ENVIRONMENTAL CHEMISTRY

Editor:
Arun Sharma
Erum Gul Naz
Surabhi Singh
Kriti Tripathi
Insha Ara

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About the Book

Welcome to "Environmental Chemistry," a thorough examination of the intricate relationship between chemical processes and the environment. This book explores the fundamental principles, applications, and implications of environmental chemistry, offering insights into the dynamic interplay between human activities and the natural world.

In the opening chapter, "Fundamentals of Environmental Chemistry," readers establish a foundation for understanding environmental systems, including pollutant sources, reactions, and fates.

About the Editors:

Arun Sharma is currently serving as Associate Professor in the department of chemistry at Career Point University, Kota (Rajasthan). His fields of research are electrochemistry, material science, immunosensors, quantum dots and warfare agents. He obtained his Ph.D. in Chemistry from Jiwaji University Gwalior (NAAC A++), in 2016.

Dr. Erum Gull Naz is a famous researcher in theoretical and computational chemistry, specializing in chemical reaction dynamics, rate constants, thermodynamics, and kinetics. She earned her Ph.D. at the prominent Indian Institute of Technology (IIT) in Jodhpur, Rajasthan. Her study also includes organo-physical chemistry and interstellar chemistry, which investigate basic processes that occur on Earth and beyond.

Surabhi Singh, a visionary leader having exemplary research, academic, & administrative experience in the field of Higher Education, obtained her Ph.D. in Environmental Chemistry from Career Point University, Kota (Rajasthan). Currently, she is serving as Associate Professor cum Head of Department of School of Basic and Applied Sciences at Career Point University, Kota (Rajasthan).

Kriti Tripathi, a highly accomplished professional in the field of Higher Education, brings a wealth of research and academic experience to her endeavors.
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CP Tower, Road No.-1, IPIA, Kota (Raj.)
Email : publication@cpil.in

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Preface

Welcome to "Environmental Chemistry," a thorough examination of the intricate relationship between chemical processes and the environment. This book explores the fundamental principles, applications, and implications of environmental chemistry, offering insights into the dynamic interplay between human activities and the natural world.

In the opening chapter, "Fundamentals of Environmental Chemistry," readers establish a foundation for understanding environmental systems, including pollutant sources, reactions, and fates.

Chapter 2, "The Impact of Various Environmental Pollutants on the Earth's Atmosphere," illuminates diverse pollutants affecting air quality and climate dynamics.

"Thermodynamic Principles and Applications in Engineering," Chapter 3, explores thermodynamics' role in environmental processes and engineering solutions, emphasizing energy considerations in sustainability efforts.

Chapter 4, "Biochemical Kinetics: Exploring Gibbs Free Energy and Enzyme Catalysis," focuses on biological transformations' mechanisms and relevance to environmental systems.

Chapters 5 through 8 delve into atmospheric chemistry, examining processes leading to inorganic and organic particulate matter formation, thermochemical and photochemical reactions, and their implications for atmospheric composition and climate change.

Chapter 9, "Green Chemistry for Water: Sustainable Solutions to Pollution," addresses the nexus between chemistry and water quality, proposing innovative approaches for mitigating pollution and promoting sustainable water management.

Lastly, Chapter 10, "Soil Chemistry," explores chemical dynamics within terrestrial ecosystems, including soil pollution, nutrient cycling, and human activities' impact on soil health.This multidisciplinary journey deepens our understanding of environmental chemistry's role in addressing contemporary challenges and fostering sustainable solutions for our planet's well-being.

We extend our heartfelt thanks to Pramod Maheshwari, Sir, Managing Director and Chairman of Career Point University, Kota, as well as the HOD and Dean for their inspiration and support during the book's development. Gratitude is also expressed to our families for their constant encouragement, and to students and the teaching community for their support. Suggestions to improve the book's quality are welcomed.

