CAI 334 IRRIGATION WATER QUALITY AND WASTE WATER MANAGEMENT

UNIT V NOTES

WATER QUALITY MANAGEMENT

Definition According to Central Pollution Control Board (CPCB) of India, Water quality isdefined as “those physical, chemical or biological characteristics of water by which the user evaluates the acceptability of water”. Water quality management deals with all the aspects ofwater quality including different beneficial uses of water, the uses consist of intake from on site and from in stream flow. For managing water quality both natural and anthropogenic factors should be taken into consideration. For the overall fitness of a human being and other organisms the water should be pure, wholesome, and potable.

Agencies for setting Water Quality Standards

There are many sources of water quality criteria and standards. Worldwide many developed countries have set their own water quality standards. For, e.g., in Europe, there are European Drinking Water Directive and in the United States the United States Environmental Protection Agency (EPA) establishes standards as required by the Safe Drinking Water Act. For the countrieswithout any standards, World Health Organization (WHO) publishes guidelines on the standards.

EPA: In the USA, the federal legislation controlling drinking water quality is the Safe Drinking Water Act (SDWA) which is implemented by the EPA, mainly through state or territorial primacy agencies. United States EPA has set Maximum Contaminant Levels standards that are the legal threshold limits on the amount of a substance that is allowed in public water systems under the Safe Drinking Water Act. To set a maximum contaminant Level for a contaminant, EPA first determines how much of the contaminant may be present with no adverse health effects. EPA's compilation of national recommended water quality criteria consist of the protection of aquatic life and human health in surface water for approximately 150 pollutants. It provides guidance for states and tribes to use to establish water quality standards and ultimately provide a basis for controlling discharges or releases of pollutants.

The standards were set with the following objectives:

- To assess the quality of water resources
- To check the effectiveness of water treatment and supply by the concerned authorities.
- Different parameters (physical, chemical and biological, toxic substances) covered include color, odour, pH, total dissolved solids, hardness, alkalinity, elemental compounds such as iron, manganese, sulphate, chloride, arsenic, zinc and coliform bacteria etc.

The standard categorises various characteristics as essential or desirable. It mentions the desirable limit and indicates its background so that the implementing authorities may exercise their discretion, keeping in view the health of the people, adequacy of treatment etc.

- These parameters apply to drinking water supplied by different Authorities/Agencies/ Departments of State Governments and Central Government, wherever applicable in the country.

In formulation of the standard for drinking water BIS has taken into consideration the following publications:
 International Standards for Drinking Water issued by World Health Organization, 1984.

- Manual of Standards of Quality for Drinking Water Supplies. Indian Council of Medical Research 1971.
- Manual on Water Supply and Treatment (third revision) CPHEEO, Ministry of Urban Development, 1989.

Need for management of water quality

- Fresh water is a precious resource but due to different anthropogenic activities like change in agriculture practices, excessive use of fertilizers, pesticides, herbicides have added excess nutrient load in water bodies have created the problem of eutrophication that have affected the water quality badly.
- Siltation due to erosion, industrialization, sewage discharge and other domestic activities have also deteriorated the water quality of lakes, rivers, groundwater as well as coastal waters

worldwide.

- There is an urgent need for addressing fecal pollution as there is a direct relationship among sanitation, nutrition and health.

- There is a need for collaboration of various pollution control bodies, Water Supply and Public Health Agencies and different scientific agencies to solve the problem of water scarcity and its management. It will help in analyzing the present and future scenario of our country through a proper planning for water usage and availability.

- The availability of sufficient water will not only meet the energy needs but will also ensure food security in India.

Factors affecting water quality

Different factors contribute to the quality of surface as well as groundwater. Water flowing over orunder the land surface can undergo different physical and chemical changes which lead to change in water quality. These changes can be due to natural or anthropogenic activities. Some important factors that affect water quality have been discussed as under:

1. Natural factors a).Weathering of bedrock minerals : The physical weathering causes mechanical breakdown of the bedrock into rock fragments and sediments that are being exposed to atmosphere and hydrosphere whereas chemical weathering chemically break down bedrock minerals into smaller fragments with the help of water and CO2. Both physical and chemical weathering effects the composition of natural waters. Increased CO2 concentration in water due to natural or man- made activities enhances the acidity of water. Chemical weathering can even reduce the rock strength that can affect the erosion rates of rivers. Suspended sediments can reduce water clarity and quality whereas fine sediments can affect aquatic organisms like clogging fish gills. If harmful substances such as heavy metals get attach to sediments and seep down into the underground water it can affect the water quality.

