Nitrogen Cycle

Introduction and Definition :

Nitrogen is the most abundant element in Earth’s atmosphere: approximately 78% of the atmosphere is nitrogen **Nitrogen** is important to all living things, including us. It plays a key role in plant growth too little nitrogen and plants cannot thrive, leading to low crop yields; but too much nitrogen can be toxic to plants. Nitrogen is necessary for our food supply, but excess nitrogen can harm the environment.

The delicate balance of substances that is important for maintaining life is an important area of research, and the balance of nitrogen in the environment is no exception. When plants lack nitrogen, they become yellowed, with stunted growth, and produce smaller fruits and flowers. Farmers may add fertilizers containing nitrogen to their crops, to increase crop growth. Without nitrogen fertilizers, scientists estimate that we would lose up to one third of the crops we rely on for food and other types of agriculture. But we need to know how much nitrogen is necessary for plant growth, because too much can pollute waterways, hurting aquatic life.

Nitrogen is a key element in the nucleic acids DNA and RNA, which are the most important of all biological molecules and crucial for all living things. DNA carries the genetic information, which means the instructions for how to make up a life form. When plants do not get enough nitrogen, they are unable to produce amino acids (substances that contain nitrogen and hydrogen and make up many of living cells, muscles and tissue). Without amino acids, plants cannot make the special proteins that the plant cells need to grow. Without enough nitrogen, plant growth is affected negatively. With too much nitrogen, plants produce excess biomass, or organic matter, such as stalks and leaves, but not enough root structure. In extreme cases, plants with very high levels of nitrogen absorbed from soils can poison farm animals that eat them.

They can re-reroute excess nutrients away from lakes and vulnerable costal zones, use herbicides (chemicals used to kill unwanted plant growth) or algaecides (chemicals used to kill algae) to stop the algal blooms, and reduce the quantities or combinations of nutrients used in agricultural fertilizers, among other techniques. But, it can often be hard to find the origin of the excess nitrogen and other nutrients. Another potential solution is called bioremediation, which is the process of purposefully changing the food web in an aquatic ecosystem to reduce or control the amount of phytoplankton.

For example, water managers can introduce organisms that eat phytoplankton, and these organisms can help reduce the amounts of phytoplankton, by eating them!

Nitrogen Cycle

The nitrogen cycle is a repeating cycle of processes during which nitrogen moves through both living and non-living things: the atmosphere, soil, water, plants, animals and **bacteria**. In order to move through the different parts of the cycle, nitrogen must change forms. In the atmosphere, nitrogen exists as a gas (N_2), but in the soils it exists as nitrogen oxide, NO, and nitrogen dioxide, NO_2, and when used as a fertilizer, can be found in other forms, such as ammonia, NH_3, which can be processed even further into a different fertilizer, ammonium nitrate, or NH_4NO_3.

There are five stages in the nitrogen cycle, and we will now discuss each of them in turn: fixation or volatilization, mineralization, nitrification, immobilization, and denitrification. In this image, microbes in the soil turn nitrogen gas (N_2) into what is called volatile ammonia (NH_3), so the fixation process is called volatilization. Leaching is where certain forms of nitrogen (such as nitrate, or NO_3) becomes dissolved in water and leaks out of the soil, potentially polluting waterways.

Steps 1: Nitrogen Fixation :

In this stage, nitrogen moves from the atmosphere into the soil. Earth's atmosphere contains a huge pool of nitrogen gas (N_2). But this nitrogen is "unavailable" to plants, because the gaseous form cannot be used directly by plants without undergoing a transformation. To be used by plants, the N_2 must be transformed through a process called nitrogen fixation. Fixation converts nitrogen in the atmosphere into forms that plants can absorb through their root systems.

A small amount of nitrogen can be fixed when lightning provides the energy needed for N_2 to react with oxygen, producing nitrogen oxide, NO, and nitrogen dioxide, NO_2. These forms of nitrogen then enter soils through rain or snow. Nitrogen can also be fixed through the industrial process that creates fertilizer. This form of fixing occurs under high heat and pressure, during which atmospheric nitrogen and hydrogen are combined to form ammonia (NH_3), which may then be processed further, to produce ammonium nitrate (NH_4NO_3), a form of nitrogen that can be added to soils and used by plants.