Dr. Arun Sharma

Dr. Erum Gull Naz

Dr. Surabhi Singh

Ms. Kriti Tripathi

Ms. Insha Ara

Environmental Chemistry

Syllabus

Unit-I (Dr. Arun)

Stoichiometry, Gibb's energy, Chemical potential, Chemical equilibria, acid-base. reactions Solubility product, solubility of gases in water, the carbonate system, unsaturated and saturated hydrocarbons, Radio nuclides.

Unit -II (Dr. Surabhi)

Classification of elements, chemical speciation, Particles, ions and radicals in the atmosphere. Chemical processes for formation of inorganic and organic particulate matter. Thermochemical and photochemical reactions in the atmosphere

Unit - III (Dr. Erum)

First law of thermodynamics, enthalpy, adiabatic transformations, second law of thermodynamics, Carnot's cycle, entropy.

Unit - IV (Dr. Erum)

Gibbs free energy, chemical potential, phase equilibria, Gibbs Donnan equilibrium, third law of thermodynamics, enzymes catalysis, Michaelis/Menten equation.

Unit - V (Ms. Kriti Tripathi)

Oxygen and ozone chemistry, Chemistry of air pollutants, Photochemical Smog, Chemistry of water, concept of D.O., B.O.D., and C.O.D, water treatment : Sedimentation, Coagulation, Filtration, tertiary and advanced treatment, redox potential. Inorganic and organic components of soil, nitrogen pathways and NPK in soils.

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Editors

Dr. Arun Sharma, Dr. Erum Gull Naz

Dr. Surabhi Singh and Ms. Kriti Tripathi

Ms. Insha Ara

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CHAPTER 9

Green Chemistry for Water: Sustainable Solutions to Pollution

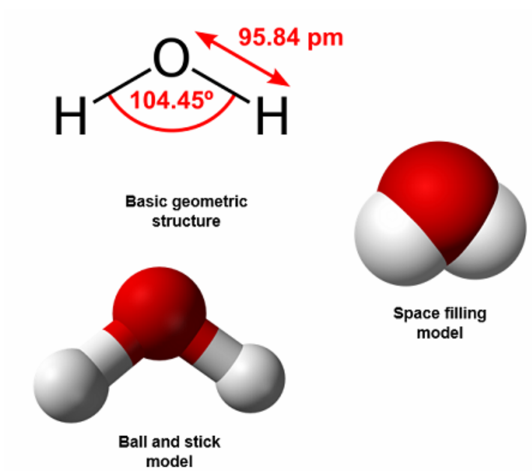
Ms. Kriti

Content-

1. The Chemistry of Water

a) **Introduction:** Water, which makes up around 71% of the Earth's surface and is transparent and odorless, is essential to life as we know it. Its distinct chemical makeup is essential for supporting a variety of life forms and influencing the environment. Comprehending the chemical composition of water is crucial for tackling global issues such as pollution, climate change, and water scarcity, in addition to satisfying scientific curiosity.

b) **Chemical Structure of Water (H_2O):**



Water; with the chemical formula H_2O, Composed of two hydrogen atoms joined by a single bond to an oxygen atom, water is a complicated chemical and physical substance. Its hydrogen atoms are bonded to the oxygen atom at a specific angle of 104.5°, giving it a distinctive electronic structure. Deuterium oxide (D_2O), commonly referred to as heavy water, is utilized as a neutron moderator in nuclear reactors and is essential in chemical research.

c) **Hydrogen Bonding:** Hydrogen bonding, a powerful intermolecular force, forms between a hydrogen atom and an electronegative atom in neighboring molecules. This interaction, common in water molecules and biological compounds, shapes properties like cohesion and high surface tension. Crucial in diverse scientific fields, hydrogen bonding influences material properties and contributes to the structure and function of biological molecules.

