

Sulphur Cycle:

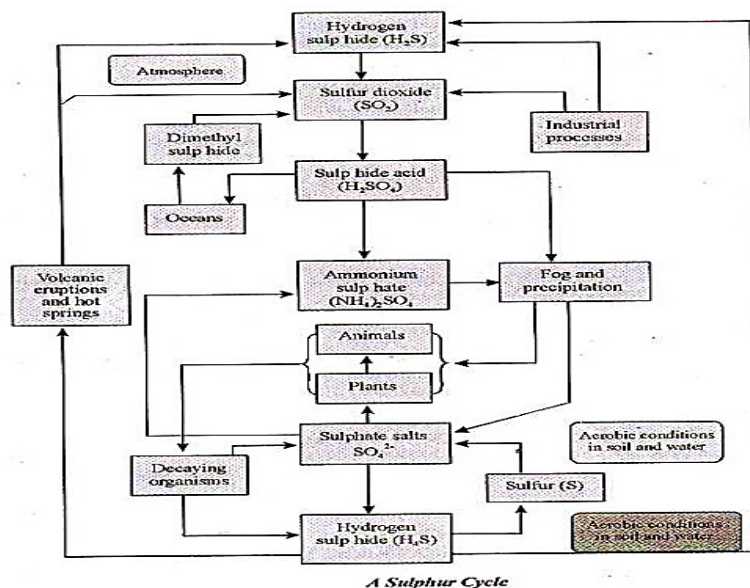
Sulphur is one of the components that make up proteins and vitamins. Proteins consist of amino acids that contain sulphur atoms. Sulphur is important for the functioning of proteins and enzymes in plants, and in animals that depend upon plants for sulphur.

It enters the atmosphere through both natural and human sources. Natural sources can be for instance volcanic eruptions, bacterial processes, evaporation from water, or decaying organisms. When sulphur enters the atmosphere through human activity, this is mainly a consequence of industrial processes where sulphur dioxide (SO_2) and hydrogen sulphide (H_2S) gases are emitted on a wide scale.

When sulphur dioxide enters the atmosphere it will react with oxygen to produce sulphur trioxide gas (SO_3), or with other chemicals in the atmosphere, to produce sulphur salts. Sulphur dioxide may also react with water to produce sulphuric acid (H_2SO_4). Sulphuric acid may also be produced from dimethyl-sulphide, which is emitted to the atmosphere by plankton species.

All these particles will settle back onto earth, or react with rain and fall back onto earth as acid deposition. The particles will then be absorbed by plants again and are released back into the atmosphere, so that the sulphur cycle will start over again.

- i. Fossil fuels like coal and petroleum are extremely important energy resources which are getting exhausted.
- ii. Hydrocarbon fuel based resources create pollution levels and green house gases. Their management is related to improved technology and finding alternative energy sources taking this into account.
- iii. An overall prudent and sustainable uses of resources both at an individual and collective level can benefit a wide cross section of society as well meet the future generations.



Nutrient cycle of Sulphur-

Sulfur is an important nutrient for organisms, being a key constituent of certain amino acids, proteins, and other biochemical. Plants satisfy their nutritional needs for sulfur by assimilating simple mineral compounds from the environment.

This mostly occurs as sulfate dissolved in soil water that is taken up by roots, or as gaseous sulfur dioxide that is absorbed by foliage in environments where the atmosphere is somewhat polluted with this gas. Animals obtain the sulfur they need by eating plants or other animals, and digesting and assimilating their organic forms of sulfur, which are then used to synthesize necessary sulfur-containing biochemical. In certain situations, particularly in intensively managed agriculture, the availability of biologically useful forms of sulfur can be a limiting factor to the productivity of plants, and application of a sulfate-containing fertilizer may prove to be beneficial. Sulfur compounds may also be associated with important environmental damages, as when sulfur dioxide damages vegetation, or when acidic drainages associated with sulfide minerals degrade ecosystems.

Sulfur (S) can occur in many chemical forms in the environment. These include organic and mineral forms, which can be chemically transformed by both biological and inorganic processes. Sulfur dioxide is a gas that can be toxic to plants at concentrations much smaller than one part per million in the atmosphere, and to animals at larger concentrations.

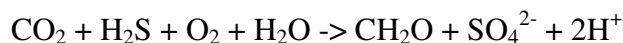
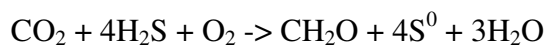
There are many natural sources of emission of SO₂ to the atmosphere, such as volcanic eruptions and forest fires. Large emissions of SO₂ are also associated with human activities, especially the burning of coal and the processing of certain metal ores.

In the atmosphere, SO₂ is oxidized to sulfate, an anion that occurs as a tiny particulate in which the negative charges are electrochemically balanced by the positive charges of cations, such as ammonium (NH⁺ 4), calcium (Ca²⁺), or hydrogen ion (H⁺). These fine particulates can serve as condensation nuclei for the formation of ice crystals, which may settle from the atmosphere.

