Biogeochemical Cycling

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Introduction

- Biogeochemical cycling describes the movement and conversion of materials by biochemical activities throughout the atmosphere, hydrosphere and lithosphere.
- This occurs both within ecosystem and on a global basis.
- Biogeochemical cycles include physical transformation such as dissolution, precipitations, volatalization and fixation.
- Chemical transformation such as biosynthesis, biodegradation and various combinations of physical and chemical changes

- Most elements are subject to some degree of biogeochemical cycling.
- The intensity or rate of biogeochemical cycling for each element roughly correlates to the amount of the elements in the chemical composition of bio
- The major elemental components of living organisms are Ex.:- C, H, O, N, P & S they are cycled most intensely.
- Minor element (Mg, K, Na), halogens and trace elements (such as B, Co, Cr, Cu, Mo, Ni & Zn etc) which are required in small quantities and not by every form of life are cycled less intensely.

- Though the energy flows is in one direction but there is a continuous exchange of material nutrients among the components of the ecosystem i.e. the organisms and the environment surrounding them.
- This exchange occurs in a cyclic manner.
- The cycles are together referred to as the biogeochemical cycle.
- Bio refers to the living organisms involved which are mainly microbes.
- Geo means Earth which may involve lithosphere or atmosphere or hydrosphere.
- Chemical refers to chemical reactions occurring during the process.

- Biogeochemical cycles may be divided into two types:–

  1. Gaseous Cycle – In such type the reservoir of the nutrient is present in the atmosphere or hydrosphere and the element is mostly in gaseous for

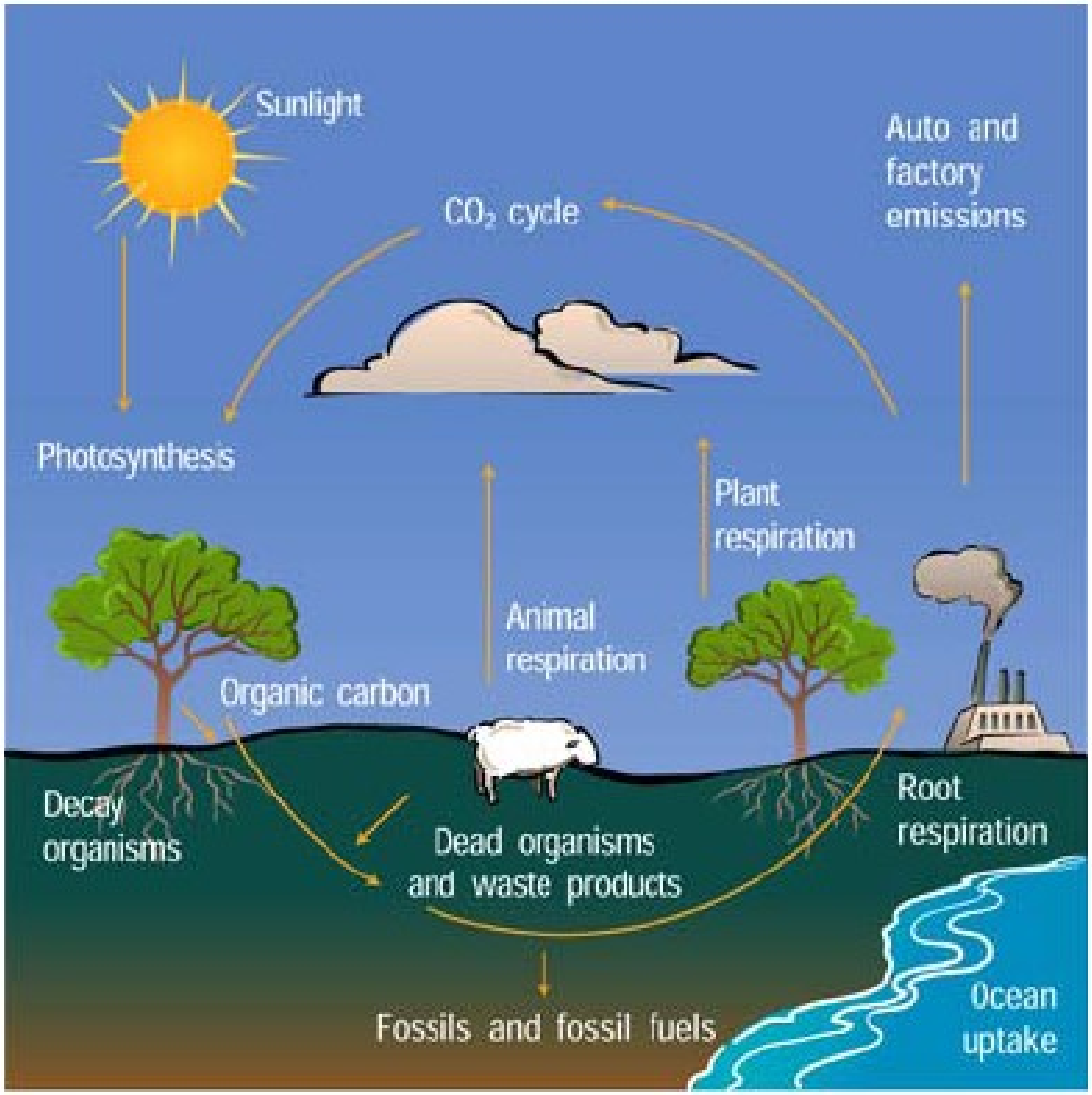
  2. Sedimentary Cycle – In such cycle the nutrient reservoir is present in the Earth's crust and the element is not in gaseous form e.g. Phosphorus, Sulphur etc. m, viz., Hydrogen, Nitrogen etc.

