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3. Biogeochemical Cycles and Its Ecological Importance

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Abstract:

All life forms require nutritional elements in high quantities. Carbon, hydrogen, nitrogen, sulfur, phosphorus, potassium, and calcium are among these elements. The biosphere components provide nutrient materials to living organisms. Because matter cannot be generated or destroyed, nutritional components must have been utilized repeatedly in the production of new generations of organisms. To put it another way, elements are continuously recycled. Biogeochemical cycles are the flow of such essential micronutrients through the biosphere's non-living and living constituents, and biogeochemical elements are nutrient constituents taken from the earth by various microorganisms for use in their various metabolic processes. In other words, Natural cycles facilitate the continuous movement of life's basic elements by expressing the changing interrelationships among biological forms and their physical environments. Material cycles can be endogenic, including mostly subterranean rocks, or exogenic, involving mostly the earth's surface.

Many of these cycles are exogenic, indicating the parts of the component's life cycle are spent in the atmosphere or in water. The most prevalent living systems - H, C, O, and N - have mostly gaseous cycles, which are rapid and generally flawless. Others, such as P, S, K, and Ca, endogenic cycles lack a gaseous ingredient. The reservoir for nutritional elements in these cycles is in the earth's sediments, hence the name sedimentary cycles, which are slow and imperfect systems. All sedimentary cycles contain salt solutions or soil solutions containing dissolved components excreted from weathering of minerals; these substances may be retained as mineral deposits or eaten as nutrition by microorganisms.

Keywords: *Biogeochemical cycle, Nutrients, Sediments, Gaseous, Sedimentary.*

3.1 Introduction:

The biosphere is a term used to describe the environment that supports life and numerous human activities. The biosphere is commonly divided into minor units or ecosystems because of its complexity and size. The biotic (living) and abiotic (non-living) components of all ecosystems can be separated into two categories. Within an ecosystem, there are dynamic interrelations among biological organisms and their surrounding environment. All life forms require nutritional elements in high quantities. The biosphere components provide nutrient materials to living organisms. Because matter cannot be generated or destroyed, nutritional components must have been utilized repeatedly in the production of new generations of organisms. Each element has its own tale, but all nutrients travel through the biogeochemical cycle, which is a more or less cyclic passage from abiotic to biotic and back to abiotic components of the ecosystem (bio for living, geo for rocks and soil and chemical for the process involved). Although the biogeochemical cycles of various key elements required by autotrophs and heterotrophs differ in detail, all biogeochemical cycles have a basic structure from the perspective of the ecosystem. Inputs, internal cycling, and outputs are the three basic components.

3.2 Classification:

The primary source of nutrient input to the environment is used to classify biogeochemical cycles. These cycles are of two types:

1. Gaseous Cycles:

Gaseous cycles are exogenic cycles in which the atmosphere and hydrosphere serve as the primary source of nutrients. As a result, gaseous cycles are clearly worldwide. Nitrogen, oxygen, and carbon dioxide are the most essential gases for life. The three gases dominate the Earth's atmosphere in stable amounts of 78 percent, 21 percent, and 0.03 percent, respectively. Gaseous cycles are referred to be 'well-buffered cycles' because they have a high potential to adjust or change.

2. Sedimentary Cycles:

The main pool for sedimentary cycles is soil, rocks, and minerals, which are in endogenic cycles. Mineral elements are derived from inorganic sources and are required by living organisms. Salts dissolved in soil are the available forms. Weathering draws mineral salts from the Earth's crust. In lakes, streams, and seas, or in water. The mineral cycle varies depending on the element, but it fundamentally comprises two phases: the rock phase and the phase of salt solution. After that, the soluble salts make their way into the water cycle. The salts are carried by water through the soil to streams and lakes, finally reaching the seas, where they are permanently deposited. Sedimentation returns other salts to the Earth's crust. They're accumulated in salt beds, silts, and limestone. They re-enter the cycle after weathering. Because the majority of the material is immobilized in the earth's crust, minor disturbances can easily interrupt sedimentary cycles.

Now we'll look at carbon, nitrogen, phosphorus, sulfur, and oxygen cycling.

