WHY IS THE RELATIVE COMPOSITION OF CHEMICAL CONSTITUENTS IN SEA WATER MAINTAINED TO BE UNIFORM?

BY

Yoshiaki FUKUO

Sea water is an aqueous solution containing a variety of dissolved salts and gases. The chemical composition of sea water has been examined by many research workers since W. Dittmar, who laid foundation for the present knowledge of the composition, and it has been established that, regardless of absolute concentration of the total solids, the ratio between the more abundant constituents are virtually constant. This result is very important because the validity of chlorinity-salinity-density relationship depends on this constant ratio. It is very interesting that the relative composition of sea water is maintained to be uniform.

Sea water is evaporated by heating of radiation and sprayed by blowing of winds. Though a large portion of these vapours and sprays will fall back directly into the water, some portion of them will fall on the land as the rain. The rain water, extracting the more soluble constituents from rocks and soils, will flow into rivers. In addition to these dissolved materials, rivers will carry a large amount of colloidal and particulate substances from their drainage areas into the sea. It is said that about ten percent of the amount of evaporation from sea surface in a year, which is nearly 37×10^3 km^3, is fallen on the land as the precipitation and the equivalent volume is returned into the ocean as the runoff and consequently the bulk of the ocean remains at constant.

From such processes of water cycle, it is infered that the relative composition of river water is quite different from that of sea water. And actually, it is so, as seen in Table 1. In the following, the relative composition of sea water in this table will be called as " normal composition ". In the coastal areas where the inflow of river water causes a lowering of chlorinity, the values of Ca/Cl, SO_4/Cl, SiO_2/Cl and so on will be increased from year to year and the relative composition of sea water will be changed gradually.

In oceanography, the specific gravity of sea water is determined from the chlorinity titration on the basis of the normal composition, and usually expressed in $\sigma_t = 1000 \times (\rho_t - 1)$ (ρ_t: the specific gravity at t°C). From the results of our investigations in coastal areas, however, it was found that the actual specific gravity σ_t' measured directly by the hydrometer, scarcely coincided with the specific gravity

Table 1. Relative composition of dissolved substances in rain, river and sea water

	Sea Water(*)	River Water		Rain water(**) (provisional estimation)
		I(*)	II(**)	
Cl	1.00	1.00	1.00	1.00
Na	0.56	1.02	1.55	0.59
Mg	0.07	0.60	1.72	0.06
K	0.02	0.37	0.34	0.03
Ca	0.02	3.58	6.30	0.08
SO_4	0.18	2.12	1.58	0.65
SiO_2	—	2.05	—	—
CO_3	0.00	6.18	7.32	—

(*) Sverdrup, H.U., Johnson, M.W. and Fleming, R.H. "The Oceans".
(**) Hutchinson, G.E. "A Treatise on Limnology—I"

σ_t. This fact implies that the relative composition of coastal water generally deviates from the normal composition. So, if the difference $\Delta\sigma_0 \equiv \sigma_0 - \sigma_0'$ is introduced, the value of $\Delta\sigma_0$ will express quantitatively the degree of anomaly of actual composition from the normal composition and the positive value of $\Delta\sigma_0$ will represent that the amount of substances dissolved in the actual composition is deficient compared with that in normal composition. Let us call the $\Delta\sigma_0$ as "salinity deficit".

In normal composition, the salinity deficit is, of course, zero. Also it is apparent that the salinity deficit is lowered through the inflow of river water as mentioned above. But in major regions of the ocean, the normal composition is kept still unchanged in view of the results of many examinations. This fact may indicate the existence of some processes by which the excessive constituents such as Ca, SO_4 and SiO_2 are excluded from the sea water and the salinity deficit is raised so as to produce the normal composition.

As is well known, the biological production is very high in the coastal areas. Plankton population is more dense, algae grows more abundantly and the cultivation of laver, oyster and pearl thrive. This fertility is due to the widespread inorganic and organic substances brought in large quantities by the inflow of river water. The materials of marine organisms are supplied from the sea water and some parts of them are finally excluded from the sea water after their death, resulting in the formation of rock and petroleum. Inferring from the little fixation of chlorine, the ratio of salinity to chlorinity of sea water will be lowered and therefore the salinity deficit will be raised by the action of marine organisms,

