Bio-Geo-Chemical Cycling

Meaning

All the elements of the biosphere circulate in a circular path from the biosphere to organisms and then from organisms to the biosphere again. These circular paths are known as bio-geo-chemical cycles. The movement of abiotic materials necessary for life is called 'nutrient cycling'.

The terms bio and geo, refer to living organisms and the earth (including rocks, air, and water), respectively. Geochemistry is a physical science which studies chemical composition of the earth and exchange of various materials between the earth's surface, hydrosphere and atmosphere.

Hutchinson (1944, 1950) used the word biogeochemistry and considered it as the study of exchange of living and non-living components of the biosphere.

Biosphere is a giant system in which several sub systems or ecosystems operate. Various nutrient chemicals are found in the organs of organisms present in ecosystems. Decomposition takes place when organisms die., and nutrients are released from their bodies. Thus, the process of change of abiotic elements into biotic phase, and again into inorganic or abiotic form is called bio-geo-chemical cycling.

The major chemical elements participating in 'bio-geo-chemical cycling' in the biosphere include oxygen, nitrogen, carbon, phosphorus, potassium, sulphur, magnesium, ferrum (iron) etc.. These elements are formed by weathering of rocks and their deposits on the surface. These elements are very useful and essential for the development of organisms. These chemical elements provide nutrition to organisms in many ways. For example, living being's have 70% content of oxygen. Oxygen increases the rate of metabolic process in organisms. Oxygen is fundamental in the formation of carbo-hydrates, fats and proteins. Organisms contain 10.5% hydrogen and 18% carbon dioxide. Nitrogen, phosphorus sulphur etc. are use in forming proteins in organisms. These elements occur in the environment as solid salts, liquid and gaseous form and synthesise into carbohydrates, protein, nuclear protein, DNA, RNA etc. by plants.

Green plants (producers) obtain various mineral elements from the environment. When plants are decomposed, these elements again reach the environment. It is a cyclic process in which several organisms, and physical and chemical phenomena participate.

Bio-geo-chemical cycles are grouped into three categories : hydrological, gaseous, and sedimentary.

1. Hydrological Cycle

Strictly speaking, this is not an elemental cycle because it follows the course of a compound, water. Nevertheless, the movement of water within and between the ecosystems is fundamental to an understanding of nutrient cycles for several reasons :

(*i*) Source of hydrogen for photosynthesis in plants,

(*ii*) Plants use large amount of water to maintain their hydrostatic skeletons and to move chemicals about their bodies,

(*iii*) Plants take elements in aqueous solution from soil.

The hydrological cycle includes all of the biospheric processes that cause water to be moved from the hydrosphere through the atmosphere and lithosphere and back to the hydrosphere.

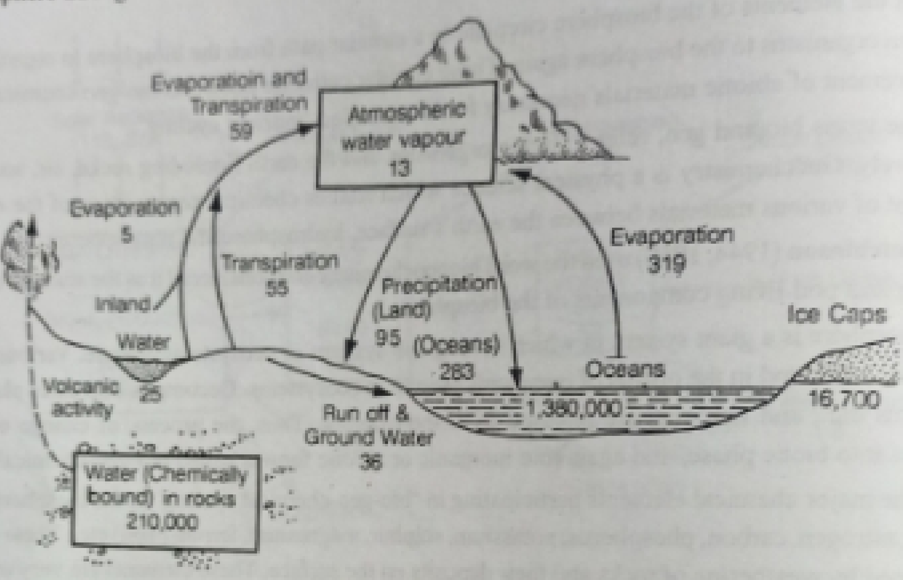

Fig. 5.12 : Hydrological Cycle

Water enters the atmosphere through solar driven vapourization from lakes, rivers, oceans (evaporation) and the leaves of plants (transpiration). It cools and condenses, forms clouds, and returns to the earth as some form of precipitation (rain, snow, hail, etc.) to begin the cycle once more. The earth's total water supply is not added to or subtracted from over time. The quality and availability of water at any one time or place, however, are dependent upon several factors : (*i*) the uses to which humans put it, (*ii*) the condition and average temperature of the earth's surface where it falls, (*iii*) and the continued ability of the soil, forests, wetlands, and lakes to absorb, clean and help store it.