a). Atmospheric processes involving evapotranspiration : Evapotranspiration can cause loss of considerable amount of water into the atmosphere from the soil surface and water bodies. In arid zones where low humidity prevails, considerable amount of water is lost in evaporation from soil surface. Water bodies with no or few vegetation on their banks have high temperature that leads toloss of water and can affect its quality.

b). Deposition of dust, salt and air pollutants by wind: Dust, salt and other pollutants from the atmosphere may be deposited directly onto the surface water bodies or by wind. Pollutants from atmosphere like gases and particulates released from different sources such as vehicular emissions, crop residue burning and industrial emissions releases compounds of nitrogen, sulphur, and heavy metals. These substances when deposited directly onto the surface of water bodies contaminate it and may cause its acidification ultimately affecting the aquatic life.

c). Natural disasters like floods and draught: Floods and droughts may bring about changes in water quality through dilution or concentration of dissolved substances. If there are low river flow rates and the temperature of atmosphere is high then the concentration of dissolved substances increases and the level of dissolved oxygen decrease that ultimately affects the water quality and the aquatic life.

2. Anthropogenic activities

a). Over-exploitation: The major part of flow of water (about 69–96%) in most of the Indian riversoccurs during monsoon season that results in limited access to freshwater. Other activities like unsustainable use of water for industries, agriculture and domestic use etc. has resulted in shrinking or drying up of both groundwater and surface water bodies. The main means ofirrigation in the country are canals, tanks and wells, including tube-wells. Wells, including dug wells, shallow tube-wells and deep tube wells provide about 61.6% of water for irrigation,followed by canals with 24.5%. States such as Gujarat and Tamil Nadu showed some improvement, traditional farming states such as Punjab and Haryana have witnessed rising exploitation of groundwater resources.

b). Agricultural runoff and change in irrigation practices: To meet the needs of the growing population, use of chemical fertilizers and pesticides have increased manifolds in agriculture inthe recent years. Major portion of freshwater is used in agriculture in India. These chemicals particularly pesticides are recalcitrant in nature that leach into the groundwater and pollute and make it a public health hazard for e.g., Selenium (Se) is a heavy metal that is present naturally in soil but with increase irrigation practices it accumulates in the soil, leaches to groundwater and causes toxic effects to both animals and humans .

c). Domestic and municipal waste: Sewage pollution accounts for more than 75 % of the surface water contamination in India. Garbage and domestic waste is directly dumped into water bodies. The municipalities dispose off their treated or partly treated even untreated wastewater intonatural drains joining rivers or lakes. It is estimated that around 80% of water consumed by a household is let of to the drains of sewers as wastewater.

d).Pathogenic pollution: One of the major water quality threats is in India is water borne diseases. This is mainly due to inadequate supply of water, improper treatment of wastewater, contamination of surface water and groundwater by sewer overflows, runoff from animal feedlots or pastures and leaking septic tanks that results in spread of a number of diseases like diarrhea, cholera, dysentery, typhoid and other enteric diseases particularly to the people residing in rural areas especially children and old age people.

e). Geogenic Pollution: The geogenic problems are mainly caused due to mixing of a large amount of contaminants like Fluoride, arsenic etc in the water. Arsenic is found in groundwater most commonly as the reduced species arsenite and the oxidized species arsenate. The acute toxicity of arsenite is greater than arsenate. WHO studies indicated that 20% of 25,000 boreholes tested in Bangladesh had arsenic concentrations exceeding 50µg/l. The occurrence of fluoride causes dental fluorosis when fluoride concentrations in groundwater exceed 1.5 mg/l.

f). Eutrophication: Globally, one of the most prevalent water quality problems is eutrophication. It results from high-nutrient loads mainly phosphorus and nitrogen from industries and agriculture runoff, domestic sewage that impairs the beneficial uses of water. Eutrophication leads to depletion of oxygen to a large extent resulting in the death of aquatic organisms and thusunbalanced aquatic ecosystem. Lakes and reservoirs are particularly more susceptible to the negative impacts of eutrophication as they act as an integrating sink for pollutants from their drainage basins due to their relatively longer water residence time. According to CPCB in metropolitan cities of India, increase of nitrates and pathogens in groundwater is a major concern whereas pollution is rising in many industrial areas like Balotra, Pali, Jodhpur (Rajasthan),Ahmadabad, Jetpur (Gujarat)

