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Hydrospheric Chemistry

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HYDROSPHERIC CHEMISTRY

CHEMISTRY OF WATER

- Water (H_2O) is a unique and essential compound with distinct chemical properties that make it vital for life and environmental processes.
- Structure and Properties:
- Molecular Structure: Water is a polar molecule with a bent shape due to its two hydrogen atoms covalently bonded to an oxygen atom. The polarity results from the difference in electronegativity between oxygen and hydrogen.
- Hydrogen Bonding: Water molecules form hydrogen bonds, leading to high surface tension, cohesion, adhesion, and capillarity.
- Solvent Properties: Water is known as the "universal solvent" because it dissolves many substances due to its polarity.

WATER QUALITY PARAMETERS

- Water quality is determined by its physical, chemical, and biological properties. These parameters are crucial for assessing the suitability of water for various uses, including drinking, agriculture, and industrial processes.
- **Physical Properties**
- Temperature: Affects the solubility of gases and the metabolic rates of aquatic organisms. Higher temperatures reduce dissolved oxygen levels.
- Turbidity: Measures the cloudiness of water, indicating the presence of suspended solids. High turbidity can reduce light penetration and affect aquatic life.
- Color: Caused by dissolved organic matter, metals, or industrial wastes. It can affect the aesthetic quality of water.
- Taste and Odor: Influenced by dissolved minerals, organic materials, or pollutants. Important for potable water quality.

CHEMICAL PROPERTIES

- pH: Measures the acidity or alkalinity of water. Affects the solubility of metals and the biological functions of aquatic organisms. Most aquatic life prefers a pH range of 6.5 to 8.5.
- Dissolved Oxygen (DO): Essential for the respiration of aquatic organisms. Low DO levels indicate poor water quality and can result from organic pollution.
- Biochemical Oxygen Demand (BOD): Measures the amount of oxygen required by microorganisms to decompose organic matter. High BOD indicates high levels of organic pollution.
- Chemical Oxygen Demand (COD): Measures the total quantity of oxygen required to oxidize organic and inorganic matter. Higher COD values indicate more pollution.
- Nutrients: Nitrogen and phosphorus are essential nutrients but can cause eutrophication in excess, leading to algal blooms and oxygen depletion.
- Salinity: The concentration of dissolved salts in water. High salinity can affect freshwater ecosystems and agricultural productivity.
- Hardness: Caused by dissolved calcium and magnesium ions. Hard water can cause scaling in pipes and affect soap efficiency.
- Heavy Metals: Metals like lead, mercury, and cadmium can be toxic to aquatic life and humans even at low concentrations.

BIOLOGICAL PROPERTIES

- **Microorganisms**: Bacteria, viruses, and protozoa can indicate contamination and pose health risks. Fecal coliforms, such as Escherichia coli, are commonly tested to assess water quality.
- **Algae**: Their presence can indicate nutrient levels and water quality. Some algae produce toxins that can harm aquatic life and human health.
- **Macroinvertebrates**: The diversity and abundance of aquatic insects and other invertebrates are indicators of water quality. Sensitive species thrive in clean water, while tolerant species dominate polluted waters.

ENVIRONMENTAL SIGNIFICANCE

- Understanding and monitoring the physical, chemical, and biological properties of water are crucial for maintaining healthy ecosystems and ensuring the safety of water for human use. Key points of environmental significance include:
- **Ecosystem Health**: Proper water quality supports diverse and balanced ecosystems, providing habitats for aquatic and terrestrial species.
- **Human Health**: Safe drinking water is essential for preventing waterborne diseases. Monitoring microbial and chemical contaminants is crucial for public health.
- **Agricultural Productivity**: Water quality affects crop growth and soil health. Salinity and nutrient levels must be managed to prevent soil degradation and crop damage.
- **Industrial Use**: Many industries require specific water quality standards for processes and cooling. Poor water quality can lead to equipment damage and reduced efficiency.
- **Regulatory Compliance**: Environmental regulations and standards ensure that water bodies are protected from pollution. Monitoring and managing water quality helps in compliance with laws and guidelines.
- By maintaining and improving water quality, we can ensure sustainable water resources for future generations and protect the health of both ecosystems and human populations.

DISTRIBUTION OF CHEMICAL SPECIES IN WATER

- The distribution of chemical species in water involves a complex interplay of physical, chemical, and biological processes. This section delves into the behavior of gases, organic matter, humic substances, heavy metals, and their interactions in natural and waste water.
- **Gases in Water**

1. **Oxygen (O_2)**:
   1. Dissolved oxygen (DO) is crucial for the survival of aerobic aquatic organisms.
   2. Solubility decreases with increasing temperature and salinity.
   3. Influenced by atmospheric exchange, photosynthesis, and respiration.
2. **Carbon Dioxide (CO_2)**:
   1. Dissolves to form carbonic acid (H_2CO_3), bicarbonate (HCO_3^-), and carbonate (CO_3^{2-}).
   2. The distribution is highly pH-dependent:
      1. Low pH: CO_2 predominates.
      2. Neutral pH: HCO_3^- predominates.
      3. High pH: CO_3^{2-} predominates.
   3. Important for buffering capacity and aquatic plant photosynthesis.

