Paper No. 130626

Getting the Most Accurate Measurements of Seawater, Saltwater & Brackish Ocean Water

ABSTRACT

Obtaining accurate field measurements of seawater salinity, density, specific gravity, and conductivity are of great interest in oceanography, research, and aquaculture.

This paper compares four of the leading methods of measuring the physical properties of seawater, saltwater, and brackish ocean water. These methods include titration, the measurement of specific gravity by hydrometer, conductivity measurement and refractometry.

This paper also examines the Palm Abbe AQUAR™ series of digital refractometers by MISCO. The MISCO Palm Abbe AQUAR is based on the latest scientific data available and can display various seawater properties on multiple scales including, specific gravity, density, sigma-t, conductivity, practical salinity units, or salinity in parts per thousand.

Introduction

The salinity in the ocean is relatively constant throughout the world. Likewise is the ratio of various components within the seawater. Of these components, salinity is the component the oceanographer and aquaculturist are most interested in.

Salinity was first defined by the amount of dissolved solids contained in seawater after a sample of seawater was completely dried at 480 °C and then weighed on a scale. Not only was this method time consuming and unsuitable for field use, it lacked accuracy since some of the dissolved solids would be burnt off as gases and any suspended solids would be measured with the dissolved solids.

Later, relying on the relatively constant ratio of chloride ions to sodium ions in seawater, titration became the accepted method of measurement. Salinity was commonly expressed in parts per thousand (ppt).

Finally, in 1978, salinity was defined in terms of Practical Salinity Units (PSU). PSU's represent the ratio of the conductivity of seawater compared to the conductivity of a Potassium Chloride reference solution at 15 °C. Since the measurement is ratio-metric, there are no units of measure associated with it; however, it is commonly reported as PSU, which in actual use is very close to ppt. The relationship between salinity, temperature, density, and depth (pressure) is well established and a number of equations can be found in the scientific literature for making accurate calculations.

Oceanographers and aquaculturists currently have four methods available for the measurement of salinity in seawater. These methods consist of Chloride Titration, the Hydrometer, the Conductivity Meter, and the Refractometer.

Chloride Titration

The Chloride Titration method relies on the relatively constant ratio of chloride ions to sodium ions. Titration is a volumetric analysis that is used to quantify the concentration of a known reactant. In the case of seawater, the reactant is the chloride ion. Titration consists of counting the drops of a reagent added to the reactant until an endpoint is reached.

To titrate seawater, the sample is diluted with distilled water and then a specific amount of Diphenylcarbazone reagent powder is dissolved into it. Next, Mercuric Nitrate is added, one drop at a time, until the color of the solutions changes from yellow to pink. The number of drops of Mercuric Nitrate required to reach the end point is related to the amount of chloride ions, which is then related to amount of sodium ions.

There are many practical limitations to using titration for field testing saline concentration. Chief among these limitations is repeatably controlling the size of the drop, the amount of time required to perform a test, and the accuracy of the results.

The Hydrometer

The traditional method of measuring Salinity in seawater involves the use of a hydrometer, a floating device that measures the specific gravity of a fluid. The limitations of the hydrometer are clearly evident to those who use them, and these limitations may in fact be what inspired you to read this paper in search of an easier method.

A hydrometer is typically comprised of a carefully weighted clear glass tube containing a card with scale divisions marked on it. The hydrometer is floated in the test solution and the card is read at the point where the surface of the fluid crosses the scale divisions of the card.

Some hydrometers may have cards with scales (units of measure) printed on them that measure directly in specific gravity and others may read in different units such as parts per thousand (ppt). Although there are numerous types of hydrometers made from different materials and with different scales and ranges, they all have a specific reference temperature.

Regardless of the type of hydrometer, it is floated in a clear container partially filled with seawater, together with a thermometer. A thermometer is necessary since specific gravity of a substance, what the hydrometer is ultimately measuring, is very temperature dependent.

The hydrometer scale is read at the point where the top surface of the seawater in the graduated cylinder crosses the hydrometer scale. Once the specific gravity is known, it can be easily converted to density or salinity.

When using any hydrometer, it is important to note and record the temperature at which the solution is measured and then do a manual calculation to compensate for temperature differences between the temperature at which the solution was measured and the reference temperature of the hydrometer.

Drawbacks to using a Hydrometer:

Although a hydrometer is relatively inexpensive, anyone with hydrometer experience is all too familiar with its shortcomings. The amount of time that it takes to fill a graduated cylinder with seawater, float the hydrometer, measure the temperature, perform a temperature correction calculation, convert the reading to PSU and then thoroughly clean everything, is considerable; especially when testing a large number of samples.

Generally, there is no method of calibrating the hydrometer and no easy way to tell when it is out of calibration. Hydrometers often have a little card sealed inside with a scale printed on it. Any movement of the card inside the hydrometer will throw off the reading.

Hydrometers must be cleaned and dried thoroughly after each use; if any of the equipment has dried salt residue on it, future readings will be inaccurate. Also, there will be the possibility of an error caused by temperature differences between the reference temperature of the hydrometer and the temperature at which seawater was measured. The greater the temperature difference, the greater the potential for error.

There is also the possibility of introducing error into the measurement when performing the calculation necessary to compensate for temperature differences, not to mention the potential for human error when using conversion tables, graphs, and charts.

Lastly, hydrometers are easily lost or broken and are really not suited for a field environment. The readings are thrown off by other dissolved solids, suspended solids, and bubbles in the water. Further, the analog scale is subjective and can be hard to read; imagine trying to read the meniscus (point where fluid surface crosses the scale) in a boat that's bobbing in the water.

