be harmful. It causes infant methaemoglobinaemia (blue baby syndrome).

**2. Biological pollution of water and diseases**

Water may contain numerous pathogenic organisms and thereby become a means of transmission for many diseases.

All water-associated disease require an infectious agent, a transmission route and the exposure of a susceptible living organisms for their spread. The relationship can be illustrated in the form of a triangle as shown in Fig. 3.1.

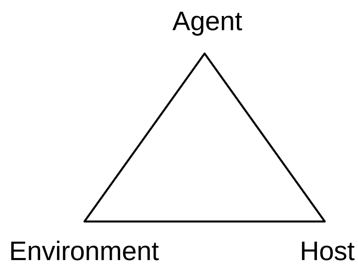


Fig.3.1. Agent-environment-host triangle
(The vicious circle which has remained hard to break).

## 3.2. Water-associated Disease

Water-associated disease can be defined as a disease in relation to water supply and sanitation. There are four categories:

1. Waterborne disease
2. Water-washed disease
3. Water-based disease
4. Water-related disease

**1. Waterborne diseases**

Several infections enteric or intestinal diseases of man are transmitted through water contamination by fecal matter. Pathogens excreted in water by an infected person include all major categories such as bacteria, viruses, protozoa and parasitic warms. Water acts only as a passive vehicle for the infectious agent. Table 3.1 shows examples of waterborne diseases.

**Table 3.1 Waterborne diseases with their etiologies**

| Types of organism | Disease Types |
|---|---|
| Bacteria | ▪ Typhoid and paratyphoid fever<br>▪ Cholera<br>▪ Diarrheas (caused by salmonella, yersinia entrocolitica, E.coli)<br>▪ Campylobacter dysentery<br>▪ Bacillary dysentery (caused by shigella) |
| Virus | ▪ Hepatitis A<br>▪ Poliomyelitis<br>▪ Viral gastroenteritis |
| Protozoa | ▪ Amoebic dysentery<br>▪ Giardia (lambliasis)<br>▪ Balantidiasis |
| Helminthes | Helminthiasis caused by Ascaris and Trichinas |

To prevent the occurrence of waterborne diseases, water treatment is very essential. The cycle of infection due to waterborne diseases is explained in Fig. 3.2.

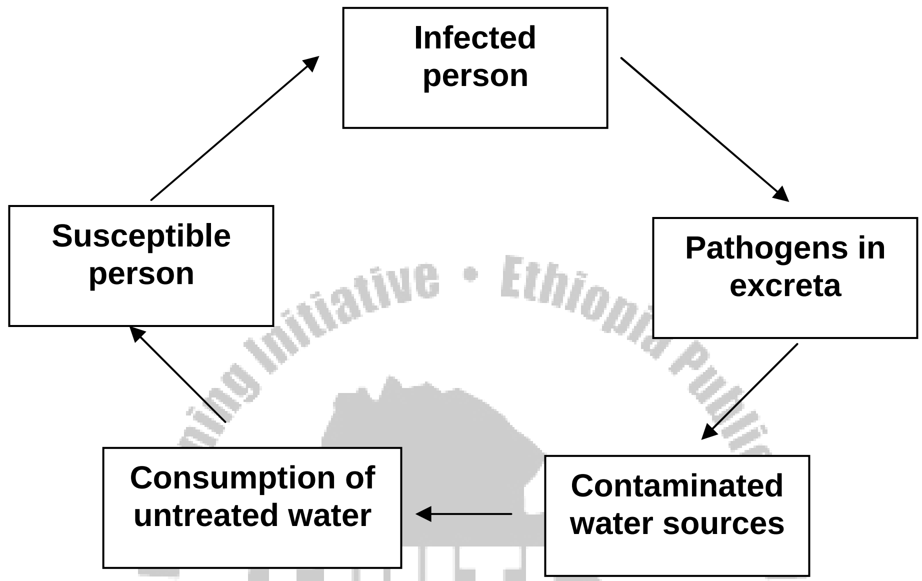


Fig.3.2. The classic waterborne disease infection cycle

**N.B.** It should be noted that waterborne diseases form part of the group of water-washed diseases as well. They may also be transmitted by any of the faeco-oral routes: dirty hands, dirty food, dirty water, etc.

**2. Water-washed diseases**

These comprise diseases linked to a lack of water for personal hygiene. Examples of water -washed diseases are:

- Dermatological disease such as scabies
- Ophthalmic disease such as trachoma and conjunctivitis

- Louse-borne diseases such as louse borne typhus and relapsing fever. Lack of good personal hygiene and unability to wash clothes encourages the proliferation of lice and the problems associated with their presence (itching, scratching, skin sores).

To prevent this type of disease, provision of an ample amount of water and personal hygiene are very essential.

**3. Water-based diseases**

These are diseases caused by infectious agents that are spread by contact with water. The essential part of the life cycle of the infecting agent takes place from an aquatic animal.

A number of diseases depend upon the pathogenic organisms spending part of their life cycle in water or in an intermediate host which lives in water. Thus, infection of humans cannot occur by immediate ingestion of, or contact with, the organism excreted by sufferers.

Many of the diseases in this class are caused by worms, which infest the sufferer and produce eggs, which are then discharged in feces or urine. Typical examples are schistosomiasis and dracunculiasis (guinea worm). See Fig. 3.3 for the cycle of transmission of schistosomiasis.

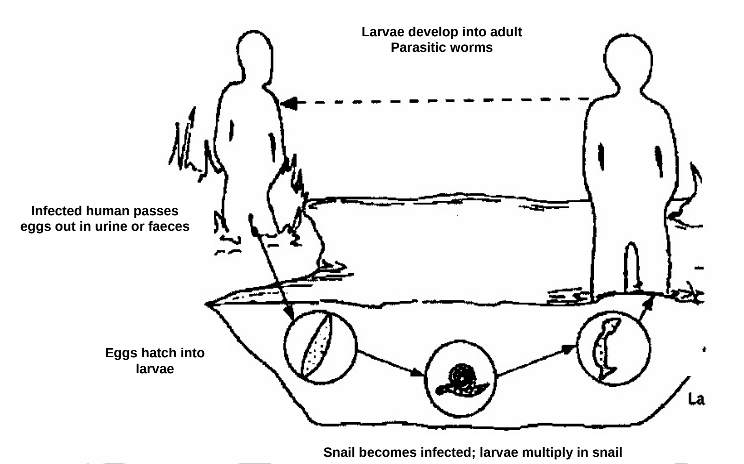


Fig. 3.3. The cycle of transmission of schistosomiasis
Source: Public Health Technician, 1994

To prevent this group of diseases, the following methods may be implemented:

- Avoidance of contact with and ingestion of contaminated water.
- Reduction of intermediate hosts (snail) by using "endod" or Lemma toxin.
- Storage of water from 24 to 72 hours to kill the cercaria.

**4. Water-related diseases**

These are diseases transmitted by insects that live close to water. Infections are spread by mosquitoes, flies and other insects that breed in water or near it.

There are a number of diseases which are spread by insects that breed or feed near water so that their incidence can be related to the proximity of suitable water sources. Infection with these diseases is in no way connected with human consumption or contact with the water.

**Example**: Malaria, sleeping sickness, yellow fever, onchocerciasis, etc.

To prevent this type of disease, making the water unsuitable for breeding of insects is essential.

**Summary**

All the waterborne and many of the water-based diseases depend for their dispersion on infecting agents from human feces getting into drinking water or into food. The chain of disease transmission may be broken effectively by sanitary disposal of feces and the provision of safe and adequate water supplies.

Improvement in the reality of community water supplies will basically only affect the waterborne disease such as bacillary dysentery, cholera and typhoid. Many of the diarrheal diseases probably are due more to a lack of safe and adequate quantities of water. Skin and eye infections are in this group of water-associated diseases.

When water supplies are developed without complementary improvements in personal hygiene, food handling and preparation, and in general health care, they are unlikely to produce the expected health benefits. Table 3.2. discusses, in comparative form, the four categories of water-associated diseases, and gives examples of typical diseases in each category, the causative agents and the preventive strategies.