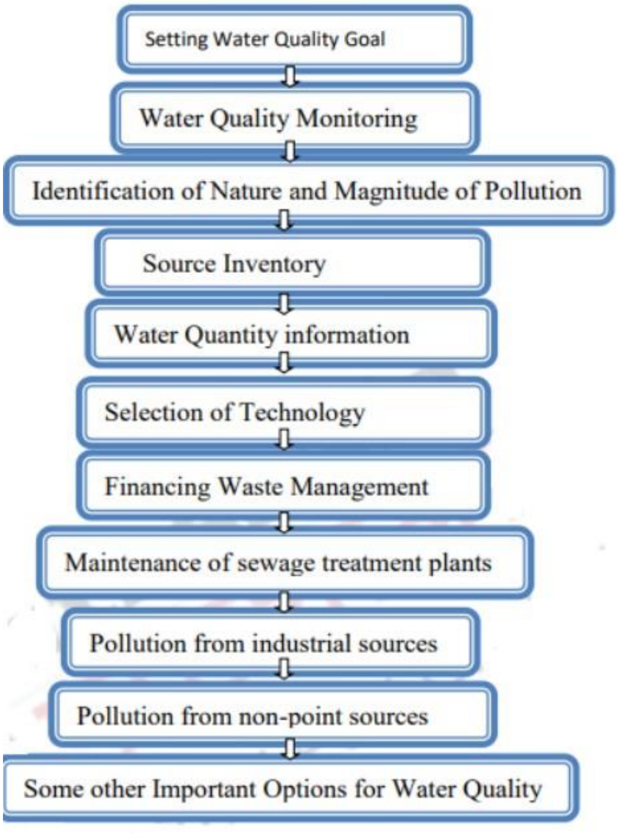
g). Salinity: Increased irrigation activities, discharges of industrial wastewaters or agricultural return water and seawater intrusion in coastal areas has led to enhanced groundwater salinity that makes the water unfit for drinking and irrigation.

h).Toxicity: Discharge of toxic effluents particularly heavy metals from industries and agriculturerun off deteriorate the quality of water making it unfit for aquatic life, human consumption and forirrigation purposes. Toxic substances especially carcinogens lead to bio- magnification and bioaccumulation thereby causing severe damage to aquatic life. For e.g., dye, textile and wool industries release cadmium, nickel, cobalt in wastewater. Similarly, Iron and steel industriesrelease Nickel, Cadmium, and iron with high chloride content.

Steps for Water Quality management

Ecological Health of water body

A large number of aquatic ecosystems support rare and threatened species and are ecologically very sensitive systems that require special protection. So, it is important that in water quality management the ecological health of the water bodies should be given extreme priority. In India the scenario is changing and now such efforts are reflected in the policy planning and legal framework for water quality protection. According to CPCB, the following steps (Fig. 1) shouldbe consider while checking for water quality management.



a). **Step-I Setting Water Quality Goal** The very first step in preparation of water quality management plan is to identify water quality goal for a water body under consideration. For this purpose firstly use(s) of water of water body like fisheries, agricultural uses, navigation purpose etc should be identified. In India, the CPCB, an apex body for the management of water quality including coastal waters in the country, has developed a concept of “designated best use”. The concept states that if a water body is used for more than one purpose then, the use that demands highest quality of water is called its “designated best use”. According to best use the particular water body is designated under different classes. This classification helps the water quality managers to identify the needs of water quality restoration programmes in the country. For e.g., Ganga Action Plan and the National River Conservation Plan are outcome of such exercise.

b). **Step-II .Water Quality Monitoring** Water quality monitoring is done to know the existing quality of water of a particular water body. For this Water Quality Assessment Authority has notified a Protocol for “Water Quality Monitoring”.

Water Quality Monitoring Protocol 1. Objectives: The main objectives for water quality monitoring for both surface and ground water are: monitoring for establishing baseline water quality observing continuously changes in water quality supervision of water for irrigation andother agricultural uses calculation of changes in different water constituents of interest groundwater pollution control and its management

2. Frequency and Parameters

2.1 Groundwater • Firstly all stations under study should be classified as baseline stations. Then 20 to 25% of stations should be classified as trend or trend-cum-surveillance stations. These stations can be further reclassified after the data has been collected for consecutive three years.