- All the cycles operate in nature with the help of the micro-organisms.
- The microbes also play a vital role in mineralisation and humification.
- During the process of cycling of various elements, physical changes take place along with physical transformations (precipitation, fixation) and chemical transformation (biodegradation, biosynthesis etc).
- During operation of these cycles energy is absorbed, converted, stored for short duration and finally dissipated in the ecosystem.

Carbon Cycle

- One of the major Biogeochemical cycles is Carbon cycle.
- It is a part of cycles of three major elements cycle, namely Carbon, Hydrogen and Oxygen.
- All three of which are cycled by the same two opposing process of photosynthesis and respiration.
- The small atmospheric CO_2 reservoir is influenced by human activities.
- This has assumed considerable importance due to the GREEN HOUSE EFFECT which is warming global climate.

Carbon Cycle



- In any element cycle its reservoir is an important aspect.
- When we talk of the reservoir – its size and how actively it is cycled should be taken into account.
- In case of carbon the atmosphere is the main source in the form of carbon dioxide. This carbon dioxide is also present in soil and water. All organic compounds synthesized naturally have carbon in them.
- Carbon is also locked up in fossil fuels in the form of carbonates. The part of carbon cycle involving weathering of rocks and dissolution of carbonates in soil and water is a slow process while the microbial population makes the process faster by decomposing the dead organic matter.
- The decomposition process in the carbon cycle plays a pivotal role as it provides both energy for growth and supplies carbon for formation of new cell materials.
- The microbial population degrades carbohydrate, sugars, lignin, fats, waxes, hydrocarbons etc.

- Most of the organic matter comprises of plant residues from animal tissues and various execretory products are also present.
- The microbial population degrading the organic matter comprise mainly of bacteria, fungi, and actinomycetes.
- Carbon is transferred mostly through the trophic levels i.e. food chain and food web.
- In living organisms, all of them depend on primary producers.
- Autotropic organisms help in fixation of carbon dioxide as organic compounds.
- Beside the green plants, photosynthetic and chemolithotropic microbes fall in this category (autotrophs) while the rest of them are heterotrophs.
- Whatever carbon is fixed by the organisms (whether micro) is returned back as carbon dioxide through the process of respiration by the living organisms into the pool.

- The organic matter is recycled both aerobically and anaerobically.
- Aerobic degradation is carried out by most of the organisms but anaerobic degradation (fermentation) is carried out by the microbial population only.
- Most of the carbon transformation takes place under aerobic conditions. A compound may not be available to the degrading organisms in a habitat and as a result it would get accumulated but the same compound could be available for degradation in another habitat, thus becoming a source of energy and carbon.
- Organisms gain more energy by respiration compared to fermentation or in other words aerobic process yields more energy than anaerobic process.