**Table 3.2.** The four mechanisms of water-associated diseases and preventive strategies

| Water-associated diseases | Example | Agent | Preventive strategies |
|---|---|---|---|
| 1. Waterborne (faecal –oral)<br>a) Low infectious dose<br>b) High infectious dose | Typhoid, cholera<br>Bacillary desentry | A<br>A | -Improve water quality<br>-Prevent usual use of other contaminated source<br>- Health education |
| 2. Water-washed<br>a) Skin and eye<br>b) Other. | Scabies, trachoma<br>Louse-borne fever | F<br>E | -Improve water quantity<br>-Improve water access.<br>- Health education |
| 3. Water-based<br>a) Penetrating skin<br>b) Ingested | Schistosomiasis<br>Guinea worms | D<br>D | -Decrease need for untreated water contact<br>-Control snail population<br>-Improve quality of water<br>-Filter out Cyclops.<br>- Health education |
| 4. Water-related<br>a) Biting near water<br>b) Breeding in water | Sleeping sickness,<br>Malaria | C<br>C | -Proper site selection of house<br>-Using personal protection materials<br>-Destroy breeding sites of insects<br>-Decrease need to visit breeding site<br>- Health education |

Key: A - Bacteria B - Virus C. Protozoa
D. - Helminthes E. - Spirochetes F. Other agents

## Review Questions

1. Why are water-associated diseases more common in developing countries than developed countries?
2. Write the two main types of water pollution.
3. How are waterborne diseases transmitted? Give some examples.
4. Write the differences between water-washed and water-based diseases.
5. Write the prevention methods of water-related diseases.

# CHAPTER FOUR

# SOURCES OF WATER

## Learning Objectives

At the end of this chapter the student will be able to:

1. Identify the different water sources
2. Describe the advantages and disadvantages of groundwater
3. Identify surface water sources
4. Describe the importance of rainwater
5. Describe the disadvantage of ocean water

## 4.1 Groundwater

**Definition**

Groundwater may be defined as that portion of the total precipitation which has percolated downward into the porous space in the soil and rock where it remains, or from which it finds its way out to the surface.

Groundwater is by far the most practical and safe in nature. It is the most important source of supply for most rural communities of the world. Examples of groundwater are wells and springs.

**Advantages of groundwater:**

A. It is comparatively likely to be free from disease causing micro-organism
B. it can be used without further treatment if properly protected and treated immediately after the completion of construction work on the well or other source where groundwater is available.
C. It is not exposed for evaporation and is used as natural storage in underground.
D. It is most practical and economical to obtain and distribute.
E. Groundwater can be found near a family or a community.

**Disadvantages of groundwater**

A. It needs pumping unless it comes from a spring
B. It may contain excess amounts of dissolved minerals.
C. It is poor in oxygen content.

**Occurrence of groundwater**

- Groundwater may be found in the form of perched water, free water or confined water.

a. **Free water**: Is groundwater occurring where there is no interruption or confining formation in the water – bearing stratum. It is free movement of water under the water table, in the impervious stratum of the soil formation.

b. **Confined water**: Is groundwater located between the overlying (upper) confined stratum and underlying (lower) confined stratum.

c. **Perched water**: may occur where the water-bearing stratum is blocked by an impervious barrier or bed, which may itself overlie on another aquifer or stratum.

- In terms of depths of occurrence of the water –bearing stratum, groundwater may be tapped by the following means.

a. **Shallow wells**: Are wells that have been dug into the uppermost permeable stratum. They have a depth of less than 30 meters. In shallow wells, the water level always stands with in “sucking” distance of a pump located at the top of the well.( See Fig 4.1)

b. **Deep wells**: Are wells that have been sunk through an impermeable formation until they tap water from a permeable stratum below it. It is sunk with drilling machines designed and produced for water. They tap water from a minimum depth of around 60 meters.

Deep wells frequently penetrate more than one water-bearing stratum; therefore they may provide a stronger flow. Also, deep sources are less affected by drought as the water bearing formations are more likely to be extensive in area.

In some areas deposits of salt, sulphur or other objectionable minerals make it unfit to drill deep for water. Such conditions can usually be determined by a survey of existing wells in the area. Deep wells are constructed for water supply in large communities. The water table in deep wells does not rapidly fluctuate, and therefore provides a large and uniform yield. (Fig. 4.1)

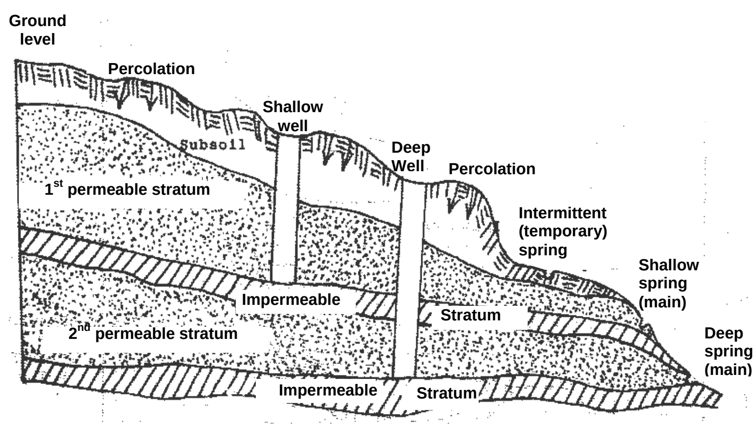


Fig.4.1. Shallow well, deep well, shallow spring, deep spring in relation to water bearing strata.

Source: Gebre Amanuel Teka, Water Supply in Ethiopia, 1973.

c. **Artesian wells**: are wells in which groundwater gushes out of its own accord above ground level. In other words, an artesian well can flow naturally, without any artificial efforts. An artesian well is formed whenever there is a favorable hydraulic gradient for groundwater to be at sufficient hydrostatic pressure to rise above the zone of saturation (Fig 4.2. a and b). In general these wells are not common.

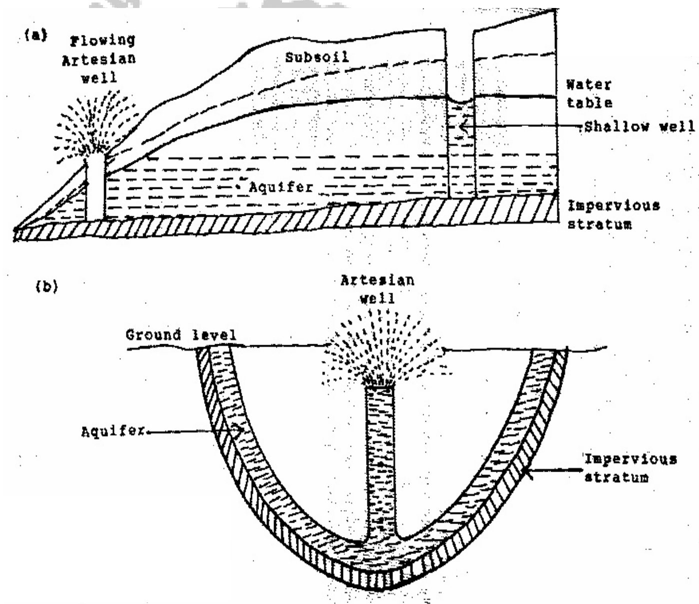


Fig. 4.2. a and b, How artesian well are formed
Source: Gebre Amanuel Teka, Water Supply in Ethiopia,1973.

d. **Springs**: Are occurrences of groundwater naturally issuing at points where the water table reaches the surface, or where the top confining layer over the water – bearing strata is broken. Springs are normally found at the foot of mountains and hills, in lower slopes of valleys, and near the banks of major rivers. The yield (flow rate) of a spring varies with the position of the water table, which in turn varies with the rainfall amount at that locality and season.

**Springs may be classified as:**

1. **Surface, intermittent or seasonal spring**: These are springs which outcrop at a point higher in the groundwater body than the impermeable stratum in the ground formation. These are in fact seepages from the subsoil or through cracks or faults in the rock formation. These springs are usually not reliable, drying up during drier seasons and appearing again during or after the rainy seasons. They should not be developed as water supply sources unless observed throughout the year for their reliability.

2. **Mainsprings**: These flow out of the ground after the infiltration water has reached an impermeable stratum in the rock layers. Such springs are sometimes known as gravity springs because the force of gravity makes them flows in the direction of the hydraulic gradient.

3. **Thermal or hot springs**: Are springs of water which have been heated before they reach the surface of the ground. There are at least two explanations for the occurrence of thermal springs:

   a) Heat escaping from hot lower levels of the earth's crust towards ground level may heat groundwater.
   b) The strata of certain regions contain radioactive elements, and heat emitted by this process may heat groundwater and produce hot springs.

