SUBJECT- ENVIRONMENTAL SCIENCE

SEMESTER –M.Sc 2nd SEMESTER (C22)

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TOPIC- ENVIRONMENTAL GEOSCIENCE

What is the Hydrosphere?

If aliens were approaching Earth right now, what would be the first thing they'd see? From millions of miles away, Earth appears as a small, blue dot. The earth has been described as the blue planet, because it's covered in water -- a full 71% of Earth's surface is covered with water. It is by far Earth's most distinctive feature, though we sometimes don't think about water a lot since we're land mammals. But how did it get that water?

The blue planet

Earth's **hydrosphere** is made up of all the water on Earth's surface, from oceans and seas to lakes and rivers. By some definitions, you should even include the water in clouds. But the earth hasn't always been here - like the entire universe, it formed billions of years ago. In this lesson, were going to talk about how Earth's hydrosphere developed.

Evolution of Hydrosphere

It is not very likely that the total amount of water at Earth’s surface has changed significantly over geologic time. Based on the ages of meteorites, Earth is thought to be 4.6 billion years old. The oldest rocks known are 3.9 billion to 4.0 billion years old, and these rocks, though altered by post-depositional processes, show signs of having been deposited in an environment containing water. There is no direct evidence for water for the period between 4.6 billion and 3.9–4.0 billion years ago. Thus, ideas concerning the early history of the hydrosphere are closely linked to theories about the origin of Earth.

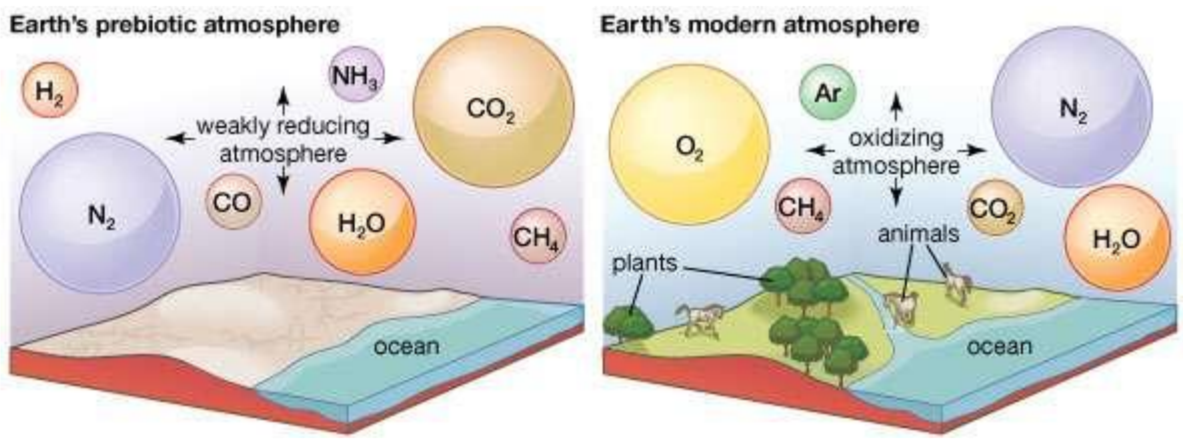
Earth is thought to have accreted from a cloud of particles around the Sun. This gaseous matter condensed into small particles that coalesced to form a protoplanet, which in turn grew by the gravitational attraction of more particulates. Some of these particles had compositions similar to that of meteorites, which may contain up to 20 percent water. Heating of this initially cool, unsorted conglomerate by the decay of radioactive elements and the conversion of kinetic and potential energy to heat resulted in the development of Earth’s liquid iron core and the gross internal zonation of the planet (i.e., differentiation into core, mantle, and crust). It has been concluded that Earth's core formed over a period of about 500 million years.

At an early stage, Earth thus did not have water or water vapour at its surface, and the topic of how water arrived on Earth's surface is a matter of substantial debate. Some scientists argue that much of the water on the planet was delivered by comet and meteor impacts. Both of these celestial objects have been shown to contain ice. Other scientists claim that most of Earth's water came from chemical reactions within the planet's interior. Once the planet's surface had cooled sufficiently, water contained in the minerals of the accreted material and released at depth could escape to the surface and, instead of being lost to space, cooled and condensed to form the initial hydrosphere. A large cool Earth most certainly served as a better trap for water than a small hot body because the lower the temperature, the less likelihood for water vapour to escape, and the larger the planetary mass, the stronger its gravitational attraction for water vapour. Whether most of the degassing took place during core formation or shortly thereafter or whether there has been significant degassing of Earth's interior throughout geologic time remains uncertain. It is likely that the hydrosphere attained its present volume early in Earth's history, and since that time there have been only small losses and gains. Gains would be from continuous degassing of Earth; the present degassing rate of juvenile water has been determined as being only 0.3 cubic km (about 0.07 cubic mile) per year. Water loss in the upper atmosphere is by photodissociation, the breakup of water vapour molecules into hydrogen and oxygen due to the energy of ultraviolet light. The hydrogen is lost to space and the oxygen remains behind. Only about 4.8 × 10−4 cubic km (about 0.0005 cubic mile) of water vapour is presently destroyed each year by photodissociation. This low rate can be readily explained: the very cold temperatures of the upper atmosphere result in a cold trap at an altitude of about 15 km (about 9.3 miles), where most of the water vapour condenses and returns to lower altitudes, thereby escaping photodissociation.