Most nitrogen fixation occurs naturally, in the soil, by bacteria. In the given diagram we can see nitrogen fixation and exchange of form occurring in the soil. Some bacteria attach to plant roots and have a symbiotic (beneficial for both the plant and the bacteria) relationship with the plant The bacteria get energy through photosynthesis and, in return, they fix nitrogen into a form the plant needs. The fixed nitrogen is then carried to other parts of the plant and is used to form plant tissues, so the plant can grow. Other bacteria live freely in soils or water and can fix nitrogen without this symbiotic relationship. These bacteria can also create forms of nitrogen that can be used by organisms.

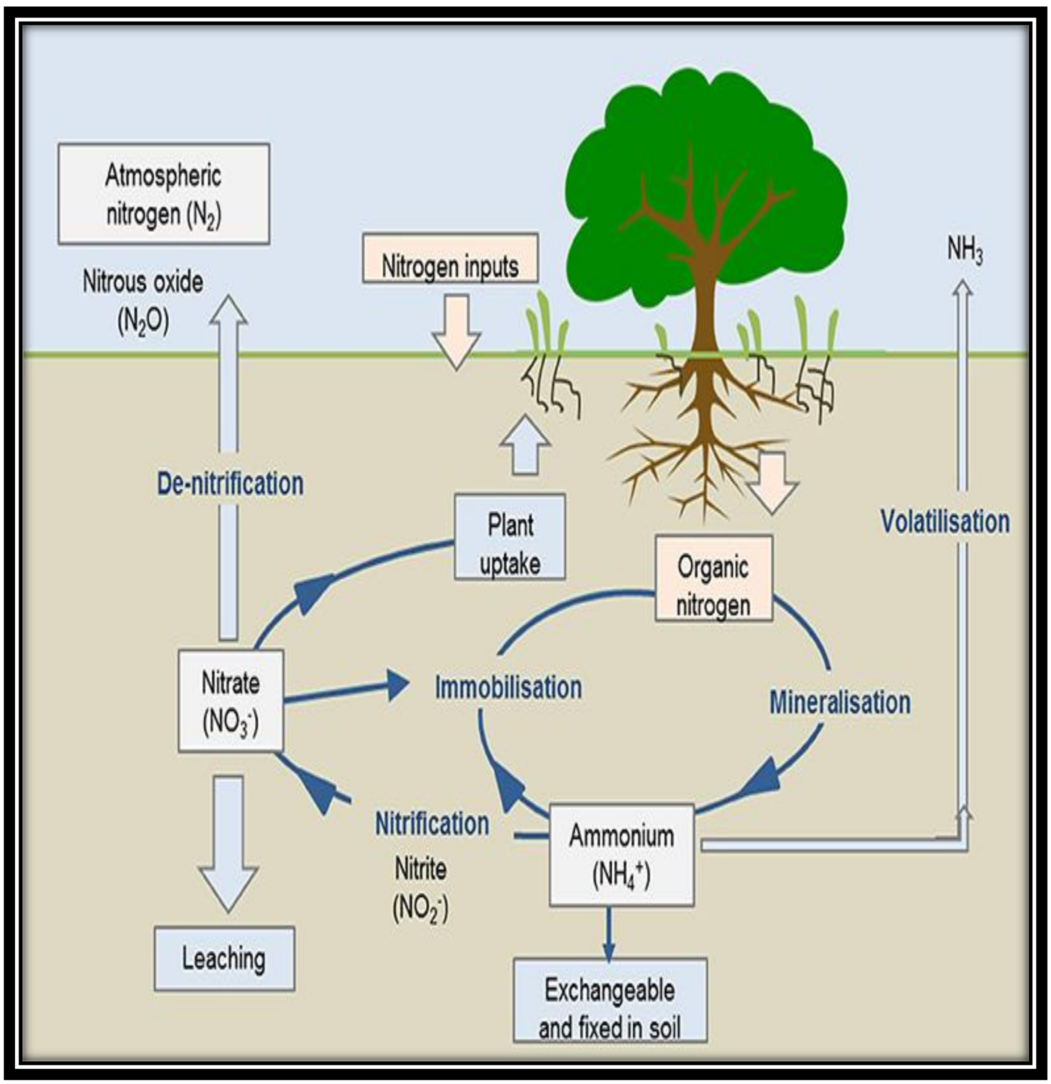

Figure 1- Steps of the nitrogen cycle.