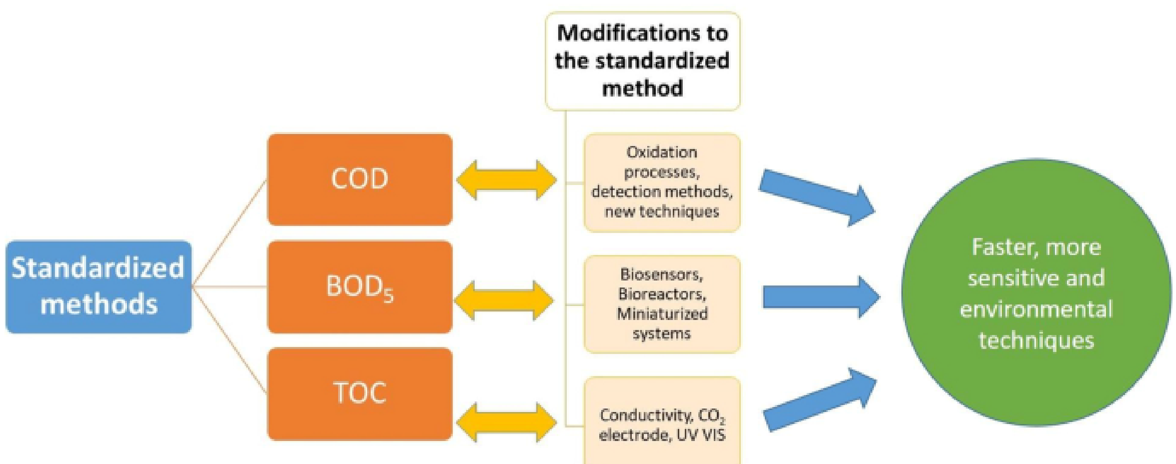
d) **Thermal Properties:** Water can absorb and store a lot of heat energy without greatly raising its temperature because it has a high specific heat capacity. To keep aquatic ecosystems' temperatures steady and to moderate Earth's climate, this characteristic is essential. A cooling effect that is essential for many different creatures and ecosystems is also provided by water's high latent heat of vaporization, which enables it to absorb heat during evaporation.

e) **Properties of Solvent:** Because of its nature of solubility, water is frequently referred to as the "universal solvent". It can interact with ions and polar molecules due to its polar nature, which facilitates the chemical reactions required for life. The movement of vital components inside water is made possible by the dissolving of salts, nutrients, and gasses.

f) **Density Anomalies:** The solid form of water, or ice, is less dense in comparison to its liquid form, exhibiting a unique density anomaly. When most materials freeze, they constrict and get thicker; however, water expands, which makes ice float. This characteristic keeps bodies of water from freezing solid and is essential for aquatic life to survive in cold climates.

2. Key Parameters In Assessing Water Quality D.O., B.O.D., And C.O.D.

a) **Introduction:** A vital component of environmental health, ecosystems, water quality affects human health, and a number of industrial operations. Scientists and environmentalists utilize dissolved oxygen (D.O.), chemical oxygen demand (C.O.D.), and biochemical oxygen demand (B.O.D.) to assess and manage water quality. These metrics offer insightful information about the condition and vigor of aquatic environments.