3.3 The Hydrological Cycle:

The hydrological cycle is a never-ending cycle that facilitates between the land, sea, living plants, atmosphere, and animals and it also facilitates the transfer of water. More than 97% of the global water is located in the oceans, with the remaining 3% found on land and in the atmosphere. However, more than 70% of it is trapped in glaciers and ice caps. Lakes, streams, and groundwater, on which humans rely so heavily, account for less than 1% of the total supply, and it is this water that is currently being used and reused in many areas worldwide. The hydrological cycle uses around 1/3rd of the solar energy absorbed by the earth’s surface. The biosphere's hydrological cycle is based on the reciprocity of evaporation and precipitation. Evaporation and transpiration (Plant receives capillary groundwater but gives off surplus water through leaves) of plants release liquid water into the atmosphere as vapor. Rain or snow restores the vapor to the Earth (precipitation). Evaporation from the oceans normally excels precipitation into the seas by around 10%. That extra 10% eventually evaporates as water vapor on the ground surface, balancing the hydrological cycle and meeting our needs for more water. As a result, the hydrological cycle has a well-balanced constant cycle of evaporation, rainfall, transpiration, surface water runoff, and groundwater circulations.

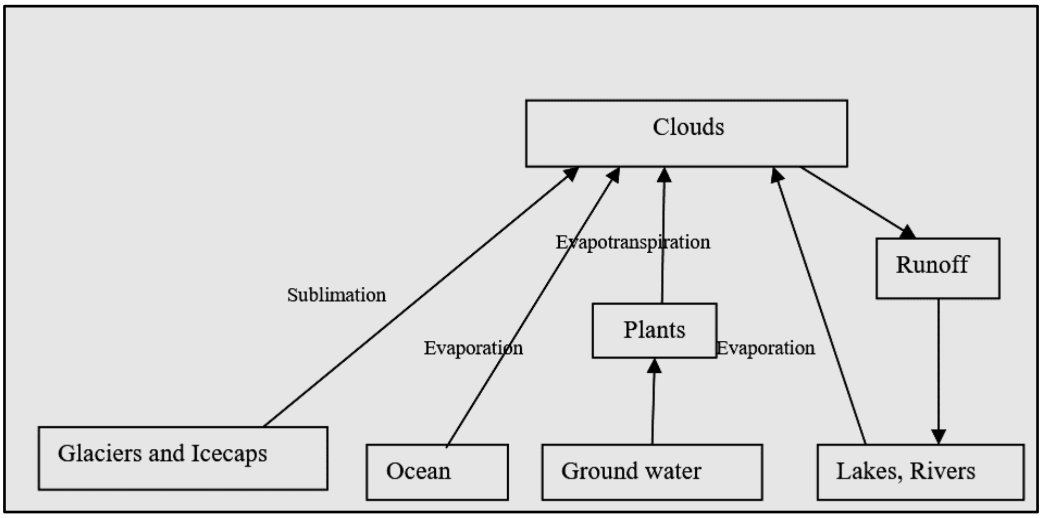

Figure 3.1: Represents the Hydrological Cycle

3.4 The Carbon Cycle:

Carbon, which is the backbone of Organic Chemistry, circulates within the ecosystem via the carbon cycle. Carbon can be found in a variety of forms in the atmosphere. Carbon dioxide is the most common, but it can also be found in organic substances like methane and ethylene in smaller concentrations. The producers convert carbon dioxide from the environment to organic carbon (CH_2O), which is a component of all life molecules, through photosynthesis. This then goes through consumers and decomposers before being reintroduced into the atmosphere via respiration and breakdown around half of the carbon-containing molecules are respired by plants and animals, while the other half is deposited in the soil as detritus (dead plants and animals). In surface and groundwater, a considerable amount of carbon is dissolved as HCO_3^-, and a significant amount is mixed in sea and ocean water, where it is finally fixed as carbonate minerals at the sea/ocean bottoms. Coal, lignite, petroleum, and natural gas are some examples of fixed carbon. The carbon cycle's importance is predicated on the movement of carbon from biological systems to the geosphere in the form of fossil carbon and fossil fuels.