1. **Nitrogen (N_2)**:
    1. Relatively inert and less reactive.
    2. Produced and consumed by nitrogen-fixing and denitrifying bacteria.
2. **Methane (CH_4)**:
    1. Produced in anaerobic conditions by methanogenic bacteria.
    2. Significant in sediment layers and anoxic zones of water bodies.

- **Organic Matter in Water**

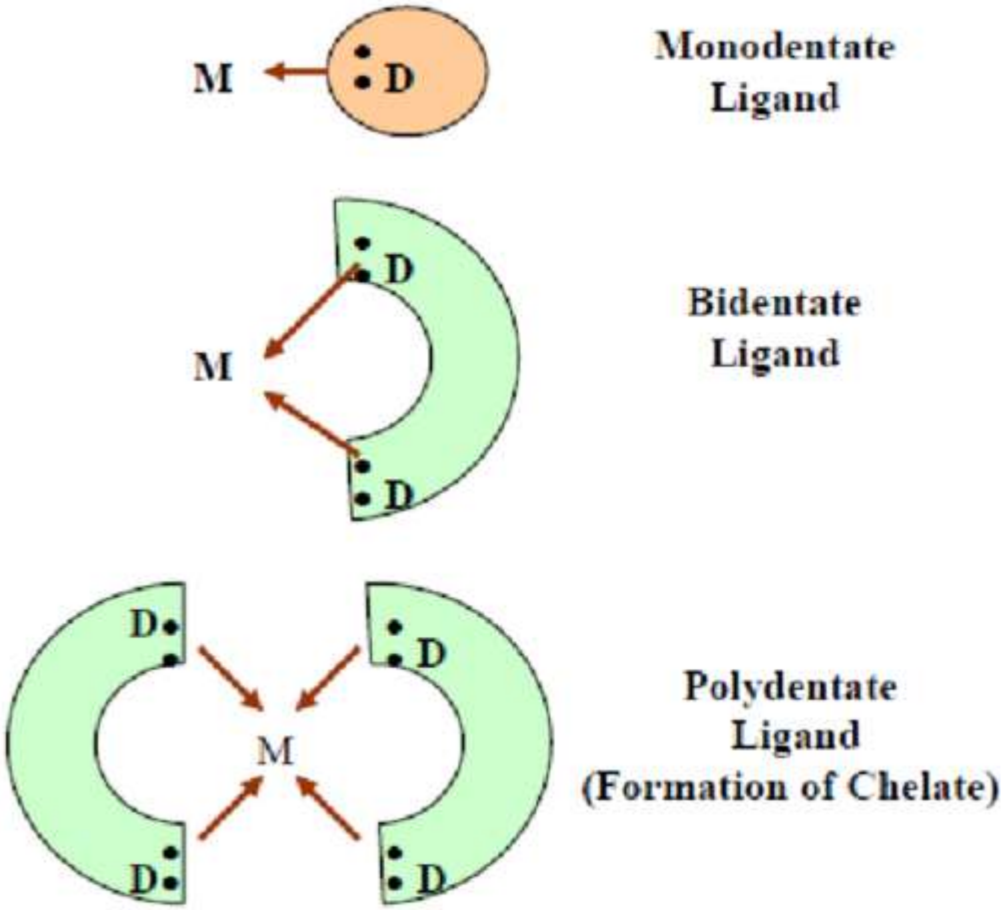
1. **Natural Organic Matter (NOM)**:
    1. Includes plant and animal debris, microbial biomass, and organic compounds from soil.
    2. Affects the color, taste, and odor of water.
    3. Can form complexes with metals, affecting their transport and bioavailability.
2. **Humic Substances**:
    1. A major fraction of NOM, includes humic acid, fulvic acid, and humin.
    2. High molecular weight and complex structure.
    3. Strongly interact with metals and influence their solubility and mobility.
    4. Contribute to the color of water and its ability to absorb UV light.

- **Ligand:** A molecule or ion that binds to a central metal atom, forming a coordination complex.
- **Chelation:** The formation of stable, ring-like structures through multiple coordination sites of a ligand to a metal ion, used in heavy metal remediation and enhancing nutrient availability.
- **Complexation:** Complexation refers to the process in which chemicals form stable and soluble complexes with ligands, influencing mineral solubility limits, adsorption, and redox state in water. It also plays a significant role in the movement of metals in the subsurface, depending on the concentration and properties of ligands.
- These processes are fundamental in environmental science for managing metal ions in natural and engineered systems, influencing the fate and transport of contaminants, and maintaining ecosystem health.