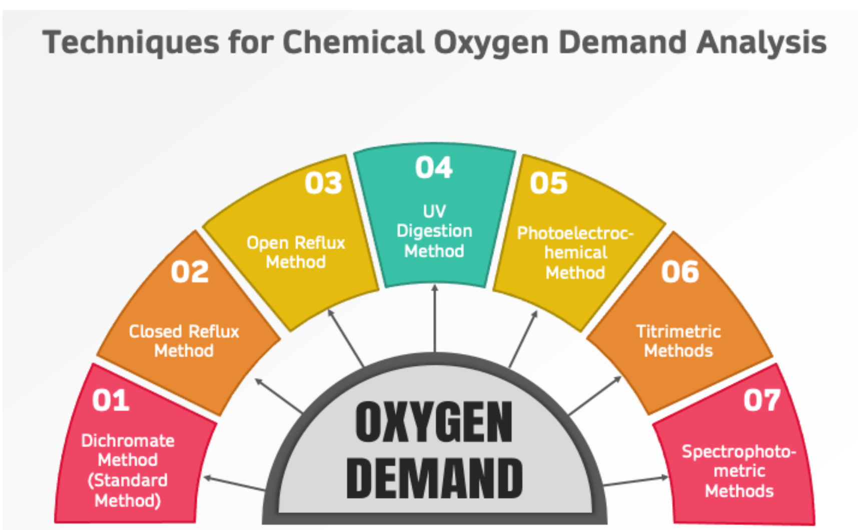


b) **Dissolved Oxygen (D.O.):** The amount of oxygen dissolved in water is measured by something called dissolved oxygen (D.O.). Because it is necessary for respiration and other metabolic activities, oxygen is vital for aquatic species to survive. Dissolved oxygen in water is mostly obtained by atmospheric exchange at the air-water interface. A number of variables, including salinity, temperature, and the presence of aquatic vegetation, might affect D.O. levels. Hypoxia brought on by low D.O. levels can have a detrimental effect on aquatic environments and the creatures that live there. In order to evaluate water quality and guarantee the health of aquatic life, D.O. monitoring is essential.

c) **Biological Oxygen Demand (B.O.D.):** Biological Oxygen Demand (B.O.D.) is a key metric for assessing water quality, indicating the amount of dissolved oxygen consumed by microorganisms during the decomposition of organic matter in a specified water volume over five days. High B.O.D. levels signal increased organic pollution, posing a threat to aquatic ecosystems by potentially depleting oxygen. Monitoring B.O.D. is crucial for managing quality of water and safeguarding aquatic life. Environmental agencies use B.O.D. measurements to regulate and mitigate the impact of human activities on water bodies, ensuring the preservation of healthy aquatic ecosystems.

BOD Level in mg/liter	Water Quality
1 - 2	**Very Good:** There will not be much organic matter present in the water supply.
3 - 5	**Fair:** Moderately Clean
6 - 9	**Poor:** Somewhat Polluted - Usually indicates that organic matter present and microorganisms are decomposing that waste.
100 or more	**Very Poor:** Very Polluted - Contains organic matter.

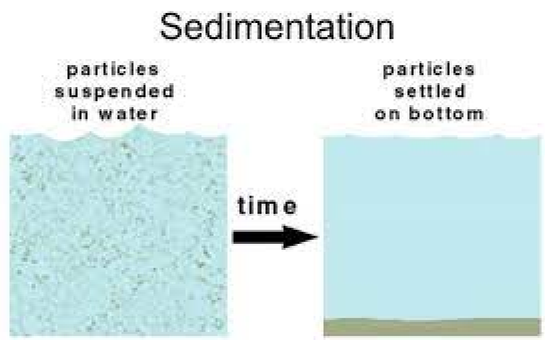
d) **Chemical Oxygen Demand (C.O.D.) :** A crucial indicator of quality of water Chemical Oxygen Demand (C.O.D.) measures the quantity of oxygen needed to chemically oxidize both organic and inorganic materials in a water sample. The measurement of the total oxygen demand by C.O.D. is based on chemical reactions, as opposed to microbiological activity, which is the basis for Biological Oxygen Demand (B.O.D.). This approach is especially helpful for monitoring industrial and wastewater treatment plants since it offers a quicker assessment, typically finished in a few hours. Higher C.O.D. levels point to possible contaminant levels in the water and emphasize the necessity of efficient water treatment techniques. Quality of water is managed and protected by environmental authorities and regulatory bodies with the aid of C.O.D. monitoring.



(e) Interconnectedness of D.O., B.O.D., and C.O.D.: D.O., B.O.D., and C.O.D. are interconnected parameters that collectively offer a comprehensive understanding the quality of water. Low D.O. levels, often associated with high B.O.D. and C.O.D., signify degraded water quality and potential harm to aquatic ecosystems. Monitoring these parameters helps authorities implement targeted measures to improve quality of water, such as implementing wastewater treatment processes, controlling industrial discharges, and preserving natural riparian habitats.