2.2 Surface Water • All the stations under study will be a combination of baseline and trend stations. For every two months for consecutive three years say in May or June, August, October, December, February, and April samples should be collected. This will result in generation of six samples every year.
from perennial rivers and about 3 to 4 samples from seasonal rivers. On the basis of the collected information, the stations will be then classified either as baseline, trend or flux station or they can even be further analyzed.

3. Sample Collection

3.1 Basic information

• Prior to one day before sampling the necessary preparations should be done. Before sample collection the containers should be properly rinsed with the sample three times to avoid any contamination. For proper mixing and analysis of sample a small air space should be left in the bottle. The sample containers should be properly labeled. For each sample a separate identification form should be filled.

3.2 Surface Water

• For surface water samples should be taken in a weighted bottle or DO samplers 30 cm below the water surface from a well-mixed section of the main stream. • For reservoir sites, samples should be taken from the outgoing canal but if no discharge is there in the canal then samples can be taken from the upstream side, directly from the reservoir. • The DO of the collected sample should be fixed instantaneously using chemical reagents.

3.3 Groundwater • For groundwater samples can be taken from following types of wells: v Open dug wells being used for domestic or irrigation water supply v Tube wells fitted with a hand pump for domestic water supply or irrigation v Piezometers, purpose-built for recording of water level.

4. Analysis and Record

4.1 Sample Receipt Register

• Each laboratory should have a proper register for registration of collected samples. 4.2 Work Assignment and Personal Registers • For assignment of work the laboratory incharge should maintain a proper register. • The laboratory analysts should mark the samples and they should have their own registers for maintaining the records.
4.3 Analysis Record and D Records of all the required parameters should be analyzed under the water quality monitoring programme.

c). Step-III. Identification of Nature and Magnitude of Pollution The water quality in different seasons of different rivers is analysed and compared with the desired water quality as per the goals set in step-I. On the basis of the observed data polluted water bodies in the country are identified which helps in identifying the gaps that will finally help in identification of nature and magnitude of pollution that are needed to be controlled. For this, in India, CPCB in collaboration with the concerned State Pollution Control Boards performs this task. It collects and analyses the water quality data at fixed number of locations. If a water body is identified as polluted then the respective State Pollution Control Boards/ Pollution Control Committees can be requested to restore the water quality. For e.g., taking BOD as an indicator of organic pollution an attempt is made to estimate the riverine length under different levels of pollution as shown below:

High Pollution: BOD > 6 mg/l Moderate Pollution: BOD = 3–6 mg/l Relatively clean: BOD < 3 mg/l

d). Step IV Source Inventory The point as well as non-point sources of pollution should be identified to understand the water quality of a water body. For point sources, the number of outfalls joining the water body should be inventoried. The quality and quantity of wastewater flowing through each outfall should be measured and then pollution load joining per unit time (normally per day) for 24/48/72 hours should be measured in terms of important pollutants. In case of nonpoint sources the human activities like open defecation, application of agrochemicals, industrial as well as commercial wastes from the upstream catchments area of the water should be inventorised. This monitoring and surveillance of water resources and the waste input helps to improve compliance, application of environmental impact assessment and geographic information systems. It also helps in appropriate national land use to prevent further degradation.

e). step V. Water Quantity information The flow data for different water bodies like in case of rivers or streams is acquired at least from the last 5 years or more from Central Water Commission (CWC), concerned State Irrigation Departments whereas for lakes and other reservoirs the data should be collected at least from the last 5 to 10 years. The mass balance should be carried out to estimate the dilution that should be available in last 5 years in different seasons. The assimilation capacity should be estimated by applying simple streeter-phelps equation to estimate the extent of pollution and the amount of excessive pollution load that is needs to be reduced to achieve the desired quality of water.

f). Step VI. Selection of Technology The Selection of technology for wastewater treatment depends upon its characteristics and on the treatment objectives. The technology should consider the technical and financial feasibility of wastewater treatment. The effluent wastewater should be treated with the aim of providing it for different uses like for public outdoor bathing, irrigation and promoting the reuse of water. The proper collection, treatment and disposal of wastewater are vital for controlling waterborne diseases. This requires non-mechanized treatment technologies like stabilization ponds, constructed wetlands etc that can improve the secondary and tertiary treatment. Furthermore technological development needs to be done as these techniques require large surface areas.

g). Step -VII. Financing Waste Management Effluent Tax One of the approaches to tackle the problem of waste management and water quality degradation is to apply the 'polluter pay principle' in which major portion of the cost for waste management should be borne by the dischargers of that pollutant like urban dwellers or industries .This approach will help in waste reduction, treatment and will also generate source of revenue for financing costly wastewater treatment investments. Taxes or fees can encourage urban organizations to adopt different water saving technologies like using left over water after cloth washing and water from water purifiers for floor cleaning, in kitchen and in garden, using water-saving devices like low volume flush toilets that uses less volume of water per flush than a standard toilet. Further educational campaigns for water conservation methods should be organized.