Microorganisms play an essential role in the carbon cycle, regulating a variety of biochemical reactions. In water, photosynthetic algae are important carbon-fixing molecules; they absorb $CO_2$and precipitate $CaCO_3$ and $CaCO_3.MgCO_3$. Microorganisms use geochemical mechanisms to transform organic carbon into fossil fuels i.e., coal, and lignite. They also convert organic carbon to CO_2 from biomass and fossil fuels before returning it to the atmosphere. The action of microorganisms is a significant way of cleaning oil spills on seas as well as carbon-containing hazardous waste. Human activities have disrupted the dynamic balance among the biosphere's primary carbon dioxide reservoirs, and the consequences of these disruptions are a matter of serious and immediate concern.

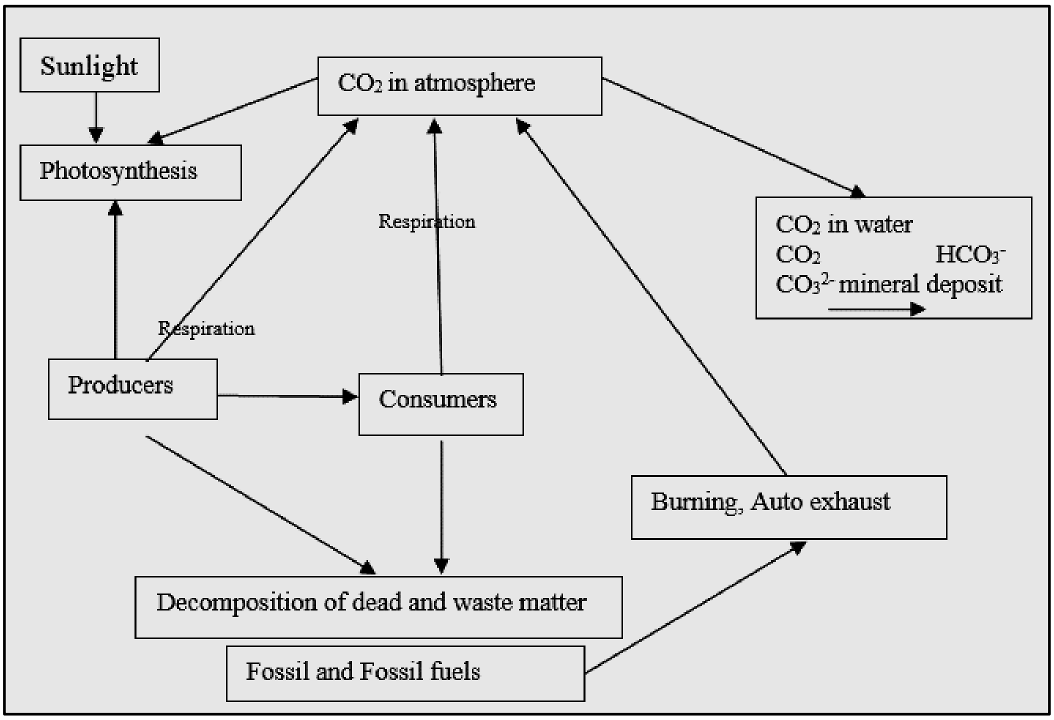

Figure 3.2: Represents the Carbon Cycle

3.5 The Nitrogen Cycle:

The gaseous form of nitrogen makes up 79 percent of the atmosphere. Nitrogen and its components are required for biological processes to continue. Most forms of life, however, cannot utilize it directly. Plants and animals can't use it till it's fixed. The nitrogen cycle begins with atmospheric nitrogen being fixed. Plants can only get nitrogen in two chemical forms: ammonium (NH4+) and nitrate (NO3-). Nitrogen enters the ecosystem through two channels, each with a different relative significance in different ecosystems. Atmospheric deposition is the first pathway. This can occur in both wet falls and dry falls, such as rain, snow, and even cloud and fog droplets, as well as aerosols and particles. The second method nitrogen enters the ecosystem is through nitrogen fixation. There are two possible causes for this fixation. The first is a high-energy fixation. The high energy required in mixing nitrogen with oxygen and hydrogen in water is provided by cosmic radiation, meteorite tracks, and lightning. Rainwater carries the ammonia and nitrates to the earth's surface. The biological approach is the second method of fixing. Nitrogen is fixed by symbiotic bacteria that live in mutualism partnerships with plants, free-living aerobic bacteria, and cyanobacteria. Fixation breaks down molecular nitrogen into two free nitrogen atoms. The two molecules of ammonia are formed when the free N atoms mix with hydrogen. Fixation of nitrogen is followed by nitrification where ammonia is converted to nitrate and nitrite provides energy. Bacteria utilize this energy to produce organic matter directly from carbon dioxide and water. Denitrification is the process of nitrate degradation that becomes more important when oxygen levels are low. Denitrifying bacteria, such as Pseudomonas, can convert nitrate to nitrite, ammonia, and molecular oxygen using the energy of the nitrate ion. By industrially fixing nitrogen, man has disrupted this natural cycle. This includes nitrogen fertilizer synthesis and nitrogen oxidation during fossil fuel burning. The majority of the extra nitrogen is carried away in rivers and lakes, eventually ending up in the ocean. Excessive runoff has considerably increased productivity in many aquatic ecosystems, contributing to the eutrophication process.