Thermal springs are quite common in various parts of the world. Examples of well-known thermal springs in Ethiopia are. "Filowha" of Addis Ababa; Wondogenet in the Southern Region; and Soderie in East Showa Zone.

In many parts of the world spring waters are believed to cure certain diseases. In Ethiopia, spring waters are believed to have a super-natural power to cure all sorts of ailments, and are known as "Tebel" (holy water).

## 4.2 Surface Water

Surface water is found non-uniformly distributed over the earth's surface. As the rain reaches the surface of the earth, it becomes surface water or runoff. Surface water includes rivers, streams, lakes, ponds, etc. The quantity and quality of surface water depend upon the conditions of the surface or catchment area over which it flows.

## 4.3 Rainwater

In regions where rainfall is abundant and frequent, rainwater can be a good source of water supply for individual families and for small communities. The storage of rainwater is particularly important in areas with a long dry season. It can be stored in cisterns or ponds. In some rural sections of Ethiopia, cistern water is used for all domestic and farm purpose, including drinking.

This is particularly true where groundwater is difficult to obtain or, if obtainable, it is for any reason unsatisfactory.

**Advantages of Rainwater:**

1. It is a reliable source even if it rains once or twice a year only.
2. It is cheap and a safe means of water supply that may not need pipes or pumps and is available at the doorstep. Its storage needs no fuel, no spare parts, but only very little skill to construct and maintain.

3. Women and children, who are normally water carriers in Ethiopia and other African countries, will be relieved of the burden of walking long distances to fetch inadequate supply.
4. Since the cistern will be in a closed container, it will not permit spreading of diseases which are often found in an unprotected source such as rivers or ponds.
5. It is a system that can be used even in arid and semi-arid areas.
6. Since rainwater is soft, little soap is needed for laundry purposes.

## 4.4 Ocean Water

Ocean water is unfit for human consumption even though it comprises the largest portion of water on the earth's surface. It is also too salty for irrigation and for domestic purposes. To make the ocean water fit for these purposes; it must pass through a process known as desalination (a process of removal of salt from water). However, it is too expensive to consider.

## Review Questions

1. List the types of ground and surface water sources.
2. What is the advantage and disadvantage of groundwater?
3. List the types of springs.
4. What is the significance of rainwater?
5. What is the disadvantage of ocean water?

# CHAPTER FIVE

# WATER SOURCES DEVELOPMENT

## Learning Objectives

At the end of this chapter the student will be able to:

- Describe water requirements.
- Identify the methods of construction of the different sources of water.
- List protection methods of the different water sources from contamination.

## 5.1 Water Requirements

The availability of an adequate and safe supply of water is one of the major requirements for the control of a large number of diseases, and to advance the standard of good general health within a community. One of the main duties of a health worker, indeed of any community development worker, should therefore be to see that a safe and plentiful water supply is available to all segments of the community at a reasonable cost.

**Quantity of water**

It is now an established fact that water is used for domestic, industrial, agricultural, public use and firefighting. Therefore, the requirement of water is of prime consideration for design of all water supply units including the intakes, pumps, treatment plants, and pipelines of the distribution system.

The total consumption largely depends on:

- The climatic condition
- Cost of water
- Hygienic practice standards
- Type of supply (continuous or intermittent)
- Custom and habits of inhabitants
- Pressure in pipe lines
- Accessibility of water source
- Population
- Amount of water available
- Percentage of area of garden and lawns
- Financial position of population
- Efficiency of management system
- Type of industrial activities
- Fire extinguishing service, etc.

**Estimation of demand of water**

The probable demand of water by a community is important because it fixes the size and capacity of water supply units. The total quantity of water can be estimated by ascertaining different purposes for which the supply is necessary and the quantity likely to be used under each item of supply. Requirement is generally expressed in terms of average number of liters of water per capita per day throughout the year.

**1. Water consumption at home:**

| Purpose | Consumption l/d/c |
|---|---|
| Drinking | 2.3 |
| Cooking | 4.5 |
| Ablution | 18.2 |
| Washing of utensils and houses | 13.6 |
| Flushing of w.c | 13.6 |
| Bathing | 27.3 |
| Total | 106.8 |

**2. Use of water by different establishments:**

| Type of building | consumption l/d/c |
|---|---|
| - Factories with bathroom | 45 |
| - Factories with no bathroom | 30 |
| - Hospitals with laundry/bed | 340 |
| - Nursing room | 135 |
| - Hostels | 135 |
| - Hotels/bed | 130 |
| - Offices | 45 |
| - Restaurant | 70 |
| - Day school | 45 |
| - Boarding school | 18.5 |

**3. Consumption by livestock:**

| Type of livestock | consumption l/d/c |
|---|---|
| - Horse | 45.5 |
| - Cow | 68.5 |
| - Hog | 6.02 |
| - Sheep | 13.6 |
| - Goat | 13.6 |

**4. Municipal purpose:**

| Purpose | consumption rate |
|---|---|
| - Public park | 1.4 $l/m^2$ /day |
| - Road watering | 1-1.5 $l/m^2$/day |
| - Sewer cleaning | 4.5 l/head/day. |

### 5. Industries

The presence of industries in towns has a great effect upon total consumption. There is no direct relation of this consumption with the population and hence the actual requirement for all industries should be estimated.

### 6. Irrigation purpose

| Purpose | Consumption rate |
|---|---|
| - Road side trees | 28150 l/km / day |
| - Public parks | 16850 l/ hect / day |
| - Private garden | 16850 l/hect/ day |

### 7. Fire demand

The water requirement for extinguishing fire depends on bulk, congestion and fire resistance of buildings. It mainly depends on population. The minimum demand is the amount and rate of supply that is required to extinguish the longest probable fire.

### 8. Loss and wastage

Leakage from water sources as a result of careless and lazy habits of consumers and inefficient management may create a loss of about 20% of a well-maintained system.

**Variation in demand from average**

Water consumption varies throughout the year. In certain hours, days and months, the demand is maximum. There are peak hours and days. Thus, the total water supply should be adequate for this peak demand.

The average daily consumption of a particular city can be found by dividing the total amount of consumption by 365 days.

The maximum daily consumption is about 180% of daily consumption.

The maximum hourly demand may be 150% of average hourly demand.

Here are a few examples:

If the daily consumption of a city is 100 million liters, the maximum daily consumption may be expected to be 100X1.8= 180X $10^6$ liters

The variations are very important to consider for the design of various units.

The main pipelines conveying the water for distribution should be capable of meeting the maximum demand.

In general, the world's water requirement for all purposes is increasing at an alarming rate in both developed and developing countries. The main reasons are:

a) The rise in population growth in practically all countries of the world.

b) Industrial growth and expansion (adequate water is an essential raw material for an industrial enterprise).

c) Increase in overall per capita consumption of water. The higher the living standard, the more water is required.

## 5.2. Method of Construction and Protection of Sources of Water from Contamination

### 5.2.1. Groundwater

**I. Methods of constructing wells**

There are six different methods of constructing wells in water-bearing strata:

A. **Hand-dug wells**: these are the oldest and most widely used wells through out the world. They are excavated by hand or by a variety of unspecialized excavation equipment. Digging is carried out until water comes out. Such wells are usually cylindrical with varying diameters, one to three meters being usual. The depth to which a well should be dug largely depends on the type of groundwater table. Private wells generally are less than 10 meters deep. Wells for communal use are frequently much deeper, 20-30 meters. The depth below the water table is normally up to 3 meters, due to the extreme difficulty of digging below the water table.

The ideal time for digging a well is the driest season (in Ethiopia April-May). This will help to get the maximum and the real depth of the water table.

Most hand-dug wells need an inner lining. For this, materials such as stone, masonry, concrete cast in shuttering inside the hole, or pre cast concrete rings are used. The lining serves several purposes. During construction, it provides protection against caving and collapse.

In consolidated ground (rock), the well may stand unlined but a lining of the upper part is always to be recommended. In unconsolidated ground, the well should be lined over its entire depth. Figure 5.1.depicts the features of a hand dug well without a pump.

**Advantages of a hand dug well**:

- Relatively unskilled and inexperienced persons can usually construct it.

- No special tools or equipments are required, except in difficult localities.
- The well provides a reservoir for storage in addition to the water source.

