Chapter 20

Water

Student Learning Outcomes

After studying this chapter, students will be able to:

- Investigate chemical tests for the presence of water using anhydrous copper (II) sulphate.
- Explain how to test the purity of water using melting point and boiling point.
- Distinguish between Distilled water and tap water with their applications in practical chemistry.
- State that water from natural sources may contain useful and harmful substances. (Some examples include:
  a. Dissolved oxygen
  b. metal compounds
  c. plastics
  d. sewage
  e. harmful microbes
  f. nitrates from fertilizers
  g. phosphates from fertilizers and detergents
- Recognize that some naturally occurring substances in water are potentially harmful (some examples include:
  a. some metal compounds that are toxic
  b. some plastics that harm aquatic life
  c. sewage that contains harmful microbes which cause disease
  d. nitrates and phosphates that lead to deoxygenation of water and damage to aquatic life (details of the eutrophication process are not required)
- Explain the treatment of the domestic water supply; (some examples of this includes:
  a. sedimentation and filtration to remove solids.
  b. Use of carbon to remove tastes and odours
  c. Chlorination to kill microbes
- Describe various water-borne diseases and the steps that can be taken to avoid them
- Identify the negative effects of water pollutants on life and the ways to avoid them.
- Explain water scarcity as an important issue faced by Pakistan and the ways in which it can be resolved.
- State that urea, ammonium salts and nitrates are used as fertilizers.
- Explain the use of NPK fertilizers to provide the elements nitrogen, phosphorus and potassium for improved plant growth.

20.1 Water

Water is essential for all forms of life on earth. All living organisms contain plenty of water in them. They also need water every day to support life.

Identifying the presence of water has many important applications which include determining the purity of substances and analyzing chemical reactions.

Test for Water

Testing water is important for food and pharmaceutical industries where the presence of water can affect the product quality and safety.

Hydrated copper(II) sulphate ($CuSO_4 . 5H_2O$) is blue in colour but when it is heated, it loses water molecules to become anhydrous copper(II) sulphate which is white in colour. A drop of water on anhydrous sample of copper(II) sulphate changes its colour from white to blue Figure 20.1.

Figure 20.1: Water test

$$\underset{\text{White}}{CuSO_4} + 5H_2O \rightleftharpoons \underset{\text{Blue}}{CuSO_4 . 5H_2O}$$

It is a very sensitive test and can detect even a small amount of water.

20.2 Purity of Water

Pure water boils at 100 °C and freezes at 0 °C under standard conditions of temperature and pressure. The impurities present in water will change both these physical constants.

1. The purity of a sample of water can be checked by determining its boiling point at STP. If it boils at 100 °C it is pure sample of water. The presence of impurities in water will slightly increase its boiling point.
2. Another test to check the purity of water is to determine melting point of the sample. For this purpose, cool the sample of water until it freezes. Observe and record the temperature at which the ice begins to melt. If its melting point is 0 °C it is pure water. A melting point below O °C suggests the presence of impurities in the sample.

The impurities present in water raise the boiling point but lowers the melting point. Both these constants are specific to standard conditions. At high altitudes or lower pressure, these values will change.

20.1 Quick Check!

How purity of water can be checked by determining its freezing point.

20.3 Difference between distilled water and tap water

Water which is supplied to our homes, shops and offices comes through taps and is readily available for any usage. This water may either come from rivers, lakes and ponds or from underground sources.

Tap water contains minerals like salts of calcium and magnesium depending upon the source from where it is obtained. It also contains chlorine and fluoride salt which are mixed with it during treatment. It is a conductor of electricity due to the presence of free ions from dissolved minerals. Its pH has the range of 6.5 to 8.5 depending upon its source.

Water obtained after the process of distillation is called distilled water. The process involves heating water to get steam and then condensing this steam back into liquid water. This process effectively removes all the dissolved minerals, microorganisms and contaminants from water leaving behind only pure water.

The purity of distilled water makes it ideal for use in the laboratories, medical procedures and pharmaceutical industry. Its purity ensures accurate scientific measurements, sterilization of medical equipments and to prevent corrosion.

Distilled water contains only water molecules without any bacteria, ions, gases or other contaminants. Its pH is 7. Although it is safe to drink but it may not have the necessary minerals needed for the body. It is also a bad conductor of electricity due to absence of ions.

20.2 Quick Check!

Why tap water is a conductor of electricity whereas distilled water is not?

20.4 Substances present in water obtained from natural sources

Water from natural sources such as rivers, lakes and aquifers contains a number of substances which maybe useful or harmful for our health.

Useful Substances

Dissolved Oxygen

Oxygen enters the natural water from the atmosphere through the process of diffusion. It is also produced by aquatic plants and algae in the process called photosynthesis.

This absorbed oxygen is then used by the aquatic organisms including fish to breathe and survive. The health and diversity of an ecosystem directly depends upon the amount of dissolved oxygen in a water body.