3. Sedimentation In Water Treatment: Settling The Particles For Purified Water

a) Introduction: Water treatment is a multifaceted process that involves several stages to ensure the delivery of clean, safe, and potable water. Sedimentation is a crucial step in this elaborate treatment process, serving as a mechanism to remove suspended particles and impurities from water. This essay delves into the significance of sedimentation in water treatment, exploring its principles, processes, and the impact it has on the production of high-quality drinking water.



b) Principles of Sedimentation: Sedimentation is based on the principle of gravity settling, where suspended particles in water are allowed to settle down due to the force of gravity. This process takes advantage of the fact that particles in water have different weights and sizes, causing them to settle at varying rates. By providing a quiescent environment, water treatment facilities create conditions conducive to the settling of these particles, allowing for their removal and subsequent purification of the water.

c) Processes Involved in Sedimentation: The sedimentation process in water treatment generally involves a series of steps to facilitate the separation of particles from the water. The water is first directed to a sedimentation basin or tank, where it is allowed to rest. The slow movement of water in these basins enables gravity to take effect, causing heavier particles to settle at the bottom. Coagulants may be added to facilitate the agglomeration of smaller particles into larger, more easily settleable flocs.

Once the particles have settled, the clarified water is carefully decanted or drawn off from the top, leaving behind the sediment particles at the bottom. The sediment, often referred to as sludge, is then removed for further treatment or disposal. The efficiency of sedimentation depends on factors such as the size and type of particles, detention time in the sedimentation basin, and the use of coagulants and flocculants to enhance the settling process.

d) Significance of Sedimentation in Water Treatment:

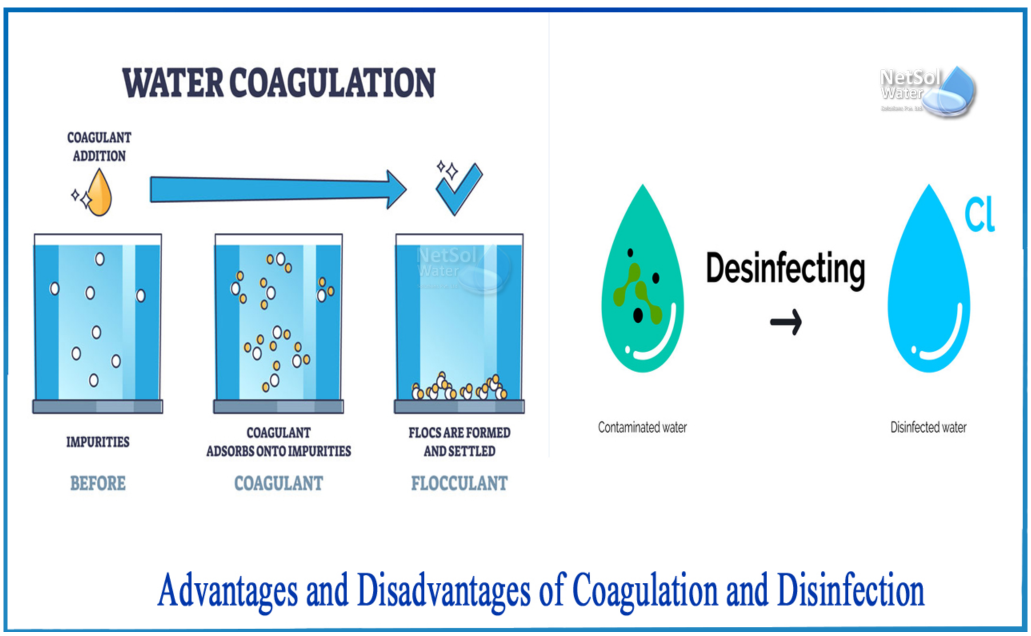
(i) **Particle Removal:** Sedimentation is highly effective in removing suspended particles, such as sand, clay, and organic matter, from water. This is crucial for enhancing the aesthetic quality of water, eliminating turbidity, and preventing the clogging of downstream treatment processes.