**Disadvantages of a hand-dug well:**

- The possibility of a hand-dug well caving, where casing is not adequate, is very high. Another possible hazard is asphyxiation, a very real danger for the people who dig the well.
- Such a well cannot be dug in a rocky locality without the use of special equipment or explosives.

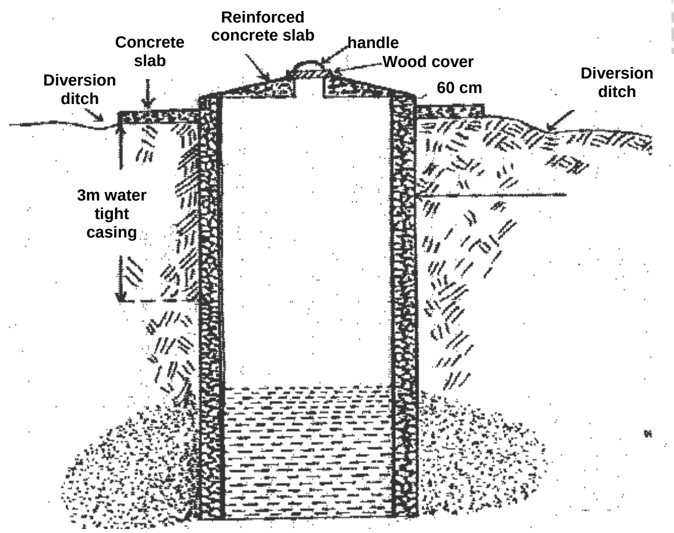


Fig.5.1. A typical protected sanitary dug well without pump
Source: Salvato, Environmental Sanitation, 1958.

B. **Driven well**: This is constructed by driving a pipe into the water table with driving tools. A specially perforated or slotted tube with a well point is driven into the ground. During driving, casing is used to safeguard the screen from damage and clogging. (their diameter ranges from 25-75mm).

Driving can be done either mechanically or by hammering on the upper end of the drive pipe. When the water table is reached, the pipe is left in the water bearing formation as the source, and the intake pipe and a hand pump are installed (fig 5.2). The diameter ranges from 3-10 cm (5-8 cm being the most common).

The location must be near a riverbed where formation is very soft, with the water table comparatively high and not fluctuating during the year. They can be installed within a matter of an hour.

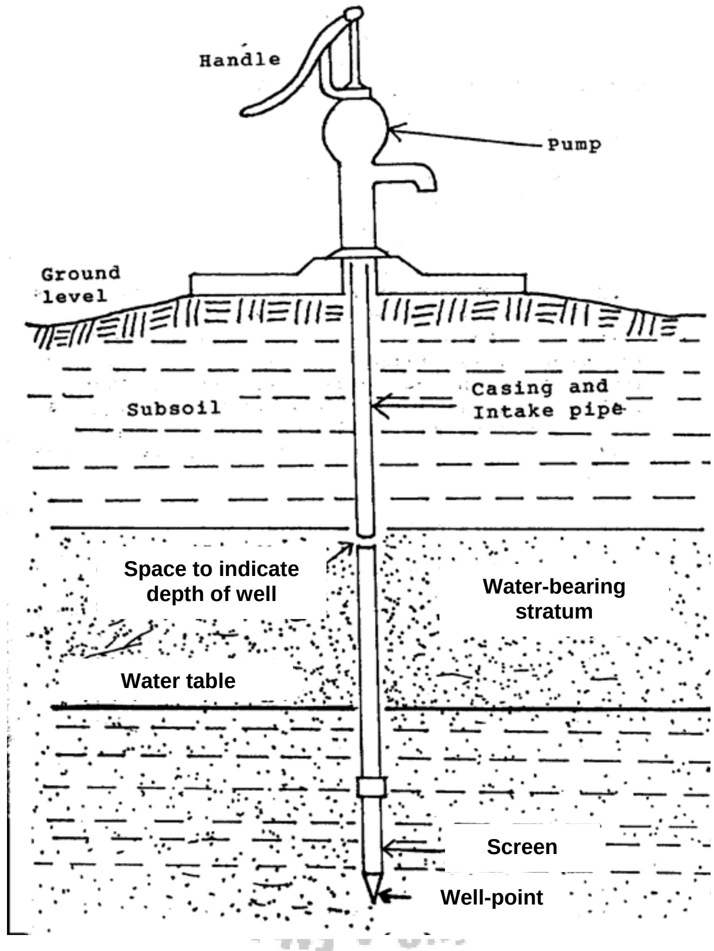


Fig.5.2. A driven well

Source: Gebre Amanuel Teka, Water Supply in Ethiopia, 1973.

C. **Bored well**: This is a well constructed with special boring equipment operated by hand. For a reliable yield, the minimum depth of a bored well should be around 6 meters but this depends very much on the level of the water table of an area. The most common boring equipment is the auger or earth-auger. Augers are made with varying diameters, the so-called small-diameter auger being usually 8-10 cm in diameter.

Bored wells vary in diameter from a few inches to 36 inches. The boring technique is used in soft ground such as sand and soft limestone. Thus, boring is particularly used in areas where these types of ground are most common. A casing of concrete pipe, verified clay pipe or metal pipe is usually necessary to prevent the relatively soft formation penetrated from caving into the well. During excavation, the soil-filled auger will be drawn until it is filled by the soil again. By this process the excavation will continue upto the desired depth. The main advantage of this method is that the construction can be completed in a very short time and in geologically favorable areas. It is suited for rapid mass construction (see fig 5.3 for a protected bored well).

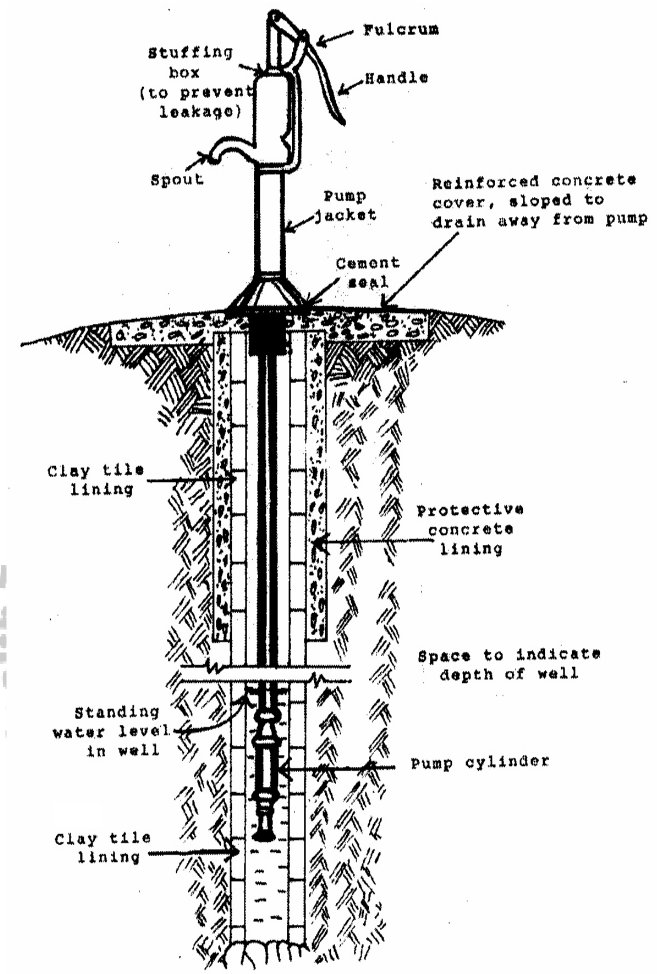


Fig. 5.3. A protected bored well
Source: Salvato, Environmental Sanitation, 1958.

D. **An Infiltration Gallery**: This can be described as a horizontal well (fig 5.4), usually constructed near a river bank and then connected to a large diameter vertical well in order to obtain an adequate quantity of water. To connect the river bank with the vertical well, a trench is dug. When the excavation is completed, a perforated pipe is laid in the bottom of the trench.

Layers of stone gravel and coarse sand are placed on top of the pipe, and finally the trench is filled again. The yield of the infiltration gallery may be increased by constructing two or more trenches as desired.

Another common method of constructing an infiltration gallery is by building a series of tunnels through a water-bearing stratum and connecting these tunnels at a suitable location where an adequate amount of water is collected. It is not advisable to construct an infiltration gallery unless the water table is relatively stable and the water intercepted is free of pollution. Water derived from infiltration galleries should be given a minimum of chlorination treatment.

