Typical chemical characteristics of full-strength seawater

20 April 2020 Claude E. Boyd, Ph.D.

Prof. Boyd offers a guide for preparing artificial seawater

The typical chemical characteristics of seawater can be used as a guide for preparing artificial seawater. Photo by Darryl Jory.

At Aquaculture America 2020 in Honolulu, several papers were presented on artificial seawater concoctions, indicating a general interest in this topic. This short article provides information on the typical chemical characteristics of seawater, which may serve as a guide for those preparing artificial seawater. Formulas for making artificial seawater are many, but these will not be considered. The purpose here is to simply describe normal seawater.

Characteristics

The salinity of seawater varies somewhat from as low as 31 ppt in some areas of the ocean to as much as 41 ppt in the Red Sea. The average value most commonly reported is 35 ppt, but some authors use 34.5 ppt.

The density (specific gravity) of seawater ranges from 1.020 to 1.030 kg per liter (or grams per cubic centimeter). The average usually is reported as 1.027 kg/L at 25 degrees-C.

The electrical conductivity of seawater ranges from 44,000 to 58,000 µmhos/cm (or µS/cm) with an average of about 50,000 µmhos/cm. Of course, conductivity and salinity are highly and positively correlated. A multiplier of 0.69 may be used to convert conductivity to salinity for practical purposes.

The pH of seawater ranges from 7.6 to 8.4. The average ocean pH is said to be 8.1, but the average pH of seawater is slowly but steadily declining as the atmospheric carbon dioxide concentration increases, resulting in a higher concentration of dissolved carbon dioxide in the ocean. Carbon dioxide is acidic and forces the pH down.

Total alkalinity of seawater varies from 100 to 130 mg per L as $CaCO_3$, with an average of 116 mg per L. The bicarbonate (HCO_3^-) concentration of seawaters multiplied by a factor of 0.82 gives a reasonable estimate of total alkalinity in milligrams per liter of $CaCO_3$.

Total hardness of seawater is between about 5,800 and 7,500 mg per L as $CaCO_3$, and the average at 34.5 ppt salinity is 6,570 mg per L as $CaCO_3$. The total hardness can be calculated from calcium (Ca^{2+}), magnesium (Mg^{2+}), and strontium (Sr^{2+}) concentrations by the following equation:

Total hardness in mg/L as $CaCO_3$ =

(Ca2+ in mg/L × 2.5) + (Mg2+ in mg/L × 4.12) + (Sr2+ in mg/L × 0.68)

Major ions

The major ion concentrations in seawater may vary slightly from place to place even when there are no differences in salinity. However, when salinity increases, the major ion concentrations all tend to increase more or less in direct proportion to the salinity.

Many authors have reported the major ion composition of seawater. Major ions are those with concentrations of 1 mg per L or more. Four different analyses of seawater given in Table 1 reveal that major ions concentrations are somewhat variable among the different analyses. Sodium (Na^+) and chloride (Cl^-) have the highest concentrations and usually comprise about 85.7 percent of the salinity. Magnesium (Mg^{2+}) and sulfate (SO_4^{2-}) are the next most abundant ions, making up about 11.2 percent of the salinity. Calcium (Ca^{2+}) and potassium (K^+) are of similar concentration and comprise about 2.3 percent of the salinity. The other major ions are at much lower concentration and comprise about 0.8 percent of the salinity.

Boyd, seawater, Table 1

	Cotruvo (2005)	Turekin (1968)	Britannica Online Encyclopedia	Goldberg (1963)
Cl-	18,980	19,400	19,162	19,000
Na+	10,556	10,800	10,679	10,500
SO4 2-	2,649	2,712	2,680	2,700
Mg2+	1,262	1,290	1,278	1,350
Ca2+	400	411	410	400
K+	380	392	395	380
HCO3-	140	142	140	142
Br-	65	67	66	65
Sr2+	13	8.1	7.9	8
Boric acid (as B)	4.78	4.45	4.4	4.6
F-	1	1.3	1.3	1.3
Silica (as Si)	1	2.9	–	3
Salinity	34.5	35.2	34.7	34.5

Table 1. Concentrations (mg/L) of major dissolved substances in ocean water.