Ligands

- A ligand is a molecule or ion that binds to a central metal atom to form a coordination complex. Ligands can be ions or molecules that donate a pair of electrons to the metal atom. Here are some key points about ligands:
- Types of Ligands:
- Monodentate Ligands: These ligands donate a single pair of electrons to the metal atom (e.g., water (H_2O), ammonia (NH_3)).
- Bidentate Ligands: These ligands have two donor atoms that can form two bonds with the metal atom (e.g., ethylenediamine .
- Polydentate Ligands: These ligands have multiple donor atoms that can form multiple bonds with the metal atom (e.g., EDTA, which can form up to six bonds).
- Chelation: This occurs when a polydentate ligand forms multiple bonds with a single metal ion, creating a ring structure. Chelating agents, such as EDTA, are often used to bind metal ions in solution.

Types of ligands



- Examples of ligands
- Anionic Ligands: Chloride (Cl^-), cyanide (CN^-)
- Neutral Ligands: Water (H_2O), ammonia (NH_3)
- Cationic Ligands: Nitrosyl (NO^+)
- Environmental Chemistry: Ligands like EDTA are used to remove heavy metals from wastewater.
- Understanding ligands and their interactions with metal atoms is essential for studying coordination chemistry and its applications in various scientific and industrial fields.

HEAVY METALS IN WATER

1. **Sources and Behavior**:
    1. Enter water bodies from natural sources (weathering of rocks) and anthropogenic sources (industrial discharge, mining, agriculture).
    2. Common heavy metals: Lead (Pb), mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), zinc (Zn), copper (Cu), and nickel (Ni).
2. **Solubility**:
    1. Depends on pH, redox conditions, and presence of ligands.
    2. Metals can precipitate as hydroxides, carbonates, or sulfides in certain conditions.
3. **Complexation**:
    1. Metals form complexes with organic and inorganic ligands.
    2. Inorganic ligands: chloride (Cl^-), sulfate (SO_4^{2-}), phosphate (PO_4^{3-}).
    3. Organic ligands: organic acids, humic substances.
    4. Complexation affects metal mobility, toxicity, and bioavailability.
4. **Chelation**:
    1. Specific type of complexation where a metal ion binds with a multidentate ligand (chelating agent) to form a stable ring structure.
    2. Common chelating agents: EDTA (ethylene diamine tetraacetic acid), NTA (nitrile triacetic acid).
    3. Used in wastewater treatment to sequester metals and reduce their toxicity.

HUMIC AND FULVIC ACIDS

- Humic acids and fulvic acids are important components of humic substances, which are complex mixtures of organic compounds found in soil, water, and sediments. They play significant roles in soil fertility, nutrient cycling, and environmental processes.
- Humic Acids-Definition and Characteristics:
- Composition: High molecular weight, heterogeneous mixtures of polymeric aromatic compounds.
- Color: Dark brown to black, imparting color to soil and water.
- Solubility: Insoluble in acidic conditions ($pH < 2$) and partially soluble in alkaline solutions ($pH > 9$).
- Origin: Formed through microbial degradation of plant and animal residues over thousands of years (humification process).
- Sources: Found in soils with high organic matter content, peatlands, and sedimentary environments.

FUNCTIONS AND ROLES:

- Nutrient Storage: Bind and store essential nutrients (e.g., nitrogen, phosphorus, potassium) in a bioavailable form for plants.
- Metal Chelation: Chelate metals (e.g., iron, aluminum), influencing their mobility, bioavailability, and toxicity in soils and water.
- Soil Aggregation: Improve soil structure and stability by promoting aggregation and enhancing water retention capacity.
- Cation Exchange Capacity (CEC): Act as ion exchange sites, buffering soil pH and retaining nutrients against leaching.
- Environmental Significance:
- Carbon Sequestration: Contribute to long-term carbon storage in soils, affecting global carbon cycling and climate regulation.
- Water Quality: Influence water chemistry, pH buffering capacity, and organic matter dynamics in aquatic ecosystems.

FULVIC ACIDS

- Definition and Characteristics:
- Composition: Lower molecular weight compared to humic acids, with higher oxygen and carboxylic acid functional groups.
- Color: Light yellow to amber, more soluble in water compared to humic acids.
- Solubility: Soluble across a wide range of pH conditions (acidic to alkaline).
- Formation and Sources:
- Origin: Derived from the degradation of humic substances and organic matter by microbial and enzymatic processes.
- Sources: Present in soils, freshwater systems (rivers, lakes), and marine environments.

