

33

WATER

Student Learning Outcomes

[C-12-C-01 to C-12-C-08]

- ⊙ Explain the chemical properties of water and how they relate to water quality and pollution.
- ⊙ Identify different types of water pollution, (some examples include point source and nonpoint source pollution).
- ⊙ Identify common water pollutants (some examples include oil, pesticides, and heavy metals).
- ⊙ Identify and explain the sources and effects of water pollution on human health and the environment.
- ⊙ Evaluate the impact of human activities on water resources, such as agriculture and industrial processes.
- ⊙ Identify and explain water treatment methods and technologies, such as filtration and purification.
- ⊙ Explain conservation and management strategies for protecting and preserving water resources.
- ⊙ Explain the laws and regulations related to water pollution and conservation.

Water is the foundation of life. It keeps humans alive and healthy through hydration and hygiene, and removes toxic materials from the body. It allows plants to perform photosynthesis and supports agriculture by enabling crop growth. Animals rely on it to regulate body functions, and countless microorganisms depend on it for survival. Human development, agriculture, and food security all revolve around a steady supply of water. In nature, water shapes the land, maintains a balance in the climate, and recharges underground reservoirs. Ecosystems like rivers, lakes, wetlands, and oceans rely on water to support diverse plant and animal life. It is vital for energy production, transportation, urban development, and scientific research. Water scarcity threatens the environment, communities, and economies.

33.1 PROPERTIES AND QUALITY OF WATER

The chemical and physical properties of water are central to studying the nature and extent of pollution in the water bodies. The water molecule (H_2O) is a permanent dipole. This polarity renders water unique properties essential for life and the environment. Some peculiar features of water that emerge from its structure are discussed here.

i. Thermal Stability

The polarity of the water molecule results in the formation of hydrogen bonds between water molecules. Hydrogen bonding gives water a high specific heat capacity and high heat of vaporisation. This means that large bodies of water are thermally stable, resisting rapid temperature changes.



ii. Unique Solvent Abilities




Polarity also makes water a good solvent for a wide range of ionic substances, such as metallic ions, nitrates (NO_3^-) and phosphates (PO_4^{3-}), by surrounding the ions. Furthermore, the ability of water to dissolve polar organic compounds means that many pesticides and herbicides easily enter the water cycle, where they can persist and undergo bioaccumulation.

iii. Amphoteric Nature

The ability of water to act as both an acid and a base is also important for water quality. The self-ionisation of water ($K_w = 1.0 \times 10^{-14}$ at 25°C) provides the baseline for the pH scale. Most of the aquatic life is highly sensitive to pH fluctuations. For example, pollution in the form of acid rain, caused by the dissolution of sulphur dioxide (SO_2) and nitrogen oxides (NO_x), increases the concentration of hydronium ions (H_3O^+). This acidity can mobilise toxic heavy metal compounds, such as aluminium hydroxide and lead salts, from sediments into the water column by increasing their solubility through protonation or by displacing them from mineral surfaces.

iv. Oxygen in Water

The oxygen gas plays crucial role in water. It is an indicator of water quality and the level of pollution. Oxygen in water can be interpreted based on its different roles.

-  Dissolved oxygen (DO) is a key indicator of water quality and aquatic ecosystem health. It refers to the amount of oxygen available in water for aquatic organisms to breathe. High DO levels generally indicate clean, unpolluted water, while low levels may suggest pollution or excessive organic matter decomposition.
-  Biochemical Oxygen Demand (BOD) is the amount of oxygen required by microorganisms to break down organic matter in water over a specific period, usually five days at 20°C . It is a key indicator of the level of organic pollution in water. High BOD values indicate a large amount of organic matter, suggesting heavy pollution, which can deplete dissolved oxygen and harm aquatic life.
-  Chemical Oxygen Demand (COD) is the amount of oxygen required to chemically oxidise organic and inorganic substances in water, using oxidising agents (KMnO_4 , $\text{K}_2\text{Cr}_2\text{O}_7$, etc.). High COD values indicate a high concentration of oxidisable chemical pollutants, suggesting poor water quality and potential contamination from industrial or domestic waste. COD is useful for assessing the total pollution load in water.

The following table outlines the typical ranges for these parameters across different types of water sources.

Table 33.1 Typical ranges of DO, BOD, and COD in water

Water Type	DO (Dissolved Oxygen) mg/L	BOD (Biochemical Oxygen Demand) mg/L	COD (Chemical Oxygen Demand) mg/L
Very Pure Water	7 – 10	< 1	< 2



Drinking Water	> 6	< 2	< 5
Moderately Polluted	4 – 6	2 – 8	10 – 20
Treated Sewage	2 – 4	10 – 30	30 – 100
Raw Sewage	< 1	100 – 400	200 – 1000
Industrial Waste	0 – 2	500 – 5000+	1000 – 20,000+

v. Redox Potential

The redox potential of water is a measure of the oxidising and reducing nature of a water body. In well-oxygenated water, chemical species exist in their most oxidised forms, such as SO_4^{2-} and CO_2 . However, in polluted or stagnant water, where oxygen is depleted, the environment becomes reducing. This leads to the formation of toxic substances like hydrogen sulphide (H_2S) and ammonia (NH_3). Understanding these chemical equilibria and the molecular behaviour of H_2O allows us to predict how specific contaminants will migrate, transform, and ultimately impact the global water supply.



Quick Check 33.1



- Explain how the polarity of water facilitates the transport of agricultural pollutants like pesticides into the water cycle.
- Differentiate between Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) as indicators of water quality.

33.2 SOURCES OF WATER POLLUTION

The sources of pollution may either be small scale and single point or a variety of locations or points adding the same or various types of pollutions. Based on this, the sources of water pollution are divided into two types.

1. Point Source Pollution

Point-source pollution is the contamination that enters a water body from a single, discrete, and identifiable location or point. Because the discharge is concentrated at one point, it often causes a pollution plume. Immediately downstream or at the site of discharge, concentrations of the pollutant (such as heavy metals or organic waste) are at their highest, leading to localized acute toxicity. An example is a factory discharging lead or mercury salts directly into a river via a specific wastewater pipe. Another example is a storage tank at a chemical plant leaking its contents into the soil and subsequently into the groundwater.