The most important basic material of life is water, one of the five panchabhutas. This is in limited supply. Living forms on terrestrial areas are dependent on water free from salts—'freshwater. Due to the solar heat water evaporates from the oceans and goes up as water vapour, and as it travel across on to land regions, gaining considerable height the vapour cools down to precipitate as water or snow. Of the total estimated water in the earth and its atmosphere.

Sulfur-oxidizing bacteria in hydrothermal vents

Hydrothermal vents emit hydrogen sulfide that support the carbon fixation of chemolithotrophic bacteria that oxidize hydrogen sulfide with oxygen to produce elemental sulfur or sulfate. The chemical reactions are as follows:



In modern oceans, *Thiomicrospira*, *Halothiobacillus*, and *Beggiatoa* are primary sulfur oxidizing bacteria, and form chemosynthetic symbioses with animal hosts. The host provides metabolic substrates (e.g., CO₂, O₂, H₂O) to the symbiont while the symbiont generates organic carbon for sustaining the metabolic activities of the host. The produced sulfate usually combines with the leached calcium ions to form gypsum, which can form widespread deposits on near mid-ocean spreading centers.

Marine sulfur cycle

The sulfur cycle in marine environments has been well-studied via the tool of sulfur isotope systematics expressed as $\delta^{34}\text{S}$. The modern global oceans have sulfur storage of 1.3×10^{21} g, mainly occurring as sulfate with the $\delta^{34}\text{S}$ value of +21‰. The overall input flux is 1.0×10^{14} g/year with the sulfur isotope composition of ~3‰. Riverine sulfate derived from the terrestrial weathering of sulfide minerals ($\delta^{34}\text{S} = +6‰$) is the primary input of sulfur to the oceans. Other sources are metamorphic and volcanic degassing and hydrothermal activity ($\delta^{34}\text{S} = 0‰$), which release reduced sulfur species (e.g., H₂S and S⁰). There are two major outputs of sulfur from the oceans. The first sink is the burial of sulfate either as marine evaporites (e.g., gypsum) or carbonate-associated sulfate (CAS), which accounts for 6×10^{13} g/year ($\delta^{34}\text{S} = +21‰$). The second sulfur sink is pyrite burial in shelf sediments or deep seafloor sediments (4×10^{13} g/year; $\delta^{34}\text{S} = -20‰$). The total marine sulfur output flux is 1.0×10^{14} g/year which matches the input fluxes, implying the modern marine sulfur budget is at steady state. The residence time of sulfur in modern global oceans is 13,000,000 years.

Economic importance

Sulfur is intimately involved in production of fossil fuels and a majority of metal deposits because of its ability to act as an oxidizing or reducing agent. The vast majority of the major mineral deposits on Earth contain a substantial amount of sulfur including, but not limited to: sedimentary exhalative deposits (SEDEX), Carbonate-hosted lead-zinc ore deposits (Mississippi Valley-Type MVT) and porphyry copper deposits. Iron sulfides, galena and sphalerite will form as by-products of hydrogen sulfide generation, as long as the respective transition or base metals are present or transported to a sulfate reduction site. If the system runs out of reactive hydrocarbons economically viable elemental sulfur deposits may form. Sulfur also acts as a reducing agent in many natural gas reservoirs and generally ore forming fluids have a close relationship with ancient hydrocarbon seeps or vents.

Important sources of sulfur in ore deposits are generally deep-seated, but they can also come from local country rocks, sea water, or marine evaporites. The presence or absence of sulfur is one of the limiting factors on both the concentration of precious metals and its precipitation from solution. pH, temperature and especially redox states determine whether sulfides will precipitate. Most sulfide brines will remain in concentration until they reach reducing conditions, a higher pH or lower temperatures.

Ore fluids are generally linked to metal rich waters that have been heated within a sedimentary basin under the elevated thermal conditions typically in extensional tectonic settings. The redox conditions of the basin lithologies exert an important control on the redox state of the metal-

transporting fluids and deposits can form from both oxidizing and reducing fluids. Metal-rich ore fluids tend to be by necessity comparatively sulfide deficient, so a substantial portion of the sulfide must be supplied from another source at the site of mineralization. Bacterial reduction of seawater sulfate or a euxinic (anoxic and H₂S-containing) water column is a necessary source of that sulfide. When present, the $\delta^{34}\text{S}$ values of barite are generally consistent with a seawater sulfate source, suggesting baryte formation by reaction between hydrothermal barium and sulfate in ambient seawater.

Once fossil fuels or precious metals are discovered and either burned or milled, the sulfur become a waste product which must be dealt with properly or it can become a pollutant. There has been a great increase in the amount of sulfur in our present day atmosphere because of the burning of fossil fuels. Sulfur acts as a pollutant and an economic resource at the same time.