



# THE SALTY SEAS

**S**ALT has been an essential addition to man's diet since time immemorial. Many legends that have come down from the past tell that the sea is salty because of a magic "salt mill" hidden somewhere at the bottom, which is steadily grinding away. Most of these aspects are similar in many respects though they are told by people of varying cultures, from different parts of the world.

**Why is  
seawater salty?**

**P. K. DINESH**

**KUMAR**

**provides some answers**

Science, however, tends to support these legends rather than deny them. Only the details need to be worked out.

Of all the water in the world, 97.2 per cent lies in the oceans; only 2.15 per cent is locked in icecaps and glaciers. Rivers, lakes and groundwater which provide most of the drinking water contain a meagre, only 0.65 per cent, of the total. Another 0.65 per

cent is in the air, the atmosphere. Johan Milton, the poet was therefore more than right when he said "Water, Water everywhere, but not a drop to drink." He was lamenting about the saltiness of sea water.

Seawater is an extremely complex solution of dissolved minerals, elements and salts. Virtually all of the known stable elements are found in seawater. On an average, it's about 96.5% water with 3.5% salt, a few parts per million living things, and an equal amount of dust. Because water is a compound of hydrogen and oxygen, these two are the most abundant elements. Sodium chloride, that is, common salt makes up the vast majority of all the dissolved salts, with magnesium, calcium and potassium and carbonates making up the rest. From Pacific Ocean to Indian Ocean, the proportion of salt in water remains remarkably constant. The only exception is the dead sea. It has a very high

salt content.

Water itself has many unusual properties that are little affected by the presence of sea salts. An example is water's capacity to absorb and give up large quantities of energy as heat with no change in temperature. On the other hand, the ocean's suitability for life is strongly influenced by the dissolved materials. Minute differences in the chemical composition can drastically alter its biological properties, causing living organisms to perish.

Salinity of seawater is most variable near the surface where air meets with water, at the boundaries of ocean currents and in coastal areas, but not much, only slightly. These slight deviations are extremely useful in tracing the movement of water.

The variation in saltiness is determined by processes that take place at the sea surface and by currents and mixing. The highest salinity values

are found in tropical latitudes where the rate of evaporation is high owing to high temperatures and strong trade winds. In the equatorial zone, however, the salinity is lower as we move polewards from the tropics, because of the excess of rainfall over evaporation. Near the coasts the salinity is reduced owing to the water flowing in from the land. Salinities higher than those in oceans occur in inland seas in mid-latitudes, where more water evaporates than that being supplied by rains and rivers. In the coastal seas in temperate latitudes there may be a range of conditions, from almost completely freshwater to the saltiness of oceans. In the deeper layers of the ocean, the variations in salinity are smaller than near the surface, but are nevertheless highly significant in their relation to the general circulation.

Air trapped in water near the sea surface forms bubbles which are formed by the breaking waves and



impact of rain drops. Bubbles provide a crucial route for gases in seawater to pass in and out of solution and for producing salt particles. Air-borne droplets evaporate, leaving tiny salt particles that are carried away by winds. Salt particles are carried high into the atmosphere where they eventually serve as nuclei around which water condenses and raindrops form. In this manner, the salt is carried back to the earth's atmosphere. The total amount of salt thrown into the air this way is about 1 billion tons per year.

But the water in rivers is distinctly different from the water in its mix of ions. If you catch it even before it tumbles down young mountains, the differences turn out to be more pronounced. Despite a very heavy flow of fresh water into it, the sea water remains more or less undiluted.

Because of its complex composition, the total quantity of dissolved solids in any given sample of seawater is difficult to determine by direct analysis, and reproducible results are not feasible by evaporation methods. These difficulties have been overcome by an arbitrary definition of the total salt content termed as salinity. There are in each 1000 kilograms of seawater about 35 kilogram of salts, so we may say that the salt content is 35 parts per thousand (35%). The salt content of oceans expressed in this way is called its salinity.

