

UNIT-3

UNIT-3: Physical, chemical and bacteriological examination of water and wastewater: Temperature, pH, colour and odour, solids, nitrogen and phosphorus, chlorides, toxic metals and compounds, BOD, COD etc. quality requirements, standards of water and waste water, disposal of wastewater on land and water bodies.

Unit outcome: Investigate physical, chemical & biological parameter of water.

Water examination

Water examination refers to the process of analyzing the chemical, physical, and biological characteristics of water samples to determine their quality and suitability for various purposes. The examination of water samples can involve a variety of tests and measurements, including:

- 1. Physical examination:** This involves assessing the color, odor, taste, turbidity, temperature, and other physical characteristics of the water sample.
- 2. Chemical examination:** This involves measuring the levels of various chemical compounds in the water, such as dissolved oxygen, nutrients, metals, and organic contaminants.
- 3. Biological examination:** This involves identifying and quantifying the types and numbers of microorganisms present in the water sample, such as bacteria, viruses, and parasites.
- 4. Radiological examination:** This involves measuring the levels of radioisotopes in the water sample, which can indicate the presence of radioactive contamination.

Water examination is essential for ensuring that water is safe for human consumption, agricultural and industrial uses, and aquatic ecosystems. By analyzing water samples, water quality experts can identify any potential health or environmental risks associated with the water and take appropriate actions to mitigate them. Physical, chemical, and biological examination of water are different aspects of water quality analysis, each assessing different characteristics of the water sample. Here are some examples of the parameters that are typically examined in each category:

1. Physical examination:

- a) Colour:** This refers to the hue of the water sample, which can indicate the presence of organic matter or chemical contaminants.
- b) Odour:** This refers to the smell of the water sample, which can indicate the presence of organic matter or other contaminants.
- c) Turbidity:** This refers to the cloudiness or haziness of the water sample, which can indicate the presence of suspended particles.
- d) Temperature:** This refers to the temperature of the water sample, which can affect its quality and the types of organisms that can thrive in it.
- e) Total suspended solids (TSS):** Total suspended solids (TSS) refer to the amount of solid particles that are suspended in water and do not settle out over time. These solids can include organic matter, silt, sediment, and other particles that are present in the water.
- f) Total dissolved solids (TDS):** This refers to the total amount of dissolved substances in the water sample, which can indicate the presence of salts, minerals, or other contaminants.

2. Chemical examination:

pH:

- pH is a measure of the acidity or alkalinity of a water sample.
- It is an important chemical parameter that can affect the suitability of water for various uses, including drinking water, irrigation, and industrial processes.
- pH is measured on a scale of 0 to 14, with 7 being neutral, values less than 7 being acidic, and values greater than 7 being alkaline or basic.
- In natural water systems, pH can vary depending on factors such as the presence of minerals, dissolved gases, and organic matter.
- Low pH (acidic) water can be corrosive to pipes and infrastructure, and high pH (alkaline) water can cause scaling and mineral deposits.
- In addition, pH can affect the solubility of chemicals in water, which can impact the transport and fate of pollutants in the environment.
- To measure pH, a water sample is tested using a pH meter or pH indicator paper.
- pH meter readings can be affected by factors such as temperature, electrode calibration, and sample preparation, so it is important to follow proper testing procedures to obtain accurate results.
- Regulatory agencies often set standards for pH levels in drinking water and other types of water to protect human health and the environment.
- For example, the World Health Organization (WHO) recommends a pH range of 6.5-8.5 for drinking water.

Dissolved oxygen (DO):

- Dissolved oxygen (DO) refers to the amount of oxygen that is dissolved in water.
- DO is an important parameter for assessing water quality, as it is essential for aquatic life to survive and thrive.
- DO can be affected by a variety of factors, including temperature, pressure, salinity, and the presence of other chemicals in the water.
- In general, colder water can hold more DO than warmer water, and water that is under higher pressure or has a higher salinity level can also hold more DO.
- Low DO levels can be an indication of pollution or other environmental stressors, as pollutants can consume oxygen as they degrade in the water.
- In addition, low DO levels can cause fish kills and other negative impacts on aquatic life.
- To measure DO, water samples are typically tested using a dissolved oxygen meter or sensor.
- The measurement is typically expressed in units of milligrams per liter (mg/L) or parts per million (ppm).
- Regulatory agencies often set standards for DO levels in different types of water to protect aquatic habitats and ensure that water is suitable for various uses, such as drinking water, irrigation, and industrial processes.
- For example, the U.S. Environmental Protection Agency (EPA) has established a water quality criterion for DO in freshwater streams and rivers of at least 5.0 mg/L to support healthy aquatic life.

