UG CBCS Semester-IV (MJC-7: Ecology)

Sulfur Cycle

The sulfur cycle has both sedimentary and gaseous phases. In the long-term sedimentary phase, sulfur is tied up in organic and inorganic deposits, released by weathering and decomposition, and carried to terrestrial ecosystems in salt solution. The gaseous phase of the cycle permits sulfur circulation on a global scale.

Sulfur enters the atmosphere from several sources: the combustion of fossil fuels, volcanic eruptions, exchange at the surface of the oceans, and gases released by decomposition. It enters the atmosphere initially as hydrogen sulfide (H_2S) which quickly interacts with oxygen to form sulfur dioxide (SO_2). Atmospheric sulfur dioxide, soluble in water, is carried back to the surface in rainwater as weak sulfuric acid (H_2SO_4) Whatever the source, sulfur in a soluble form is taken up by plants and incorporated through a series of metabolic processes, starting with photosynthesis, into sulfur-bearing amino acids. From the primary producers, sulfur in amino acid is transferred to consumers.

Excretion and death carry sulfur from living material back to the soil and to the bottom of ponds, lakes, and seas, where bacteria release it as hydrogen sulfite or sulfate. One group, the colorless sulfur bacteria, reduces hydrogen sulfide to elemental sulfur and then oxidizes it to sulfuric acid. Green and purple bacteria, in the presence of light, use hydrogen sulfide during photosynthesis. Best known are the purple bacteria found in salt marshes and in the mudflats of estuaries. These organisms can transform hydrogen sulfide into sulfate, which is then recirculated and taken up by producers or used by bacteria that further transform the sulfates. Green bacteria can transform hydrogen sulfide into elemental sulfur.

Sulfur, in the presence of iron and under anaerobic conditions, will precipitate as ferrous sulfide (FeS_2) This compound is highly insoluble in neutral and low pH (acidic) conditions, and it is firmly held in mud and wet soil. Sedimentary rocks containing ferrous sulfide, called pyritic rocks, may overlie coal deposits. When exposed to air during deep and surface mining for coal, the ferrous sulfide reacts with oxygen. In the presence of water, it produces ferrous sulfate ($FeSO_4$) and sulfuric acid.

In this manner, sulfur in pyritic rocks, suddenly exposed to weathering by human activities, discharges sulfuric acid, ferrous sulfate, and other sulfur compounds into aquatic ecosystems. These compounds destroy aquatic life. They have converted hundreds of kilometers of streams in the eastern United States to lifeless, highly acidic water.

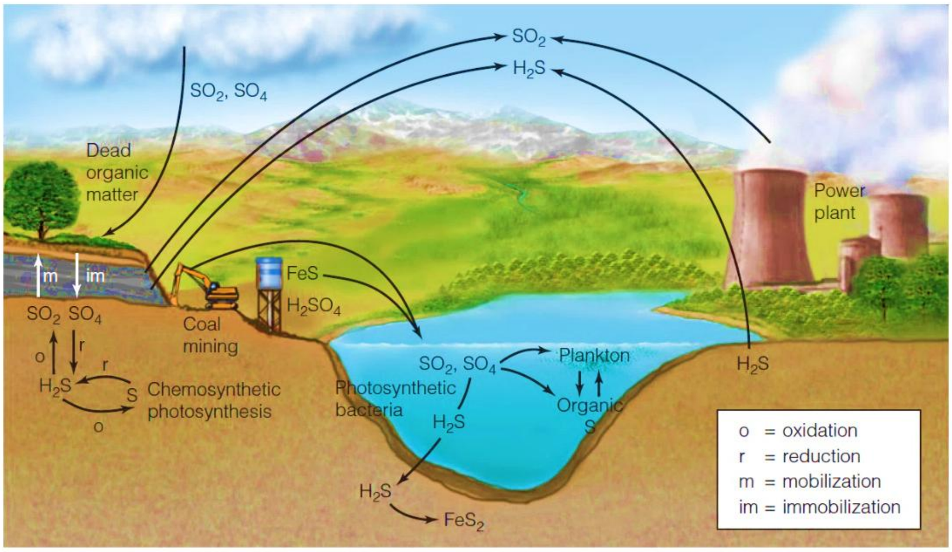

Figure 23.11 The sulfur cycle. Note the two components: sedimentary and gaseous. Major sources from human activity are the burning of fossil fuels and acidic drainage from coal mines.