Benefit Tax The benefit tax should be charged from the beneficiaries from waste management. The waste management benefits the following: 1. Local citizens residing in the area 2. Improvement of public health 3. Protection and improvement of environment 4. Improvement of and availability of water resources like clean water supply for drinking and for irrigation purposes.
5. Industrial use 6. Enhanced tourism

h). Step VIII. Maintenance of sewage treatment plants (STPs) The operation and maintenance of the sewage treatment plants and pumping stations requires money and therefore it is a money intensive work. Untrained staff normally runs the STPs. Also, the operational parameters are not analyzed regularly. The concerned agencies should provide adequate funds and trained staff as well regular inspection should be done for the proper functioning and the maintenance of STPs. Facilities like public toilets, electric crematoria, etc. should be maintained by the local authorities. The treated effluent can be used for different activities like for irrigation, treated sludge as a manure etc.

i). Step -IX. Pollution from industrial sources v Control of pollution at source The industries should follow the proper recommended procedure for treatment of waste water effluent before discharging it into a water body. At every step of product generation water saving methods should be followed. Those industries who have given commitment under Corporate Responsibility on Environment Protection (CREP) should properly follow it. Advanced and new emerging technologies such as aerobic composting, vermiculture, etc. at secondary treatment step should be adopted for reduction of organic waste. More attractive incentives for pollution control measures need to be given by the government. A regular auditing of the industries by State Pollution Control Boards of the respective state should be done to control the pollution.

v Reuse or recycling of treated industrial waste and resource recovery Reusing and recycling of industrial wastes would help in reducing the pollution. The segregation of waste water streams would help in reducing waste water volume. For e.g., the quantity of wastewater generated in a continuous fermentation distilleries is 7 liters per liter of alcohol produced, as compared to 14–15 liters per liter of alcohol produced in batch fermentation process distilleries. Similarly in a sugar industry if recycling techniques like recycling wash and reboiler systems are adopted then the overall quantity of effluent generated could be reduced from 300 liters to 50 liters per ton of cane crushed. Also in paper and pulp industries, the wastewater monitored in motor vehicle emissions and stricter rules for industrial waste disposal as well as ecologically sound integrated pest management policy should be evolved.

k). Step -XI. Other significant Options for Water Quality Management The following measures can be considered for solving the problem of water scarcity and for restoration of water bodies

Encouraging the traditional practices of water conservation like revive of bawdies(old watertanks) in water deficient areas as well encouragement of integrated watershed management can provide relief from water shortage to some extent. The government as well the local residents of the area are required to collaborate together. In March, 2017 the Uttarakhand High Court has recognized the rivers Ganga and Yamuna as a living entity, which means that anybody found polluting the river would be seen as harming a human being

- Conservation of rain water by construction of rain water harvesting system or underground pit formation. Contour terraces can help to retain soil at its place and prevent it from erosion especially in hilly areas like in Himalayas and in North-East part of the country
- Artificial recharge of water table can be done by digging recharge wells that can transfer water from the surface to underground in the fresh water aquifers. Another option can be spreading of water to allow the water to remain in contact with soil that ensures the maximum quantity of water to seep underground. This has been done in different states of the country like Maharashtra and Gujarat.
- Adoption of drip and sprinkler irrigation: Drip irrigation where a limited area near plant is irrigated could be the suitable method of irrigation in water scarce areas. This method is Particularly useful in row crops. Similarly sprinkler method is also suitable for such water scarce areas. Today a variety of sprinkler systems ranging from simple hand-move to large self-propelled systems are used worldwide. About 80% water consumption can be reduced by drip irrigation system.
- Selection of crop varieties: Abiotic stress resistant crops like heat and cold tolerant varieties do not require more water for irrigation than the older ones. They are also disease

tolerant that reduces the excess application of pesticides. Overall these types of crops reduce the economic burden on the farmers. For e.g. Sahbhagi Dhan (IR74371-70-1-1) have been developed through conventional breeding programme and are being disseminated to farmers in drought-prone areas.