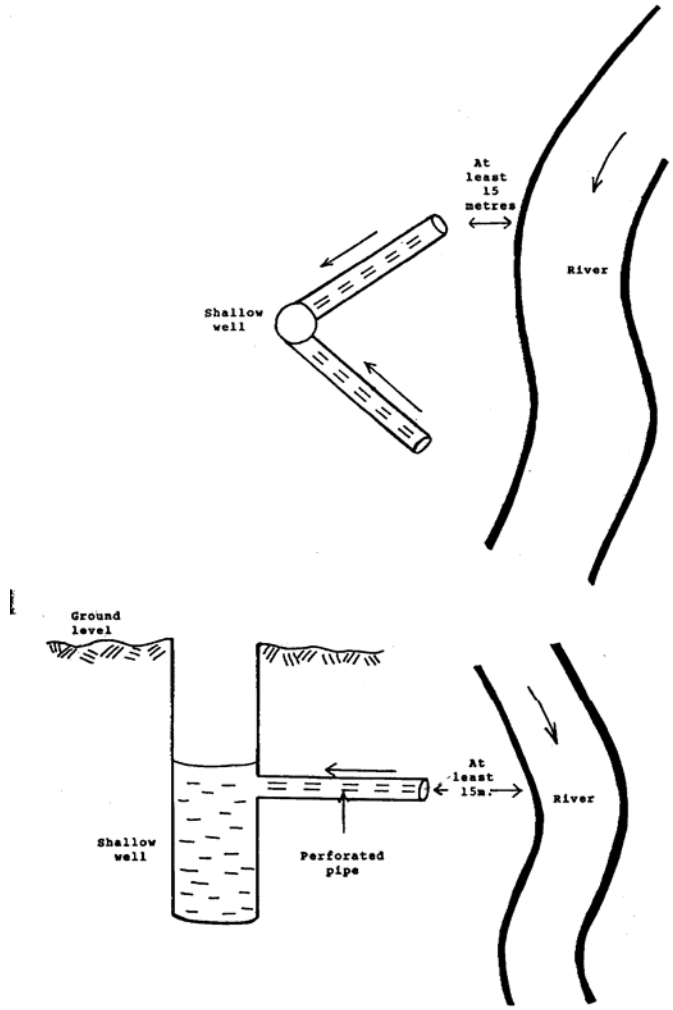


Fig. 5.4. An infiltration gallery

Source: Gebre Amanuel Teka, Water Supply in Ethiopia, 1973.

**E. Jetted well**: This is a well constructed by means of boring equipment using water jetted under high pressure to facilitate rapid boring as in fig 5.5. It doesn't differ much from driven wells but the point at the lower end of the screen is hollow instead of solid and the well is bored through the erosive action of a stream of water jetting from the point. Compared with driven wells, jetted well construction is much faster. Jetted wells can only be sunk in unconsolidated formations.

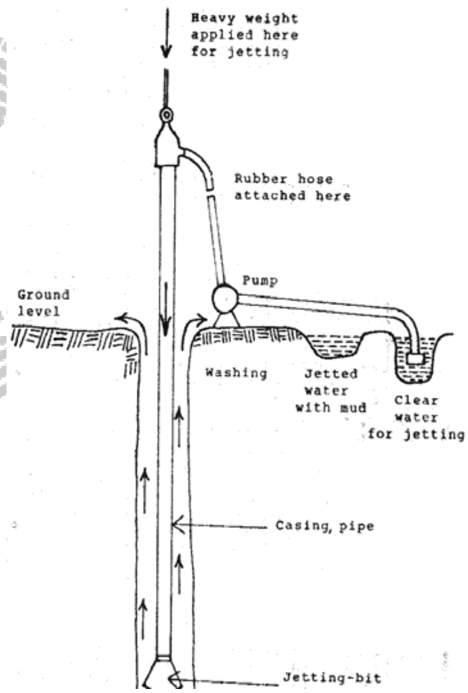


Fig.5.5. A jetted well

Source: Gebre Amanuel Teka, Water Supply in Ethiopia, 1973.

**F.** **Deep wells**: Deep wells can be constructed by different techniques:

1. **The standard (cable tool) method**. It is the first and oldest method, which is used in both hard and soft soil ground.
2. **Rotary drilling**: This involves rotation of pipes string, which has a hardened cutting tool at the lower end. Water with a mixture of additives (called drilling mud) is pumped down the well either through the pipe or between the pipe and the side of the well. The return flow carries the cuttings to the top of the well where they are separated from the flow to prevent the side of the well from collapsing.
3. **Jetting**: It is a useful technique for small wells in soft ground. A relatively high velocity steam of water is directed down through a nozzle at the bottom of a pipe string. As the string is raised, turned and lowered, the high velocity flow washes out the materials. The casing is dropped by its weight or driven as the hole advances.
4. **Core drilling**: Employing a ring fitted with hardened still teeth, the ring is rotated while a stream of water washes cuttings from the working face. The core rises within the ring as drilling advances and must be periodically broken off and withdrawn from the well. This technique is used only in consolidated materials.

**II. Protection of groundwater from contamination**:

The techniques of protecting groundwater from contamination are based on a good understanding of the geology, topography, drainage basin, vegetation and human habitation of the locality.

Since the most common methods of tapping groundwater are by wells (particularly dug wells) and springs, we will limit ourselves to the protection methods for these two sources. To begin with, the rate of contamination of groundwater by pathogenic organisms or by dangerous chemical pollutants depends upon the following factors:

**A. The nature of the aquifer**: in particular the permeability of the ground formation in relation to contaminants flowing towards the water.

**B. The hydraulic gradient**: this is the slope where water finds the easiest way to flow.

**C. The depth to the water table**: If the water table is high and near ground level, there will be less chance for the pathogenic organisms to be filtered out before the contaminated water reaches the water table. This holds true when the contaminants infiltrate through the soil formation.

**D. Distance from the source of contaminants:** It is obvious that the further away the water source is from the sources of contaminants, the less is the chance for contamination. The most important source of contaminants for groundwater is human excreta, reaching the water source in the form of sewage, septic tank effluents, or leaching out from pit privies, etc. The micro-organisms excreted with the human wastes are not able to move by their own, but are carried either vertically or horizontally by seeping water, rain or urine. The distance they travel (accompanied by leaching water) varies with the porosity of the soil. Under normal conditions, the vertical downward travel in reasonably porous soil will not exceed 60cm and the horizontal or lateral travel is about 30cm. But in limestone formations, contaminants may travel unlimited distances in underground channels and caves.

**E. Ways in which well water may be contaminated:**

- Contaminants may infiltrate into the well from nearby privies, cesspools, septic tanks etc.
- Polluted surface water (flood) may enter the well at or near the top or mouth of the well.
- Pollutants such as dirt carrying viable micro-organisms, insects, and small animals may fall into the well if it has no cover.
- Use of an unsanitary bucket and ropes may contaminate the well water.

**F. Prevention of contamination of a well**:

1. The well should be situated on a higher level than the source of contaminants– privies, cesspits, etc. In other words, the natural flow of the groundwater (the hydraulic gradient) should be from the well towards the source of contaminants; never vice versa.
2. In a normal soil formation, the minimum distance between the well and the source of contaminants should not be less than 15 meters (observe Fig 5.6). This doesn't work with limestone formations.

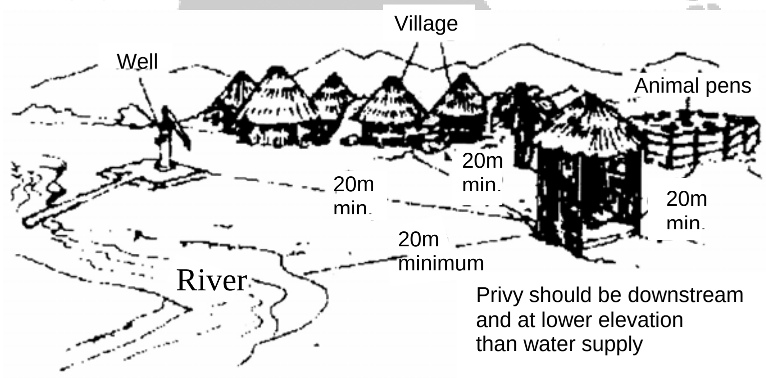


Fig. 5.6 Proper location of a well
Source: Health and Environment Sustainable Development Five Years After the Earth Summit, WHO, 1994.