Harmful substances and their effects on the quality of water

(i) Harmful Microbes

Both surface and ground water which are vital sources of fresh water can be contaminated by various human activities. Harmful microorganisms like bacteria, viruses and parasites enter into natural water through human and animal wastes, landfills, agricultural runoff and waste water from industries. Sewage from wastewater treatment plants or from faulty septic tanks can release pathogens directly into nearby water body. These bacterial contents can cause such infectious diseases as dysentery, typhoid, hepatitis and cholera.

(ii) Heavy metals and their compounds

Heavy metals like lead, mercury, cadmium and chromium and their compounds can enter in natural water through many routes. Waste water from factories may contain heavy metals and their compounds, which are eventually released into rivers and other water bodies. Similarly, mining operations and use of fertilizers and pesticides can contaminate both ground and surface water with heavy metals and their compounds.

Heavy metals and their compounds not only damage vital organs like liver and kidney, they can also lead to neurological problems. Arsenic and cadmium are known to increase the risk of certain cancers.

(iii) Plastics

Very small particles of plastics called microplastics are present in both tap

and bottled water. These tiny particles can enter water through wastewater, rainwater when it carries plastic debris to water sources, and by degradation of plastic waste. Plastic tiny particles have been found in some human organs like lungs and blood. These particles can disturb the immune and reproductive systems.

(iv) Nitrates and Phosphates

Nitrates and phosphates enter natural waters through weathering of rocks. They can also enter in water through human sources such as agriculture fertilizers, detergents and industrial wasterwater. They are essential nutrients for plant and animal life. However, if amounts of these compounds exceed a limit they can affect the quality of water and cause eutrophication. Eutrophication is the name of the process which starts in a water body containing excess of phosphorus and nitrogen nutrients. The excessive amounts of these nutrients cause algae and other aquatic plants to grow excessively. This overgrowth of algae, in turn, can decrease the dissolved oxygen level in water which is not only harmful for aquatic life but can also disrupt the entire ecosystem.

20.5 Treatment of Domestic Water Supply

Three types of impurities are mostly present in water obtained from natural sources.

1. Dissolved impurities
2. Suspended impurities
3. Microorganisms

In order to remove these impurities different methods are applied which include sedimentation, filtration, distillation and treatment with liquid chlorine etc.

(1) Sedimentation

Insoluble impurities present in natural water include soil, pieces of plants and other organic matter and sand. These impurities are bigger in size and are often removed by the process called sedimentation. In this process water

obtained from natural sources is pumped into sedimentation tanks (Figure 20.2) where water is allowed to stand for a few hours. The suspended particles present in water settle down at the bottom of the tank due to gravity and form a layer of sendiment. The cleaner water at the top can then be extracted for the next stage.

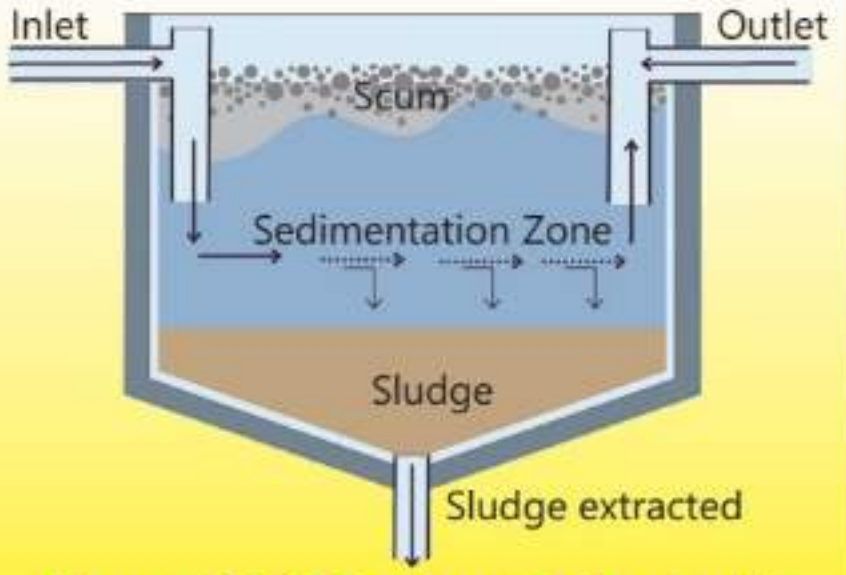

Figure 20.2: Sedimentation tank

(2) Filtration

This process is used to remove suspended particles of smaller size which are generally not removed in the sedimentation process. For this purpose water is allowed to trickle through layer of sand and gravel filters which trap these solid particles.

(3) Chlorination

Water must be sterilized before humans can use it. For this purpose all harmful bacteria and other microbes, must be killed.