- Reducing evapotranspiration: Evapotranspiration losses can be reduced by reducing the evaporation from soil surface and transpiration from the plants particularly in arid and semi-arid areas. This can be prevented by putting water tight mulches on the soil surface, zero or no tillage practice, wind breaks. Use of materials like papers, plastic foils on the surface can also prevent evaporation losses. Use of drought tolerant species and practicing dry farming. Regular removal or clearing of weeds from the fields can reduce competition among the crop plants for nutrients, water and sunlight that can affect overall production.
- Conservation of water in domestic use: Water can be easily conserved at household level with minor changes in regular activities. Closing of taps while not in use, preventing leakage of taps, use of left over water after cloth washing and water from water purifiers for cleaning purposes as well as in garden. Use of low volume flush toilets than standard toilets can alone save a lot of water.

Water quality management

Water quality management involves the assessment, protection, and improvement of water resources to ensure they meet specified standards for various uses, including drinking, industrial processes, agriculture, and ecosystem health. Effective water quality management encompasses monitoring, regulation, and remediation efforts. Here's a detailed overview:

1. Monitoring and Assessment: Water Quality Parameters: Regular monitoring of key parameters such as pH, dissolved oxygen, nutrients, heavy metals, pathogens, and other contaminants. Sampling: Collecting water samples from various sources, including rivers, lakes, groundwater, and treated wastewater. Data Analysis: Analyzing collected data to assess water quality trends and identify potential issues.

2. Water Quality Standards and Regulations: Establishment of Standards: Governments and regulatory bodies set water quality standards based on health, environmental, and intended use criteria. Compliance Monitoring: Ensuring that water bodies and water sources meet established standards through routine monitoring and assessment. Enforcement: Implementing and enforcing regulations to address non-compliance and prevent pollution.

3. Source Water Protection: Watershed Management: Protecting the upstream areas of water bodies to prevent contamination from land-use activities, agriculture, and urban development. • Land Use Planning: Implementing zoning and land use practices that minimize the impact on water quality.

4. Treatment Technologies: Water Treatment Plants: Employing various treatment processes, such as coagulation, sedimentation, filtration, disinfection, and advanced treatment methods

(e.g., reverse osmosis), to ensure water meets quality standards. Wastewater Treatment: Treating wastewater before discharge to prevent pollution of receiving water bodies.

5. Stormwater Management: Green Infrastructure: Implementing green practices like permeable pavements, green roofs, and vegetated swales to reduce stormwater runoff and improve water quality. Detention Basins: Constructing basins to capture and treat stormwater, preventing contaminants from reaching water bodies.

6. Public Awareness and Education: Community Engagement: Involving communities in water quality management efforts and fostering a sense of responsibility. Education Programs: Informing the public about the importance of water conservation, pollution prevention, and sustainable water use.

7. Ecosystem-Based Approaches: Habitat Restoration: Rehabilitating degraded ecosystemsto improve water quality and biodiversity. Buffer Zones: Establishing vegetated buffer zonesalong water bodies to reduce nutrient and sediment runoff.

8. Emerging Challenges and Technologies: Emerging Contaminants: Addressing the presence of pharmaceuticals, personal care products, and other emerging contaminants in water. Data Analytics and Remote Sensing: Utilizing technology for real-time monitoring, data analysis, and remote sensing to enhance water quality management. 9. International Collaboration: Shared Water Resources: Collaborating with neighboring countries to manage shared water bodies and address transboundary water quality issues. Global Initiatives: Participating in global efforts to address water quality challenges and share best practices.

Water quality management is a multidisciplinary and collaborative effort involvinggovernments, regulatory bodies, industries, communities, and individuals. It plays a crucial role in safeguarding public health, protecting ecosystems, and ensuring sustainable water resources for current and future generations.

Principles of water quality

The principles of water quality provide a framework for understanding, assessing, and managing the characteristics of water that determine its fitness for various purposes, including drinking, recreation, agriculture, and ecosystem health. These principles guide the evaluation and protection of water quality and help establish standards and regulations. Here are key principles of water quality: 1. Chemical, Physical, and Biological Parameters: Chemical Composition: Assessing the presence and concentration of substances such as nutrients, heavy metals,pesticides, and organic compounds. Physical Characteristics: Examining physical attributes like temperature, turbidity, color, and conductivity. Biological Indicators: Monitoring the presence and health of organisms as indicators of water quality, such as macroinvertebrates or algae.