Since the early formation of the hydrosphere, the amount of water vapour in the atmosphere has been regulated by the temperature of Earth's surface—hence its radiation balance. Higher temperatures imply higher concentrations of atmospheric water vapour, while lower temperatures suggest lower atmospheric levels.

The early hydrosphere

The gases released from Earth during its early history, including water vapour, have been called excess volatiles because their masses cannot be accounted for simply by rock weathering. These volatiles are thought to have formed the early atmosphere of Earth. At an initial crustal temperature of about 600 °C (about 1,100 °F), almost all of these compounds, including water (H_2O), would have been in the atmosphere. The water would have condensed into an early hot ocean. At this stage, the hydrogen chloride would have dissolved in the ocean and early acid ocean would have reacted vigorously with crustal minerals, dissolving out silica and cations and creating a residue composed principally of aluminous clay minerals that would form the sediments of the early ocean basins.



Earth's early and modern atmospheres: Comparison of Earth's prebiotic and modern atmospheres. Before life began on the planet, Earth's atmosphere was largely made up of nitrogen and carbon dioxide gases. After photosynthesizing organisms multiplied on Earth's surface and in the oceans, much of the carbon dioxide was replaced with oxygen.

This is one of several possible pathways for the early surface of Earth. Whatever the actual case, after Earth’s surface had cooled to 100 °C, it would have taken only a short time for the remaining acid gases to be consumed in reactions involving igneous rock minerals. The presence of cyanobacteria (e.g., blue-green algae) in the fossil record of rocks older than three billion years attests to the fact that Earth’s surface had cooled to temperatures lower than 100 °C by this time, and neutralization of the original acid volatiles had taken place. It is possible, however, that, because of increased greenhouse gas concentrations early in the Archean Eon ,Earth’s surface could still have been warmer than today

If most of the degassing of primary volatile substances from Earth’s interior occurred early, the chloride released by the reaction of hydrochloric acid with rock minerals would be found in the oceans, and the oceans would have a salinity and volume comparable to that of today. This conclusion is based on the assumption that there has been no drastic change in the ratios of volatiles released through geologic time. The overall generalized reaction indicative of the chemistry leading to the formation of the early oceans can be written in the form:

primary igneous rock minerals + acid volatiles + H2O → sedimentary rocks + oceans + atmosphere.

The most likely situation was that major degassing occurred early in Earth’s history, after which minor amounts of volatiles were released episodically or continuously for the remainder of geologic time. The salt content of the oceans based on the constant proportions of volatiles released would depend primarily on the ratio of sodium chloride locked up in evaporites to that dissolved in the oceans. If all the sodium chloride in evaporites were added to the oceans today, the salinity would be approximately doubled. This value gives a sense of the maximum salinity that the oceans could have attained throughout geologic time.

One component absent from the early Earth’s surface was free oxygen; it would not have been a constituent released from the cooling crust. Early production of oxygen was by the photodissociation of water in Earth’s atmosphere, a process that was triggered by the absorption of the Sun’s ultraviolet radiation. The reaction is

$H2O$ (liquid) + $h\nu \rightarrow H2$ (gas) + $O2$ (gas)

in which $h\nu$ represents the photon of ultraviolet light. The hydrogen produced would escape into space, while the oxygen would react with the early reduced gases by reactions such as $2H2S + 3O2 \rightarrow 2SO2 + 2H2O$.

Oxygen production by photodissociation gave the early reduced atmosphere a start toward present-day conditions, but it was not until the appearance of photosynthetic organisms approximately three billion years ago that oxygen could accumulate in Earth’s atmosphere at a rate sufficient to give rise to today’s oxygenated environment.

The transitional hydrosphere

The nature of the rock record from the time of the first sedimentary rocks (approximately 3.8 billion years ago) to about one to two billion years ago suggests that the amount of oxygen in Earth’s atmosphere was significantly lower than it is today . The chemistry of rocks shifted dramatically during this transitional period. The chief difference between reactions involving mineral-ocean equilibria at this time and the present day was the role played by ferrous iron (i.e., reduced state of iron). The concentration of dissolved iron in modern oceans is low because of the insolubility of oxidized iron oxides. During the transition stage and earlier, oxygen-deficient environments were prevalent, and these favoured the formation of minerals containing ferrous iron from the alteration of rocks slightly more rich in basalt than those of today.

