Phosphorus Cycle

Phosphorus occurs in only minute amounts in the atmosphere. Therefore, the phosphorus cycle can follow the water (hydrological) cycle only part of the way—from land to sea. Because phosphorus lost from the ecosystem in this way is not returned via the biogeochemical cycle, phosphorus is in short supply under undisturbed natural conditions. The natural scarcity of phosphorus in aquatic ecosystems is emphasized by the explosive growth of algae in water receiving heavy discharges of phosphorus-rich wastes.

The main reservoirs of phosphorus are rock and natural phosphate deposits. Phosphorus is released from these rocks and minerals by weathering, leaching, erosion, and mining for use as agricultural fertilizers. Nearly all of the phosphorus in terrestrial ecosystems comes from the weathering of calcium phosphate minerals. In most soils, only a small fraction of the total phosphorus is available to plants. The major process regulating phosphorus availability for net primary production is the internal cycling of phosphorus from organic to inorganic forms. Some of the available phosphorus in terrestrial ecosystems escapes and is exported to lakes and seas. In marine and freshwater ecosystems, the phosphorus cycle moves through three states: particulate organic phosphorus, dissolved organic phosphates, and inorganic phosphates.

Organic phosphates are taken up quickly by all forms of phytoplankton, which in turn are eaten by zooplankton and detritus-feeding organisms. Zooplankton may excrete as much phosphorus daily as it stores in its biomass, returning it to the cycle. More than half of the phosphorus zooplankton excretes is inorganic phosphate, which is taken up by phytoplankton. The remaining phosphorus in aquatic ecosystems exists in organic compounds that may be used by bacteria, which fail to regenerate much dissolved inorganic phosphate. Bacteria are consumed by the microbial grazers, which then excrete the phosphate they ingest. Part of the phosphate is deposited in shallow sediments and part in deep water. In the process of ocean upwelling, the movement of deep waters to the surface brings some phosphates from the dark depths to shallow waters, where light is available to drive photosynthesis. These phosphates are taken up by phytoplankton. Part of the phosphorus contained in the bodies of plants and animals sinks to the bottom and is deposited in the sediments. As a result, surface waters may become depleted of phosphorus, and the deep waters become saturated. Much of this phosphorus becomes locked up for long periods of time in the hypolimnion and bottom sediments, while some is returned to the surface waters by upwelling.

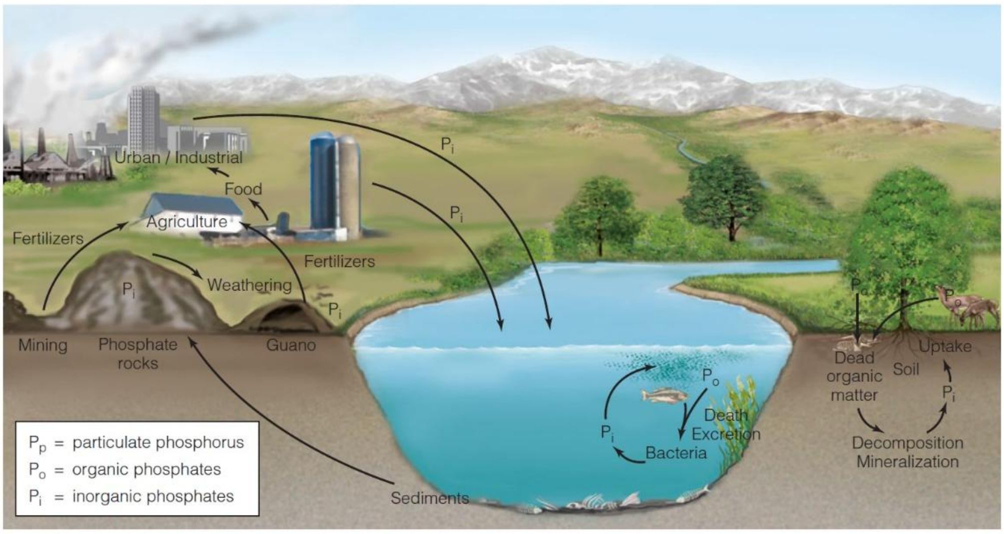

Figure 23.9 The phosphorus cycle in aquatic and terrestrial ecosystems.

The global phosphorus cycle is unique among the major biogeochemical cycles in having no significant atmospheric component, although airborne transport of P in soil dust and sea spray is of the order 1×10^{12} g P/yr. Rivers transport approximately 21×10^{12} g P/yr to the oceans, but only about 10 percent of this amount is available for net primary productivity. The remainder is deposited in sediments.
The concentration of phosphorus in the ocean waters is low, but the large volume of water results in a significant global pool of phosphorus. The turnover of organic phosphorus in the surface waters occurs within days, and the vast majority of phosphorus taken up in primary production is decomposed and mineralized (internally cycled) in the surface waters.
However, approximately 2×10^{12} g/yr is deposited in the ocean sediments or transported to the deep waters. In the deep waters, organic phosphorus converted into inorganic, soluble forms remain unavailable to phytoplankton in the surfacewaters until transported by upwelling. On a geological timescale, uplifting and subsequent weathering return this phosphorus to the active cycle.

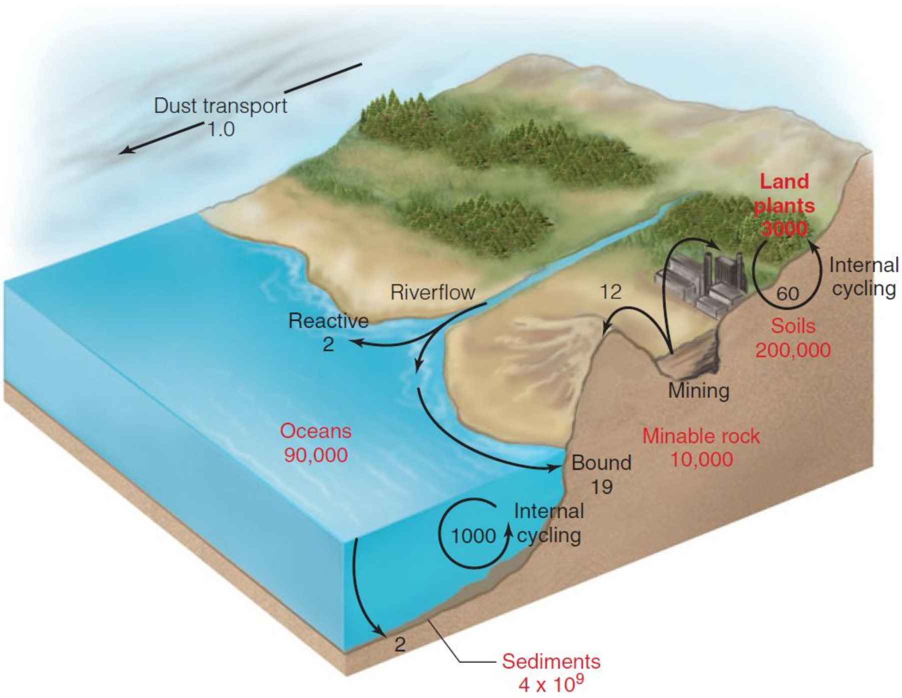

Figure 23.10 The global phosphorus cycle. Each flux is shown in units of 10^{12} g P/yr.
(Adapted from Schlesinger 1997.)