2. Water Quality Standards: Establishment: Defining specific criteria and limits for various water quality parameters based on health, environmental, and intended use considerations. Regulatory Compliance: Ensuring that water bodies meet established standards to protect public health and the environment.

3. Protective Action Levels: Precautionary Measures: Implementing protective action levels that trigger measures to prevent or mitigate potential water quality issues before they become severe.

4. Use Classifications: Categorization: Classifying water bodies based on their designated use, such as drinking water supply, recreation, fisheries, or industrial processes. Adaptability: Recognizing that different water bodies may have distinct classifications based on their ecological and human uses.

5. Non-Point Source Pollution: Addressing Runoff: Recognizing and managing pollutants originating from diffuse sources, such as agricultural runoff, urban stormwater, and atmospheric deposition.

6. Source Water Protection: Watershed Approach: Focusing on the protection of entire watersheds to prevent contamination at the source and maintain water quality.

7. Precautionary Principle: Anticipating Risks: Taking preventive measures even in the absence of complete scientific certainty when potential risks to water quality are identified.

8. Biological Integrity: Ecosystem Health: Evaluating the overall health and diversity of aquatic ecosystems as a measure of water quality. Biotic Indices: Using indicators such as macroinvertebrate indices to assess the biological integrity of water bodies.

9. Integrated Water Resources Management: Holistic Approach: Considering the interconnectedness of water quantity, quality, and ecosystem health in water resources management. Collaboration: Encouraging collaboration among various stakeholders for integrated decisionmaking.

10. Adaptive Management: Continuous Improvement: Recognizing that water quality management strategies should be flexible and adaptable based on evolving scientific understanding and changing environmental conditions.

11. Transboundary Cooperation: Shared Water Resources: Promoting cooperation and collaboration among neighboring regions or countries that share water bodies to address transboundary water quality issues.

12. Public Awareness and Participation: Informed Decision-Making: Encouraging public awareness, education, and engagement in water quality issues to foster a sense of shared responsibility.

Understanding and applying these principles help guide the development of effective water quality management programs, policies, and practices. The goal is to safeguard water resources for human use, protect ecosystems, and ensure the sustainable management of this vital natural resource.

Water quality classification

Water quality classification involves categorizing water bodies based on the concentrations of specific physical, chemical, and biological parameters. These classifications help in assessing the fitness of water for various uses, such as drinking, recreation, agriculture, and ecosystem health. The criteria for classification often depend on regulatory standards set by government agencies. Here are details about the key aspects of water quality classification:

1. Designated Uses: Categories: Water bodies are classified into different categories based on their designated uses, such as:

• Class I: Drinking water supply Class II: Recreation (e.g., swimming, fishing) Class III: Agricultural and industrial water supply Class IV: Ecosystem protection and wildlife habitat

2. Parameters Considered: Physical Parameters: Includes temperature, turbidity, color, and conductivity. Chemical Parameters: Involves measurements of nutrients, heavy metals, pesticides, organic compounds, and pH. Biological Parameters: Involves the health and diversityof aquatic organisms, often assessed using indicators like macroinvertebrates or algae.

3. Water Quality Standards: Establishment: Regulatory bodies set specific water quality standards for each parameter based on health, environmental, and intended use considerations. Numeric Criteria: Standards may include numeric concentration limits for certain pollutants or conditions.

4. Monitoring and Assessment: Regular Monitoring: Periodic sampling and analysis of water samples to assess the concentration of various parameters. Data Analysis: Collected data is analyzed to determine compliance with established water quality standards.

5. Adaptive Management: Flexibility: Recognizing that water quality conditions may change over time due to natural processes or human activities. Adjustments: Authorities may modify classifications and standards based on evolving scientific knowledge and changing environmental conditions.

6. Non-Attainment Areas: Identification: Areas where water quality standards are not met are designated as non-attainment areas. Remediation: Specific measures are often implemented to address and improve water quality in non-attainment areas.

7. Use of Classification in Management: Decision-Making: Water quality classifications guide decision-making processes related to water resource management, land use planning, and pollution control. Resource Allocation: Governments and agencies allocate resources for monitoring, enforcement, and remediation efforts based on the identified classifications.