2. Carbon Cycle

Like the hydrological cycle, carbon cycle is also very important for man. The small amount of carbon dioxide (0.03 percent) in the atmosphere is the only source of all carbon that passes through the organisms along the food chains. Carbon moves from the atmospheric pool to green plants (producers), then to animals (consumers) and finally to bacteria and other micro-organisms (decomposers) that return into the atmosphere, through decomposition of dead organic matter. The carbon dioxide has the unique property of absorbing infra red radiation and its small quantity helps in keeping the earth warm. A part of this cycle also operates in the ocean.

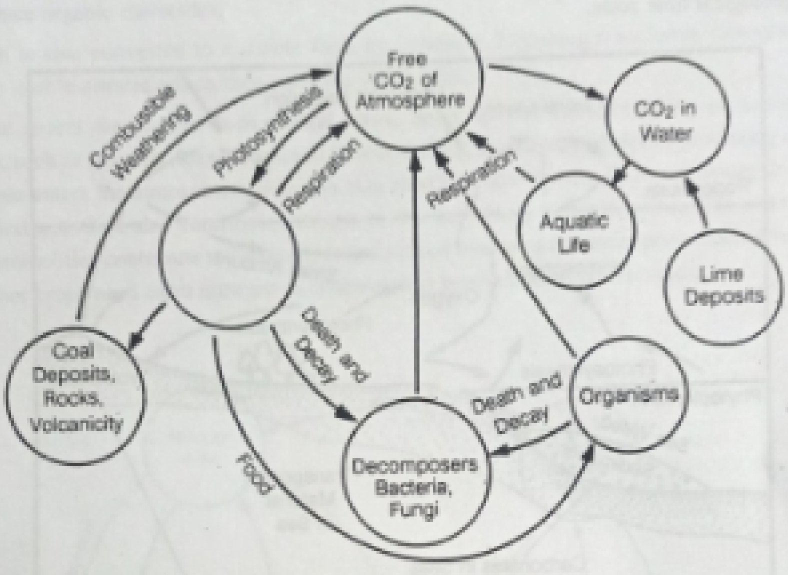

Fig. 5.13 : Carbon Cycle

3. Oxygen Cycle

Oxygen is very essential element for the living organisms because it supports life. The circulation of oxygen also helps in the cycling of other elements in the biosphere. It generally forms about 70% atoms in living matter and plays an important role in the formation of carbohydrates, fats and proteins. It is required for respiration and for photosynthesis processes. The oxygen cycle in the biosphere is very much complicated because of its various chemical forms *e.g.* molecular oxygen (O_2), water (H_2O), carbon dioxide (CO_2), different organic compounds as oxides, carbonates, etc.

Believably, there was no oxygen in the original earth-atmosphere. The molecular oxygen was formed only after the development of photosynthessing organisms. The residence time of oxygen in the atmosphere is 2000 years. The oxygen continued to concentrate in the atmosphere from the time of its formation, and now it constitutes about 21% of the total gaseous composition of the atmosphere.

Oxygen is produced through the process of photosynthesis by the autotrophic green plants and phytoplanktons and to a lesser extent by the reduction of various mineral oxides. Oxygen, thus produced, enters the atmospheric storage pool. Volcanic eruptions also add some oxygen to the atmosphere. Oxygen from the atmospheric storage pool is used by marine and terrestrial animals during respiration. Oxygen is also consumed during burning of wood and fossil fuels. Some portion of oxygen in the form of oxides is incorporated in the drainage waters and ultimately reaches the oceans and is incorporated in the sediment. Thus, oxygen enters the sedimentary storage pool and remains there for considerably longer period of geological time scale.