**G. Protection of the well**

1. **Casing:** the inside wall of the well should be made water proof by cementing from the top of the well down to a minimum depth of 3 meters. The deeper it is extended, the better. The casing of the well should also be extended for a minimum of 60cm above the surrounding ground level.
2. **Cover**: A concrete cover should be fitted over the casing to prevent dust, insects, small animals, etc. from falling in to the well and also to prevent leakage of flushed water.
3. **Sanitary water drawing device**: Ideally, a pump should be installed, but if a pump is not available a sanitary bucket and rope system should be used (See Fig. 5.7)
4. **Fencing:** The immediate area of the well should preferably be fenced to keep animals away.
5. **Diversion ditch:** The area surrounding the well should be graded off in order to prevent the flow of storm water into the well.

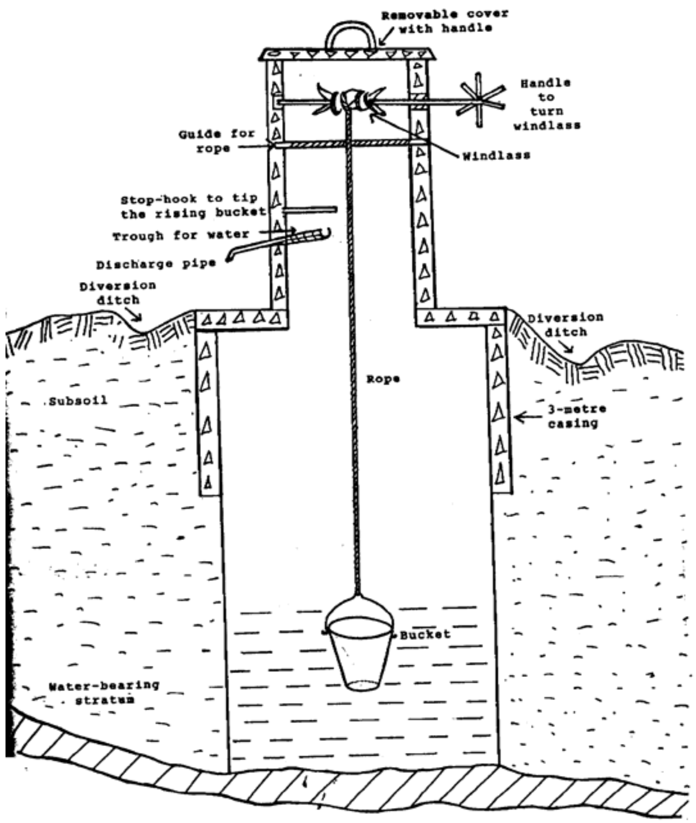


Fig. 5.7. A sanitary rope – and – bucket well

Source: Gebre Amanuel Teka, Water Supply in Ethiopia, 1973.

**H. Prevention of contamination of a spring**

**1. Siting of the spring**: Before deciding to develop a spring as a source of water supply, a thorough sanitary survey should be carried out, and should include such things as the nature of the water-bearing stratum, topography, vegetation, potential sources of contamination, and the adequacy of the yield, particularly in dry seasons. If the results of the sanitary survey are satisfactory, the eye of the spring, that is where it issues or originates, should be located by digging out the area around the spring down to the impervious layer.

**2. Protection of the spring:**

A. After the eye, or eyes, of the spring is located and the adequacy of the source is determined, a concrete water-proof protection box should be constructed over the spring to prevent all actual and potential sources of contamination.

B. It is advisable always to construct a collection box in order to ensure adequate protected storage of the water supply.

C. The installation of a faucet on the intake pipe should be discouraged, as this may cause the spring to divert its direction.

D. It is preferable to construct a retention wall in the front part of the protection box as this holds the water to the delivery pipe.

E. Drainpipe or scourage pipe should be installed in the collection box, to facilitate washing or cleaning the container as needed.

F. The intake and overflow pipes should be screened so that blockage of the flow by small animals such as frogs, or by large pieces of gravel, will be minimized.

G. A diversion ditch with a radius of 10 to 15 meters should be made around the protection box, in order to carry away surface water during heavy rains, to prevent its infiltration.

H. If possible, the area surrounding the spring should be fenced around. For details of spring protection, see fig 5.8 below.

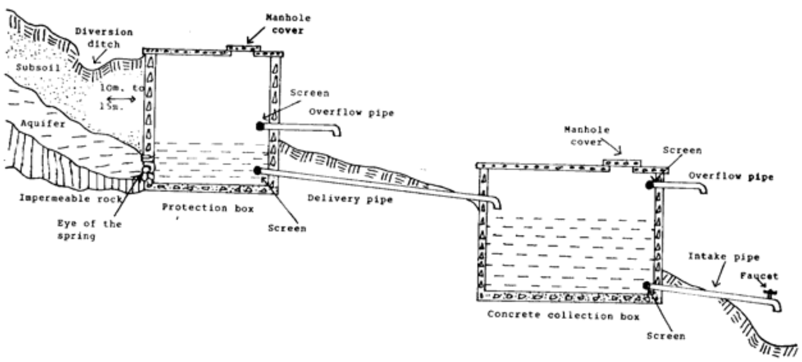


Fig. 5.8 A protected spring with a collection box.

Source: Gebre Amanuel Teka, Water Supply in Ethiopia, 1973.

### 5.2.2 Surface Water

Surface water is developed where the population size is large. In urban areas and industrial towns, the main cause of contaminants of surface water is dumping of untreated sewage and industrial wastes into streams. In rural towns and villages, the main contaminants are those resulting from human activities such as improper disposal of excreta, washing, farming and contamination from domestic and wild animals. In any case, surface water shall never be used as a source of water supply without treatment.

**1. Surface water intake**

An intake structure is required to withdraw water from a river, lakes, or reservoir. Typical intakes are towers, submerged ports and shoreline structures (see fig 5.9 for a typical example). Their primary functions are:

- To supply the highest quality water
- Protect piping and pumps from damage or clogging as a result of wave action, flooding and floating and submerged debris.

Towers are common for lakes and reservoirs with fluctuating water levels or variation of water quality with depth. Ports at several depths permit selection of the desirable water quality and season of the year.

A submerged intake consists of a concrete block supporting and protecting the end of a withdrawal pipe. Because of the low cost of such under water units, they are widely used for small rivers and lake intakes. Their disadvantage is when repair is needed.

The intake consists of an opening and a conduit, which conveys the flow to a pump from which the water may be pumped out to the treatment plant. The opening should be screened in order to prevent the entrance of debris.

**In the designing and locating intake the following must be considered**:

1. The source of supply (lake, river, etc).
2. The character of the surroundings (i.e. the depth of water and the effect of current floods upon the structure). For a river which has great depth, it is preferable to provide inlets at different depths.
3. The location with respect to the source of pollution.
4. The prevalence of floating matter such as logs, debris etc.

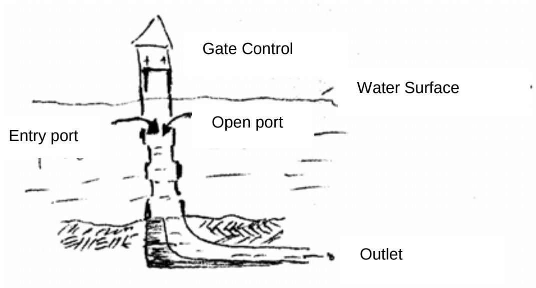


Fig. 5.9 River intake structure

**Self-purification of stream**

A polluted stream will never purify itself to the extent of being fit for human consumption without treatment.

However, it has been proven through various studies that definite improvements take place in the bacteriological, chemical and physical properties of the stream during its course of flow.

**Self-purification occurs by the following methods**:

**Sedimentation:** Sedimentation is the process of settling or deposition of heavy suspended material in the water. Immediately after heavy rain, streams become highly turbid, but after several hours the stream become clear. This is because some of the particles that are carried by the streams gradually settle down during the course of flow. The rate of sedimentation will depend upon the size and specific gravity of the suspended particles, and upon the rate of flow of the stream. The more gently the stream flows, the more the chance for sedimentation. Sedimentation will speed up the reduction and removal of intestinal parasites (pathogens) through the process of letting them sink to the bottom of the stream bed.