Figure 33.1 Urban Sewage polluting water channels (point source pollution)



2. Non-Point Source (NPS) Pollution

Non-point source pollution, also known as diffused pollution, occurs when rainfall or snowmelt moves over and through the ground. As the water moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, and coastal waters. Unlike point sources, NPS pollution is heavily dependent on weather events like heavy storms. It results in a mixture of various pollutants at lower concentrations across a much wider area. Some examples of non-point pollution sources are:

- 🌿 Rain washing excess ammonium nitrate (NH_4NO_3), fertilizers, and pesticides from thousands of hectares of farmland into a river system.
- 🌿 Stormwater moving over impermeable surfaces (roads and car parks), collecting leaked engine oils (hydrocarbons), zinc from tires, and road salts.



Quick Check 33.2



- a) Classify these as point or non-point sources of water pollution, explain your choice.
 - i) The outfall pipes used to release treated sewage into a bay or river from wastewater treatment plants.
 - ii) The "acid rain" caused by the nitrogen oxides (NO_x) from distant traffic or power stations dissolved in rainwater.
- b) Give two major differences between point and non-point pollution sources.

33.3 COMMON WATER POLLUTANTS

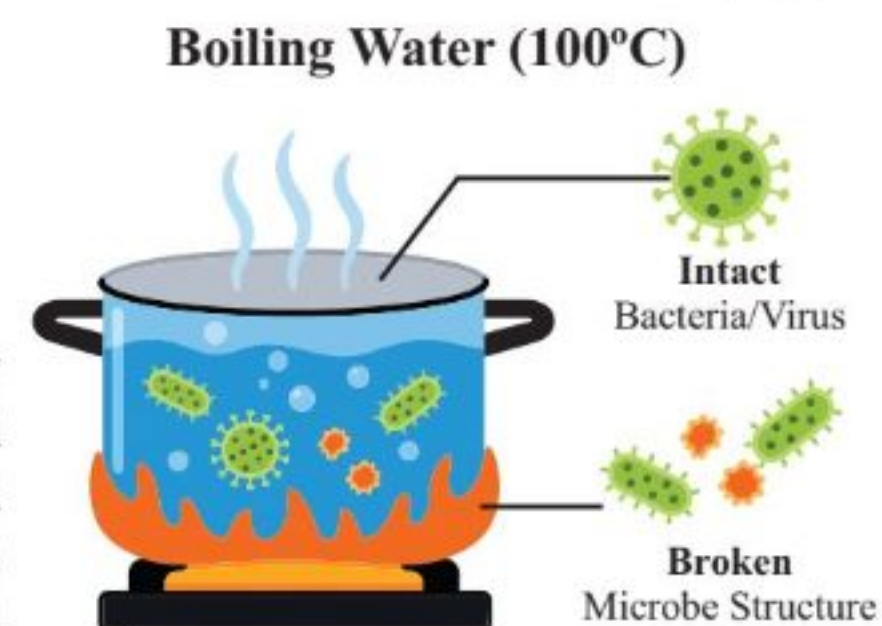
1. Microbiological Pollutants

Microbiological pollution is the contamination of water by harmful microorganisms, such as bacteria, viruses, protozoa, and parasites which can pose serious health risks to humans and animals. This type of pollution typically results from the discharge of untreated or inadequately treated sewage, animal waste, hospital waste, and runoff from agricultural lands into water bodies. Common pathogens found in microbiologically polluted water include Escherichia coli, Salmonella, and Giardia. Microorganisms in water, such as bacteria, viruses, and protozoa are the major cause of water-borne diseases. Common water-borne diseases include cholera, typhoid, dysentery, and hepatitis A.

2. Chemical Pollutants (Heavy Metals and Pesticides)

a) Heavy Metals

This type of pollution often includes toxic heavy metals like mercury, lead, arsenic, and cadmium and agricultural chemicals such as pesticides and herbicides. Heavy metals can enter water systems through industrial discharge, mining operations, and improper waste disposal. Sources of some heavy metals are given below.



Boiling can kill most of bacteria, viruses and protozoa to make water drinkable. But other pollutants cannot be removed by boiling only.



- Mercury can enter water primarily from coal combustion, gold mining, and industrial waste from thermometer or battery manufacturing. In aquatic sediments, bacteria convert inorganic mercury into methylmercury ($[\text{CH}_3\text{Hg}]^+$), which is more dangerous.
- The major sources of lead are leaded petrol (which is now banned worldwide); old plumbing (lead pipes), lead-acid batteries, and paints. Lead ions (Pb^{2+}) often enter water systems through the corrosion of pipes.
- Metal plating, plastic stabilisers, and phosphate fertilizer impurities are major sources of cadmium in water. These chemicals are usually of non-biodegradable nature and can accumulate in the food chain, posing long-term risks to aquatic life and humans, equally.

Health effects of Heavy Metals

Heavy metals have high atomic weights and densities. Due to their non-biodegradable nature, they tend to accumulate in the tissues of living organisms, and are particularly dangerous. Some common heavy metals and their hazards are given in the following lines.

- Methyl mercury ($[\text{CH}_3\text{Hg}]^+$) is highly fat-soluble, allowing it to easily cross biological membranes and undergo **biomagnification**. It is a potent neurotoxin that crosses the blood-brain barrier. Long term exposure leads to Minamata disease, characterized by ataxia, numbness in the hands and feet, and general muscle weakness.
- Lead interferes with the production of haemoglobin, leading to anaemia. In children, it acts as a cumulative poison that causes irreversible neurological damage and developmental delays.
- Long-term ingestion of cadmium (Cd) leads to "Itai-itai" disease, where cadmium replaces calcium in the bones, making them extremely brittle. It also causes severe kidney damage (nephrotoxicity).

The limiting concentrations (mg/L) of some heavy metals are provided in **Table 33.2**.



Cd^{2+} ions have higher charge density so they can replace Ca^{2+} ions in bones

Table 33.2 WHO permissible limits of heavy metals in drinking water

Heavy Metal	WHO Limit (mg/L)
Arsenic (As)	0.01
Chromium (Cr)	0.05
Copper (Cu)	2.0
Lead (Pb)	0.01
Cadmium (Cd)	0.003
Mercury (Hg)	0.006



Did You Know?

The Minamata Disaster was a severe case of industrial pollution that occurred in the 1950s in Minamata, Japan. Caused by the release of methylmercury into the water, it led to widespread mercury poisoning, affecting thousands of people with neurological damage and causing birth defects, deaths, and environmental devastation. At right is the picture of a patient inflicted by such a neurological disease.



a) Pesticides and Herbicides

Pesticides and Herbicides such as DDT and Glyphosate are another hazardous material that pollute water and cause severe human health issues. The major sources of these are agricultural runoff and domestic gardening. They are non-polar and insoluble in water but highly soluble in the fatty tissues of fish and birds. Many older pesticides like DDT are persistent organic pollutants (POPs). Pesticides are linked to hormonal disruption and developmental problems. Chemical pollution also degrades water quality, reduces biodiversity, and disrupts aquatic ecosystems.