The Nitrogen Cycle: Nitrogen cycling through the various forms in soil determines the amount of nitrogen available for plants to uptake.

Steps 2: Mineralization

This stage takes place in the soil. Nitrogen moves from organic materials, such as manure or plant materials to an inorganic form of nitrogen that plants can use. Eventually, the plant's nutrients are used up and the plant dies and decomposes. This becomes important in the second stage of the nitrogen cycle. Mineralization happens when microbes act on organic material, such as animal manure or decomposing plant or animal material and begin to convert it to a form of nitrogen that can be used by plants. All plants under cultivation, except legumes (plants with seed pods that split in half, such as lentils, beans, peas or peanuts) get the nitrogen they require through the soil. Legumes get nitrogen through fixation that occurs in their root nodules, as described above.

The first form of nitrogen produced by the process of mineralization is ammonia, NH_3.

The NH_3 in the soil then reacts with water to form ammonium, NH_4. This ammonium is held in the soils and is available for use by plants that do not get nitrogen through the symbiotic nitrogen fixing relationship described above.

Steps 3: Nitrification

The third stage, nitrification, also occurs in soils. During nitrification the ammonia in the soils, produced during mineralization, is converted into compounds called nitrites, NO_2^-, and nitrates, NO_3^-. Nitrates can be used by plants and animals that consume the plants. Some bacteria in the soil can turn ammonia into nitrites. Although nitrite is not usable by plants and animals directly, other bacteria can change nitrites into nitrates—a form that is usable by plants and animals. This reaction provides energy for the bacteria engaged in this process. The bacteria that we are talking about are called nitrosomonas and nitrobacter. Nitrobacter turns nitrites into nitrates; nitrosomonas transform ammonia to nitrites. Both kinds of bacteria can act only in the presence of oxygen, O_2. The process of nitrification is important to plants, as it produces an extra stash of available nitrogen that can be absorbed by the plants through their root systems.

Stage 4: Immobilization

The fourth stage of the nitrogen cycle is immobilization, sometimes described as the *reverse* of mineralization. These two processes together control the amount of nitrogen in soils. Just like plants, microorganisms living in the soil require nitrogen as an energy source. These soil microorganisms pull nitrogen from the soil when the residues of decomposing plants do not contain enough nitrogen. When microorganisms take in ammonium (NH_4^+) and nitrate (NO_3^-), these forms of nitrogen are no longer available to the plants and may cause nitrogen deficiency, or a lack of nitrogen. Immobilization, therefore, ties up nitrogen in microorganisms. However, immobilization is important because it helps control and balance the amount of nitrogen in the soils by tying it up, or immobilizing the nitrogen, in microorganisms.

Stage 5: Denitrification

In the fifth stage of the nitrogen cycle, nitrogen returns to the air as nitrates are converted to atmospheric nitrogen (N_2) by bacteria through the process we call denitrification. This results in an overall loss of nitrogen from soils, as the gaseous form of nitrogen moves into the atmosphere, back.

Nitrogen Is Crucial for Life

The cycling of nitrogen through the ecosystem is crucial for maintaining productive and healthy ecosystems with neither too much nor too little nitrogen. Plant production and biomass (living material) are limited by the availability of nitrogen. Understanding how the plant-soil nitrogen cycle works can help us make better decisions about what crops to grow and where to grow them, so we have an adequate supply of food. Knowledge of the nitrogen cycle can also help us reduce pollution caused by adding too much fertilizer to soils. Certain plants can uptake more nitrogen or other nutrients, such as phosphorous, another fertilizer, and can even be used as a "buffer," or filter, to prevent excessive fertilizer from entering waterways.

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