Mostly a small amount of liquid chlorine is added which has the power to kill all these germs.

THINGS TO KNOW

Water from different sources requires different treatment methods.

(4) Removal of odours

Water is passed through powdered activated carbon in the form of charcoal to remove tastes and odours. Activated carbon removes a wide range of organic compounds responsible for taste and odour through absorption. Odour can also be removed by exposing water to air in a process called aeration.

20.6 Effects of pollutants present in water

Water pollution affects human health, ecosystems, aquatic organisms and industries that are dependent on good water quality.

How to Control the Negative effects of Pollutants

Water Pollutants can disrupt aquatic ecosystems through eutrophication and destruction of habitats. Polluted water can also lower crop yields and

contaminate food sources.

Negative effects due to water pollution can be controlled by taking a number of steps:

1. Sewage and industrial wastewater should be treated before it is discharged into water bodies.
2. Plastics must be reused or recycled to minimize their production.
3. Chemical cleaners, fats or oils and grease should never be thrown down the drain.
4. Minimize the use of pesticides and fertilizers in agriculture.
5. General public should be made aware of the harmful effects of water pollution through public campaigns.
6. Implement and enforce laws for the strict control of all types of water pollution.

20.3 Quick Check!

1. Which pollutants are harmful for aquatic life?
2. How to identify if water is polluted?

Water-borne Diseases

The World Health Organization (WHO) has estimated that 80% of the sickness and diseases in the world are caused by polluted water and lack of sanitation. Water-borne diseases include cholera, typhoid, malaria, nausia and leprosy. In all nearly 500 million people suffer from water-borne diseases every year in the world. For example, millions of persons are suffering from a disease called 'trachoma' which often causes blindness. This disease is particularly prevalent among babies and children in developing countries. The liver diseases particularly viral hepatitis is also caused by drinking contaminated water.

Prevention of water-borne diseases

Water-borne diseases can be avoided if we strictly follow the following instructions.

1. Drink clean water after removing impurities and boiling to kill the germs.
2. Practice hygiene by keeping your body especially hands clean. Ensure proper sanitation facilities are available.

20.7 Water Scarcity in Pakistan

Our world is divided into different regions depending upon the annual rainfall which they receive every year. Pakistan is included in a semi-arid region and hence receives a low rainfall annually. Northern Pakistan including Punjab generally receives rainfall within the range 250-600 mm per year mostly during monsoon season. In southern Pakistan precipitation is scarce, below 200mm per year.

Pakistan, at present, is facing a severe water scarcity crisis due to a number of different factors. Less rainfall, growth in population, flood irrigation, climate change, depleting aquifers and poor water management are some of the reasons responsible for this scarcity. If the current situation continues then Pakistan could face very serious challenges in coming years.

The problem can be addressed by taking a number of steps which are as follows:

1. Collecting rain water especially during monsoon season by constructing water reservoirs and other water storage facilities.
2. Using better crop irrigation techniques.
3. Taking appropriate measures to face effects of climate change.
4. Effective management of water resources.

20.4 Quick Check!

How can we conserve water at home?

20.8 Elements Essential for Plant Growth

Plants need nutrients from the soil for a healthy growth. The elements essential for the plant growth can be classified as micro-nutrients and macro-nutrients.

Micro-nutrients (Trace elements)

The nutrients which are required in a very small amount for the growth of plants are called micro-nutrients. These include boron, copper, iron, manganese, zinc, molybdenum and chlorine. Only minute amounts of these elements are needed for healthy plant growth and it may be dangerous to add too much quantity because they are poisonous in larger quantities. These are generally required in quantities ranging from 6 grams to 200 grams per acre.

Macro-nutrients

The nutrients which are required in a large amount for the growth of plants, are called macro-nutrients. These include nitrogen, phosphorous, potassium, calcium, magnesium, sulphur, carbon, hydrogen and oxygen. These are generally required in quantities ranging from 5 Kg to 200 Kg per acre.

20.9 Fertilizers

Fertilizers are the substances added to the soil to make up the deficiency of essential elements like nitrogen, phosphorus and potassium (NPK) required for the proper growth of plants. Fertilizers enhance the natural fertility of the soil and provide the chemical elements taken up from soil by the previous crops.

Requirements of a Fertilizer

Every compound of the desired elements cannot be a fertilizer. The desired elements should be present in the compound in a water soluble form readily available to the plants. The compound employed as fertilizer should be stable in soil as well as in storage e.g., it should not absorb moisture or set to hard stony materials with time. Above all it should be cheap to manufacture.

Essential Qualities of a Good Fertilizer

The essential requisites of a good fertilizer are:

(i) The nutrient elements present in it must be readily available to the plants.
(ii) It must be fairly soluble in water so that it thoroughly mixes with the soil.
(iii) It should not be injurious to plants.
(iv) It should be inexpensive.
(v) It must be stable so that it is available for a longer time to the growing plants.
(vi) It should not alter the pH of the soil.
(vii) By rain or water, it should be converted into a form, which the plant can absorb easily.