Health Effects

Many pesticides act as endocrine disruptors like natural hormones, e.g., estrogen. This can lead to the reproductive failure in wildlife (e.g., thinning of eggshells in birds) and is linked to hormonal cancers in humans. Polychlorinated biphenols (PCBs) have been used in electrical transformers as coolants; they leak into water from hazardous waste sites. PCBs are classified as probable human carcinogens. They also suppress the immune system and cause skin conditions, such as chloracne.

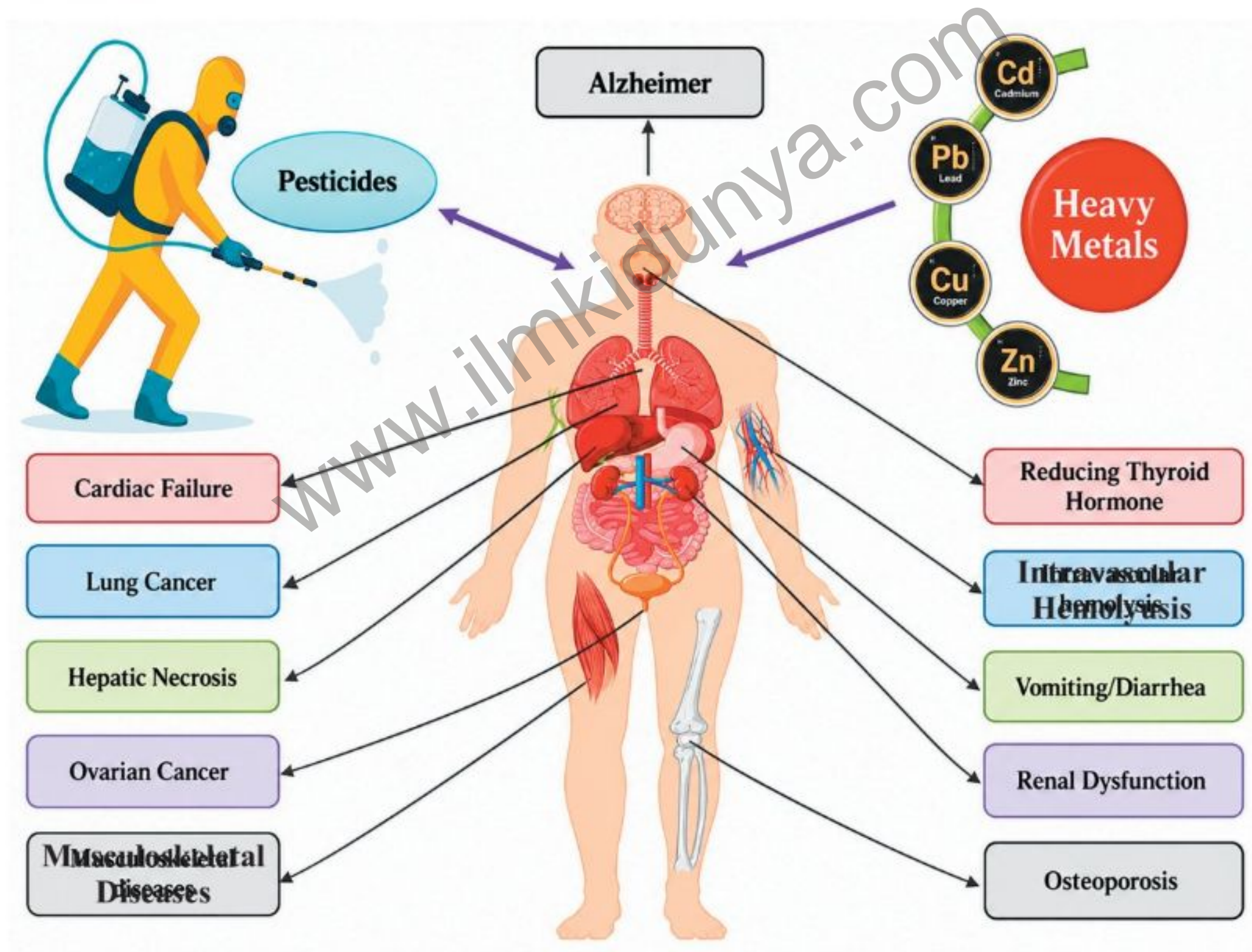


Figure 33.2 Effects of heavy metals and pesticides on the human body



3. Eutrophication

Nutrient pollution, also known as **eutrophication**, occurs when excessive amounts of nutrients, primarily nitrogen and phosphorus, enter into water bodies, usually from agricultural runoff, wastewater discharge, and stormwater. Although these nutrients are essential for plant growth, their excess in aquatic environments leads to the rapid growth of algae, commonly referred to as algal blooms. These blooms can block sunlight from reaching underwater plants. When they die and decompose, they consume large amounts of oxygen, creating hypoxic or “dead zones” where aquatic life cannot survive. Eutrophication severely disrupts aquatic ecosystems, reduces biodiversity, harms fisheries, and affects water quality for recreational and drinking purposes. High nitrate levels in drinking water are particularly dangerous for infants. It can lead to "Blue Baby Syndrome" (Methaemoglobinaemia), where nitrates reduce the blood's capacity to carry oxygen.

4. Oil

Oil pollution in oceans, particularly from oil leaks and spills caused by ships, is a major environmental threat. When oil is accidentally released into the sea, it spreads rapidly across the water surface, forming a layer that blocks sunlight and reduces oxygen exchange. This severely harms marine life, including fish, birds, and mammals. Marine mammals can ingest the toxic oil while grooming, and fish may suffer from long-term health issues due to exposure to hydrocarbons. Oil pollution also damages coastal habitats such as mangroves, coral reefs, and beaches.



(a)



(b)

Figure 33.3 (a) Eutrophication in water bodies damages aquatic life, (b) Marine life suffers from oil pollution

5. Plastic and Solid Waste

Plastic and solid waste pollution in oceans and other water bodies is a growing environmental crisis. Millions of tons of plastic waste including bottles, bags, fishing nets, and microplastics are dumped into rivers, lakes, and oceans every year. Unlike organic materials, plastics do not biodegrade; instead, they break down into smaller particles that persist in the environment for centuries.

