

Measurement of Water Salinity in Water Towers



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Declaration

1. I know that plagiarism is wrong. Plagiarism is to use another's work and pretend that it is one's own.
2. I have used the IEEE convention for citation and referencing. Each contribution to, and quotation in, this report 'The Measurement of Water Salinity in Water Towers' from the work(s) of other people has been attributed and has been cited and referenced. Any section taken from an internet source has been referenced to that source.
3. This report 'The Measurement of Water Salinity in Water Towers' is my own work and is in my own words (except where I have attributed it to others).
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The terms of reference page is an agreement between yourself and your supervisor outlining what is expected of you in your final year project. Please make sure that this is discussed and written at the beginning of your thesis project.

Acknowledgments

Make relevant acknowledgements to people who have helped you complete or conduct this work, including sponsors or research funders.

Abstract

- Open the **Project Report Template.tex** file and carefully follow the comments (starting with %).
- Process the file with **pdflatex**, using other processors may need you to change some features such as graphics types.
- Note the files included in the **Project Report Template.tex** (with the .tex extension excluded). You can open these files separately and modify their contents or create new ones.
- Contact the latex manual for more features in your document such as equations, subfigures, footnotes, subscripts & superscripts, special characters etc.
- I recommend using the **kile** latex IDE, as it is simple to use.

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Glossary

PSU Practical Salinity Unit 6

‰ Parts per thousand 6

Acronyms

EIS Electrical Impedance Spectroscopy 5

ML Machine Learning 5

Chapter 1

Introduction

1.1 Background to the study

A very brief background to your area of research. Start off with a general introduction to the area and then narrow it down to your focus area. Used to set the scene[?].

1.2 Objectives of this study

1.2.1 Problems to be investigated

Description of the main questions to be investigated in this study.

1.2.2 Purpose of the study

Give the significance of investigating these problems. It must be obvious why you are doing this study and why it is relevant.

1.3 Scope and Limitations

Scope indicates to the reader what has and has not been included in the study. Limitations tell the reader what factors influenced the study such as sample size, time etc. It is not a section for excuses as to why your project may or may not have worked.

1.4 Plan of development

Here you tell the reader how your report has been organised and what is included in each chapter.

I recommend that you write this section last. You can then tailor it to your report.

Chapter 2

Literature Review

2.1 Introduction

Accurate salinity measurement is fundamental to oceanographic research. Traditional measurement techniques have evolved from labour-intensive chemical titration methods to modern electronic sensors, with electrical conductivity emerging as the predominant approach due to its combination of accuracy, speed, and practical deployability. This literature review examines the current state of salinity measurement technology with particular emphasis on conductivity-based methods and emerging machine learning approaches for electrochemical data interpretation. The review is organised into three main sections. First, we establish the fundamental concepts of salinity and provide a comprehensive comparison of available measurement techniques. Second, we examine the theoretical foundations and practical implementation of electrical conductivity measurements for salinity determination, including instrumentation, calibration procedures, and current limitations. Finally, we explore the application of Electrical Impedance Spectroscopy (EIS) and Machine Learning (ML) as advanced approaches for enhanced salinity analysis, examining how frequency-domain measurements and intelligent data processing can overcome limitations of traditional single-frequency conductivity methods. This comprehensive review provides the theoretical and methodological foundation for developing a machine learning-enhanced impedance spectroscopy approach for salinity determination.

2.2 Salinity: Definition

Salinity is a fundamental characteristic of water, and is most commonly defined as the total amount of dissolved salts in water, and in the context of oceanography, seawater. It is typically expressed in ‰ or PSU [1]. The concept of salinity has evolved significantly from its early definition, which was based on chlorinity measurements. Modern salinity is defined through the Practical Salinity Scale 1978 (PSS-78), where salinity is based on the conductivity ratio of standard seawater solutions, to a standard Potassium Chloride solution, and is dimensionless [2]. The salinity-conductivity relationship is however, quite complex, requiring corrections and calibrations needed for depth and temperature, as these both play a factor in the conductivity of the water.