Conductivity

Conductivity is simply the measure of the flow of electricity through the water. For measuring seawater, special conductivity meters are used that measure the ratio of the conductivity of a sample of seawater compared with a reference solution of KCl. These high precision units are expensive and are not suitable for quick field tests. Portable conductivity meters, designed for field use, measure only the direct conductivity of seawater and not the ratio of seawater with respect to a KCl reference cell. The standard unit of measure for conductivity is millSeimens per centimeter (mS/cm).

A typical portable conductivity meter, with the range necessary to accurately measure seawater, costs between $350 and $700. These instruments typically have a range from 0-200 mS/cm, with a resolution of 0.1 mS/cm, and a precision between +/- 2 to 3 mS/cm. This translates to a precision of between +/- 2.6 to 3.9 ppt. Portable conductivity meters generally just give a reading in uS/cm or mS/cm which must be converted to PSU or density.

Because conductivity meters measure total conductivity, they do not discriminate between the ions present in a solution. Therefore, estuaries or small bodies of water that have a significant contribution from runoff or failing sewage treatment systems could have a significantly higher reading due to the presence of chlorides, sulfates, calcium, phosphates, and nitrates. The presence of certain ions, like calcium and sulfates, can present another problem in that they have a higher conductivity than sodium and chloride ions and therefore can create a greater error. Further, the presence of oil or fuel in the water can reduce conductivity.

Just as with the hydrometer and specific gravity, conductivity is very temperature dependent. The difference between the conductivity of 35 PSU seawater at 10 °C and 20 °C, for example, would be different by nearly 10 mS/cm. This would be enough to skew a PSU calculation by about 8 PSU.

One last word about conductivity meters. It is important to thoroughly clean and rinse the conductivity electrodes with deionized water between tests and then thoroughly dry them. Failure to do so will lead to erroneous readings. Lastly, conductivity meters require special calibration solutions.

The Refractometer

The refractometer has long been an accepted method for measuring seawater salinity. Traditional analog refractometers, for field use, can now be found for a little as $100, while digital instruments, such as the MISCO Palm Abbe, can cost between $445-$535.

Traditional analog refractometers display the reading at the point a shadowline crosses a tiny glass reticle. Many are not automatically temperature compensated, which means that the reading can be off significantly for every degree Celsius the instrument temperature varies from 20 °C (68 °F). Readings on analog refractometers are subjective and they are difficult to read in a boat bobbing on the water.

Most significantly, some of these refractometers are simply salinity refractometers based on the relationship between sodium chloride and water, not seawater! Hence, these instruments should not be relied on to give the most accurate readings for seawater. Other refractometers may claim to be seawater refractometers, but they are based on antiquated data and display results in ppt or 0/00 instead of PSU.

The MISCO Palm Abbe AQUAR series of digital handheld refractometers offer state of the art seawater measurement. Designed specifically for oceanography, aquaculture, professional aquariums, desalination plants, and research, these refractometers are based on the latest scientific research and accepted scientific standards published by the United Nations Educational, Scientific & Cultural Organization ("UNESCO").

The MISCO Palm Abbe AQUAR series represent the most stable and precise digital handheld refractometers available. With a precision of +/- 0.0005 specific gravity, the Palm Abbe AQUAR rivals many bench-top laboratory instruments costing thousands of dollars more. In addition, the seawater scales on these refractometers use the most up to date scientific data from UNESCO to relate refractive index to the physical properties of seawater.

Two AQUAR base models are available; however, any five seawater scales may be mixed and matched from the list below to create a truly custom instrument. The Model AQUAR H20 has two direct reading scales. One scale reads Practical Salinity Units and the other measures specific gravity.

The AQUAR H50 has five scales and is the most advanced handheld refractometer available for oceanography and aquaculture. It has scales for PSU, Sigma-t Density, Specific Gravity, Conductivity, and Chlorinity.

Measuring seawater on the Palm Abbe is fast and efficient. The instrument can be zero set to fresh water and will make accurate repeatable measurements in the blink of an eye. Just place a sample of seawater in the measuring well, close the evaporation cover, and press the <GO> button. The automatically temperature compensated reading will be displayed on the large 24-character display in seconds. The user can scroll through and select the appropriate scale (unit of measure) by pressing the <MENU> button. Calibration to water is automatic and does not require turning any screws or making any adjustments.

Summary

Chloride Titration, Hydrometers, Conductivity Meters, and the Refractometers are all methods available to the oceanographer and aquaculturist for testing the salinity and other physical properties of seawater. With the exception of refractometers, all these tests will resolve a single physical property that may have to be converted to another physical property or unit of measure of interest.

Of these methods, refractometers clearly represent the most efficient, accurate, and flexible method available for field testing the properties of seawater.

The MISCO Palm Abbe AQUAR series of digital refractometers stand alone as the best alternative for professionals interested in measuring the physical properties of seawater. The Palm Abbe scales are based on the latest scientific data available and can display various seawater properties on multiple scales.

ABOUT THIS PAPER

MISCO Refractometer, in business since 1949, is a leader in a very small world-wide community of professional refractometer manufacturers and is very visible within that industry. MISCO has great respect for its competitors and, although comparison between products is inevitable in a free market economy, an attempt has been made here to offer only fair and objective head-to-head comparisons. In the end, it's the customer's ultimate decision to select the company they wish to honor with their business.

We have tried to present the data in such a way that it compares the strength and weakness of all the comparison instruments. Some instruments will naturally fair better in different categories than others. In the event that a customer or competitor finds an error in the data presented here, please contact us and we will gladly update this document.

RESOURCES

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