**Dilution:** The amount and nature of the dilutents (that is the pollutants, sewage or industrial waste) entering a stream are important determinants of the self-purification of the stream. The strength of dilutents, whether it is sewage or organic industrial waste, is usually measured in terms of the Biochemical Oxygen Demand (BOD) of the particular organic waste in question. Another way to look at dilution as an important determinant is from the point of view of the number of infective doses of intestinal pathogens which may be available when a small amount of infected water enters into a large volume of water. The chance of consuming a viable number of pathogens at any one time may be less after dilution.

**Oxidation of the impurities by Dissolved Oxygen (DO) in the water:** Water exposed to the atmosphere absorbs free oxygen from the air until saturation point is reached. This absorbed oxygen in the water is called Dissolved Oxygen. The solubility and concentration of oxygen in water varies mainly with the temperature of the water and the pressure of the oxygen in the atmosphere.

Unpolluted natural stream water normally has a DO concentration of 8 – 12 PPM (mg/l) depending chiefly on the temperature. The DO concentration level is maintained by several complicated and interrelated phenomena such as diffusion, aeration, re-aeration, DO consumption by bacterial oxydation, and effects of photosynthesis. The level of concentration of DO is one of the most important means of measuring the purity of stream. When large concentrations of oxidisable waste such as sewage, organic industrial waste, etc., are introduced into a stream, the aerobic bacteria in water immediately starts to break down those wastes by causing them to combine with oxygen. In the process, waste matters will be eliminated to the extent possible. However, if the amount of oxygen cannot cope in oxidizing the waste, pathogens and other life forms may be present. Generally, however, the stream will replenish its lost DO through the process of diffusion and reaeration, etc. provided the BOD of the waste is within the limit that the stream can cope with. We can see, therefore, that DO along with the volume of the oxidisable wastes is an important determinant of the purification of stream.

**Presence of plankton and other aquatic organisms**: Plankton are plants of minute size, mostly microscopic, that are found floating in natural waters.

Most plankton move about freely, but some are attached to surfaces in water. Some plankton (phytoplankton) carry out photosynthesis in water, as a result of which more oxygen is added to maintain the optimum level of DO concentration. Plankton preys on bacteria, thus reducing the number of bacteria in water. The presence of plankton in these ways helps the purification of a stream.

**Temperature and sunlight**: As a general rule, almost all biochemical reactions are affected by temperature, and the biochemistry of streams is not an exception. As we have noted above, temperature affects the rate of solubility of dissolved oxygen. Temperature and sunlight determine the rate of growth and multiplication of aquatic life, particularly that of plankton, algae, etc., and hence influence the process of photosynthesis and reaeration. Furthermore, sunlight, especially the ultraviolet rays, have a bactericidal effect, and can decrease the number of micro-organisms depending on the main body of the stream. The effect of both temperature and sunlight on the process of purifying a stream is therefore obvious.

**Protection of stream from gross pollution**

In small villages and rural communities where streams are the only water source and where proper treatment is virtually impossible, the quality of stream water can be improved by avoiding or drastically reducing the dumping of human and animal wastes, factory wastes, etc., into the streams.

A stream can be zoned according to its intended uses; that is, the uppermost section, presumably the cleaner portion, should be fenced and set aside for drinking purposes, and the sections immediately below this should be kept for washing and for domestic animals respectively. However, zoning of streams should not be considered as a treatment, but merely as a temporary method of reducing gross pollution of streams.

### 5.2.3 Rainwater

**Contamination of rainwater**

From the sanitary point of view, rainwater may be the purest of all sources of water in nature, but it is liable to contamination under the following conditions:

- It is likely to be contaminated as it falls through the atmosphere. It may dissolve various gases in the lower portion of the atmosphere, and may pick up dust particles, soot, plant pollen, bacteria, etc., if these substances are present in the air.
- As soon as rainwater touches the collecting surface, its purity will depend on the cleanliness of the collecting surface.
- Rainwater may be contaminated during storage and distribution.

The protection of rainwater from contamination basically aims at eliminating the aforementioned three ways in which it is likely to be contaminated.

**Rainwater Harvesting**

Rainwater as source of water supply can be harvested from:

1. **Roof catchments**: Reasonably pure rainwater can be collected from house roofs made of tiles, slates, (corrugated) galvanized iron or aluminum cement sheeting. Thatched or lead roofs are not suitable because of health hazards and thatched roofs have poor water-tight character, with high infiltration or permeability.

The roof guttering should slope evenly towards the drain pipe. To safeguard the quality of the collected rainwater, the roof and guttering should be cleaned regularly.

2. **Ground catchments**: The amount of rainwater that can be collected in the ground catchments will be dependent on whether the catchment is flat or sloping and the water tightness of the top layer. A considerable reduction of such water losses can be obtained by laying tiles, concrete, asphalt or plastic sheeting to form a smooth impervious surface on the ground.
3. **Hand-dug ponds**: It is possible to dig and develop a pond in a convenient place from the runoff. This could help serve small villages, households, livestock and vegetable growing. Points to be considered while choosing reliable supply are: location, soil surface, amount of rainfall, climate and capacity of the pond.
4. **Other catchment areas**: In arid areas where there is a dry sandy riverbed and the rain is once or twice a year, a type of collection known as a sub-surface dam could be used to store water.

   There are three types:

   a. The easiest and cheapest one is to construct a clay or other non-porous barrier across the river bed. (This rests on the weakest point).

b. The second is a granite, concreted dam or weir, which is situated across the watercourse. This also reaches the non-porous bedrock. If projects above the riverbed to catch more water, thereby increasing the volume of the reservoir.

c. The third is an arch weir built of blocks or concrete as a thin walled arch across the riverbed.

**Advantage of a sub-surface dam**

a. The reservoir is silted up by coarse sand. Silting will increase filtration (bacteria may be filtered).

b. Water is stored between solids, so evaporation is eliminated to almost zero.

c. Mosquito, guinea worm and other parasites that breed, grow, or bite near or in water will be avoided. Therefore, there will not be an increase in malaria incidence or other infection.

d. Because people, livestock and wild animals cannot see the water it is easier to prevent contamination.

e. It is always possible to maintain clean, and reliable water source (because it has a sort of filtration).

f. Water drainage could be accomplished using gravity or from wells located either upstream or downstream of the dam.

g. This sub-surface dam could be used in our case also to store water in areas where rainwater is scarce.

**Sanitary method of collecting rainwater**

In the rural parts of the country, corrugated iron sheets are replacing thatched roofs in almost all regions. These surfaces are likely to be contaminated by insects, bacteria, etc. Therefore, when rain falls, the first 10 to 15 minutes of the rainwater should be allowed to flow into the waste drain tank. This allows the rainwater to wash off dirt which might be on the collecting surface. After the waste drain tank is full, the rest of the rainwater (clean water) flows in the collection tank.

The wastewater in the drain tank should be emptied out before the next rainfall. In addition, the pipe leading to the collection tank should have a sanitary cover and must be sealed at the junction of the pipe and the tank in order to avoid contamination.

If one can afford, the above system can be replaced by an automatic device (separator) that will reject automatically the first few minutes of rainfall and will collect clean water thereafter. An alternative method to this method could also be using a sand filter. The rainwater flowing through the drainpipe should be made to pass through a sand filter before it enters the storage tank. The sand filter will strain out suspended solid substances, including bacteria that may be in the rainwater. Fig. 5.10 is a typical system of roof catchments.

**Protection of storage**: The storage/collection tank can be above or below ground. Whichever type of storage is selected, adequate enclosure should be provided to prevent any contamination from humans, animals, leaves, dust or other pollutants entering the storage container. A tight cover should ensure dark storage conditions as to prevent algae growth and the breeding of mosquito larvae. When the storage is empty, it should be washed before being used for the next collection. The water should preferably be drawn through a faucet. Metal storage tank, reinforced concrete tank and Ferro-cement tank are some of the different types of tanks used for storage.