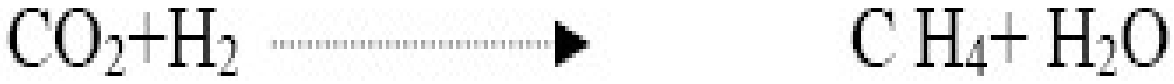
Methanogens (bacteria) convert carbon dioxide to methane Using hydrogen liberated during fermentation

$$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$$

- The microbes also cycle carbon monoxide. Carbon monoxide is released in the atmosphere as a result of photochemical oxidation of methane and other hydrocarbons.
- Carbon monoxide is converted to carbon dioxide in the atmosphere by photochemical reaction and by the microbial population of soil and water.

$$CO + H_2O \dashrightarrow CO_2 + H_2$$

- Carbon dioxide is metabolized both aerobically as well as anaerobically by microorganisms capable of doing so.
- Aerobically e.g. *Pseudomonas carboxidoflava, Pseudomonas carboxydohydrogena.*
- Anaerobically e.g. *Methanosarcina barkeri*



- *Clostridium thermoaceticum* reduce carbon monoxide to acetate. Reaction is as follows:-

- The degradation and decomposition of the organic matter is accomplished mainly by the microbial community present in that habitat.
- This results in the conversion of complex compounds into simple ones and release of energy as well as utilization of stored energy, thus helping in the cycling process.
- Organic matter largely comprises of residues of plant origin which is an important part of carbon cycle.
- The plant remains comprise of cellulose (15- 60%), hemicelluslose (10-30%), lignin (5-30%), Sugars, amino acids, organic acids (5-30%) which are water soluble.
- Fat, oils, resins which are soluble in organic solvents such as alcohol/ether, proteins (10%), mineral constituents present vary from (1-13%).

- **Cellulose** degradation is carried out by fungi in humid soil in semi arid conditions the task is accomplished by bacteria.
- Cellulose decomposition could be aerobic or anaerobic.
- During aerobic process carbon dioxide is the major product formed while under anaerobic conditions carbon dioxide, ethanol and various organic acids (e.g. acetic, lactic, succinic) are formed.

- **Hemicellulose** is another major component which is very much different from cellulose.
- Many enzymes are reported to breakdown this polymer.
- Degradation of hemicellulose is slowed by Calcium, Iron, and Aluminium because of the formatin of complexes.
- Fungal and bacterial population both take part in it’s degradation.
- The end products of hemiecellulose degradation are carbon dioxide, cell biomass and simple carbohydrates (monomers or dimers).

- **Starch** is also an important component since it is the reserve food material of the plants.
- Starch decomposes rapidly by most of the soil microbial population.
- Starch has α linkages which easily get hydrolysed by the microbial enzymes compared to β linkages of cellulose.
- Starch is broken into simpler units by the extracellular hydrolytic enzyme amylase.

- **Lignin** is supposed to be one of the major constituent of the plant tissue.
- It is resistant to degradation and is highly branched with no defined structure.
- Lignin degrades in nature at a much slower rate. Lignin is degraded by the action of fungi.
- The enzyme degrading lignin are called as ligninase.
- The decomposition of lignin is the result of secondary metabolism of the organisms. In wet condition which are not anaerobic, soft rot fungi helps in its degradation.
- Lignin decomposition results in the formation of phenols, aromatic alcohols.
- Some of these products eventually get converted to carbon dioxide and water while the phenolic compounds may form humic compounds.

- **Chitin** is another important component. It is the constituent of fungal cell walls and exoskeleton of insects.
- The enzymes degrading chitin are known as chitinase.
- Actinomycetes play a major role in chitin degradation.
- **Pectin** is another plant component degraded with the help of enzyme Pectinase.

- The organic matter in aquatic habitats is a bit different from the terrestrial habitat. It is lower in amount and less complex in aquatic habitats.
- Some limiting factors in the biodegradation process of carbon compounds are lack of oxygen, high acidity, high concentration of phenolic compounds and tannins e.g. histosols (muck soils) peat deposits and some of the aquaticsediments.
- As a result carbon gets locked up and finally gets depleted from the cycle as fossil fuel deposits.
- In soil, the humic substance present are found to be quite stable and they are observed to persist for a longer duration in peat and muck soils.
- Humic acid in soil reduces the rate of cycling and even at times immobilizes carbon and also the stored energy.

- Degradation of compounds present in the organic matter results in the formation of simple organic compounds.
- During the decomposition process the physical state of some compounds gets changed like production of carbon dioxide or methane or change from liquid to solid state, this brings about change in the availability of the carbon source to the organisms in any habitat.
- In nutshell the carbon cycle involves formation of CO_2 along with many other carbon products mentioned above.
- This carbon dioxide is utilized by plants in the process of photosynthesis.
- If we summarise this cycle it is – carbon is present in atmosphere as carbon dioxide.
- This carbon dioxide is fixed by photosynthesis into carbohydrate and other compounds.
- These compounds are metabolized aerobically to carbon dioxide and anaerobically to methane and carbon dioxide.