Redefinition of Salinity[1]

Warren S. Wooster
Arthur J. Lee
Gunter Dietrich

Two definitions of salinity have been in use since the early part of the present century (Knudsen 1901, Forch et al. 1902). According to the procedural definition, salinity is the amount (in grams) of dissolved solid material in a kilogram of seawater after all the bromine has been replaced by an equivalent quantity of chlorine, after all the carbonate has been converted to oxide, and after all of the organic matter has been destroyed. In practice, this procedure is difficult to carry out with high precision, and an empirical relationship between salinity and chlorinity has been used as a working definition:

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

This relationship is useful because of the relative constancy of proportions of the major constituents of seawater 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. Carritt and Carpenter (1959) have estimated that the uncertainty of a computed value of salinity from a measured value of chlorinity, using this relationship, can be as much as 0.04‰ because of variations in the composition of seawater.

With the development of precise methods for measuring the electrical conductivity of seawater to a precision of 1 in 10^5, it has become possible to consider a new definition of salinity based on conductivity. Accordingly, Roland Cox investigated extensively the conductivity/chlorinity relationship, using a large number of seawater samples from all parts of the world ocean; the results of this research have been described by Cox et al. (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),

1. Accepted for publication and submitted to press 1 May 1969.

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* (UNESCO 1966) were published jointly by UNESCO and the National Institute of Oceanography in Great Britain. These Tables contain a new definition of salinity, as discussed below. At the same time, ICES urged all oceanographers to use only these Tables for computing salinity of seawater from conductivity. In October 1967, the Tables, the definition of salinity, and the stated relationship between salinity and chlorinity were endorsed by IAPSO, which recommended that they be used by oceanographers and that all future oceanographic data reports include an explicit statement of the particular tables used in determining the values of the salinity reported. In the same month, the salinity definition was endorsed by the Executive Committee of SCOR.

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

$$S‰ = 1.80655\ Cl‰. \tag{2}$$

This relationship is compatible with eq. (1) relative to older data of lower precision, such as those resulting from chlorinity titrations; this gives identical results at a salinity of 35‰ and differs by only 0.0026‰ at salinities 32‰ and 38‰.

The relationship between salinity and conductivity ratio (R_{15}[2]) was based on precise determinations of chlorinity and R_{15} on 135 natural seawater samples; all of the samples were collected within 100 m of the surface and included samples from all oceans as well as the Baltic, Black, Mediterranean, and Red seas. After chlorinity was converted to salinity, using eq. (2), the following polynomial was computed by using least squares:

$$\left.\begin{aligned} S‰ = {} & -0.08996 + 28.29720\ R_{15} + 12.80832\ R_{15}^2 - 10.67869\ R_{15}^3 + \\ & + 5.98624\ R_{15}^4 - 1.32311\ R_{15}^5. \end{aligned}\right\} \tag{3}$$

The root-mean-square deviation between a single point and the line was 0.002‰ in chlorinity for samples having a chlorinity above 15‰ and 0.005‰ for samples having concentrations below 15‰. Because of the variable composition of the diluting river water, the estimation of salinity is less precise in certain regions such as estuaries and in 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 (Cox et al. 1967).

2. 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.

Expression (3) constitutes the recommended definition of salinity. The *International Oceanographic Tables* include a tabulation of this expression for conductivity ratios R_{15} from 0.85000 to 1.17999 (at intervals of 0.00001) and for salinities from 29.196 to 42.168‰; it also includes correction tables for measurements at other temperatures. Recently, new tables connecting refractive index anomaly with salinity have been added (from the measurements of Rusby 1967).

The conductivity method is now widely used in determining salinity, and the redefinition of salinity is required for its use. On behalf of the international organizations that have endorsed the new salinity definition and the associated Tables, we wish 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* Physical and Chemical Properties of Sea Water, pp. 67–86. Nat. Acad. Sci. Pub. 600; 202 pp.

Cox, R. A., F. Culkin, and J. P. Riley
1967. The electrical conductivity/chlorinity relationship in natural sea water. Deep-sea Res., *14*: 202–220.

Forch, C., Martin Knudsen, and S. P. Sørensen
1902. Berichte über die Konstantenbestimmungen zur Aufstellung der hydrographischen Tabellen. K. Danske Vidensk. Selsk. Skr., 8, Nat. Math., *12* (1).

Knudsen, Martin
1901. Hydrographical Tables. Copenhagen.

Rusby, J. S. M.
1967. Measurements of the refractive index of sea water relative to Copenhagen standard sea water. Deep-sea Res., *14*: 427–440.

Unesco
1966. International Oceanographic Tables. UNESCO Office of Oceanography, Paris.

Warren S. Wooster, President, SCOR.
Arthur J. Lee, Chairman, ICES
Hydrography Committee.
Gunter Dietrich, President, IAPSO.