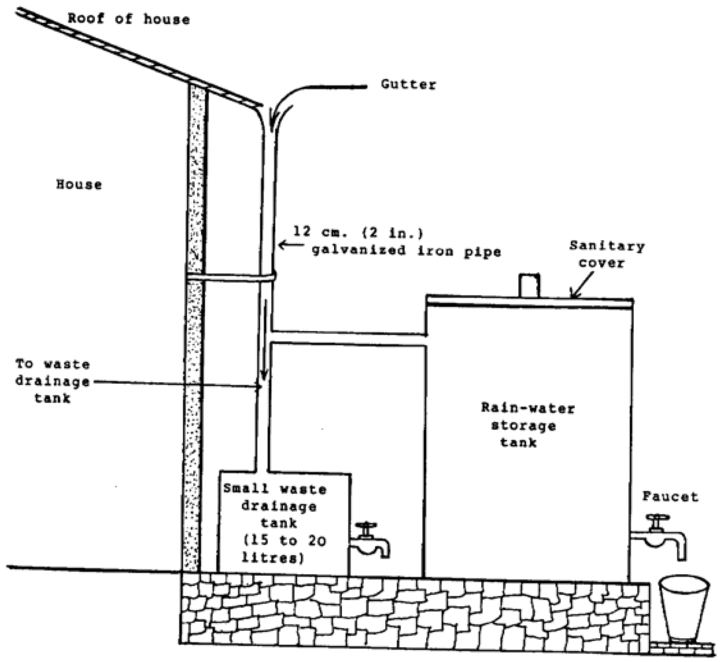


Fig. 5.10 A simple sanitary installation for collecting rainwater
Source: Gebre Amanuel Teka, Water Supply in Ethiopia, 1973.

**How to estimate the quantity of rainwater available for domestic use**

The quantity of rainwater that can be collected depends upon:

1. The amount of average annual rainfall of the locality
2. The horizontal surface area that is available for collection (i.e., the area of the roof catchment basin, etc.)

The average annual rainfall of an area is more or less constant, while the collection surface can be varied, depending on the amount of rainwater needed.

A formula to estimate the quantity of rainfall that could be available is:

Rule; Q = A x R

Where Q = number of liters per year actually falling on the collecting surface,

A = horizontal surface area in square meters, adjusted to allow for evaporation etc.

R = average rainfall in cm per year.

N.B/ "Q" varies with the type of collecting surface. If the collecting surface is made of corrugated iron sheeting then Q should be adjusted to 80% since only losses due to evaporation are considered. If, however, the collecting surface is a thatched roof, Q is about 50% because the thatch absorbs rainwater.

Example 1. The average annual rainfall of an area is 50cm (=50/100 meters). To calculate the quantity of rainwater that can be collected over a corrugated iron roof, which has an area of 60 sq.m., you do the following:

Solution. Rule : Q = A x R

$$= \frac{80}{100} \times A \times R$$

$$= \frac{80}{100} \times 60 \times 50/100$$

Quantity of rainwater available annually is equal to **24 cu.m. or 24,000 litres.**

Example 2. A rural family consisting of 8 persons is to be supplied with 20 liters (=20/1000 cu.m) of water each per day. The source is direct rainfall, to be collected from a corrugated iron roof. The average annual rainfall of the area is 60cm. (= 60/100m). Calculate the area of collecting surface required.

Solution. Rule Q= A x R

$$\frac{80}{100} \times A \times R$$

$$= \frac{80}{100} \times A \times \frac{60}{100}$$

But $Q = \frac{8 \times 20 \times 365}{1000}$ cu.m.

So $A = \frac{8 \times 20 \times 365}{1000} \times \frac{100}{80} \times \frac{100}{60}$ sq.m.

Collecting surface area required = **122 sq.m.**

## 5.3 Water Supply and Community Involvement

One of the factors which contributes to the problems related to water supply in Ethiopia is the lack of community involvement as observed in the earlier water systems built. The water supply project in most cases will not be sustainable if done without the involvement and will of the community. Therefore, taking the conditions of the locality in to account, the community should participate from the planning to implementation phases particularly in small-scale water development projects.

Active involvement is highly needed during the construction activity. The community in this phase may involve:

- In collecting local construction materials (i.e., sand, gravel, stone, etc. if available).
- In the construction activities (i.e., in excavation work, mixing of mortar, fencing etc.)

In general, active involvement of the community is very essential in water source development activities, in order to have sustainable projects and feeling of ownership.

## Review Questions

1. Write the factors which influence the total consumption of water.
2. The total quantity of water can be estimated by ascertaining different purposes for which the supply is necessary. What are these?
3. Describe the method for construction of hand dug wells, driven wells, and an infiltration gallery.
4. Write the ways in which well water may be contaminated.
5. How can a stream be protected from gross pollution in a sanitary manner?

## Glossary

Where a term is adequately defined in the text, the term is not necessarily included in this glossary.

**Algae:** a simple form of plant life.

**Basalt**: a rock made of solidified lava, caused by volcanic action.

**Casing:** the substance which encloses something (e.g., the wall of a well.)

**Cercaria**: a larval stage of a parasite, which can penetrate a suitable host.

**Cesspool**: a tank used for collecting sewage and other liquid wastes, which are drained into the surrounding soil.

**Cistern:** a tank or reservoir for storing liquid.

**Clogging**: prevention of movement because of dirt or other substances.

**Contamination**: the presence of an agent of infection on a body, article or substance.

**Desalination**: the removal or reduction of salt.

**Environment**: surrounding conditions influencing life.

**Evapotranspiration**: the giving off of vapor from plant surfaces

**Evaporate**: to turn into steam or vapor.

**Fluoride**: a compound of fluorine.

**Gutter**: a shallow channel or trough

**Helminth**: a parasitic intestinal worm

**Hygiene:** the science concerned with establishing and maintaining health.

**Intermediate host**: a host used by a parasite during its life cycle.

**Jetting bit:** the cutting edge of a tool designed to send out a jet of water.

**Leach**: to pass through or to cause to pass through a substance with water or another liquid.

**Magma**: rock material made liquid by heat under the earth's surface.

**Micro-organisms**: a very small or microscopic cell

**Mineral**: a substance occurring naturally in the earth.

**Pathogen**: disease causing organism.

**Perforate**: to make a hole through, to bore through

**Pesticide**: substance that can kill plants and animals that are considered harmful to man.

**Pond**: a fairly small body of water formed either by nature or man.

**Precipitation**: mist, rain, hail, etc. When it falls on the earth the settling of a substance at the bottom of its container.

**Privy:** literally "private", a building used for urination and/or defecation.

**Pump**: a machine designed to raise a liquid by suction and/or pressure.

**Reservoir**: any living organism or inanimate object in which an agent of infection can survive and pass onto a non-resistant host; storage tank or other means of keeping a quantity of water.

**Runoff**: rainwater which flows over a land surface.

**Sanitation**: creation of conditions favorable to health.

**Schist**: a crystalline type of metamorphic rock.

**Shale**: rock made of layers of solidified clay or silt.

**Silt**: small loose rock particles which easily form sediment.

**Siphons**: a method of continuously transferring a liquid to a lower point by air pressure forcing it up the shorter end of a bent tube which discharges at the lower level.

**Slate:** a fine-grained type of metamorphic rock.

**Stratum** (singular) **strata** (plural): a layer or sheet of a type of rock

**Topography**: the physical features natural or man made of an area.

**Toxic**: poisonous

**Vector:** a carrier of disease.

## References

1. Admassu M., Water Supply for Sanitarians, Environmental Health Department, Gondar College of Medical Sciences, Ministry of Education, Sep., 1996.
2. Ethiopian Journal of Health Development., vol 16, Number 1, Addis Ababa, April 2002.
3. Health and Environment in Sustainable Development Five Years after the Earth Summit, WHO, 1997.
4. Health and Health Related Indicators, Planning and Programming Department, MOH, 1993.
5. Hodges L., Environmental Pollution, second edition, New York, 1996.
6. M. Ehlers and W. Steel. Municipal and Rural Sanitation. Tafa Megraw - Hill Publishing Company L.T.D. New Delhi, 1958.
7. Public Health Technician, Medicines Sans Frontiers, 1994.
8. Purdom P.W., et.al, Environmental Science., Charles E. Merill Publishing Co. Columbus, Ohio, 1980.
9. Salvato J.A., Environmental Sanitation, John Wiley and Sons, Inc., New York, London, 1958.
10. Teka G.E., Water Supply in Ethiopia: An Introduction to Environmental Health Practice, Addis Ababa, Addis Ababa University Press, 1973.
11. Wright F.B., Rural Water Supply and Sanitation, third edition, Robert E. Krieger Publishing Company, Huntington, New York, 1977.