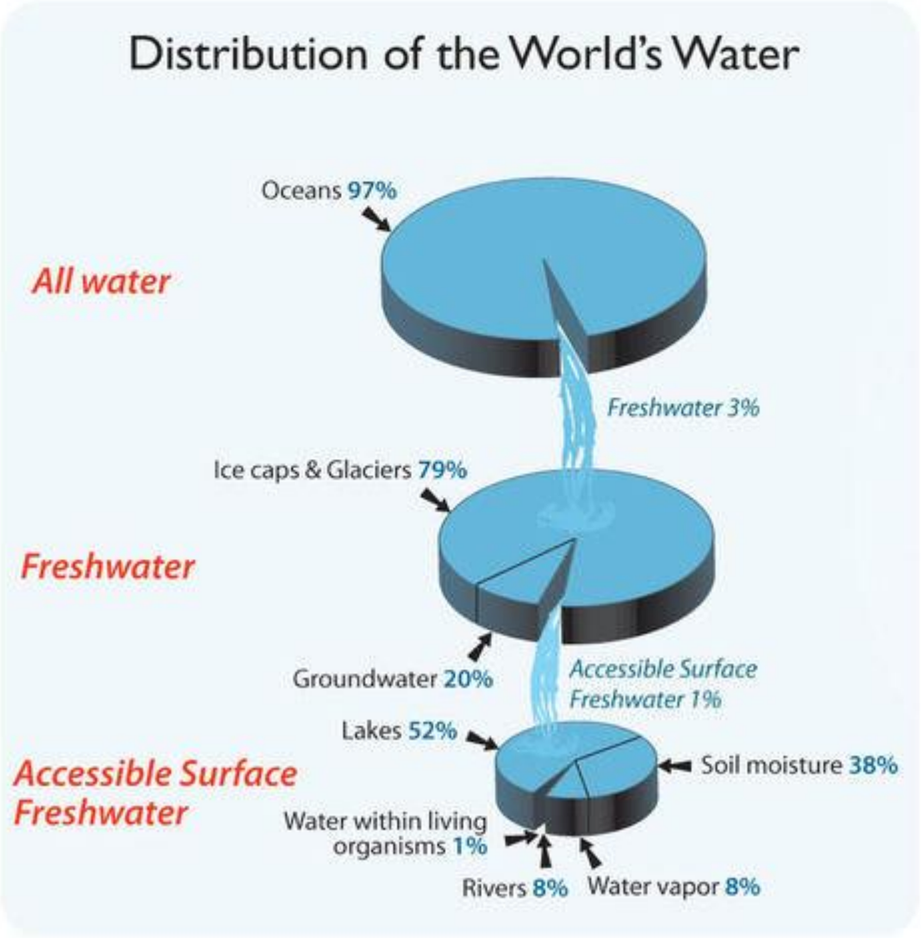
If this newly created ocean were left undisturbed for several hundred million years, its waters would evaporate and be transported onto the continents (in the form of precipitation); streams would transport their loads into it. The sediments produced in this ocean would be uplifted and incorporated into the continents. The influence of the continental debris would gradually be felt and the pH might change somewhat. Iron would be oxidized out of the ferrous silicates to yield iron oxides, but the composition of the water would not vary substantially.

The modern hydrosphere

It is likely that the hydrosphere achieved its modern chemical characteristics about 1.5 billion to 2 billion years ago. The chemical and mineralogical compositions and the relative proportions of sedimentary rocks of this age differ little from their counterparts of the Paleozoic Era (from 541 million to 252 million years ago). Calcium sulfate deposits dated to the late Precambrian (about 1.6 billion to 541 million years ago) attest to the fact that the acid sulfur gases had been neutralized to sulfate by this time. Chemically precipitated ferric oxides in late Precambrian sedimentary rocks indicate available free oxygen. It therefore appears that continuous cycling of sediments similar to those of today has occurred for 1.5 billion to 2 billion years and that these sediments have controlled hydrospheric, and particularly oceanic, composition.

It was once thought that the saltiness of the modern oceans simply represents the storage of salts (that is, compounds that form when part of an acid is replaced by a metal or something like a metal) derived from rock weathering and transported to the oceans by fluvial processes. With increasing knowledge of the age of Earth, however, it was soon realized that, at the present rate of delivery of salts to the ocean or even at much reduced rates, the total salt content and the mass of individual salts in the oceans could be attained in geologically short time intervals compared with the planet's age. The total mass of salt in the oceans can be accounted for at today's rates of stream delivery in about 12 million years. The mass of dissolved silica in ocean water can be doubled in just 20,000 years by the addition of stream-derived silica. To double the sodium content would take 70 million years. It then became apparent that the oceans are not merely an accumulator of salts. Rather, as water evaporates from the oceans, together with some salt, the salts introduced must be removed in the form of minerals deposited in marine sediments. Accordingly, the concept of the oceans as a chemical system changed from that of a simple accumulator to that of a steady-state system in which rates of inflow of materials equal rates of outflow.

Modern seawater chemistry has been characteristic of roughly the past 600 million years of ocean history. Nonetheless, it seems likely that fluctuations did occur, particularly in the concentrations of calcium, magnesium, and sulfate ions.



Minerals in Ocean Water