The Global Sulfur Cycle Is Poorly Understood

The global sulfur cycle is presented in figure. Although a great deal of research now focuses on the sulfur cycle, particularly the role of human inputs, our understanding of the global sulfur cycle is primitive. The gaseous phase of the sulfur cycle permits circulation on a global scale. The annual flux of sulfur compounds through the atmosphere is of the order 30×10^{12} g. The atmosphere contains not only sulfur dioxide and hydrogen sulfide, but sulfate particles. The sulfate particles become part of dry deposition (dryfall); the gaseous forms combine with moisture and are transported in precipitation (wetfall). The oceans are a large source of aerosols that contain sulfate (SO_4); however, most are redeposited in the oceans as precipitation and dryfall. Dimethylsulfide [$(CH_3)_2S$] is the major gas emitted from the oceans that is generated by biological processes. Estimates of 16×10^{12} g S/yr make it the largest natural source of sulfur gases released to the atmosphere.

Various biological sources of sulfur emissions from terrestrial ecosystems exist, but collectively they cause only a minor flux to the atmosphere. The dominant sulfur gas emitted from freshwater wetlands and anoxic (oxygen-depleted) soils is hydrogen sulfide (H_2S). Emissions from plants are poorly understood, but forest fires emit on the order of 3×10^{12} g S annually. It is almost impossible to estimate the biological turnover of sulfur dioxide, due to the complicated cycling within the biosphere. Estimates of the net annual assimilation of sulfur by marine plants are of the order 130×10^{12} g. Adding the anaerobic oxidation of organic matter brings the total to an estimated 200×10^{12} g.

Volcanic activity also contributes to the global biogeochemical cycle of sulfur. Major events, such as the eruption of Mt. Pinatubo in 1991, release on the order of 5×10^{12} to 10×10^{12} g S. When volcanic activity is averaged over a long period, the annual global flux is of the order 10×10^{12} g S. Human activity plays a dominant role in the biogeochemical cycle of sulfur. Thus, to complete the picture of the global sulfur cycle, we must include the inputs due to industrial activity.

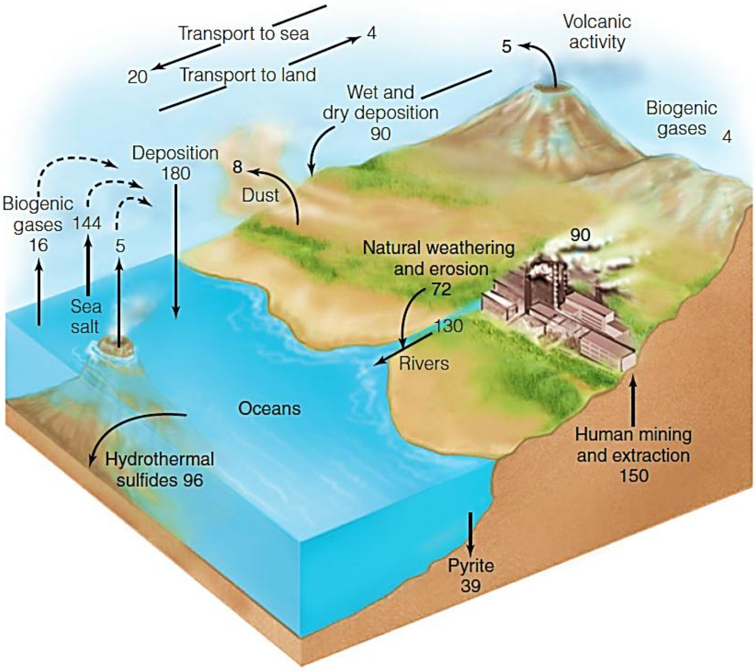

Figure 23.12 The global sulfur cycle. Each flux is shown in units of 10^{12} g S/yr. (Adapted from Schlesinger 1997.)