As the ocean waters are well mixed, and they have an early constant composition, the most abundant constituent chloride

(Cl<sup>-</sup>) is used as the index of the amount of salt present in a given amount of seawater. The usual method of determining the salinity of seawater is to measure its conductivity. Conductivity of water is controlled by ion movement through water. The more abundant the ions, faster is the flow of electricity. In actual practice, the total weight of salt in seawater is never determined. Instead, the amount of chloride ion is carefully measured and

a total for all other ions is computed.

In 1715, Edmund Halley suggested that the age of the ocean and thus that of the world can be estimated from the rate of salt transported by rivers. Using this method John Jolly in 1899, gave an age of some 90 million years. A. L. Lavoisier conducted the first analysis of seawater by fractional crystallisation thereby obtaining a se-

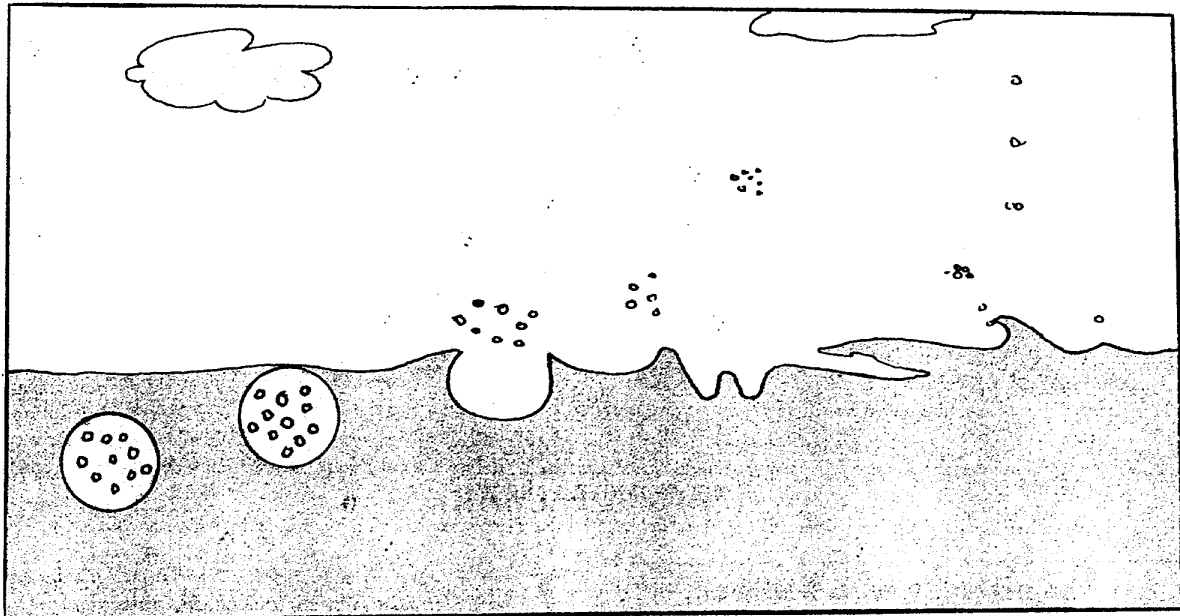


*Differentiation of the mantle continues in regions of volcanic activity*

ries of compounds like calcium carbonate, gypsum, common salt, and Glauber's salt. He also noted that slight changes in experimental conditions gave rise to large shifts in the relative amounts of the various salt crystallised. The total quantity of dissolved salts has been estimated variously as  $5.50 \times 10^6$  metric tons. These salts have been little exploited. Sodium chloride, magnesium metal and its salts and bromine, together with small amounts of potassium salts, calcium compounds and iodine, comprise the whole list of substances extracted on a commercial scale.