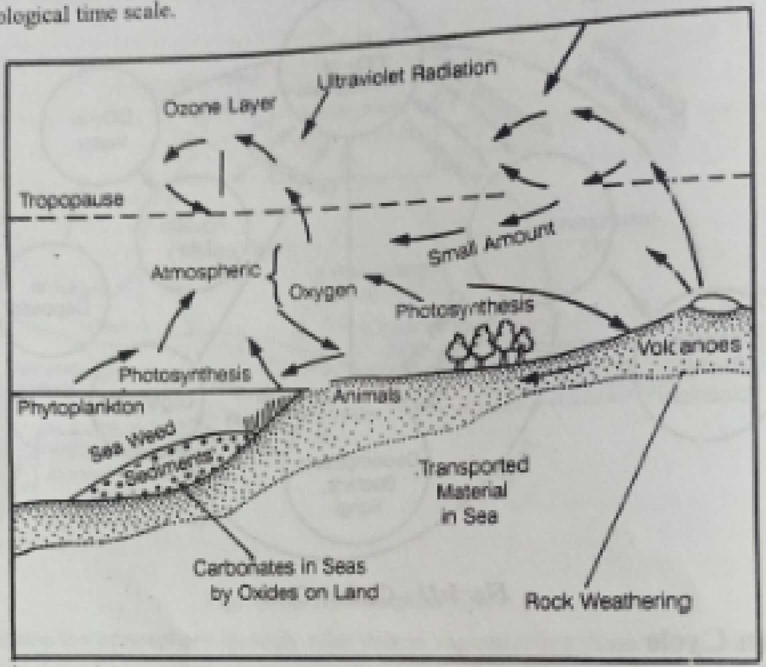

Fig. 5.14 : Oxygen Cycle

4. Nitrogen Cycle

Nitrogen forms nearly 78% of the total gases of the atmosphere. It is an essential element of all forms of life, but is never taken directly from the atmosphere. Plants can use nitrogen only when it is in the form of inorganic compounds, principally ammonium, or nitrates. Animals obtain the nitrogen they need by eating plant or animal tissues. Because plants cannot use gaseous nitrogen directly, and the conversion of nitrogen to ammonium or nitrates is slow and complicated, nitrogen is often a limiting factor for plants, especially terrestrial plants.

Nitrogen is converted to a usable form in three major ways. First, some kinds of bacteria, either free-living in the soil, or living in nodules in plant roots, convert free nitrogen to nitrates or to ammonia which is further converted to usable ammonium. This process is called **nitrogen fixation.** The nitrogen-fixing bacterium Rhizobium lives within the root nodules of legumes (such as peas, beans, alfalfa, locus trees, etc.). It converts nitrogen to usable forms for the plant, the legume, in turn, provides the bacterium with a place to live and a food source, sugars.

Decomposition also makes nitrogen available to plants in a usable form. Some decomposers reduce tissues and waste products to less complex forms, eventually converting proteins and amino acids to ammonium. Other decomposers convert ammonium to nitrates and nitrates, forms that can be used by plants to produce organic molecules.

Nitrogen is also converted to a usable form by lightning. Lightning transforms nitrogen in the atmosphere to usable nitrates which then enter the soil in rain.

Nitrogen enters the biosphere in several ways. Some special bacteria living in nutrient-rich environments, such as estuaries, lakes, bogs, and the ocean floor, are capable of slowly producing nitrogen gas, which then enters the atmosphere. Nitrogen also enters the atmosphere from volcanoes. Industrial and agricultural activities also contribute nitrogen to the biosphere. Emissions from factories, power plants and automobiles contribute millions of tons of nitrous oxides to the atmosphere each year. Maize and many other crops need extra nitrogen to enhance their production of amino acids.

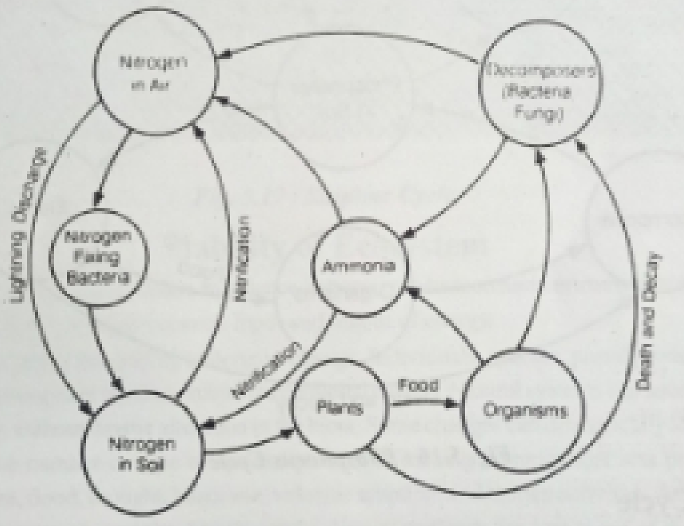

Fig. 5.15 : Nitrogen Cycle

5. Phosphorus Cycle

This is a sedimentary cycle. Phosphorus is a major component of genetic material, energy molecules, and cellular membranes. It is also the major structural component of the shells, bones and teeth of animals.

Phosphorus cannot be absorbed in its elemental form, but instead enters the environment in several ways. Decomposers convert phosphorus into phosphate, that can be used by producers. Wind and water erode phosphate from phosphate rich rocks. Even though small amounts are slowly lost to streams, rivers, and to the oceans, most phosphate continues to cycle in the ecosystem. The phosphate that does eventually make its way to the oceans is lost to the biosphere for long periods of time. Sea bird droppings (guano) deposited on the land, and ocean floor uplifting help counteract this loss, but these are slow processes.