- Functions and Roles:
- Chelation and Complexation: Form stable complexes with metals, enhancing their solubility and availability to plants and microbes.
- Nutrient Transport: Facilitate the uptake and transport of nutrients (e.g., minerals, trace elements) across cell membranes in plants and microorganisms.
- Antioxidant Properties: Act as antioxidants, scavenging free radicals and protecting cells from oxidative stress.
- Environmental Significance:
- Biological Activity: Stimulate microbial activity and enzymatic processes in soils and sediments, enhancing nutrient cycling and decomposition.
- Water Quality: Influence water color, transparency, and nutrient dynamics in aquatic ecosystems.
- Humic acids and fulvic acids are integral components of humic substances, playing diverse roles in soil health, nutrient cycling, and environmental quality. Understanding their properties, interactions, and environmental impacts is essential for sustainable agriculture, water management, and ecosystem conservation efforts worldwide.

ROLE OF MICROORGANISMS IN AQUATIC CHEMICAL REACTIONS

- Microorganisms play a crucial role in aquatic chemical reactions, significantly influencing the cycling of nutrients, the breakdown of organic matter, and the transformation of various chemical species in water. These activities are essential for maintaining the health and balance of aquatic ecosystems. Here are some key roles of microorganisms in aquatic chemical reactions:
- **1. Nutrient Cycling**
- **Nitrogen Cycle**
- **Nitrogen Fixation**: Certain bacteria (e.g., cyanobacteria, Azotobacter) convert atmospheric nitrogen (N_2) into ammonia (NH_3), making nitrogen available to other organisms.
- **Nitrification**: Nitrifying bacteria (e.g., Nitrosomonas, Nitrobacter) oxidize ammonia to nitrite (NO_2^-) and then to nitrate (NO_3^-), which plants can assimilate.
- **Denitrification**: Denitrifying bacteria (e.g., Pseudomonas, Paracoccus) convert nitrate to nitrogen gas (N_2) or nitrous oxide (N_2O), releasing it back into the atmosphere, thus completing the nitrogen cycle.
- **Phosphorus Cycle**
- **Mineralization**: Microorganisms decompose organic phosphorus compounds into inorganic phosphate (PO_4^{3-}), which can be taken up by plants.
- **Solubilization**: Phosphate-solubilizing bacteria and fungi release inorganic phosphate from insoluble mineral phosphates through the secretion of organic acids.

- **2. Decomposition of Organic Matter**
- **Aerobic Decomposition**: Aerobic bacteria and fungi decompose organic matter in the presence of oxygen, resulting in the production of CO_2, water, and energy.
- **Anaerobic Decomposition**: In oxygen-depleted environments, anaerobic bacteria decompose organic matter, producing methane (CH_4), CO_2, hydrogen sulfide (H_2S), and other compounds.
- **3. Biogeochemical Transformations**
- **Sulfur Cycle**
- **Sulfate Reduction**: Sulfate-reducing bacteria (e.g., Desulfovibrio) reduce sulfate (SO_4^{2-}) to hydrogen sulfide (H_2S) under anaerobic conditions.
- **Sulfur Oxidation**: Sulfur-oxidizing bacteria (e.g., Thiobacillus) convert hydrogen sulfide back to sulfate or elemental sulfur, typically in aerobic environments.
- **Carbon Cycle**
- **Photosynthesis**: Photosynthetic microorganisms (e.g., cyanobacteria, algae) convert CO_2 into organic matter using sunlight, producing oxygen as a byproduct.
- **Respiration**: Heterotrophic bacteria and fungi break down organic matter, releasing CO_2 and water, and generating energy.

- **Metal Transformation**
- **Metal Reduction**: Certain bacteria can reduce metal ions to less soluble forms, affecting their mobility and toxicity. For example, iron-reducing bacteria (e.g., Geobacter) reduce Fe^{3+} to Fe^{2+}.
- **Metal Oxidation**: Some bacteria oxidize metals to more soluble or bioavailable forms. For instance, manganese-oxidizing bacteria convert Mn^{2+} to MnO_2.
- **5. Bioremediation**
- **Degradation of Pollutants**: Microorganisms can degrade organic pollutants, such as hydrocarbons, pesticides, and industrial chemicals, into less harmful substances. This process is used in bioremediation to clean up contaminated water bodies.
- **Biosorption and Bioaccumulation**: Certain microorganisms can accumulate heavy metals and other contaminants from water, reducing their concentrations and toxicity.