It is only during the past 50 years that geochemists have become interested in the chemical processes of the seas for what they can tell us about the history of the earth. Many theories on evolution state that the present atmosphere and oceans are not primordial but have been liberated from chemical and mechanical entrapment in solid rock. Perhaps, four million years ago, or a little less, there was a "grand catastrophe" in which the earth's core, mantle, crust, ocean and atmosphere were differentiated from an original homogeneous accumulation of materials. Estimates of water released during the catastrophe range from a third to a ninety percent of the present volume of the ocean. The catastrophe is not completed yet, since differentiation of the mantle continues in regions of volcanic activity. The "mill", as it is visualized today in current geophysical theory, is the "mid-ocean" rift that meanders for 40,000 miles through all the ocean basins. Fresh basalt flows up the rift from the earth's plastic mantle in regions where the seafloor is spreading apart at a rate of several centimetres per year. Accompanying this mantle rock is "juvenile" water — water that was never before in the liquid phase — containing in solution many of the components of seawater, including chlorine, bromine, iodine, carbon, boron, nitrogen and various trace elements. Additional juvenile water, equally salty but of somewhat different composition, is released by volcanoes that rim certain continental margins, where the seafloor seems to be disappearing into deep trenches.

The elements most abundant in juvenile water are precisely those that cannot be accounted for if the solids dissolved in the sea were simply those provided by the weathering of rocks on the earth's surface. The "missing" elements such as chlorine, bromine and iodine were once called "excess volatiles" and were attributed solely to volcanic emanations. It is now recognized that juvenile water may have



*Bubbles burst at the sea surface, forming water droplets in the atmosphere of which a part evaporates leaving salt particles which act as condensation nuclei for rain drops*

nearly the same chlorinity as seawater but is much more acidic due to the presence of one hydrogen ion for every chloride ion. In due course, due to some chemical reactions, the hydrogen ions are removed and replaced by sodium ions yielding the concentration of ordinary salt that constitutes over 90 percent of all "salt" in the sea.

There is evidence that the salinity of the ocean has not changed much since the ocean was formed; in any event the salinity has been nearly constant for the past 200 million years (5% of the total geologic time). The composition of ancient sediment suggests that the ratio of sodium to potassium in seawater has risen from roughly 1:1 to 3:1 as organisms removed calcium by building shells of calcium carbonate. It is significant, however, that the total amount of each pair of ions varied much less than their relative amounts.

The overall geochemical cycle which keeps the marine ions closely in balance involves a complex interchange of material over decades, centuries and millennia among the atmosphere, the ocean, the rivers, the

crystal rocks, the oceanic sediments and ultimately the mantle. To understand how the earth maintains this geochemical poise over a billion-year time scale, we must look into the weathering and unweathering processes of the geochemical cycle. It begins with the primordial igneous rock, squeezed from the mantle. Ignoring the relatively minor heavy metals such as iron, we can assume that the rock consists of aluminium, silicon and oxygen combined with the alkali metals — potassium, sodium and calcium. The resulting metals are feldspars. The rainwater picks up carbon dioxide from the air and falls on the feldspars. The reaction of water, carbon dioxide and feldspars typically yields a solution of alkali ions and bicarbonate ions which contain suspended hydrated silicate. The residual detrital aluminosilicate can be approximated by the clay kaolinite. A mountain stream carries off the ions and silica. The kaolinite fraction lags behind, first as a friable surface on weathering rock, then as soil material and finally as alluvial deposits in river valleys. In mature river systems, the

kaolinite fraction reaches the sea as suspended sediment. Encountering an ion rich environment for the first time, the aluminosilicate must reorganise itself into new minerals. These type of reactions may take decades or centuries and are poorly understood.

Ages pass and the geochemical cycle toils on, converting ocean-bottom clay into hard rock such as granite. When old seafloor finally reaches a region of high pressure and temperature under a continental block, it still contains some free ions that can react with the clay to reconstitute hard rock. After a score of multiple reactions, the final goal of the geochemical exercise will be attained. But even today, we have barely scratched the true complexity and subtlety of seawater. On many occasions we can only guess what the natural marine form of an element is because even now our detection techniques are not so advanced.

---

Shri P. K. Dinesh Kumar is a Scientist at the National Institute of Oceanography, Regional Centre, P.B. No. 1913, Cochin-682 018