2.3 Overview of Salinity Measurement Methods

There are a multitude of methods which can be used to measure salinity, each with their own advantages, limitations and levels of accuracy. Traditional methods include gravimetric analysis, chemical titration (such as the Mohr-Knudsen method for chlorinity), and refractometry. While these techniques can provide accurate results, they are often time-consuming, require skilled operators, and are not easily adaptable to in-situ or automated measurements. Modern approaches predominantly rely on electrical conductivity sensors, which offer rapid, repeatable, and automated salinity determination. Other techniques, such as optical methods and ion-selective electrodes, have also been explored, but are less commonly used in oceanographic applications due to issues with robustness, calibration, or specificity. The choice of method depends on the required accuracy, operational environment, and available resources.

2.3.1 Historical Methods

Chlorinity Titration

Early salinity measurements relied on chemical titration methods, in particular the Mohr-Knudsen chlorinity titration, which used silver nitrate. The chlorinity of a solution has the definition ‘the mass of silver required to precipitate completely the halogens in 0.3285234kg of the ocean-water sample’ This method was highly accurate, with results

within (± 0.001 PSU). However, it relied heavily on toxic chemicals, and was a time-consuming laboratory procedure, with limited practical application in the field.

Gravimetric Methods

Gravimetric analysis, a technique used to determine an amount of a substance, by measuring its change in mass, involves evaporation and the weighing of dissolved solids. This method directly provided measurements of the salt content, within accuracies of (± 0.001 PSU), under controlled laboratory conditions. This method remains the reference standard for calibration processes, but is however, extremely slow.

2.3.2 Physical Property Based Methods

There are several methods that utilise the relationship between salinity and the physical properties of water.

Hydrometric and Density Methods

Hydrometric methods using density measurements via hydrometers, offer salinity measurements that are low-cost, and electronics free. However, they are limited in precision with accuracies of $\pm 1 - 2$ PSU, and require large sample volumes. The hydrometer is a floating instrument, that sinks to different depths depending on the density of the solution, and by measuring how high or low it floats, the density of the solution can be determined. The following equation is used to map the relationship between salinity and density.

$$\rho = \rho_0(1 + kS) \quad (2.1)$$

where ρ is the density, ρ_0 is the density of fresh water, S is the salinity and k is the proportionality constant.

This can then be inverted to give Salinity from Density:

$$S = \frac{\frac{\rho}{\rho_0} - 1}{k} \quad (2.2)$$

This however, does not include temperature correction.

Refractometric Thechniques

Refractometric techniques measure the refractive index changes cuased by the dissovled salts. The refractive index of seawater is influenced by wavelength, temperature, salinity, and pressure. Within the range of 500-700 nm wavelength, 0-30°C temperature, 0-40 PSU salinity, and 0-11000 dbar pressure, the refractive index equation provides an accuracy of 0.4-80 ppm PSU, with accuracy decreasing as pressure increases. Refractometers, which require only a small sample volume, are compact devices, making them suitable for portable field measurements. Fibre optic refractometers have improved portability and reduced temperature sensitivity, with moderate accuracy (± 0.5 -1 PSU), making them increasingly popular in aquaculture applications.

Freezing Point Osmometry

Freezing point depression osmometry exploits the colligative (i.e. relating to the binding together of molecules) properties of dissolved salts. The main principle relies on freezing point depression, which is the phenomenon where a solvents freeving point is lowered when a solute is added to it. To perform the measurement, the water is cooled till its freezing point and the temperature drop is measured, which is then used to calculate the osmolality. This method can achieve accuracies as high as (± 0.001 PSU), however its requirement for precise temperature control limits its usage to laboratory applications.

Interferometry

Interferometry is a measurement technique which measures how electro-magnetic waves are affected by changes in a solution. Two identical light waves are passed through two solutions, one benchmark and one test sample solution. The gain and phase shift between the waves is then used to calculate the salinity. This method requires precisely aligned mirrors to direct the light waves, causing it to be relatively large.