(ii) **Pathogen Removal:** It efficiently gets rid of contaminants including silt, clay, and organic materials that can contaminate water and be harmful to human health.. By allowing these particles to settle, the risk of waterborne diseases is significantly reduced, contributing to the production of safe drinking water.

(iii) **Pre-Treatment for Further Processes:** Sedimentation serves as a pre-treatment step for subsequent processes in the water treatment train. By removing bulk impurities, sedimentation helps optimize the performance of downstream treatment processes, such as filtration and disinfection.

4. Coagulation In Water Treatment: Agglomerating For Purity

a) **Introduction:** Water treatment is a multifaceted process aimed at ensuring the delivery of clean and safe drinking water. Coagulation, a fundamental step in water treatment, plays a pivotal role in removing impurities that contribute to turbidity, color, and the presence of contaminants. This essay explores the significance of coagulation in water treatment, examining its principles, processes, and the positive impact it has on the production of high-quality potable water.



b) **Principles of Coagulation:** Coagulation is based on the principle of destabilizing suspended particles in water by introducing coagulants. These coagulants are chemicals that neutralize the repulsive forces among particles, promoting their aggregation into larger, settleable flocs. The formation of these flocs facilitates subsequent processes like sedimentation and filtration, ultimately leading to the removal of impurities from water.

c) **Processes Involved in Coagulation:** The coagulation process typically involves the addition of coagulants to the raw water at the beginning of the treatment train. Common coagulants include aluminum sulfate (alum), ferric chloride, and polyaluminum chloride. Once added, these coagulants neutralize the negative charges on suspended particles, allowing them to come together and form larger, heavier aggregates.

The coagulated water then proceeds to a flocculation basin, where gentle mixing or stirring promotes the growth of flocs through collisions and adhesion. This stage encourages the development of well-formed, larger flocs that are more easily removable in subsequent treatment steps.

d) **Significance of Coagulation in Water Treatment:**

(i) Turbidity Reduction: Coagulation is highly effective in reducing turbidity, which refers to the cloudiness or haziness caused by suspended particles in water. By promoting the agglomeration of these particles, coagulation aids in their removal, contributing to clearer and aesthetically pleasing water.

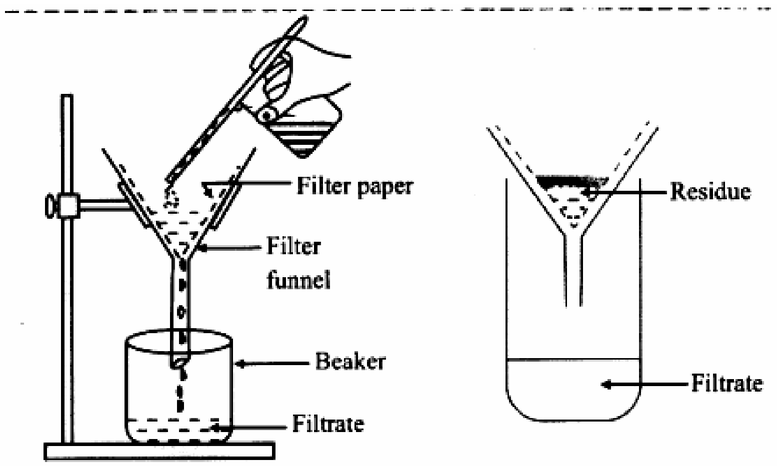
(ii) Pathogen Removal: The process of coagulation aids in the removal of potential bacteria, viruses, and other microbes from water. Greater flock production increases the effectiveness of later procedures like filtration and sedimentation, which lowers the amount of waterborne pathogens and increases water safety.

(iii) Precursor Removal for Disinfection: Coagulation also addresses dissolved organic matter and other precursors that can react with disinfectants, forming potentially harmful disinfection by products. By removing these precursors through coagulation, water treatment plants can optimise the efficiency of disinfection processes and enhance the safety of the treated water.