When one makes or has an independent laboratory make an analysis of the seawater, the cation-anion balance principle may be used to check the probable reliability of the analysis. This is illustrated below for the Goldberg seawater analysis (Table 1):

Cations

10,500 mg/L Na^+ ÷ 23 mg Na^+/meq = 456.52 meq/L

1,350 mg/L Mg^{2+} ÷ 12.15 mg Mg^{2+}/meq = 111.11 meq/L

400 mg/L Ca^{2+} ÷ 20.04 mg Ca^{2+}/meq = 19.96 meq/L

380 mg/L K^+ ÷ 39.1 mg K^+/meq = 9.72 meq/L

8 mg/L Sr^{2+} ÷ 43.81 mg Sr^{2+}/meq = 0.18 meq/L

Sum = 597.49 meq/L

Anions

19,000 mg/L Cl^- ÷ 35.45 mg Cl^-/meq = 535.97 meq/L

2,700 mg/L SO_4^{2-} ÷ 48.0 mg SO_4^{2-}/meq = 56.25 meq/L

142 mg/L HCO_3^- ÷ 61.0 mg HCO_3^-/meq = 2.33 meq/L

65 mg/L Br^- ÷ 79.97 mg Br^-/meq = 0.81 meq/L

Sum = 595.36 mg/L

The cations and anions very nearly balance (a ratio of 1.000 would be perfect agreement), so the analysis was quite accurate.

Trace elements

In the event someone is interested in the trace element composition of seawater, three reports of several common trace elements are provided (Table 2). Note that the variation is much greater than for the major ions. But, of course, it is much more difficult to make accurate analysis of trace elements than of major ions. Seawater contains many more trace elements than are reported in Table 2. Nearly every natural element in the periodic table likely occurs in seawater, but most are at exceedingly low concentrations.

Boyd, seawater, Table 2

Element	Goldberg (1963)	Turekin (1968)	Schroeder (1974)
Fe (Iron)	10	3.4	3.4
Mn (Manganese)	2	0.4	1
Zn (Zinc)	10	5	15
Cu (Copper)	3	0.9	10
Cd (Cadmium)	0.11	0.11	0.03
Co (Cobalt)	0.50	0.39	0.1
Mo (Molybdenum)	10	10	14
Cr (Chromium)	0.05	0.20	2
V (Vanadium)	2	1.9	5
Ni (Nickel)	20	6.6	3
I (Iodine)	60	6.4	50
Se (Selenium)	4	0.9	4
As (Arsenic)	3	2.6	3

Table 2. Normal concentrations (µg/L) of selected trace elements dissolved in ocean water.

One other point of possible interest to readers is that seawater is usually at or very near calcium carbonate saturation. Thus, liming materials applied to marine aquaculture waters often do not dissolve.

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Responsibility

Accuracy of custom water analyses varies

The reliability of trace element analyses reported by custom laboratories cannot be checked by simple techniques, and results may not always be accurate. One should check the reliability of major ion analyses by determining the charge balance and comparing the measured total ion concentration with the total ion concentration estimated from conductivity.

Responsibility

Efficiency of mechanical aeration

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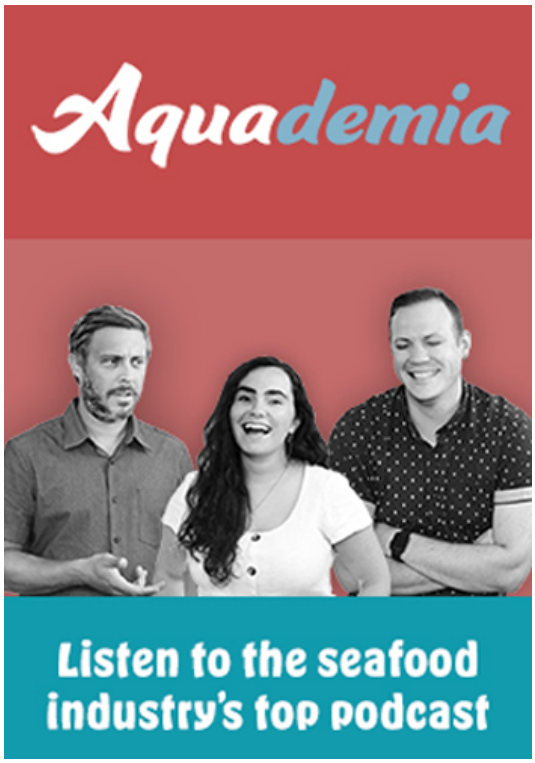

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