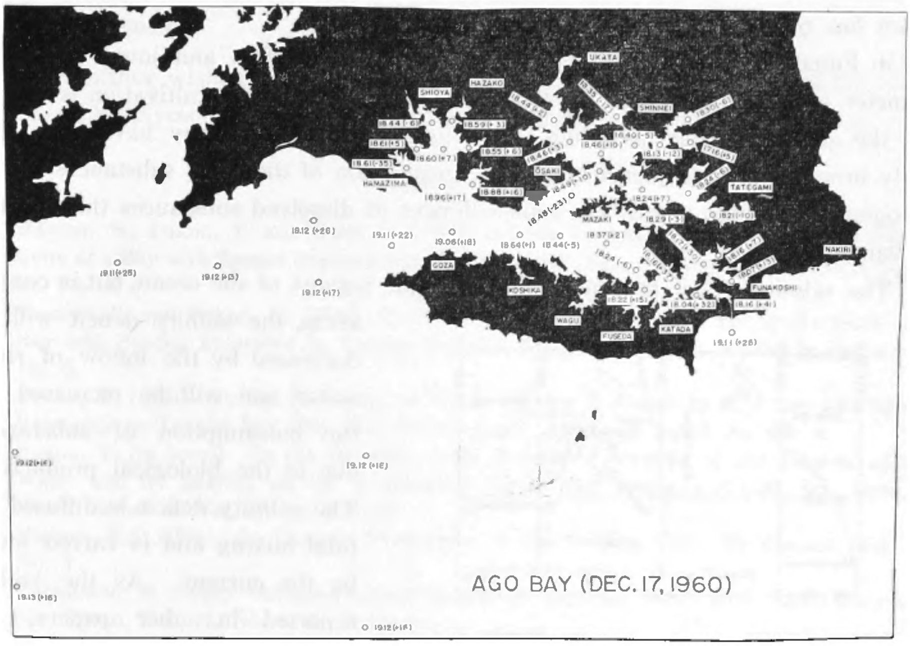

Fig. 1 Distribution of the chlorinity and salinity deficit in Ago Bay.

Fig. 1 shows the distributions of chlorinity and salinity deficit at surface layer in Ago Bay, pacific coast of Japan, where the cultivation of pearls has been flourished. The figures in parentheses are the values of $\Delta\sigma_0$ in 10^{-3} c.g.s. Although the distribution is complicated, it will be seen that, except in south-eastern part, that is, Funakoshi inlet, the salinity deficit of inlet water is smaller than that of water outside the bay. This may suggest that the inflow of river water causes to lower the salinity deficit. The lowering of the salinity deficit means the increase of the excessive amount of substances and consequently may bring the increase of substances contributed for the growth of marine organisms. Fig. 2 shows the relation between the salinity deficit and the diameter of pearl at the end of the definite periods during which the pearl-oysters were cultivated at various stations in Ago Bay. The diameter may be regarded as the mean growth rate of pearl-oyster for the cultivated term. It is seen that the diameter increases accordingly as the salinity deficit decreases. This result may suggest that the salinity

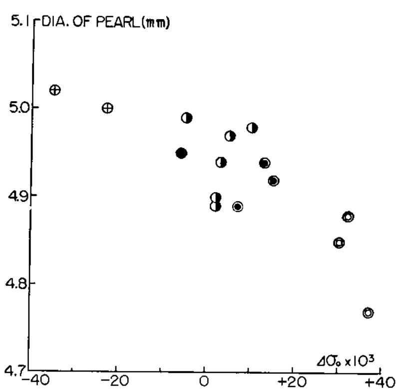

Fig. 2 Relation between the salinity deficit and the diameter of pearl (Ago bay, 1960)

deficit has relation to the fertility of sea water.

In Funakoshi inlet, the higher values of salinity deficit and lower values of diameter of pearl are found. In this inlet, it is said that the cultivation is surplus and the quality of pearl is falling. The high salinity deficit may have been probably brought in consequence that the consumption of dissolved substances by the biological production exeeds the replenishment of dissolved substances through the exchange of water.

The salinity deficit may not exist in major regions of the ocean, but in coastal areas, the salinity deficit will be decreased by the inflow of river water and will be increased by the consumption of substances due to the biological production. The salinity deficit is diffused by tidal mixing and is carred away by the current. As the author reported in other papers, the variation of salinity deficit may be treated quantitatively by the diffusion equation as well as the temperature, chlorinity and other physical properties. In this equation, the biological production may be taken as a kind of source of salinity deficit and the discharge of river water, which fluctuates in connection with the precipitation, may be dealt with as the influx of salinity deficit at the boundary of bay. Fig. 3 shows the result of investigation which was carried out at some points of the pacific coast along two survey lines stretched about 20 km offshore. It is interesting to note that the distribution of salinity deficit undulates along both lines, and especially along the line II, the value of salinity deficit is likely to converge to zero offshore.

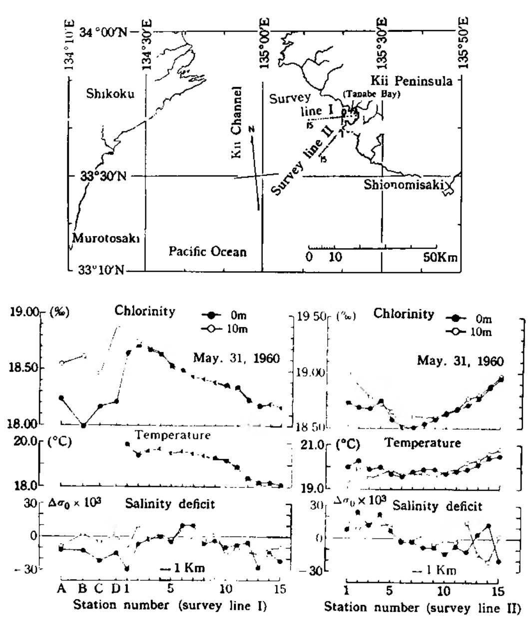

Fig. 3 Distribution of the chlorinity, salinity deficit and temperature outside the bay of Tanabe.

Althogh the precise relation between the salinity deficit and biological production, is not yet clearly known, it is sure that the activity of marine organisms play a fair role in turning the relative composition of river water into the normal composition of sea water.

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