Chemical oxygen demand (COD):

- COD is a test that measures the amount of oxygen required to chemically oxidize the organic material and inorganic nutrients, such as Ammonia or Nitrate, present in water.
- COD stands for Chemical Oxygen Demand, which is a measure of the amount of organic matter present in a water sample.
- Specifically, COD represents the amount of oxygen required to oxidize the organic matter in the sample chemically.
- COD is commonly used as an indicator of the quality of water and wastewater, as high COD levels can indicate the presence of organic pollutants and can lead to reduced oxygen levels in aquatic environments, which can have negative impacts on aquatic life.
- The COD test involves adding a strong oxidizing agent to the water sample, which chemically oxidizes the organic matter present.
- The amount of oxidizing agent required to fully oxidize the organic matter is then measured and used to calculate the COD of the sample.
- The COD test is commonly used in water and wastewater treatment plants to monitor the effectiveness of treatment processes and to ensure that discharge limits for organic pollutants are met.
- It is also used in industrial processes to monitor the levels of organic pollutants in wastewater and to evaluate the effectiveness of treatment processes

Biochemical Oxygen Demand (BOD):

- BOD is a measure of the amount of oxygen required by microorganisms to break down the organic matter in a water sample. The permissible limit of BOD in water depends on the intended use of the water.
- For example, the Central Pollution Control Board (CPCB) in India has set the following BOD limits for various water bodies:
 - a) Drinking water: less than 2 mg/L
 - b) Irrigation: less than 3 mg/L
 - c) Industrial: less than 30 mg/L
 - d) Surface water: less than 3 mg/L for Class A (drinking water source),
 - e) less than 6 mg/L for Class B (recreation and irrigation), and less than 30 mg/L for Class C (agricultural and industrial use)
- It's important to note that different countries and regions may have different permissible limits for BOD in water.
- These limits are set to protect public health and the environment from the negative impacts of high organic pollutant levels in water, including oxygen depletion and the death of aquatic life.
- Monitoring BOD levels in water is important to assess the effectiveness of wastewater treatment processes and to ensure that discharge limits for organic pollutants are met.
- Regular monitoring of BOD can also help identify potential pollution sources and allow for timely corrective actions to be taken.

Total organic carbon (TOC):

- Total organic carbon (TOC) is a measure of the amount of carbon-containing organic compounds present in a water sample.
- TOC is an important parameter for assessing water quality, as it can provide information about the presence of contaminants or other substances that can affect the water's taste, odour, or suitability for various uses.
- TOC can be derived from both natural and human-made sources, such as decaying plant matter, wastewater discharges, and agricultural runoff.
- High TOC levels can also indicate the presence of other pollutants, such as pesticides or industrial chemicals that can degrade and release organic carbon into the water.
- TOC can be measured using a variety of methods, such as combustion or oxidation, which convert the organic carbon in the sample into carbon dioxide (CO₂) that can be quantified using a carbon analyzer.
- The measurement is typically expressed in units of milligrams per liter (mg/L) or parts per million (ppm).
- Regulatory agencies often set standards for TOC levels in different types of water to protect public health and the environment.
- For example, the U.S. Environmental Protection Agency (EPA) has established a maximum contaminant level (MCL) of 2.0 mg/L for TOC in public drinking water systems.