Electromagnetic Induction and Magnetic Permeability

2.3.3 Advanced Analytical Methods

2.3.4 Remote Autonomous Sensing

2.4 Conductivity-Based Salinity Measurements

2.4.1 Theoretical Foundation

Electrical conductivity has emerged as the predominant method for salinity measurement due to its practical implementation, high accuracy and fast response time. The technique utilises the strong correlation between dissolved ionic content and electrical conductivity.

The conductivity of a liquid is measured by its ability to conduct electrical current. The relationship between conductivity and salinity is based on the concentration of dissolved ions in seawater. The main ions found in sea water, these being Na , Cl , Mg^{2+} , SO_4^{2-} , Ca^{2+} and K , maintain a relatively constant proportional relationship, in ocean waters. This enables robust corrections between conductivity and total dissolved salt content. The Practical Salinity Scale 1978 (PSS-78) defines salinity through the conductivity ratio, as shown below:

$$K_{15} = \frac{C(S, 15, 0)}{C(KCl, 15, 0)} \quad (2.3)$$

where $C(S, 15, 0)$ represents the conductivity of seawater sample S at 15°C and standard atmospheric pressure (1 atm/101.325 kPa), and $C(KCl, 15, 0)$ is the conductivity of a standard KCl solution under identical conditions.

2.4.2 Temperature Compensation

Chapter 3

Methodology

This is what I did to test and confirm my hypothesis.

You may want to split this chapter into sub chapters depending on your design. I suggest you change the title to something more specific to your project.

This is where you describe your design process in detail, from component/device selection to actual design implementation, to how you tested your system. Remember detail is important in technical writing. Do not just write I used a computer give the computer specifications or the oscilloscopes part number. Describe the system in enough detail so that someone else can replicate your design as well as your testing methodology.

If you use or design code for your system, represent it as flow diagrams in text.

IMPORTANT: Include a motivation for your selection of an appropriate technique, or engineering or IT tool to solve your project problem. Discuss any limitations if appropriate.

Chapter 4

Results

These are the results I found from my investigation.

Present your results in a suitable format using tables and graphs where necessary. Remember to refer to them in text and caption them properly.

4.1 Simulation Results

4.2 Experimental Results

Chapter 5

Discussion

Here is what the results mean and how they tie to existing literature...

Discuss the relevance of your results and how they fit into the theoretical work you described in your literature review.

Chapter 6

Conclusions

These are the conclusions from the investigation and how the investigation changes things in this field or contributes to current knowledge...

Draw suitable and intelligent conclusions from your results and subsequent discussion.

Chapter 7

Recommendations

Make sensible recommendations for further work.

Bibliography

- [1] R. H. Stewart, “Introduction to Physical Oceanography,” 2008. Publisher: Robert H. Stewart.
- [2] UNESCO, “Tenth report of the joint panel on oceanographic tables and standards,” *UNESCO Technical Papers in Marine Science*, vol. 36, pp. 1–25, 1981.

Appendix A

Additional Files and Schematics

Add any information here that you would like to have in your project but is not necessary in the main text. Remember to refer to it in the main text. Separate your appendices based on what they are for example. Equation derivations in Appendix A and code in Appendix B etc.

IMPORTANT: Appendix A (see the table below) should provide a summary of how you have met the GAs associated with the course, and where in the report the evidence can be found.

If you have used AI in writing your report, you need to provide details in one of the appendices of how you used it.

If appropriate, in a subsequent appendix, provide a link to any GitHub repository where the code and additional materials for your project can be found.

GA	Requirement	Justification and section in the report
1	Problem-solving	Description here
4	Investigations, experiments and data analysis	Description here
5	Use of engineering tools	Description here
6	Professional and technical communication (Long report)	Description here
8	Individual work	Description here
9	Independent learning ability	Description here

Appendix B

Addenda

B.1 Ethics Forms

Appendix C

GitHub Repository

[Click here to access the GitHub repository.](#)

GitHub Structure