20.10 Classification of Fertilizers

Fertilizers are classified according to the nature of the elements like nitrogen, phosphorus and potassium which they provide to the soil. This classification gives the following types of fertilizers.

(i) Nitrogenous fertilizers
(ii) Phosphatic fertilizers
(iii) Potassium fertilizers

Interesting Information

Biofertilizers are environment friendly. They provide the soil essential nutrients as well as microbes required for the growth of plants. Biofertilizers improve soil health and structure. They also increase biodiversity and reduce the need for harmful chemicals. They also prevent soil degradation.

Nitrogenous Fertilizers

These fertilizers supply nitrogen to the plants or soil. Nitrogen is required during the early stage of plant growth for the development of stem and leaves. It is the main constituent of proteins, imparts green colour to the leaves and enhance the yield and quality of the plants. Some examples of nitrogen fertilizers are: ammonium sulphate, calcium cyanamide, ammonia, ammonium nitrate, ammonium phosphate, ammonium chloride and urea.

Urea is a high quality nitrogenous fertilizer. It contains about 46% nitrogen and is the most concentrated solid nitrogen fertilizer. It is the most widely used nitrogen fertilizer in Pakistan.

Ammonium nitrate is a useful fertilizer for many crops except paddy rice because the microbial bacteria in flooded fields decompose it to nitrogen gas. It is also used in combination with limestone. It is hygroscope in nature.

Phosphatic Fertilizers

These fertilizers provide phosphorus to the plants or soil. Phosphorus is required to stimulate early growth and to accelerate the seed and fruit formation during the later stages of growth. It also increases resistance to diseases. The various phosphatic fertilizers have different compositions, due to which they have different solubilities. The two most important water soluble fertilizers are super phosphate (calcium super phosphate) $Ca(H_2PO_4)_2$, and triple phosphate (diammonium-phosphate $(NH_4)_2 HPO_4$).

Potassium Fertilizers

These fertilizers provide potassium to the plant or soil. Potassium is required for the formation of starch, sugar and the fibrous material of the plants. They increase resistance to diseases and make the plants strong by helping in healthy root development. They also help in ripening of seeds, fruits and cereals. Potassium fertilizers are especially useful for tobacco, coffee, potato and corn.

Some common examples of potassium fertilizers are potassium chloride, potassium sulphate and potassium nitrate.

20.5 Quick Check! 1. Which is the most concentrated solid nitrogen fertilizer?

EXERCISE

A Multiple Choice Questions

Choose and tick the correct answer from the given choices.

1. The pH of distilled water is:
   (a) 6.5 (b) 8.5
   (c) 7 (d) 7.5
2. The unpleasant odours in water can be removed by:
   (a) adding chlorine (b) treating it with activated charcoal
   (c) sedimentation (d) filtration
3. The source of harmful microbes in natural water:
   (a) human and animal wastes (b) fertilizers used for crops
   (c) industrial waste-water (d) microbes in rocks
4. Which gases are dissolved in natural water from the atmosphere through diffusion?
   (a) O_2 and CO_2 (b) N_2 and CO_2
   (c) O_2 and N_2 (d) O_2, N_2 and CO_2
5. The fertilizer harmful to paddy rice is:
   (a) Super phosphate (b) Ammonium nitrate
   (c) Urea (d) Potassium sulphate

6. Fertilizers which increase the resistant of plants towards diseases and make plants strong by healthy root development are:

(a) Nitrogenous fertilizers (b) Phosphate fertilizers

(c) Potassium fertilizers (d) Magnesium fertilizers

B Short Answer Questions

20.1 Name two methods to check the purity of water.

20.2 What is the main difference between tap water and distilled water?

20.3 How water is distilled in the laboratory?

20.4 Name useful and harmful substances present in water.

20.5 How would you remove harmful bacteria and other microbes present in water?

20.6 What is the difference between sedimentation and filtration?

20.7 Name any three water-borne diseases.

20.8 Why fertilizers containing nitrogen element are added into the soil?

20.8 What is trachoma disease?

C Constructed Response Questions

20.1 Describe the negative effects of using plastics in every day life.

20.2 Explain one method to remove dissolved impurities present in water.

20.3 Why urea is regarded as a good nitrogenous fertilizer?

20.4 Why Pakistan is facing a severe shortage of water?

D Descriptive Questions

20.1 How domestic water supply can be made fit for drinking?

20.2 Which measures should be taken to avoid water-borne disease?

20.3 What are fertilizers? Mention the essential qualities of a good fertilizer.

20.4 What are the main functions of nitrogenous, phosphatic and potassium fertilizers?

20.5 How can you avoid the negative effects of pollutants present in water?