Nutrients (nitrogen, phosphorus):

- Nutrients, including nitrogen and phosphorus, are important chemical parameters for assessing water quality.
- These elements are essential for the growth of plants and other aquatic organisms, but excessive levels can lead to eutrophication, a process that can cause harmful algal blooms, fish kills, and other negative impacts on aquatic habitats.
- Nitrogen and phosphorus can enter waterways from a variety of sources, including agricultural runoff, sewage discharges, and atmospheric deposition.
- Once in the water, these nutrients can stimulate the growth of algae and other aquatic plants, leading to a cascade of negative impacts as the excess biomass consumes dissolved oxygen and blocks sunlight from reaching the water below.
- To measure nutrients in water samples, various tests can be performed.
- Common methods for measuring nitrogen include the determination of total nitrogen, ammonia, nitrate, and nitrite. For phosphorus, common methods include the determination of total phosphorus, orthophosphate, and organic phosphorus.
- Regulatory agencies often set limits on the amount of nutrients that can be discharged into waterways to prevent eutrophication and protect aquatic habitats.
- For example, the U.S. Environmental Protection Agency (EPA) has established water quality criteria for nitrogen and phosphorus in various types of water bodies to protect aquatic life and human health

Metals (lead, copper, arsenic):

- Metals such as lead, copper, and arsenic can have toxic effects on human health and the environment, so it is important to monitor their levels in various materials and substances. Here are some key facts about each of these metals:
- **Lead:**

Exposure to lead can cause neurological damage, especially in young children and pregnant women. Sources of lead exposure include lead-based paints, contaminated soil and dust, and lead pipes in older buildings. The CDC recommends that blood lead levels in children be below 5 micrograms per deciliter.

- **Copper:**

Copper is an essential nutrient that is needed for many biological processes in the body, but high levels can cause health problems. Sources of copper exposure include contaminated water, certain foods, and copper pipes or cookware. Symptoms of copper toxicity include nausea, vomiting, and liver damage.

- **Arsenic:**

Arsenic is a naturally occurring element that can be found in soil, water, and certain foods. Exposure to high levels of arsenic can cause skin lesions, cancer, and other health problems. The EPA has set a maximum contaminant level of 10 micrograms per liter for arsenic in drinking water. Overall, monitoring the levels of these metals in various materials and substances can help to prevent health problems and ensure safe living environments.

Chlorine residual

- Chlorine residual refers to the amount of chlorine that remains in water after it has been treated with chlorine disinfectant.
- Chlorine is commonly used as a disinfectant in water treatment plants to kill harmful bacteria, viruses, and other microorganisms that may be present in the water.
- Once chlorine is added to the water, it reacts with the microorganisms to kill them, and any excess chlorine that is not consumed in this process remains in the water as a residual.
- The amount of residual chlorine that is maintained in the water is important because it ensures that the water remains safe for consumption.
- The appropriate level of chlorine residual in water varies depending on the specific application.
- For example, the EPA recommends a minimum chlorine residual of 0.2 mg/L in drinking water distribution systems to ensure that the water remains safe as it travels through the pipes and to consumers' homes.
- In swimming pools and spas, the recommended chlorine residual level is typically higher, around 1-3 mg/L, to ensure that the water remains free of harmful microorganisms that can cause infections.
- Chlorine residual can be measured using a variety of methods, such as colorimetric test kits, titration methods, or electronic sensors.
- Regular monitoring of chlorine residual is important to ensure that water remains safe for consumption and use.

Pesticides and herbicides:

- Pesticides and herbicides can be tested using a variety of methods, depending on the specific application and the type of chemical being tested. Here are some examples of common methods used to test for pesticides and herbicides:
- **Chromatography:** Chromatography is a technique used to separate and identify the different components of a mixture. Gas chromatography (GC) and liquid chromatography (LC) are commonly used to analyze pesticides and herbicides in environmental samples, such as soil and water.

- **Immunoassays:** Immunoassays use antibodies to detect and measure the presence of a specific substance, such as a pesticide or herbicide, in a sample. Immunoassays can be used to test for the presence of these chemicals in food, water, or soil.
- **Mass spectrometry:** Mass spectrometry is a technique used to identify and measure the chemical composition of a sample. Mass spectrometry can be used to detect and quantify the levels of pesticides and herbicides in environmental samples.
- **Bioassays:** Bioassays use living organisms, such as bacteria or plants, to test the toxicity of a substance. Bioassays can be used to test the effectiveness of pesticides and herbicides in killing pests and weeds, as well as their potential impacts on non-target organisms.
- **Residue analysis:** Residue analysis involves testing for the presence of pesticide or herbicide residues in food or environmental samples. This can be done using chromatography or other analytical techniques.
- Overall, testing for pesticides and herbicides is an important part of ensuring the safety and efficacy of these chemicals in controlling pests and weeds while minimizing their potential risks to human health and the environment.