Marine animals often mistake plastic for food, leading to ingestion, choking, or internal injury, which can be fatal. Sometimes entanglement in old fishing gear and other debris in the sea bed also causes injury or death to countless sea creatures, including turtles, dolphins, and birds.



Furthermore, microplastics have entered the food chain, raising concerns about their impact on human health. Solid waste pollution also clogs waterways, disrupts aquatic habitats, and reduces water quality.

**Quick Check 33.3**

- i. Name the sources of heavy metals.
- ii. How oil spill is hazardous to the marine life?
- iii. Pesticides like DDT are "non-polar and insoluble in water" yet they "pollute water and cause severe human health issues. Explain.

33.4 WATER POLLUTION DUE TO HUMAN ACTIVITIES

Human activities are a major cause of water pollution across the globe. As populations grow and industries expand, more waste and pollutants are introduced into water bodies. Improper waste management and lack of environmental regulations often lead to contaminants reaching rivers, lakes, and oceans.

1. Industrial Activities

Industrial activities are the major source of water pollution. Factories often discharge harmful chemicals, heavy metals, and toxic waste directly into rivers, lakes, and oceans. The common industries that release pollution, are oil refineries, chemical plants, automobile industry, fertilizers, tanneries, etc.

2. Agricultural Activities

Agricultural activities contribute significantly to water pollution through the runoff of fertilizers, pesticides, and herbicides into nearby water bodies. Poor irrigation practices can increase soil erosion, washing sediments into rivers and streams. In many areas, drainage from farmlands carries pollutants that contaminate both surface and groundwater sources.

3. Domestic and Municipal Waste

Domestic and municipal waste is one of the major sources of water pollution. In many areas, untreated or poorly treated sewage and solid waste from cities is discharged directly into rivers, lakes, or oceans, introducing harmful bacteria and viruses. Household waste such as detergents, oils, and chemicals often enter drains and eventually reach water bodies. Especially, plastics are frequently dumped in or near water channels, leading to blockages and long-term pollution.

4. Deforestation and Land Use for Urban Development

Deforestation and land use significantly contribute to the water pollution. When trees and vegetation are removed, the soil becomes loose and more prone to erosion, leading to increased sediment in rivers and streams. This sediment can clog waterways, harm aquatic habitats, and reduce water quality. Urban development and construction activities often introduce pollutants and debris into runoff water.

5. Recreational Activities

Recreational activities such as boating, swimming, and camping can contribute to water pollution



if not properly managed. Boats often release oil, fuel, and other chemicals into the water, harming aquatic life. Littering by visitors, including plastics, food wrappers, and other waste, can pollute lakes and rivers.

6. Marine Transport

Marine transport activities contribute to water pollution through the discharge of oil, fuel, and other chemicals from ships and boats. Accidental oil spills, wastewater and sewage from vessels, and ships are major causes of pollution. Routine maintenance, such as hull cleaning and painting, can also release toxic substances into the water. These practices collectively harm aquatic life and reduce water quality.



Quick Check 33.4



- a) A river passes by three regions in a country: a rural area with vast agricultural land and a lot of cattle; an industrial area with many paint and battery industries; and a large residential area of a big city:
- Predict which type of pollutants will be added to the river in the rural area; organic, inorganic, or both? Name two of them.
 - Which metals are most likely to pollute the water near the industrial area?
 - Name the regions that will contaminate the water with chemicals that lead to Eutrophication.
 - Name four contaminants that will pollute the water near the residential area.

33.5 EFFECT OF WATER POLLUTION ON THE ENVIRONMENT

Pollutants can alter the physical and chemical properties of water, making it difficult for plants and animals to survive. Common environmental impacts include **loss of biodiversity, habitat destruction, disruption of food chains, and decline in water quality.**

1. Destruction of Eco Systems and Biodiversity

Water pollution, such as oil, heavy metals, and pesticides severely damages ecosystems and aquatic life by introducing harmful chemicals, plastics, and waste into rivers, lakes, and oceans. Polluted water reduces oxygen levels, causing hypoxia and making it difficult for aquatic life to survive. It damages coral reefs and disrupts food chains. Toxic chemicals, sewage, and industrial waste can kill or harm aquatic organisms, reducing the variety of life in rivers, lakes, and oceans. Polluted water disrupts breeding cycles, food sources, and migration patterns, leading to population decline and even extinction of sensitive species. It also affects birds and animals that rely on water bodies for survival.

2. Nutrient Overload (Eutrophication)

Nutrient overload from water pollution, especially excess nitrogen and phosphorus from fertilizers and sewage, leads to a rapid growth of algae, which block sunlight and reduce oxygen levels in the water. Eutrophication disrupts ecosystems, kills fish and other marine species, and damages water quality.



3. Bioaccumulation and Magnification

Bioaccumulation and biomagnification are serious adverse effects of water pollution, where toxic substances like mercury, lead, and pesticides build up in organisms over time. These toxins accumulate in the bodies of aquatic animals and become more concentrated as they move up the food chain. Top predators, including humans, often receive the highest doses.

4. Soil Degradation and Plant Life Damage

Water pollution significantly contributes to soil degradation and damages plant life. Contaminants like heavy metals, industrial waste, and excessive nutrients seep into the soil, altering its structure and fertility. Accumulated chemicals disrupt the soil's natural microbial activity, essential for plant health. Plants exposed to polluted water may exhibit stunted growth, leaf discoloration, and even die.

5. Methane Emission by Decaying Organic Matter

When sewage, agricultural runoff, or industrial waste enters water bodies, it boosts the growth of algae and other organisms. As these organisms die and decompose in oxygen-poor (anaerobic) conditions, methane, a potent greenhouse gas, is released. The excess methane contributes to climate change and worsens global warming.



Quick Check 33.5



- a) Methylmercury ($[\text{CH}_3\text{Hg}]^+$) is "highly fat-soluble," allowing it to cross biological membranes and the blood-brain barrier.
 - i. Contrast the chemical structure of the methylmercury cation ($[\text{CH}_3\text{Hg}]^+$) with the inorganic mercury ion (Hg^{2+}). Explain why the presence of the methyl group ($-\text{CH}_3$) alters its solubility in lipid bilayers of living cells compared to the inorganic ion.
 - ii. Predict the impact on the "biomagnification" process if ($[\text{CH}_3\text{Hg}]^+$) was highly water-soluble but had low fat solubility.
- b) How the water pollution can contribute to the global warming?