Crucial Nitrogen Transformations:

Nitrogen fixation

Nitrogen + water combined by bacteria to give ammonia and oxygen.

Nitrification

Ammonia + oxygen combined by bacteria to give nitrite (oxide of nitrogen) and hydrogen and water.

Denitrification

Nitrate + water is combined by bacteria to give molecular nitrogen, oxygen and hydroxide.

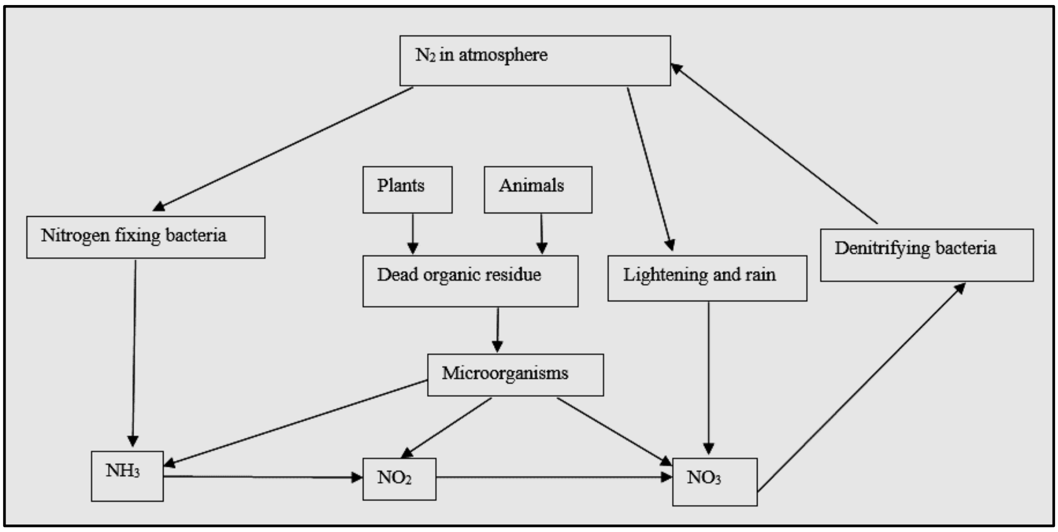

Figure 3.3: Represents the Nitrogen Cycle

3.6 The Phosphorus Cycle:

Phosphorus is essential for the development of living tissue. Bacteria eventually break down organic substances to phosphates, which are then available to autotrophs. Organophosphates are required for cell division and the generation of nuclear DNA and RNA. Phosphates are necessary for animal bone and teeth growth and maintenance.

There is no atmospheric pool in the phosphorus cycle. The main phosphate reservoirs include land, rock, and natural phosphate deposits. Phosphates are released into ecosystems as these deposits degrade.

Phosphorus is delivered into the soil by rain and other natural processes and much of it is taken up by soil particles or is fixed in the soil. However, some of it is lost to water bodies such as lakes and streams and finally ends up in the ocean, where the phosphate is deposited in both shallow and deep sediments.

The weathering of calcium phosphate minerals provides approximately all of the phosphorus in the terrestrial ecosystem. The phosphorus cycle occurs in three stages in marine and freshwater ecosystems: organic phosphorus dissolved organic phosphates, and inorganic phosphates.