3. Biological examination:

1. Total coliforms and E. coli:

Total coliforms and E. coli are two types of bacteria that are commonly used as indicators of water quality and potential contamination.

- **Total coliforms:**
Total coliforms are a group of bacteria that are commonly found in the environment, including in soil and vegetation, as well as in the digestive tracts of humans and animals. Total coliforms are not harmful themselves, but their presence in water can indicate the potential presence of harmful bacteria, viruses, or other pathogens. The presence of total coliforms in drinking water is an indicator that the water may be contaminated and requires further testing.
- **E. coli:**
E. coli is a type of coliform bacteria that is found in the intestines of warm-blooded animals, including humans and livestock. While most strains of E. coli are harmless, some can cause serious illness, including diarrhea, vomiting, and even kidney failure. The presence of E. coli in drinking water is a clear indicator of fecal contamination and poses a significant risk to human health. Both total coliforms and E. coli can be tested using standard microbiological methods, such as membrane filtration or the multiple-tube fermentation technique. These tests can determine the presence or absence of these bacteria in water samples, as well as the concentration of bacteria in the sample. Regular monitoring of total coliforms and E. coli in drinking water sources is important to ensure that the water is safe for consumption and to identify any potential sources of contamination.

2. Fecal coliforms:

- Fecal coliforms are a group of bacteria that are found in the intestines of warm-blooded animals, including humans and livestock, and are used as an indicator of fecal contamination in water.

- Fecal coliforms are a subgroup of the larger group of coliform bacteria, which also includes total coliforms and E. coli.
- However, unlike total coliforms, fecal coliforms are specifically associated with fecal matter and are therefore considered a more accurate indicator of fecal contamination in water.
- The presence of fecal coliforms in water is a clear indication of potential contamination with pathogens that can cause serious illness, including diarrhea, vomiting, and other gastrointestinal symptoms.
- High levels of fecal coliforms in water can also indicate the presence of other harmful organisms, such as viruses or parasites.
- Fecal coliforms can be tested using standard microbiological methods, such as membrane filtration or the multiple-tube fermentation technique.
- These tests can determine the presence or absence of fecal coliforms in water samples, as well as the concentration of bacteria in the sample.
- Regular monitoring of fecal coliform levels in drinking water sources, as well as in recreational waters such as swimming pools and lakes, is important to ensure that the water is safe for human contact and consumption, and to identify any potential sources of contamination.

3. Total bacterial count:

- Total bacterial count is a measure of the total number of bacteria present in a given sample. It is commonly used to assess the microbial load or contamination level of food, water, and other environmental samples. Total bacterial count can be determined using various methods, including:
 - **Plate count method:** This method involves culturing the sample on a nutrient agar plate and counting the number of colonies that grow after incubation. The number of colonies is then multiplied by a factor to estimate the total bacterial count in the original sample.
 - **Microscopic count method:** This method involves directly counting bacterial cells using a microscope and a specialized counting chamber.
 - **Turbidity measurement:** This method involves measuring the cloudiness of the sample using a spectrophotometer or other instrument, which is then correlated to the bacterial count based on a calibration curve.
- Total bacterial count can be used as an indicator of the overall cleanliness and hygiene of a sample. In the food industry, for example, high total bacterial counts can indicate poor sanitation practices, while in water quality testing, high total bacterial counts can indicate potential health risks from exposure to pathogens. It is important to note that total bacterial count does not provide information about the specific types of bacteria present, and therefore additional testing may be necessary to identify any harmful bacteria that may be present in the sample.

4. Algae and cyanobacteria

- Algae and cyanobacteria are photosynthetic microorganisms commonly found in water bodies such as lakes, rivers, and ponds.
- They are important components of aquatic ecosystems, as they play a crucial role in the food chain and contribute to the production of oxygen through photosynthesis.