33.6 WASTEWATER TREATMENT

Depending on the type and severity of pollution, such as organic matter, chemicals, or pathogens, different water treatment methods are used. These techniques are used at different levels of water treatment, i.e., primary treatment (removal of physical debris), secondary treatment (biological processing), and tertiary treatment (chemical purification). In the following steps different technologies (physical, biological, and chemical) suitable to remove various contaminants in water are being provided

I. Screening and Sedimentation

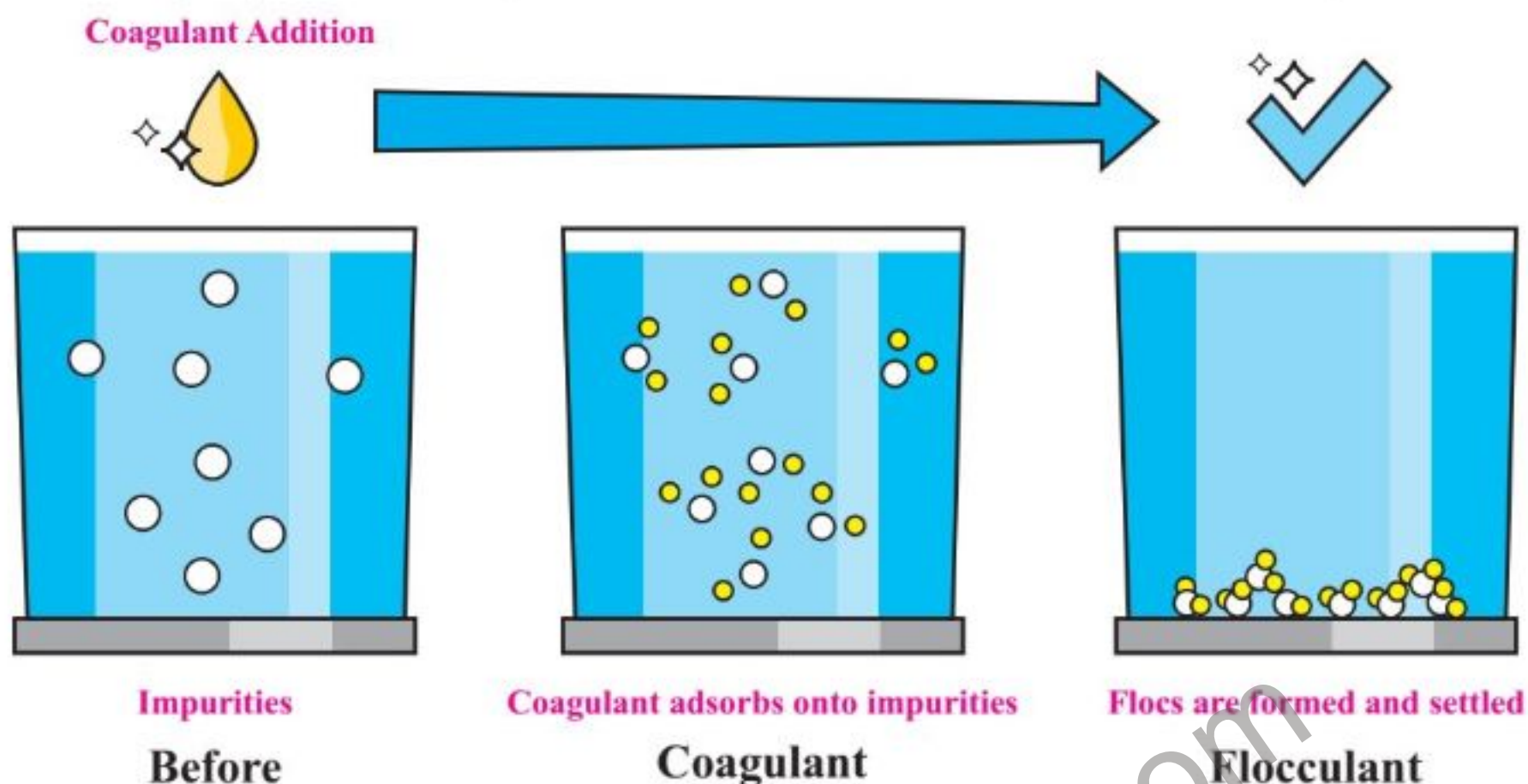
The initial stage of water treatment typically involves screening and sedimentation. Large insoluble particles are removed by passing water through metal screens. This is followed by sedimentation, where water is held in large tanks to allow suspended solids to settle at the bottom under the influence of gravity.

ii. Coagulation and Flocculation

To speed up the settling of finer colloidal particles, coagulation and flocculation are employed. This process is done if required. It involves the precipitation of dissolved contaminants (e.g.,



heavy metals, phosphates) into insoluble forms for removal. Chemical coagulants, such as aluminium sulphate ($\text{Al}_2(\text{SO}_4)_3$), are added to the water. These chemicals cause the smaller particles to clump together into larger masses called "floc", which are then easily removed.



iii. Filtration

Once the bulk of the solids has been removed, the water undergoes filtration. This is a mechanical process designed to remove the remaining fine suspended matter and some microorganisms. In a standard treatment plant, water passes through layers of graded sand and gravel. The sand acts as a physical barrier, trapping particles within the pores between grains. For more advanced purification, activated carbon is used.

iv. Disinfection

Filtration alone cannot remove dissolved ions or microscopic pathogens; therefore, chemical purification is necessary. Chlorination is the most common method of disinfection. The other methods include sodium hypochlorite (NaOCl); ozone (O_3) or sometimes with hydrogen peroxide (H_2O_2). When chlorine gas or sodium hypochlorite is added to water, it forms hypochlorous acid (HOCl), which penetrates the cell walls of bacteria and viruses, disrupting their cell functions.

iv. Reverse Osmosis (RO) and Ion Exchange Methods

For the production of high-purity water, such as that required in laboratory settings or regions with high salinity, reverse osmosis (RO) and ion exchange method are utilized.

The RO method uses a semi-permeable membrane, which filters out dissolved salts, bacteria, and other impurities under pressure. Ion exchange is an important technology for "softening" water. Hard water contains high concentrations of Ca^{2+} and Mg^{2+} ions, which interfere with industrial processes and soap efficiency. In an ion-exchange column, these ions are swapped for Na^+ or H^+ ions.



