Chapter 1
Biogeochemical Cycles of Nitrogen and Phosphorus: Implications of Anthropogenic Activities

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ABSTRACT

The study of biogeochemical cycles is important to understand the circulation of elements through aquatic, aerial and terrestrial ecosystems. Among others, N and P are considered as the limiting nutrients that determine the productivity of organisms. Since human activity is increasing its influence over these cycles at a global scale, it is important to analyze the implications of anthropogenic variations in order to detect the sources and try to prevent or reduce their impact. Moreover, not only the increasing or diminished concentration of nitrogen and phosphorus in nature by human resource exploitations is needed to account today. As metals play a crucial role in the dynamics of these essential elements, their presence in the environment also requires a significant attention.

INTRODUCTION

Many chemical elements such as carbon (C), nitrogen (N), phosphorus (P) and sulphur (S) are essential to form the fundamental molecules which organisms depend on. The circulation of these elements at local and global scale, known as biogeochemical cycles, has been widely studied. This concept includes the interactions through both biotic ("bio-") and abiotic ("geo-") parts of an ecosystem of different chemical elements and compounds ("chemical-") along with their fluxes ("cycles"). The abiotic factors comprise water (hydrosphere), land (lithosphere) and air (atmosphere), whereas the biotic part is referred as the biosphere. Elements and compounds can be held for extended periods of time in certain places (reservoirs) or transported (fluxes). Biogeochemical cycles of different elements are closely linked, creating interactions that maintain order in the ecosystem with fluxes from highly reduced to highly oxidized forms

DOI: 10.4018/978-1-5225-1037-6.ch001

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and back (Madsen, 2011). However, as human population continues increasing, its impact on Earth's environment becomes more and more significant. Many of these anthropogenic actions may change the global cycles of different chemical elements (Butcher, Charlson, Oriand, & Wolfe, 1992). Thus, the knowledge of these cycles is essential to understand and predict the behavior of certain compounds that may be hazardous to human health (Pepper, Gerba, & Gentry, 2015).

The addition of limiting nutrients may dramatically change the dominant species in both aquatic and terrestrial ecosystems, which can originate a decrease in the biological diversity. The eutrophication is one of the best-documented consequences of anthropogenic alterations on nitrogen and phosphorus cycles in aquatic environments (Vitousek et al., 1997). It consists in the increase of algae growth on the surface of the water and the development of anoxic environments, also known as "algal blooms". The availability of oxygen in depth decreases due to the high algae growth on the surface of the water, which leads to the death of fishes and changes the composition of the biota. The main organisms involved in this "blooms" are cyanobacteria (*Anabaena*, *Aphanizomenon*, *Occillatoria*) and algae (*Asterionella*, *Dinophysis*) (Smil, 2000). Therefore, the main consequences of eutrophication are changes in animal species composition and oxygen fluxes, along with the increase of sulfide concentrations by sulfate reduction under anoxic conditions.

Even though there are other important biogeochemical cycles, this chapter is focused in two main nutrients: N and P. They are essential for organisms to live because they are considered as the nutrients that most often limit the productivity and functioning of terrestrial and aquatic ecosystems (Wang, Houlton, & Field, 2007). The transformations of reactive species throughout the cycles in different ecosystems will be analyzed for both chemical elements. Moreover, human activity may provoke an unbalance in the biogeochemical cycles by the accumulation of chemical at toxic concentrations or the scarcity of essential compounds for organisms. Therefore, the implications of anthropogenic activities that break the equilibrium in those biogeochemical cycles will be discussed, with special attention to the role of the metals.

Biological reactions involved in nitrogen and phosphorus cycles require metals for the activity of specific enzymes that attend reactions across which different oxidation states of nitrogen and phosphorus help to cell-sustaining. The cell has a fine-tuning mechanism to handle the uptake and storing metals (e.g. Fe, Cu, Zn, Ag, and Cd). Many human activities have a significant impact on the release of metals to the environments, causing that the metal concentrations can be lethal for organisms, due that the mechanism to homeostasis is not sufficient to maintain the cellular stability. In this section, we review metals involved in biological reactions in the N and P cycles and the concentrations that can delay the biogeochemical move of these important elements for ecosystems functions. A microbiological and proteomic point view is used to illustrate the enzymes involved in each step of biological transformation of nitrogen and phosphorous compounds.

NITROGEN

Nitrogen Cycle

Nitrogen is present in a wide variety of chemical forms: organic compounds (urea, amines, proteins, nucleic acids), reduced inorganic forms (NH_4^+ and NH_3), and oxidized inorganic forms (N_2O, NO, NO_2^-, NO_3^-). The chemical form of nitrogen present in a certain ecosystem depends on the reservoir. The

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