- However, excessive growth of algae and cyanobacteria, known as an algal bloom, can cause a range of environmental problems, including decreased water clarity, oxygen depletion, and production of toxins harmful to human and animal health.
- Biological examination of water samples can be used to assess the presence and abundance of algae and cyanobacteria, as well as to identify any harmful species.
- This examination can be done by analyzing the water sample under a microscope, using staining techniques to visualize the cells, and identifying the species based on their morphological features.
- In addition to microscopic examination, molecular techniques such as polymerase chain reaction (PCR) can also be used to detect and identify specific species of algae and cyanobacteria, including those that produce harmful toxins.
- Regular monitoring of algae and cyanobacteria in water bodies is important to identify potential harmful algal blooms and to take appropriate measures to mitigate their impacts on the environment and public health.

5. Viruses:

- Viruses are microscopic infectious agents that can cause a range of diseases in humans and animals.
- They are also commonly found in water and can pose a risk to public health if they are present in high concentrations.
- Biological examination of water samples can be used to detect the presence of viruses and determine their concentration.
- This examination involves filtering the water sample through a specialized filter that can capture viruses, and then extracting and concentrating the virus particles from the filter.
- There are several methods available to detect and quantify viruses in water samples, including:
 - a) Cell culture: This method involves infecting a specific type of cell with the virus and monitoring the growth of the virus in the cell culture over time.
 - b) Polymerase chain reaction (PCR): This method uses specific primers to amplify and detect the viral DNA or RNA in the water sample.
 - c) Enzyme-linked immunosorbent assay (ELISA): This method uses antibodies to detect the presence of viral antigens in the water sample.
- Monitoring of viruses in water is particularly important for water sources used for drinking and recreational purposes, as they can cause a range of illnesses, including gastroenteritis, hepatitis, and respiratory infections.
- In addition to routine monitoring, specific measures such as disinfection with chlorine or ultraviolet light can be used to reduce the concentration of viruses in water.

Physical examination provides information about the appearance and basic physical characteristics of the water, while chemical examination measures the concentration of various chemical compounds present in the water. Biological examination identifies and quantifies microorganisms present in the water sample, which can indicate potential health or environmental risks. By conducting a comprehensive examination of water samples that includes physical, chemical, and biological analysis, experts can develop a complete picture of the quality and suitability of the water for various purposes.

This information can then be used to make informed decisions about how to treat and manage the water to protect public health and the environment.

Quality requirements

The quality requirements for water and wastewater can vary depending on the intended use of the water and the regulatory requirements of the country or region. Here are some general quality requirements for water and wastewater:

Drinking water: Drinking water must meet strict quality standards to ensure that it is safe for human consumption. These standards typically include limits on parameters such as turbidity, pH, total dissolved solids, bacterial and viral pathogens, heavy metals, and organic pollutants.

Irrigation water: Water used for irrigation must meet standards that ensure that it will not harm crops or soil quality. These standards typically include limits on parameters such as salinity, pH, total dissolved solids, and heavy metals.

Industrial water: Water used in industrial processes must meet quality standards that ensure that it will not harm equipment or products. These standards typically include limits on parameters such as hardness, alkalinity, acidity, suspended solids, and organic pollutants.

Recreational water: Water used for recreational purposes such as swimming must meet quality standards that ensure that it is safe for human contact. These standards typically include limits on parameters such as bacterial and viral pathogens, turbidity, and pH.

Wastewater: Wastewater must meet quality standards before it can be discharged into the environment. These standards typically include limits on parameters such as BOD, COD, total suspended solids, nitrogen, and phosphorus.

Regulatory agencies such as the Environmental Protection Agency (EPA) in the United States and the Central Pollution Control Board (CPCB) in India have established specific quality requirements for water and wastewater that must be met in order to protect public health and the environment.

Monitoring water and wastewater quality is important to ensure compliance with these standards and to identify potential pollution sources.

Standards for water and wastewater quality

Standards for water and wastewater quality are set by regulatory agencies in each country or region. These standards specify the maximum allowable concentration or level of various physical, chemical, and biological parameters that are considered safe for human health and the environment. Here are some examples of water and wastewater standards in different regions:

United States Environmental Protection Agency (EPA) - Safe Drinking Water Act: The EPA sets standards for drinking water quality in the United States. These standards include maximum contaminant levels for various parameters such as disinfectants, disinfection by products, inorganic and organic chemicals, and microbial contaminants.

World Health Organization (WHO) - Guidelines for Drinking-water Quality: The WHO sets global standards for drinking water quality, which are used as a reference by many countries.