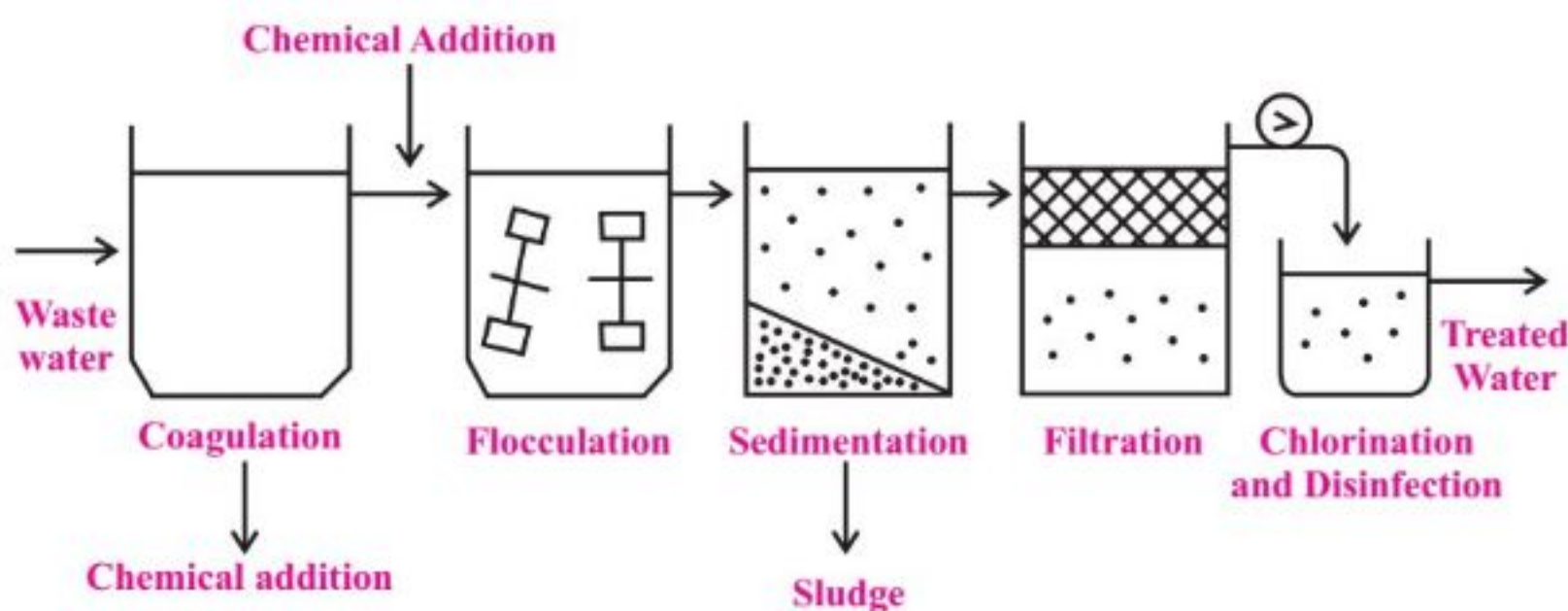


Figure 33.4 A sketch of water treatment plant

33.7 PROTECTION AND CONSERVATION OF WATER RESOURCES

33.7.1 Pollution Control

It can be done by the following strategies.

- 🔧 Imposing strict discharge standards for industries and municipalities to prevent harmful pollutants from entering water bodies.
- 🔧 By upgrading and expanding sewage treatment plants (STPs), installing Effluent Treatment Plants (ETPs), and adopting modern technologies, such as membrane filtration and bioreactors.
- 🔧 By continuous water quality monitoring, which enables the detection of pollutants, ensuring timely responses to contamination events.
- 🔧 By implementing strict penalties for polluters and offering incentives for clean practices. This approach discourages environmental violations while encouraging industries and communities to adopt sustainable, pollution-free operations.

33.7.2 Efficient Use of Water

Conservation of water is of utmost importance in the current era due to water shortage faced by a large pollution fraction of the world. Following strategies help conserve water.

- 🔧 Water-saving technologies in agriculture such as, drip irrigation and sprinkler irrigation in agriculture significantly reduced water wastage while improving crop yield and efficiency.
- 🔧 Reusing and recycling greywater, such as household laundry, dishwashing, and bathing water for landscaping, toilet flushing, and industrial cooling helps conserve freshwater resources and reduces the burden on sewage treatment systems.
- 🔧 Implementing rainwater harvesting systems in both urban and rural areas is a sustainable method to capture and store valuable water resources.
- 🔧 Regular repair and maintenance of water supply infrastructure minimize leaks and water loss, ensuring efficient delivery and reduced resource wastage.



- Constructing small dams and recharge wells helps store rainwater and replenish groundwater levels, providing a reliable source of water during dry periods.
- Community engagement and awareness through public education campaigns on water-saving behaviours and involvement of local communities in water body protection.

33.8 RULES AND REGULATIONS REGARDING WASTE POLLUTION AND CONSERVATION

The Government of Punjab has made several acts and laws to address the water pollution within its jurisdiction. The Punjab Environmental Protection Agency (EPA) Punjab regularly issues relevant rules and regulations for all concerned stakeholders. Below is a comprehensive overview of the key self-explanatory rules and regulations issued by EPA Punjab (Pakistan) related to water pollution control and conservation.

Table 33.3 Key environmental regulations and conservation measures

Act / Regulation	Primary Scope and Powers	Penalties for Non-Compliance
Punjab Environmental Protection Act, 1997	Pollution prevention.	Fines up to Rs 5 million, plus additional daily fines of up to Rs 100,000.
Punjab Water Act, 2019	Prohibits discharging pollutants or blocking flow.	Up to 3 months imprisonment and/or a Rs 500,000 fine.
Punjab Irrigation, Drainage and Rivers Act, 2023	Sets water usage and drainage fees, regulates discharge permits to prevent industrial/agricultural pollution.	—————
Punjab Water and Sanitation Authority Act, 2025	Establishes the Authority in major cities (Lahore, Multan, etc.) for integrated resource management and groundwater conservation.	—————



Did You Know?

The penalty for the use of hosepipes for car-washing and flood irrigation in domestic lawns or gardens is a Fine of Rs 10,000 under the Pakistan Penal Code.



