REDEFINITION OF SALINITY

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IHB Note : In view of the importance of the definition of salinity in oceanography, the IHB has judged it necessary to reprint this article in the *International Hydrographic Review.*

Two definitions of salinity have been in use since the early part of the present century (M. KNUDSEN [1901], C. FORCH, M. KNUDSEN and S. P. SØRENSEN [1902]). The procedural definition is that salinity is the amount (in grams) of dissolved solid material in a kilogram of sea water after all the bromine has been replaced by an equivalent quantity of chlorine, all the carbonate converted to oxide, and all of the organic matter destroyed. In practice, this procedure is difficult to carry out with high precision, and an empirical relation between salinity and chlorinity has been used as a working definition :

$$S\,‰ = 0.030 + 1.8050\ Cl\,‰ \qquad (1)$$

This relation is useful because of the relative constancy of proportions of the major constituents of sea water, and because of the availability of a precise chemical method for determining chlorinity. However, it is based on only nine salinity determinations; the constant 0.030 results from the use of Baltic Sea water for the low concentrations. D. E. CARRITT and J. H. CARPENTER [1959] have estimated that the uncertainty of a computed value of salinity from a measured value of chlorinity using this relation can be as much as $0.04^0/_{00}$, due to variations in the composition of sea water.

With the development of precise methods for measuring the electrical conductivity of sea water to a precision of 1 in 10^5, it became possible to consider a new definition of salinity based on conductivity. Accordingly, Roland Cox undertook an extensive investigation of the conductivity/chlorinity relationship, using a large number of seawater samples from all parts of the world ocean; the results of this research are described by R. A. COX, F. CULKIN and J. P. RILEY [1967]. To supervise the preparation

of oceanographic tables based on these investigations, an international Joint Panel on Oceanographic Tables and Standards was established by UNESCO, the International Council for the Exploration of the Sea (ICES), the Scientific Committee on Oceanic Research (SCOR) and the International Association for the Physical Sciences of the Ocean (IAPSO).

In October 1966, International Oceanographic Tables were published jointly by the National Institute of Oceanography of Great Britain and UNESCO. These tables contain a new definition of salinity, as discussed below. At the same time, ICES urged all oceanographers to use only these tables in the future for computing salinity of sea water from conductivity. In October 1967, IAPSO endorsed the Tables and the definition of salinity and the relation between salinity and chlorinity contained therein, recommended their use by oceanographers, and recommended that all oceanographic data reports henceforth should include an explicit statement of the particular tables used to establish the values of salinity reported. In the same month, the salinity definition was endorsed by the Executive Committee of SCOR.

In preparing the Tables, the following arbitrary relation between salinity and chlorinity was used :

$$S\,‰ = 1.80655\ Cl\,‰ \qquad (2)$$

This relation is compatible with (1) with respect to older data of lower precision, such as those resulting from chlorinity titrations, giving identical results at salinity $35‰$ and differing by only $0.0026‰$ at salinities 32 and $38‰$.

The relation between salinity and conductivity ratio R_{15} (*) was based on precise determinations of chlorinity and R_{15} on 135 natural sea water samples, all collected within 100 m of the surface, and including samples from all oceans and the Baltic, Black, Mediterranean and Red Seas. After chlorinity was converted to salinity, using (2), the following polynomial was computed by least squares :

$$S\,‰ = -\,0.08996 + 28.29720\,R_{15} + 12.80832\,R_{15}^2 - 10.67869\,R_{15}^3 + 5.98624\,R_{15}^4 - 1.32311\,R_{15}^5 \qquad (3)$$

The root mean square deviation between a single point and the line was $0.002‰$ in chlorinity for samples having chlorinity above $15‰$ and $0.005‰$ for lower concentrations. Because of the variable composition of the diluting river water, the estimation of salinity is less precise in regions such as estuaries and the surface layers of the Baltic Sea. There is also evidence that for deep oceanic waters (below 2000 m), the mean salinity from chlorinity is about $0.003‰$ lower than that from conductivity (R. A. Cox *et al.* [1967]).

Expression (3) constitutes the recommended definition of salinity. The International Oceanographic Tables include a tabulation of this expression

(*) Conductivity ratio, R_t, is the ratio of the conductivity of a water sample to that of water having a salinity of exactly $35‰$, both samples being at the same temperature (15 °C for R_{15}) and under a pressure of one standard atmosphere.

for conductivity ratios R_{15} from 0.85000 to 1.17999 (at intervals of 0.00001) and salinities from 29.196 to 42.168$^0/_{00}$, along with correction tables for measurements at other temperatures. Recently, new tables connecting refractive index anomaly with salinity have been added (from the measurements of J.S.M. RUSBY [1967]).

On behalf of the international organizations that have endorsed the new salinity definition and the associated tables, we would like to encourage their use by all oceanographers.

REFERENCES

CARRITT, D. E. and J. H. CARPENTER, 1959 : The composition of sea water and the salinity-chlorinity-density problems. *In* : Conference on Physical and Chemical Properties of Sea Water, p. 67. Publ. Nat. Acad. Sci., Wash. No. 600.

COX, R. A., F. CULKIN and J. P. RILEY, 1967 : The electrical conductivity/chlorinity relationship in natural sea water. *Deep-Sea Res.*, **14**, 203.

FORCH, C., M. KNUDSEN and S. P. SØRENSEN, 1902 : Berichte über die Konstantenbestimmungen zur Aufstellung der hydrographischen Tabellen. D. Kgl. Danske Videnok, Selsk. Skr., 6 Raekke, naturvidensk. og math. Afd. **XII**, 1.

KNUDSEN, M., 1901 : Hydrographical Tables, Copenhagen.

National Institute of Oceanography of Great Britain and UNESCO, 1966 : International Oceanographic Tables. Wormley, Paris.

RUSBY, J. S. M., 1967 : Measurements of the refractive index of sea water relative to Copenhagen Standard Sea Water. *Deep-Sea Res.*, **14**, 427.