All types of phytoplankton quickly absorb organic phosphates, which are then consumed by zooplankton and detritus-feeding animals. Zooplanktons may excrete as much phosphorus as they store in their biomass on a daily basis, reintroducing it into the cycle. Phytoplankton absorbs more than half of the phosphorus excreted by zooplankton in the form of organic phosphate.

The remaining phosphorus in aquatic habitats is found in organic molecules that bacteria can utilize because dissolved inorganic phosphate is not regenerated. Phosphate is deposited in shallow sediments and deep water in equal amounts.

The migration of deep waters to the surface during ocean up-welling transports some phosphate from the dark depths to shallow waters. Phytoplankton consumes these phosphates. A portion of the phosphorus in plants and animals' bodies sinks to the bottom and is deposited in sediments.

As a result, phosphorus levels in surface water may drop, while deep waters may become saturated. Because phosphorus as a nutrient would be in short supply, the net one-way displacement of phosphorus reserves from land to the ocean is of some concern. As a result, it could be classified as a growth determinant nutrient.

Soil infertility is caused by a lack of phosphorus in the soil, and synthetic fertilizers are now widely applied to supplement the lost phosphorus. The phosphorus cycle has been significantly impacted by the increased use of fertilizers and synthetic detergents. Phosphorus contamination has aided in the eutrophication of many water bodies and may have a negative impact on natural food systems.

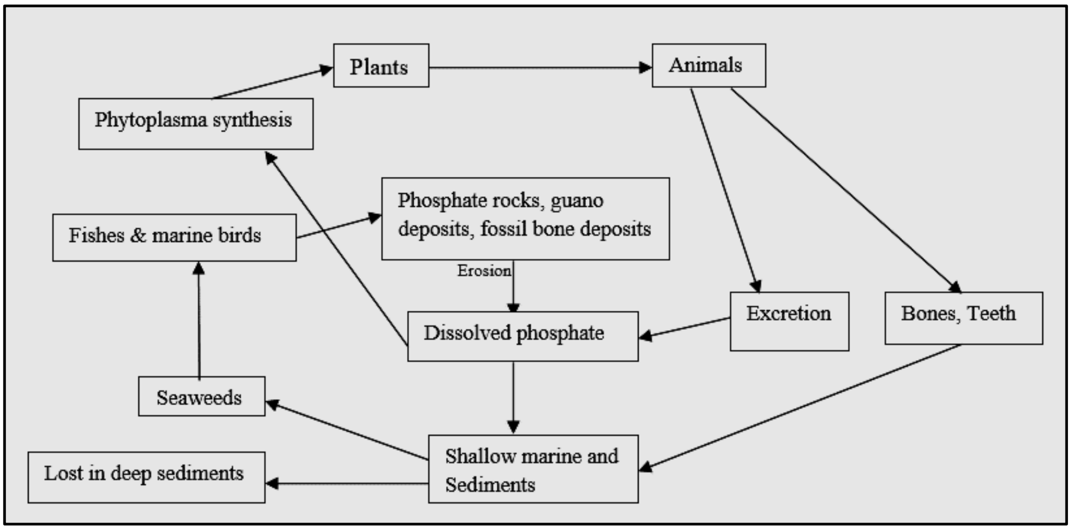

Figure 3.4: Represents the Phosphorus Cycle

3.7 The Sulphur Cycle:

Sulfur, like nitrogen, is a fundamental component of plant and animal proteins. It can be found in a number of forms across the biosphere. There are sedimentary and gaseous phases to the sulfur cycle. The primary gaseous forms are sulfur dioxide (SO_2) and hydrogen sulfide (H_2S), whereas the sulfate ion (SO_4^{2-}) is the most prevalent form found in water and soil. Sulfur enters the atmosphere via a variety of sources; including fossil fuel burning (SO_2), volcanic eruptions (H_2S, SO_2, SO_4^{2-}), ocean surface exchange (SO_4^{2-}), and microbial breakdown gases (H_2S).