- **Microbially mediated redox reactions** in water involve the transformation of chemical species by microorganisms, which serve as catalysts in various oxidation-reduction (redox) reactions. These processes play a crucial role in biogeochemical cycles, nutrient cycling, and the transformation of contaminants in aquatic environments.
- 1. Microbial Metabolism:
- Redox Reactions: Microorganisms utilize redox reactions to gain energy by transferring electrons from electron donors (reduced compounds) to electron acceptors (oxidized compounds).
- Examples: Aerobic respiration, anaerobic respiration (using alternative electron acceptors like nitrate, sulfate, or metals), and fermentation.
- 2. Types of Microbial Redox Reactions:
- Oxidation of Organic Matter: Microorganisms break down organic compounds (e.g., sugars, lipids) to generate energy, producing carbon dioxide and water as by-products in aerobic conditions.
- Anaerobic Respiration: In the absence of oxygen, microorganisms use alternative electron acceptors such as nitrate (NO_3^-), sulfate (SO_4^{2-}), iron (Fe^{3+}), manganese (Mn^{4+}), and carbon dioxide (CO_2).
- Methanogenesis: Microbial production of methane (CH_4) under anaerobic conditions, utilizing carbon dioxide or acetate as electron acceptors.

- Denitrification: Reduction of nitrate (NO_3^-) to nitrogen gas (N_2) by facultative anaerobic bacteria, releasing nitrogen to the atmosphere.

- Sulfate Reduction Reduction of sulfate (SO_4^{2-}) to hydrogen sulfide (H_2S) by sulfate-reducing bacteria, affecting sulfur cycling and metal solubility.

- Iron Oxidation: Iron-oxidizing bacteria oxidize ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}), contributing to the formation of iron oxides and ochre deposits.

- Iron Reduction: Iron-reducing bacteria use ferric iron (Fe^{3+}) as an electron acceptor, reducing it to ferrous iron (Fe^{2+}) under anaerobic conditions.

- Manganese Oxidation: Manganese-oxidizing bacteria oxidize soluble manganese (Mn^{2+}) to insoluble manganese dioxide (MnO_2), influencing water quality and sediment chemistry.

- Manganese Reduction: Manganese-reducing bacteria reduce manganese dioxide (MnO_2) to soluble manganese (Mn^{2+}) in anaerobic environments.

- Microbially mediated redox reactions are pivotal in shaping the biogeochemistry of water bodies, influencing nutrient availability, contaminant fate, and ecosystem health. Understanding these processes is crucial for environmental management, water quality assessment, and the development of sustainable strategies for natural resource utilization and pollution control.

CARBON TRANSFORMATION PROCESSES BY BACTERIA

- Carbon Fixation : Bacteria convert inorganic carbon (usually carbon dioxide, CO_2) into organic carbon compounds through carbon fixation.

- Types: Photosynthetic Bacteria: Use light energy to fix carbon dioxide into organic molecules, similar to plants.

- Chemolithotrophic Bacteria : Utilize energy from inorganic chemical reactions (e.g., oxidation of iron, sulfur) to fix carbon dioxide. The chemolithotrophic bacteria and archaea are defined by their ability to oxidize inorganic atoms or molecules as a growth-supporting reductant and energy source.

- Organic Matter Decomposition:

- Heterotrophic Bacteria: Break down organic matter (e.g., dead plants, animals, organic compounds) into simpler compounds through enzymatic reactions.

- Aerobic Decomposition: Bacteria decompose organic matter in the presence of oxygen, producing carbon dioxide and water.

- Anaerobic Decomposition: Occurs in the absence of oxygen, leading to the production of carbon dioxide, methane (CH_4), and other reduced compounds.

- Methanogenesis: Methanogenic Bacteria: Anaerobic bacteria that produce methane (CH_4) as a metabolic byproduct by reducing carbon dioxide or acetate. Methane Production: In environments like wetlands, rice paddies, and digestive systems of animals, methanogenic bacteria play a crucial role in methane emission.

- Carbon Respiration:Cellular Respiration: Bacteria use organic carbon compounds as energy sources by oxidizing them with oxygen or other electron acceptors (e.g., nitrate, sulfate).

- Production of Energy: During respiration, bacteria release carbon dioxide as a metabolic waste product.

- Carbon Sequestration:Soil Bacteria: Some bacteria contribute to carbon sequestration by converting organic carbon into stable forms (e.g., humic substances) that resist decomposition, thus storing carbon in soils for longer periods.

- Bacteria play diverse and crucial roles in carbon transformation processes across terrestrial and aquatic environments. Their activities influence nutrient cycling, greenhouse gas emissions, soil fertility, and ecosystem health. Understanding bacterial carbon metabolism is essential for managing carbon cycles, mitigating climate change impacts, and preserving ecosystem services in natural and managed environments.

