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TYPOLOGY AND SIGNIFICANCE OF BIOGEOCHEMICAL CYCLES : A CONCEPTUAL STUDY

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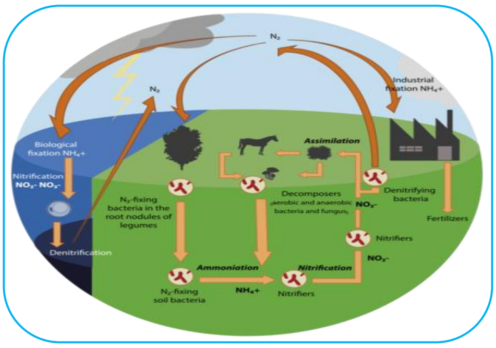
ABSTRACT:

These cycles illustrate how energy is utilized. Within the ecosystem, these cycles transport essential elements necessary for life to thrive. They are crucial as they recycle and store elements while also regulating vital components through physical processes. These cycles highlight the connection between living organisms and non-living entities in ecosystems, facilitating their ongoing survival. Understanding these cycles is essential to recognize their impact on living beings. Certain human activities disrupt some of these natural cycles, consequently affecting the ecosystems connected to them. A detailed examination of these processes can assist us in mitigating and preventing their harmful effects. This paper aims to explore the classification and importance of Biogeochemical Cycles.



KEYWORDS: *Biogeochemical Cycles, Carbon Cycle, Phosphorus Cycle, Oxygen Cycle.*

INTRODUCTION:

Biogeochemical Cycles

The term bio-geochemical is derived from “bio” meaning biosphere, “geo” meaning the geological components and “chemical” meaning the elements that move through a cycle. The matter on Earth is conserved and present in the form of atoms. Since matter can neither be created nor destroyed, it is recycled in the earth’s system in various forms. The earth obtains energy from the sun which is radiated back as heat, rest all other elements are present in a closed system. The major elements include:

- Carbon
- Hydrogen
- Nitrogen
- Oxygen
- Phosphorus
- Sulphur

These elements are recycled through the biotic and abiotic components of the ecosystem. The atmosphere, hydrosphere and lithosphere are the abiotic components of the ecosystem.

Types of Biogeochemical Cycles Biogeochemical cycles are basically divided into two types:
- Gaseous cycles – Includes Carbon, Oxygen, Nitrogen, and the Water cycle.
- Sedimentary cycles – Includes Sulphur, Phosphorus, Rock cycle, etc.

Water Cycle
The water from the different water bodies evaporates, cools, condenses and falls back to the earth as rain. This biogeochemical cycle is responsible for maintaining weather conditions. The water in its various forms interacts with the surroundings and changes the temperature and pressure of the atmosphere. There's another process called Evapotranspiration (i.e. vapour produced from leaves) which aids this process. It is the evaporation of water from the leaves, soil and water bodies to the atmosphere which again condenses and falls as rain.

Carbon Cycle
It is one of the biogeochemical cycles in which carbon is exchanged among the biosphere, geosphere, hydrosphere, atmosphere and pedosphere. All green plants use carbon dioxide and sunlight for photosynthesis. Carbon is thus stored in the plant. The green plants, when dead, are buried into the soil that gets converted into fossil fuels made from carbon. These fossil fuels when burnt, release carbon dioxide into the atmosphere. Also, the animals that consume plants, obtain the carbon stored in the plants. This carbon is returned to the atmosphere when these animals decompose after death. The carbon also returns to the environment through cellular respiration by animals. Huge carbon content in the form of carbon dioxide is produced that is stored in the form of fossil fuel (coal & oil) and can be extracted for various commercial and non-commercial purposes. When factories use these fuels, the carbon is again released back in the atmosphere during combustion.

Nitrogen Cycle
It is the biogeochemical cycle by which nitrogen is converted into several forms as it circulates through the atmosphere, terrestrial and marine ecosystems. Nitrogen is an essential element of life. The nitrogen in the atmosphere is fixed by the nitrogen-fixing bacteria present in the root nodules of the leguminous plants and made available to the soil and plants. The bacteria present in the roots of the plants convert this nitrogen gas into a usable compound called ammonia. Ammonia is also supplied to plants in the form of fertilizers. This ammonia is converted into nitrites and nitrates. The denitrifying bacteria reduce the nitrates into nitrogen and return it into the atmosphere.

Oxygen Cycle
Oxygen cycle, along with the carbon cycle and nitrogen cycle plays an essential role in the existence of life on the earth. The oxygen cycle is a biological process which helps in maintaining the oxygen level by moving through three main spheres of the earth which are:
- Atmosphere
- Lithosphere
- Biosphere

This biogeochemical cycle explains the movement of oxygen gas within the atmosphere, the ecosystem, biosphere and the lithosphere. The oxygen cycle is interconnected with the carbon cycle.

The atmosphere is the layer of gases presents above the earth's surface. The sum of Earth's ecosystems makes a biosphere. Lithosphere is the solid outer section along with the earth's crust and it is the largest reservoir of oxygen.

Stages of the Oxygen Cycle
The steps involved in the oxygen cycle are:

Stage-1: All green plants during the process of photosynthesis, release oxygen back into the atmosphere as a by-product.