Sulfur in soluble form is absorbed by plants and integrated into sulfur-containing amino acids through a series of metabolic activities, beginning with photosynthesis. After being absorbed from the soil by plants and microbes, the sulfate ion is reduced and eventually integrated into proteins as the sulphydryl group (-SH). Some sulfates are converted directly to sulfides, such as H_2S, or to elemental sulfur under anaerobic conditions by Desulfovibrio bacteria, which are mostly found at the ocean's bottom. The resulting hydrogen sulfide gas escapes into the environment, replenishing the sulfur lost by precipitation. H_2S is rapidly converted to sulfates by bacteria of the species Thiobacillus in the presence of oxygen. Several bacteria, such as Chlorobacteriecae and Thiorhodaeceae, may oxidize H_2S to elemental sulfur even in the absence of oxygen.

The majority of sulfur, in the form of SO_2 or H_2S, is transformed intosulfurtrioxide (SO_3), which dissolves in water droplets and is delivered back to the surface as weak sulfuric acid in rainwater (H_2SO_4). The sulfur cycle is overburdened as a result of the ever-increasing use of fossil fuels. As a result, SO_2 discharged into the atmosphere as a result of this process accounts for a considerable portion of total worldwide sulfur transport. This increased sulfur content in rainwater is usually converted to sulphuric acid, which has negative ecological consequences.

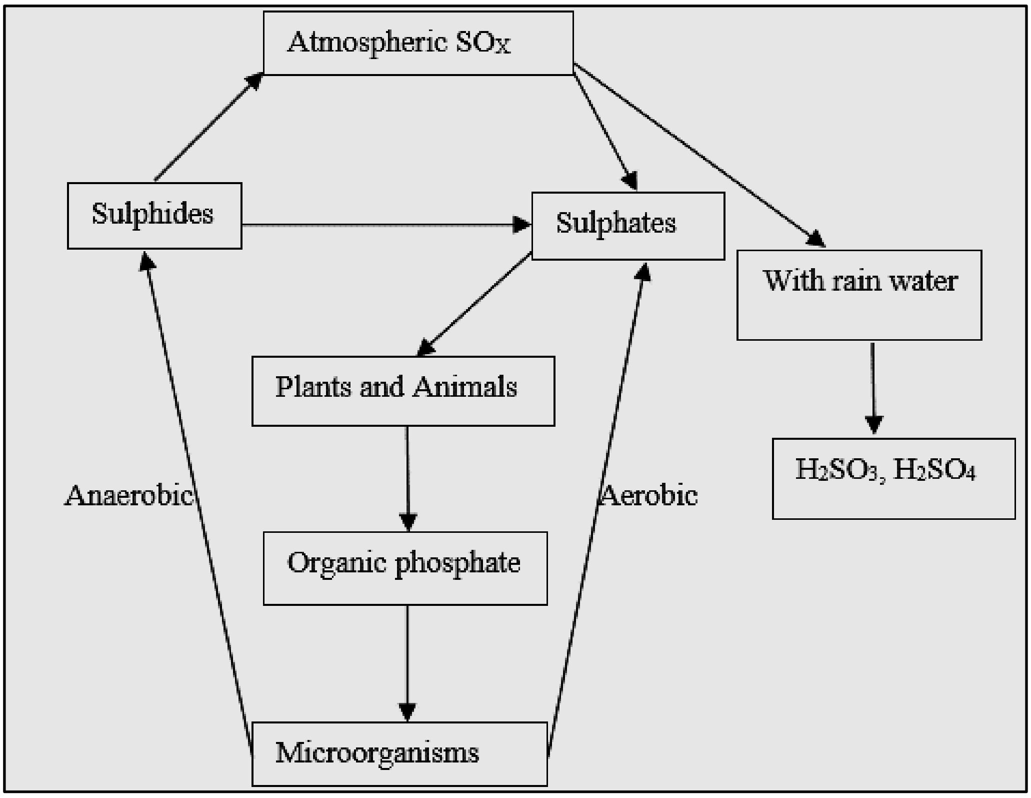

Figure 3.5: Represents the Sulfur Cycle

All these cycles play a vital role in the functioning of the ecosystem. A biogeochemical cycle is acontinuous process by which a component, in some cases, an element like water, circulates among its different biotic and abiotic forms. The relevance of chemistry, geology, and biology in understanding these cycles is necessary.

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