NITROGEN TRANSFORMATION BY BACTERIA

- Nitrogen transformation by bacteria encompasses a series of biological processes where microorganisms catalyze the conversion of nitrogen compounds into various forms, impacting nutrient availability, environmental quality, and ecosystem dynamics. Here’s an overview of key nitrogen transformation processes mediated by bacteria:
- Nitrogen Fixation-Definition: Conversion of atmospheric nitrogen (N_2) into ammonia (NH_3) or ammonium (NH_4^+) ions by nitrogen-fixing bacteria (e.g., Rhizobium spp., Azotobacter spp.) and cyanobacteria.
- Mechanisms:
- Symbiotic Fixation: Occurs in symbiotic relationships between bacteria (e.g., Rhizobium) and leguminous plants, where bacteria reside in root nodules and fix nitrogen for plant use.
- Free-Living Fixation: Bacteria like Azotobacter and cyanobacteria fix nitrogen independently in soil and aquatic environments, respectively.
- Nitrification-Nitrification: Oxidation of ammonia (NH_3/NH_4^+) to nitrite (NO_2^-) and then to nitrate (NO_3^-) by nitrifying bacteria such as Nitrosomonas and Nitrobacter.
- Process:Ammonia Oxidation: Ammonia is oxidized to nitrite (NO_2^-) by ammonia-oxidizing bacteria (e.g., Nitrosomonas).
- Nitrite Oxidation: Nitrite is further oxidized to nitrate (NO_3^-) by nitrite-oxidizing bacteria (e.g., Nitrobacter).

- Denitrification
- Reduction of nitrate (NO_3^-) and nitrite (NO_2^-) to nitrogen gas (N_2) or nitrous oxide (N_2O) by denitrifying bacteria (e.g., Pseudomonas, Paracoccus) under anaerobic conditions.
- Process:
- Nitrate Reduction: Denitrifying bacteria use nitrate or nitrite as an electron acceptor, converting them into nitrogen gas or nitrous oxide.
- Environmental Conditions: Occurs in oxygen-depleted environments such as wetlands, sediments, and waterlogged soils.
- Environmental Impact:
- Nitrogen Loss: Removes biologically available nitrogen from ecosystems, contributing to nitrogen balance and mitigating nitrogen pollution.
- Greenhouse Gas Production: Denitrification produces nitrous oxide, a potent greenhouse gas contributing to climate change.

- Ammonification: Breakdown of organic nitrogen compounds (e.g., proteins, nucleic acids) into ammonia (NH_3) or ammonium (NH_4^+) by ammonifying bacteria and fungi.
- Process:
- Organic Matter Decomposition: Bacteria and fungi decompose organic nitrogen-containing compounds, releasing ammonia as a byproduct.
- Nitrogen Recycling: Provides ammonia for subsequent nitrification or uptake by plants and microorganisms.
- Bacteria are pivotal in nitrogen transformation processes that regulate nitrogen availability, cycling, and environmental quality in terrestrial and aquatic ecosystems. Understanding these microbial processes is essential for managing nutrient dynamics, soil fertility, water quality, and ecosystem sustainability. Efforts to study and harness bacterial nitrogen transformations are crucial for agricultural practices, environmental conservation, and mitigating nitrogen-related impacts on global ecosystems.

MICROBIAL TRANSFORMATION OF PHOSPHORUS

- Phosphorus Cycling:
- Phosphate Solubilization: Some bacteria and fungi release organic acids (e.g., citric acid, gluconic acid) that solubilize insoluble forms of phosphorus (e.g., calcium phosphate) in soil, making it available to plants.
- Phosphorus Mineralization: Microorganisms decompose organic matter containing phosphorus (e.g., nucleic acids, phospholipids), releasing inorganic phosphate (PO_4^{3-}) through enzymatic processes known as mineralization.
- Phosphate Uptake: Microorganisms, including bacteria and fungi, absorb phosphate ions from the environment for their growth and metabolism.
- Environmental Impact:
- Nutrient Availability: Microbial transformation of phosphorus enhances its availability for plant uptake, influencing plant growth and productivity.
- Eutrophication: Excess phosphorus runoff from agricultural and urban areas, facilitated by microbial processes, can contribute to eutrophication in aquatic ecosystems.
- Phosphorus immobilization: Microbes can immobilize phosphorus, incorporating it into microbial biomass or organic compounds, thereby reducing its availability in the environment

MICROBIAL TRANSFORMATION OF SULFUR

- Sulfur Cycling:
- Sulfate Reduction: Sulfate-reducing bacteria (e.g., Desulfovibrio) utilize sulfate (SO_4^{2-}) as a terminal electron acceptor in anaerobic conditions, reducing it to hydrogen sulfide (H_2S).
- Sulfur Oxidation: Sulfur-oxidizing bacteria (e.g., Thiobacillus) oxidize reduced sulfur compounds (e.g., elemental sulfur, hydrogen sulfide) to sulfate, contributing to sulfur cycling.
- Assimilatory Sulfate Reduction: Microorganisms assimilate sulfate into organic compounds (e.g., cysteine, methionine) for protein synthesis and other cellular processes.
- Microbial transformation of phosphorus and sulfur is essential for nutrient cycling, soil fertility, and ecosystem sustainability. Understanding these processes helps in managing nutrient availability, mitigating environmental impacts like eutrophication and hydrogen sulfide production, and enhancing agricultural productivity. Further research into microbial communities and their metabolic capabilities is crucial for developing sustainable practices and interventions in natural and managed ecosystems.