(iv) Improved Filtration: Coagulation enhances the performance of filtration processes by forming larger and heavier flocs that are easier to separate from the water. This results in improved filter efficiency and extends the lifespan of filtration media.

5. Filtration In Water Treatment: A Crucial Barrier To Contaminants

a) **Introduction:** Water treatment is a complex and vital process that aims to purify water for consumption and various industrial applications. Filtration, a key component of this process, serves as a crucial barrier against a wide range of contaminants. This essay explores the significance of filtration in water treatment, examining its principles, methods, and the role it plays in ensuring the delivery of clean and safe drinking water.



Process of filtration

b) Principles of Filtration:

The concepts of water filtration cover a range of methods to guarantee that the water is pure. While chemical filtration uses materials like activated carbon to remove dissolved contaminants, mechanical filtering uses physical barriers like sand to catch bigger particles. Depth filtration is the process of running water through a thick layer of filter material; biological filtration uses microorganisms to break down pollutants. An electric field is used in electrokinetic filtration to draw in and hold charged particles. When combined, these ideas provide a thorough strategy that tackles a variety of contaminants and guarantees the provision of safe, clean water for drinking and other uses.

c) Methods of Filtration:

(i) Slow Sand Filtration: A bed of sand is used in slow sand filtration, a technique for purifying water, to extract pollutants. Sand filters water by allowing it to percolate through it, with the help of microorganisms that live on the surface of the sand. Improved water quality is ensured by this sustainable and practical technology that efficiently lowers pathogens, suspended sediments, and pollutants.

(ii) Rapid Sand Filtration: Rapid sand filtration is a more expedited version of slow sand filtration, utilizing a finer sand medium and higher flow rates. Coagulants and flocculants may be added before filtration to enhance the removal of smaller particles. This method is commonly used in water treatment plants for its efficiency in removing turbidity and suspended solids.

(iii) Granular Activated Carbon Filtration: "G1 Granular Activated Carbon Filtration," using the term "GAC" instead of "G1" may be more accurate. One popular technique for treating water is granular activated carbon (GAC) filtration. The porous carbon particles that make up GAC offer a lot of surface area for adsorption. Water is filtered via the GAC bed, where impurities including chemicals and organic substances stick to the carbon surface. To improve the taste and odor of water, this technology successfully eliminates contaminants. It is frequently used in point-of-use filtration systems and water treatment plants.

(iv) Membrane Filtration: Membrane filtration is a method of treating water that uses semipermeable membranes to extract and eliminate impurities, particles, and microbes. This technique is based on the size exclusion principle, which states that a membrane permits water molecules to pass through while obstructing larger things. Reverse osmosis, microfiltration, ultrafiltration, nano filtration, and other types of membrane filtration are among them; each has a distinct pore size and set of uses. Smaller particles, ions, and dissolved materials can be removed using reverse osmosis and nano filtration, while bacteria and suspended solids can be removed using microfiltration and ultrafiltration. Membrane filtration plays a major role in the creation of high-quality drinking water by being widely used in desalination, wastewater treatment, and water purification procedures.

d) Role of Filtration in Water Treatment:

(i) Removal of Suspended Solids: Filtration is instrumental in removing suspended solids, such as sand, clay, and organic matter, from water. This not only improves the aesthetic quality of water by reducing turbidity but also prevents the clogging of pipes and equipment in subsequent treatment processes.

(ii) Pathogen Removal: Filtration acts as a barrier against bacteria, viruses, and other microorganisms present in water. This is crucial for preventing waterborne diseases and ensuring the safety of drinking water.

(iii) Adsorption of Organic Compounds: Filtration methods like activated carbon filtration are effective in adsorbing organic compounds, pesticides, and chemicals, contributing to the removal of taste and odor issues in water.

(iv) Optimization of Disinfection: Filtration enhances the efficiency of downstream disinfection processes by reducing the load of particles and microorganisms. This ensures that disinfectants like chlorine can work more effectively in eliminating any remaining pathogens.