Stage-2: All aerobic organisms use free oxygen for respiration.

Stage-3: Animals exhale Carbon dioxide back into the atmosphere which is again used by the plants during photosynthesis. Now oxygen is balanced within the atmosphere.

Phosphorous Cycle

Phosphorus is an important element for all living organisms. It forms a significant part of the structural framework of DNA and RNA. They are also an important component of ATP. Humans contain 80% of phosphorus in teeth and bones.

Phosphorus cycle is a very slow process. Various weather processes help to wash the phosphorus present in the rocks into the soil. Phosphorus is absorbed by the organic matter in the soil which is used for various biological processes.

Since phosphorus and phosphorus-containing compounds are present only on land, atmosphere plays no significant role in the phosphorus cycle.

Let us have a brief look at the phosphorus cycle, its steps and the human impact on phosphorus cycle.

Following are the important steps of phosphorus cycle:

1. Weathering
2. Absorption by Plants
3. Absorption by Animals
4. Return to the Environment through Decomposition

SULPHUR CYCLE

The sulfur cycle describes the movement of sulfur through the atmosphere, mineral forms, and through living things. Although sulfur is primarily found in sedimentary rocks or sea water, it is particularly important to living things because it is a component of many proteins.

Sulfur is released from geologic sources through the weathering of rocks. Once sulfur is exposed to the air, it combines with oxygen, and becomes sulfate SO_4. Plants and microbes assimilate sulfate and convert it into organic forms. As animals consume plants, the sulfur is moved through the food chain and released when organisms die and decompose.

Some bacteria – for example Proteus, Campylobacter, Pseudomonas and Salmonella – have the ability to reduce sulfur, but can also use oxygen and other terminal electron acceptors. Others, such as Desulfuromonas, use only sulfur. These bacteria get their energy by reducing elemental sulfur to hydrogen sulfide. They may combine this reaction with the oxidation of acetate, succinate, or other organic compounds.

The most well known sulfur reducing bacteria are those in the domain Archea, which are some of the oldest forms of life on Earth. They are often extremophiles, living in hot springs and thermal vents where other organisms cannot live. Lots of bacteria reduce small amounts of sulfates to synthesize sulfur-containing cell components; this is known as assimilatory sulfate reduction. By contrast, the sulfate-reducing bacteria considered here reduce sulfate in large amounts to obtain energy and expel the resulting sulfide as waste. This process is known as dissimilatory sulfate reduction. In a sense, they breathe sulfate.

Sulfur metabolic pathways for bacteria have important medical implications. For example, Mycobacterium tuberculosis (the bacteria causing tuberculosis) and Mycobacterium leprae (which causes leoprosy) both utilize sulfur, so the sulfur pathway is a target of drug development to control these bacteria.

Impact of Environmental Factors on Biogeochemical Cycles

Environmental factors, including soil characteristics, moisture levels, pH, temperature, and other conditions, play a critical role in regulating the rate of release of nutrients into the atmosphere.

- Soil Characteristics: Sandy soils tend to drain quickly and may release nutrients more rapidly, while clayey soils can retain nutrients, making them less available to plants and potentially slowing nutrient release.
- Moisture: Adequate moisture is essential for microbial activity and the processes involved in nutrient transformation.
- Drought conditions can reduce nutrient release rates, while waterlogging can lead to leaching of nutrients.
- Acidity or Alkalinity: Different nutrients have varying solubility and availability at different pH levels.
    - Example: Acidic soils can lead to increased release of aluminum and manganese, which can be toxic to plants, while alkaline soils can lead to reduced availability of some essential nutrients like iron.
- Temperature: Warmer temperatures generally accelerate nutrient release and transformation processes, while colder temperatures can slow them down. Example: In cold climates, the decomposition of organic matter may be slower, affecting the release of nutrients.
- Microorganisms: Microbial populations are sensitive to temperature, moisture, and organic matter availability. These microorganisms play a crucial role in nutrient cycling by breaking down organic matter and facilitating nutrient transformations.

Ecosystem Dynamics: The Significance of Biogeochemical Cycles

- Fundamental to Life: They ensure the availability of essential elements and compounds, such as carbon, nitrogen, phosphorus, and water, that are needed for the growth and maintenance of all living organisms.
- Nutrient Recycling: Biogeochemical cycles help maintain environmental balance and stability by preventing the depletion of resources and helps regulate ecosystem dynamics.
- Climate Regulation: They play a crucial role in regulating the Earth's climate by controlling the concentration of greenhouse gases in the atmosphere.
- Soil Fertility: Biogeochemical cycles contribute to soil fertility as the availability of nutrients in the soil is essential for plant growth and agriculture.
- Conservation: Biogeochemical cycles are crucial for conserving the planet's resources.
- Responsible resource management is essential to avoid overexploitation and depletion of natural resources.

CONCLUSION

Biogeochemical cycles are the essential mechanisms that sustain life on Earth and maintain the planet's ecological balance. They are crucial for environmental health, climate stability, and human well-being, and understanding and managing these cycles is essential for the long-term sustainability of our planet.

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