8. Integration with Watershed Management: Watershed Approach: Recognizing that water quality is influenced by activities within the entire watershed. Holistic Management: Integrating water quality classifications into broader watershed management strategies.

9. Public Awareness: Communication: Communicating water quality classifications to the public to raise awareness and encourage responsible water use. Informed Decision-Making: Providing information to support informed decision-making by communities and individuals.

10. Transboundary Considerations: Shared Water Bodies: Collaborative efforts and agreements between regions or countries that share water bodies to address transboundary water quality issues. Consistent Standards: Working towards harmonized water quality classifications and standards to ensure consistency.

Water quality classification is a crucial aspect of water resource management, ensuring that water bodies are protected and used in a sustainable manner. Regular updates and adaptations toclassifications based on scientific advancements and changing conditions are vital for effectiveand adaptive water quality management.

Water quality standards

Water quality standards are established guidelines or criteria that define the acceptable levels of various physical, chemical, and biological parameters in water bodies. These standards are set by regulatory agencies to protect public health, aquatic ecosystems, and designated water uses such as drinking, recreation, and agriculture. The development and enforcement of water quality standards play a crucial role in water management and pollution control.

Here are details about water quality standards:

1. **Parameters Covered by Standards**: □ Physical Parameters: □ Temperature: Regulates the thermal conditions of water bodies to protect aquatic life. □ Turbidity: Measures the cloudiness or haziness of water caused by suspended particles. □ Color: Indicates the presence of dissolved organic matter. □ Chemical Parameters: □ Nutrients: Concentrations of nitrogen and phosphorus toprevent nutrient pollution. □ Heavy Metals: Limits on metals like lead, mercury, and cadmium dueto their toxicity. □ pH: Measures the acidity or alkalinity of water. □ Biological Parameters: □ Biotic Indices: Indicators of the health and diversity of aquatic ecosystems, such as macroinvertebrate indices.

2. **Numeric Criteria:** □ Specific Concentrations: Standards often include specific numeric criteria indicating the maximum allowable concentrations of pollutants. □ Varied Criteria: Different criteria may be set for different designated uses, such as drinking water, recreation, or aquatic habitat protection.

3. **Designated Uses:** □ Categories: Water bodies are classified into use categories (e.g., drinking water supply, recreation, aquatic habitat) based on their intended purpose. □ Use-Specific Standards: Standards are tailored to the specific needs of each use category.

4. **Human Health Criteria**: □ Drinking Water Standards: Set to protect human health from exposure to contaminants through the consumption of drinking water. □ Maximum Contaminant Levels (MCLs): The highest permissible concentration of a contaminant in public drinking water supplies.

5. **Ecological Criteria:** □ Aquatic Life Criteria: Established to protect aquatic ecosystems and organisms from the harmful effects of pollutants. □ Tolerance Limits: Indicate the maximum allowable concentrations that aquatic species can withstand without adverse effects.

6. **Anti-Degradation Policies**: □ Prevention of Deterioration: Policies aimed at preventing the deterioration of water quality in areas that meet or exceed established standards. □ Protection of High-Quality Waters: Measures to maintain and protect pristine or high-quality water bodies

7. **Risk Assessment:** □ Human Health Risk Assessment: Evaluation of potential health risks associated with exposure to contaminants in water. □ Environmental Risk Assessment: Assessing the impact of pollutants on aquatic ecosystems and wildlife.

8. **Enforcement and Compliance:** □ Monitoring Programs: Regular monitoring of water bodies to assess compliance with established standards. □ Permitting: Regulating discharges through permits that include compliance with water quality standards.

9. **Adaptive Management:** □ Review and Revision: Periodic review and revision of water quality standards based on new scientific information and changing environmental conditions. □

Flexibility: Adjustments to standards as needed to address emerging contaminants or unforeseen issues. 10. Public Participation: Public Input: Involving the public in the development andreview of water quality standards. Transparency: Ensuring transparency in the establishment andenforcement of standards.

11**. International Considerations**: Harmonization: Efforts to harmonize water quality standardsacross regions or countries, especially in the case of shared water bodies.

Water quality standards serve as a cornerstone for water resource management, providing a basis for regulatory actions, pollution prevention, and sustainable water use. Their continuous review and adaptation are essential to address emerging challenges and ensure the protection of water resources for both human and environmental well-being.