These guidelines cover a range of parameters such as microbiological, chemical, and radiological contaminants.

European Union (EU) - Drinking Water Directive: The EU sets drinking water standards for its member states through the Drinking Water Directive. This directive specifies maximum levels for various parameters such as microbiological and chemical contaminants, and requires monitoring of these parameters.

Central Pollution Control Board (CPCB) - National Water Quality Monitoring Programme: The CPCB sets water quality standards for India through its National Water Quality Monitoring Programme. These standards include maximum permissible limits for various parameters such as pH, dissolved oxygen, BOD, COD, and heavy metals.

Australian Drinking Water Guidelines: The Australian Drinking Water Guidelines set standards for drinking water quality in Australia. These guidelines specify maximum levels for various parameters such as microbiological, chemical, and radiological contaminants.

Canadian Water Quality Guidelines: The Canadian Water Quality Guidelines set standards for water quality in Canada. These guidelines cover a range of parameters such as microbiological, chemical, and physical contaminants.

It's important to note that different countries and regions may have different standards for water and wastewater quality depending on their local environmental and health concerns. Compliance with these standards is monitored through regular water quality testing and analysis

The Central Pollution Control Board (CPCB) is the national regulatory body for water and wastewater quality in India. CPCB has established standards for water and wastewater quality through the National Water Quality Monitoring Programme, which sets maximum permissible limits for various parameters in surface water, groundwater, and wastewater.

Here are some examples of the CPCB standards for water and wastewater quality:

pH: The maximum permissible limit for pH in surface water and groundwater is 8.5-9.2.

Dissolved Oxygen (DO): The minimum permissible limit for DO in surface water and groundwater is 5 mg/L.

Biological Oxygen Demand (BOD): The maximum permissible limit for BOD in surface water and groundwater is 3 mg/L.

Chemical Oxygen Demand (COD): The maximum permissible limit for COD in surface water and groundwater is 10 mg/L.

Total Coliforms: The maximum permissible limit for total coliforms in surface water is 5000 MPN/100ml and in groundwater is 50 MPN/100ml.

Nitrate: The maximum permissible limit for nitrate in surface water and groundwater is 45 mg/L.

Total Dissolved Solids (TDS): The maximum permissible limit for TDS in surface water and groundwater is 500 mg/L.

Heavy metals: The maximum permissible limit for heavy metals such as lead, cadmium, and mercury in surface water and groundwater is 0.01 mg/L.

It's important to note that CPCB standards may differ for different types of water sources and uses, such as drinking water, irrigation, and industrial use. Compliance with these standards is monitored through regular water quality testing and analysis.

Disposal of wastewater on land and water bodies

The disposal of wastewater on land and water bodies can have significant environmental and health impacts. Here are some common methods of wastewater disposal and their potential impacts:

Land application: Wastewater can be applied to land for irrigation, fertilization, and groundwater recharge. This method can be effective in treating wastewater and providing nutrients to crops, but it may also pose a risk to human health and the environment if contaminants are present in the wastewater. Proper management practices, such as monitoring and controlling application rates and timing, can help reduce these risks.

Ocean discharge: Wastewater can be discharged into oceans or other large bodies of water. This method can be effective in diluting and dispersing the wastewater, but it may also cause environmental harm if the wastewater contains high levels of nutrients, pathogens, or toxic chemicals. Regulation and monitoring of ocean discharge is important to minimize these impacts.

River discharge: Wastewater can be discharged into rivers or other smaller bodies of water. This method can be effective in transporting wastewater away from populated areas, but it may also cause water quality problems downstream if the wastewater contains high levels of nutrients, pathogens, or toxic chemicals. Regulation and monitoring of river discharge is important to minimize these impacts.

Groundwater recharge: Wastewater can be treated and then injected into the ground for groundwater recharge. This method can be effective in replenishing depleted aquifers and treating wastewater, but it may also cause groundwater contamination if the wastewater contains contaminants that are not adequately treated. Proper treatment and monitoring of the wastewater is essential to minimize these risks.

In general, the best method of wastewater disposal depends on local environmental and health concerns, as well as the availability of treatment and disposal options. Proper treatment and management of wastewater is critical to minimizing the potential impacts of disposal on land and water bodies.