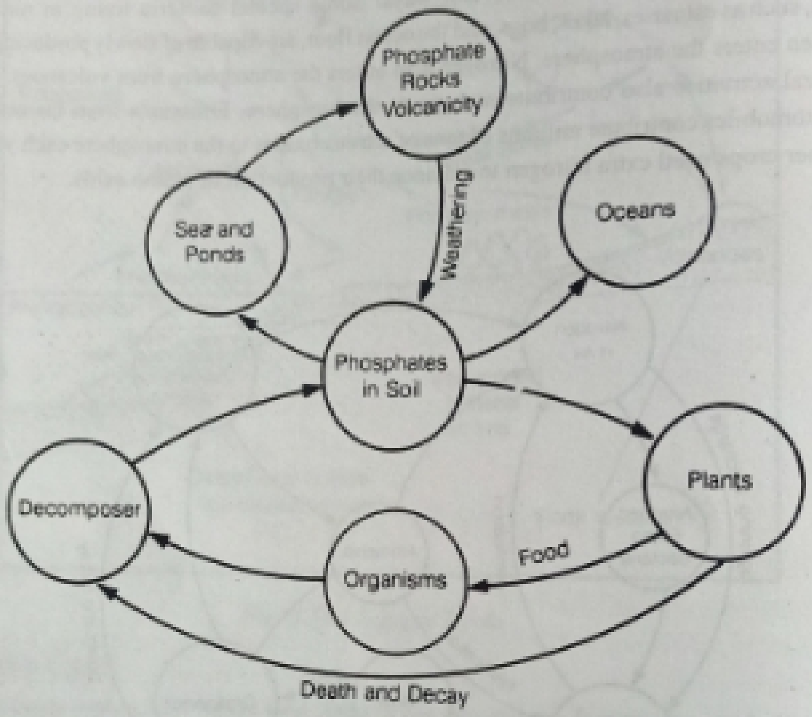

Fig. 5.16 : Phosphorus Cycle

6. Sulphur Cycle

The sulphur cycle links air, water and soil, where microbes play an important role. Sulfur is a constituent of amino acids and proteins. It helps to activate enzymes. It is important in energy metabolism and it becomes a part of some vitamins. Like phosphorus, sulfur cannot by absorbed by plants in its elemental form. Instead, it is absorbed as sulfates which are produced from the weathering of rocks and soils. Sulfates released to the atmosphere contribute to the formation of sulfuric acid and ammonium sulfide. Sulfur also enters the atmosphere as hydrogen sulfide which is produced by volcanoes, hot springs, decomposers, and industrial sources. Human-made sources *e.g.* power plants and industrial activities new account for the greatest release of sulfur into the atmosphere.

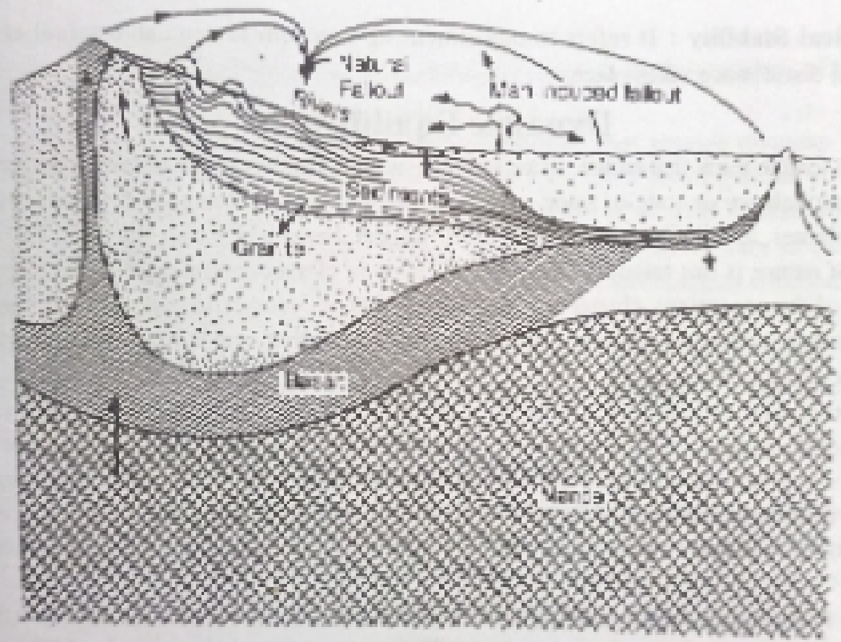

Fig. 5.17 : Sulphur Cycle

Stability of Ecosystem

The stability of ecosystem refers to balance between production and consumption of each elem... ecosystem, or the balance between input and output of energy.

Nature is not static, everything undergoes change. Individuals, species, populations, communities ... systems and the biosphere itself are subject to continual change. Natural systems continually compensa... such variability without drastic alteration in the biota. Some changes can dramatically alter ecosystem...