Exercise

Q1. MULTIPLE CHOICE QUESTIONS:

1. Four choices are given for each questions. Select the correct choice.

- I. Which property of water is primarily responsible for its ability to resist rapid temperature changes in large aquatic ecosystems?
- Amphoteric nature
 - High specific heat capacity
 - The permanent dipole
 - High redox potential
- II. A water sample is found to have a very high Biochemical Oxygen Demand (BOD). What does this most likely indicate about the water body?
- Highly oxygenated and healthy
 - High concentration of nitrates and phosphates.
 - High organic pollution
 - A high pH
- III. Which of the following best describes the formation of a "pollution plume"?
- Agricultural runoff
 - Discharge of heavy metal salts
 - The mixture of hydrocarbons and road salts
 - Snowmelt through uncontaminated forest soil.
- IV. Why is Non-Point Source (NPS) pollution considered "weather-dependent" compared to Point Source pollution?
- NPS pollutants are only toxic when the temperature of the water rises.
 - NPS pollution requires precipitation to wash diffuse surface contaminants into water bodies.
 - Point sources only discharge waste during specific industrial seasons.
 - Rainfall neutralizes the localized acute toxicity of point source plumes.
- V. Bacteria in aquatic sediments convert inorganic mercury into methylmercury ($[\text{CH}_3\text{Hg}]^+$). Which statement best explains why this conversion increases the ecological hazard?
- Methylmercury dissolves more readily in the water
 - Methyl mercury is biodegradable and enters nutrient cycle.
 - Methylmercury is highly fat-soluble
 - Methylmercury is a solid that clogs the gills of fish.
- VI. Which condition is a direct result of Cadmium (Cd) replacing Calcium (Ca) in the skeletal system?
- Minamata disease
 - Blue Baby Syndrome
 - Itai-itai disease
 - Chloracne
- VII. What is the primary chemical role of Aluminium Sulphate ($\text{Al}_2(\text{SO}_4)_3$) in the wastewater treatment process?
- To kill pathogenic bacteria.



- b) To act as a semi-permeable membrane.
- c) Converting colloidal particles to floc.
- d) To adsorb organic contaminants.

VIII. Ion exchange technology "softens" water by replacing calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions with:

- a) Chlorine (Cl_2) or ozone (O_3)
- b) Sodium (Na^+) or hydrogen (H^+) ions
- c) Aluminum (Al^{3+}) or iron (Fe^{3+}) ions
- d) Carbonate (CO_3^{2-}) or phosphate (PO_4^{3-}) ions

Q2. SHORT-ANSWER QUESTIONS:

- a) Differentiate between Point Source and Non-Point Source pollution in terms of the "concentration" of pollutants at the site of entry.
- b) Using an example from the text, explain how an underground storage tank can become a point source of pollution.
- c) Identify two types of chemical pollutants commonly found in urban storm water runoff.
- d) Differentiate between the "solubility" of pesticides like DDT and inorganic nutrients like nitrates in the context of the water cycle.
- e) Explain why microplastics are considered a "growing environmental crisis" differently than organic solid waste.
- f) How an oil spill physically disrupts the chemical balance of a marine ecosystem?
- g) Why are synthetic organic pollutants, like PCBs and pesticides, considered "persistent" in the environment?
- h) How do the decomposition of organic matter in polluted water contributes to global warming?
- i) Name four methods used for water conservation.
- j) What is the role of "industrial discharge" in water pollution?
- k) Both reverse osmosis (RO) and ion exchange methods are used to obtain high-purity water?
 - a) Differentiate between the processes involved in both these methods.
 - b) What impurities do these methods target?

Q3. CONSTRUCTED RESPONSE QUESTIONS

- a) Explain the relationship between acid rain and the presence of toxic heavy metals in aquatic environments.
- b) Analyze the environmental impact of agricultural runoff as a Non-Point Source of pollution. Reference specific chemicals in your answer.
- c) Evaluate the role of agricultural runoff" in contributing to different types of water pollution.
- d) Evaluate the benefits and the long-term chemical risks involved in the use of chlorine as a disinfectant.

DESCRIPTIVE QUESTIONS:

- Q4. Describe the effects of heavy metals and pesticides on the human body.
- Q5. Explain the different sources of heavy metals and organic compounds.
- Q6. Describe various technologies used in water treatment.
- Q7. Explain the difference between DO, BOD, and COD; How they relate to the water pollution?



Instructions for Preparation of Exam Paper of Chemistry for Class 12

ESSENTIAL INSTRUCTIONS FOR PAPER SETTERS

The paper of Chemistry for class 12 will consist of eighty-five (85) marks. Timing of the paper will be three (03) hours. The paper will be made as per following details:

Part-I: Objective:	Q-1: One multiple-choice question (MCQ) from each chapter.	$1 \times 17 = 17$																														
Part-II: Subjective:	Q-2: 8 short answer questions have to be answered out of 12. The detail is as follows: <table border="1" data-bbox="528 896 1634 1032"> <tbody> <tr> <td>Chapter</td> <td>17</td> <td>18</td> <td>19</td> <td>20</td> <td>24</td> <td>25</td> </tr> <tr> <td>No. of Short Questions</td> <td>1</td> <td>1</td> <td>3</td> <td>2</td> <td>3</td> <td>2</td> </tr> </tbody> </table>	Chapter	17	18	19	20	24	25	No. of Short Questions	1	1	3	2	3	2	$2 \times 8 = 16$																
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Q-3: 8 short answer questions have to be answered out of 12. The detail is as follows: <table border="1" data-bbox="528 1214 1634 1349"> <tbody> <tr> <td>Chapter</td> <td>21</td> <td>22</td> <td>23</td> <td>27</td> <td>28</td> <td>29</td> </tr> <tr> <td>No. of Short Questions</td> <td>1</td> <td>1</td> <td>2</td> <td>2</td> <td>3</td> <td>3</td> </tr> </tbody> </table>	Chapter	21	22	23	27	28	29	No. of Short Questions	1	1	2	2	3	3	$2 \times 8 = 16$																	
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Q-4: 6 short answer questions have to be answered out of 9. The detail is as follows: <table border="1" data-bbox="528 1531 1511 1666"> <tbody> <tr> <td>Chapter</td> <td>26</td> <td>30</td> <td>31</td> <td>32</td> <td>33</td> </tr> <tr> <td>No. of Short Questions</td> <td>1</td> <td>2</td> <td>2</td> <td>2</td> <td>2</td> </tr> </tbody> </table>	Chapter	26	30	31	32	33	No. of Short Questions	1	2	2	2	2	$2 \times 6 = 12$																			
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Part-III: Subjective:	<p>This section will contain five detailed questions bifurcated in two-part a & b (carrying 4 & 4 marks each) and students have to attempt 3 questions The detail is as follows:</p> <table border="1" data-bbox="528 1955 993 2128"> <caption>Question No 5:</caption> <tbody> <tr> <td>Chapter</td> <td>17</td> <td>21</td> </tr> <tr> <td>Part</td> <td>a</td> <td>b</td> </tr> </tbody> </table> <table border="1" data-bbox="528 2200 993 2344"> <caption>Question No 6:</caption> <tbody> <tr> <td>Chapter</td> <td>18</td> <td>26</td> </tr> <tr> <td>Part</td> <td>a</td> <td>b</td> </tr> </tbody> </table> <table border="1" data-bbox="528 2416 993 2560"> <caption>Question No 7:</caption> <tbody> <tr> <td>Chapter</td> <td>20</td> <td>31</td> </tr> <tr> <td>Part</td> <td>a</td> <td>b</td> </tr> </tbody> </table> <table border="1" data-bbox="1159 1955 1625 2128"> <caption>Question No 8:</caption> <tbody> <tr> <td>Chapter</td> <td>22</td> <td>32</td> </tr> <tr> <td>Part</td> <td>a</td> <td>b</td> </tr> </tbody> </table> <table border="1" data-bbox="1159 2200 1625 2344"> <caption>Question No 9:</caption> <tbody> <tr> <td>Chapter</td> <td>23</td> <td>33</td> </tr> <tr> <td>Part</td> <td>a</td> <td>b</td> </tr> </tbody> </table>	Chapter	17	21	Part	a	b	Chapter	18	26	Part	a	b	Chapter	20	31	Part	a	b	Chapter	22	32	Part	a	b	Chapter	23	33	Part	a	b	$3 \times 8 = 24$
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xiii) The types of transitions possible in UV-visible region for a compound with molecular formula C_2H_4 are:

- a) $n \rightarrow \pi^*$ b) $n \rightarrow \sigma^*$ c) $\sigma \rightarrow \sigma^*$ d) $\pi \rightarrow \pi^*$

xiv) NMR relies on the magnetic properties of nuclei known as:

- a) Chemical shift b) Nuclear density c) Nuclear spin d) Signal intensity

xv) Which property makes ceramics suitable for furnace bricks?

- a) Conductivity b) Low density c) High melting point d) Flexibility

xvi) Which N-P-K nutrient promotes protein synthesis and chlorophyll?

- a) Nitrogen b) Phosphorus c) Potassium d) Sulphur

xvii) Which condition is a direct result of Cadmium (Cd) replacing Calcium (Ca) in the skeletal system?

- a) Minamata disease b) Blue Baby Syndrome c) Itai-itai disease d) Chloracne

Subjective Type (Part I)

Time allowed: 2.40 Hrs.

Max. Marks: 68

Q. 2: Write short answers to any eight (08) questions:

(16)

- i. Give the products of the thermal decomposition of barium nitrate. (17)
- ii. Define a bidentate ligand and state how many bonds it forms to the central ion. (18)
- iii. Give the names and examples of two functional groups containing oxygen.
- iv. Define catenation. Give its importance.
- v. Alkanes have no functional group. Justify.
- vi. Differentiate between the chocolate and coffee by drawing their structures.
- vii. Describe, with the help of a diagram, the bonding in benzene.
- viii. Explain why electrophiles, such as bromine, react much more readily with phenol than with benzene.
- ix. What is the chromophore in azo dyes? What are its functions in dyes?
- x. Why amides are less basic than ammonia?
- xi. Differentiate between synthesis and retrosynthesis.
- xii. How a carboxylic group is converted to an amide group?

Q. 3: Write short answers to any eight (08) questions:

(16)

- i. Which among haloalkanes or haloarenes, is more reactive towards electrophiles?
- ii. Which alcohol can't change color of acidified potassium dichromate?
- iii. Explain why carboxylic acid is more acidic than ethanol.
- iv. Give reaction of methanal with the Tollen's reagent.
- v. What is the role of iron in the body?
- vi. How enzyme inhibitors are important in our body and medicine?
- vii. Why is TLC not suitable for large-scale separation?



- viii. What is the function of injector port in GC?
- ix. Differentiate between partition and adsorption chromatography.
- x. Write the ranges of electromagnetic spectrum.
- xi. How the chemical composition of a substance can be investigated by using spectroscopy?
- xii. Predict two fragment ions that you would expect to see in the mass spectrum of butan-1-ol and state the m/e value of each ion.

Q. 4: Write short answers to any six (06) questions: (12)

- i. Name two different polymers used in artificial organs and state the specific application for each.
- ii. What does the number of peaks in a ^{13}C NMR spectrum represent?
- iii. Why do O-H and N-H peaks disappear after a D_2O shake?
- iv. Define energy density and give one example.
- v. Name two specific semiconductors mentioned in the text and their modern applications.
- vi. How structure of penicillin allows it to inhibit the transpeptidase enzyme?
- vii. What is the concept of pesticide resistance in a target pest population, linking it to the principles of natural selection and repeated application?
- viii. Name four methods used for water conservation.
- ix. What is the role of "industrial discharge" in water pollution?

Subjective Type (Part II)

Note: Attempt any three questions.

Q.5:

- (a) Explain the solubility of sulphates and hydroxides of Group 2 elements, and discuss the trend in their solubility down the group with appropriate examples. (4)
- (b) Describe the $\text{S}_{\text{N}}1$ and $\text{S}_{\text{N}}2$ mechanisms of nucleophilic substitution in halogenoalkanes. (4)

Q.6:

- (a) Discuss the redox reaction of transition metals giving one example in detail. (4)
- (b) Define the condensation polymer. Discuss the formation of polyester. (4)

Q.7:

- (a) In contrast to benzene, the reaction of an alkene with bromine does not need a halogen carrier. Compare the different reactivities of benzene and alkenes towards chlorine. (4)
- (b) Explain how X-rays interact with crystals to produce diffraction patterns and how these patterns help determine atomic positions. (4)

Q.8:

- (a) Write any two reactions of phenol involving substitution on the benzene ring. (4)
- (b) What are important safety measures which must be followed while working in different chemical industries? Make a checklist to verify their adoption. (4)

Q.9:

- (a) Prepare carboxylic acid starting from ester, alcohol, alkane nitril and methyl benzene. (4)
- (b) Evaluate the benefits and the long-term chemical risks involved in the use of chlorine as a disinfectant. (4)



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