MICROBIAL TRANSFORMATION OF IRON

- Iron Cycling:
- Iron Oxidation: Iron-oxidizing bacteria (e.g., Gallionella, Leptothrix) oxidize soluble ferrous iron (Fe^{2+}) to insoluble ferric iron (Fe^{3+}), forming iron oxides or hydroxides.
- Environmental Impact: This process contributes to the formation of ochre deposits and affects water quality by releasing iron oxides into aquatic environments.
- Iron Reduction: Iron-reducing bacteria (e.g., Geobacter, Shewanella) reduce ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}) under anaerobic conditions.
- Environmental Impact: Anaerobic iron reduction affects the solubility and mobility of iron in sediments and groundwater, influencing biogeochemical cycles and metal speciation.
- Iron Uptake: Microorganisms, including plants and bacteria, absorb iron ions (Fe^{2+} and Fe^{3+}) from the environment for various metabolic processes and growth.

What is the difference between Complexing Agent and Chelating Agent?

Complexing Agent vs Chelating Agent	
A complexing agent is an ion, molecule or a functional group which can bind with metal ion through one or several coordination bonds.	A chelating agent is a chemical compound which can bind with metal ions through multiple coordination bonds to form stable, water-soluble complexes.
Binding Sites	
A complexing agent may have single or multiple binding sites.	A chelating agent has multiple binding sites but not a single binding site per molecule.
Number of Atoms Involved	
A complexing agent can bind with a metal ion through a single atom or multiple atoms.	A chelating agent binds with a metal ion with at least two atoms, but not with a single atom.
Nature of Agent	
A complexing agent can be an ion, molecule or a functional group.	A chelating agent is always an organic molecule.
Nature of Binding	
A complexing agent can bind with a metal ion by surrounding it or as a bridge that connects two metal ions.	A chelating agent always binds with a metal ion by surrounding it, making a chelate.
Denticity	
Complexing agents can be monodentate or multidentate.	Chelating agents cannot be monodentate; they are always multidentate.

Summary – Complexing Agent vs Chelating Agent

- Ligands are chemical species which can bind with metal ions through coordination bonds.
- Complexing agents and chelating agents are such ligands which are very useful in industry.
- The main difference between complexing agent and chelating agent is that complexing agent is an ion, molecule or a functional group that can bind with a metal ion through one or several atoms to form a large complex
- whereas a chelating agent is a compound that can bind with a metal ion to produce a chelate through several atoms in the same molecule.

HUMUS, HUMIC AND FULVIC ACID

HUMIC SUBSTANCES

- Humic substances, play a vital role in soil fertility and plant nutrition. Plants grown on soils which contain adequate humin, humic acids (HAs), and fulvic adds (FAs) are less subject to stress, are healthier, produce higher yields; and the nutritional quality of harvested foods and feeds are reported to be superior.
- The value of humic substances in soil fertility and plant nutrition relates to many functions these complex organic compounds perform as a part of the life cycle on earth.
- The life death cycle involves a recycling of the carbon containing structural components of plants and animals through the soil and air and back into the living plant.

- **ORGANIC MATTER:** Organic matter is defined as a group of carbon containing compounds which have originated from living beings and deposited on or within the earth's structural components.
- Soil organic matter includes the remains of all plant and animal bodies which have fallen on the earth's surface or purposely applied by man in the form of organically synthesized maerials eg., biopesticides.
- A fertile soil should contain from 3-5 percent organic matter, most soils contain less than 2%. In acid, leached soils, which are often sandy, substantial portions of the organic matter is in the form of plant debris and fulvic acids (FAs). In neutral and alkaline soils a large percentage of the organic matter is present in the form of humic acids (HAs) and humin.

HUMUS

- Humus is defined as a brown to black complex variable of carbon containing compounds . Humus is separated from the non humic substances such as carbohydrates (a major fraction of soil carbon), fats, waxes, alkanes, peptides, amino acids, proteins, lipids and organic acids by the fact that distinct chemical formulae can be written for these non humic substances.
- Most small molecules of non humic substances are rapidly degraded by microorganisms within the soil. In contrast soil humus is slow to decompose (degrade) under natural soil conditions. When in combination with soil minerals, soil humus can persist in the soil for several hundred years. Humus is the major soil organic matter component, making up 65% to 75% of the total. Humus assumes an important role as a fertility component of all soils, far in excess of the percentage contribution it makes to the total soil mass.
- Humic substances can be subdivided into three major fractions (1) HUMIN, (2) HUMIC ACIDS (HAs), and (3) FULVIC ACIDS (FAs). These sub divisions are arbitrarily based on the solubility of each fraction in water adjusted to different acid alkaline (pH levels) conditions.

HUMINS

- Humins are that fraction of humic substances which are not soluble in alkali (high pH) and are not soluble in acid (low pH). Humins are not soluble in water at any pH. Humin complexes are considered macro organic (very large) substances because their molecularweights (MW) range from approximately 100,000 to 10,000,000. In comparison the molecularweights of carbohydrates (complex sugars) range from approximately 500 to 100,000. Thechemical and physical properties of humins are only partially understood.
- Humins present within the soil is the most resistant to decomposition (slow to breakdown) of all the humic substances. Some of the main functions of humins within the soil are to improve the soil's water holding capacity, to improve soil structure, to maintain soil stability, to function as an cation exchange system, and to generally improve soil fertility. Because of these important functions humin Is a key component of fertile soils.

HUMIC ACIDS

- Humic acids (HAs) comprise a mixture of weak aliphatic (carbon chains) and aromatic (carbon rings) organic acids which are not soluble in water under acid conditions but are soluble in water under alkaline conditions. Humic acids consist of that fraction of humic substances that are precipitated from aqueous solution when the pH is decreased below 2.
- Humic acids (HAs) are termed polydisperse because of their variable chemical features. From a three dimensional aspect these complex carbon containing compounds are considered to be flexible linear polymers that exist as random coils with cross linked bonds. On average 35% of the humic acid (HA) molecules are aromatic (carbon rings), while the remaining components are in the form of aliphatic (carbon chains) molecules. The molecular size of humic acids (HAs)range from approximately 10,000 to 100,000. Humic acid (HA) polymers readily bind clay minerals to form stable organic clay complexes. Peripheral pores in the polymer are capable of accommodating (binding) natural and synthetic organic chemicals in a lattice (clathrate) type arrangements.
- Humic acids (HAs) readily form salts with inorganic trace mineral elements. An analysis of extracts of naturally occurring humic acids (HAs) will reveal the presence of over 60 different mineral elements present. These trace elements are bound to humic add molecules in a form that can be readily utilized by various living organisms. As a result humic acids (HAs) functionas important ion exchange and metal complexing (chelating) systems.

FULVIC ACIDS

- Fulvic acids (FAs) are a mixture of weak aliphatic and aromatic organic acidswhich are soluble in water at all pH conditions (acidic, neutral and alkaline). Their compositionand shape is quite variable. The size of fulvic acids (HFs) are smaller than humic adds (HAs),with molecular weights which range from approximately 1,000 to 10,000. Fulvic acids (FAs)have an oxygen content twice that of humic acids (HAs). They have many carboxyl (COOH)and hydroxyl (COH) groups, thus fulvic acids (FAs) are much more chemically reactive. Theexchange capacity of fulvic acids (FAs) is more than double that of humic acids (HAs). Thishigh exchange capacity is due to the total number of carboxyl (COOH) groups present. The number of carboxyl groups present in fulvic acids (FAs) ranges from 520 to 1120 cmol (H+)/kg.
- Fulvic acids collected from many different sources and analyzed, show no evidence of methoxy groups (CH3) groups, they are low in phenols, and are less aromatic compared to humic acids from the same sources.Because of the relatively small size of fulvic acid (FA) molecules they can readily enter plant roots, stems, and leaves. As they enter these plant parts they carry trace minerals from plant surfaces into plant tissues. Fulvic acids (FAs) are key ingredients of high quality foliarfertilizers. Foliar spray applications containing fulvic acid (FA) mineral chelates, at specificplant growth stages, can be used as a primary production technique for maximizing the plants productive capacity.
- Once applied to plant foliage fulvic acids (FAs) transport trace minerals directly to metabolic sites in plant cells. Fulvic acids (FAs) are the most effective carbon containing chelating compounds known. They are plant compatible, thus non toxic, when applied at relatively low concentrations.

HUMIN	HUMIC ACID		FULVIC ACID	
Molecular weight decreasing				
10,000,000	1,00,000		10,000	1000
Cation exchange capacity (c mol/kg) and acidity increasing				
100	300		500	1000
Carbon content (g/kg) decreasing				
550	620	560	520	430
Oxygen content (g/kg) increasing				
340	290	360	440	510
Nitrogen content (g/kg) decreasing				
46	55		43	7
Hydrogen content (g/kg) variable				
55	29	67	33	
Fertilizer properties - plant response increasing				
Slow response			Rapid response	

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