KONSTAN
JURNAL FISIKA DAN PENDIDIKAN FISIKA
Volume 9, Number 1, June 2024
E-ISSN : 2460-9129 dan P-ISSN : 2460-9110
http://jurnalkonstan.ac.id/index.php/jurnal

DESIGN AND DEVELOPMENT OF A PORTABLE CONDUCTIVITY-BASED SALINITY MEASUREMENT SYSTEM FOR COASTAL WELL WATER

Mohammad Rasyidi Azhari[1,*)], Lalu Sahrul Hudha[1], Dian Wijaya Kurniawidi[1], Rima Buna Prahastiwi[2]

[1)] Program Studi Fisika, Universitas Mataram, Mataram, Nusa Tenggara Barat, Indonesia
[2)] Program Studi Tadris Fisika, Universitas Islam Negeri Mataram, Mataram, Nusa Tenggara Barat, Indonesia

*E-mail korespondensi: rasyidiazharimohammad@gmail.com

Article Info:

Sent:
June 12, 2024

Revision:
July 15, 2024

Accepted:
July 26, 2024

Keywords:

Conductivity, Data Logger, Salinity, Sensor.

Abstract

Seawater intrusion increases groundwater salinity and affects the quality of residents' healthy water around coastal areas. Therefore, simple mapping of seawater intrusion distribution based on the salinity values of healthy water around coastal areas is necessary. This mapping can be done by measuring the salinity of the water using a portable and real-time instrument. The existing measurement system is not resistant to corrosion, does not have a data logger system, and does not have a display system capable of showing real-time salinity value graphs. In this study, a portable salinity measurement system resistant to corrosion caused by high salt levels was developed. The salinity measurement method used is the conductivity method. The salinity value of the solution is proportional to the measured conductivity value of the solution. Conductivity measurement uses two electrodes connected to a voltage divider circuit with an AC power source to avoid electrode polarization and electrochemical reactions. The output voltage of this voltage divider circuit is proportional to the conductivity value of the solution in which the two electrodes are immersed, based on Ohm's law. This output voltage is fed into a signal conditioning circuit consisting of an amplifier, filter, and full-wave rectifier. Subsequently, an Atmega 328 microcontroller processes this data for real-time display on a TFT LCD and real-time storage on a data logger module. Testing and calibration are then carried out to obtain the relationship between the solution's salinity value and the measured output voltage, expressed as a 2nd-order polynomial function Vout = -0.0012C2 + 3.5126C + 14.194. Additionally, it is known that salinity measurement results using the conductivity method are influenced by temperature, so temperature measurement using the DS18B20 sensor is required to obtain a compensation factor due to temperature changes. The higher the temperature, the higher the measured salinity value for the exact solution measurement.

INTRODUCTION

Salinity is a quantity or variable that indicates the amount of salt or salinity dissolved in water [1]. Water salinity levels can be affected by various factors, including seawater intrusion. This is particularly evident in coastal areas, where the seawater influx can significantly increase freshwater bodies' salinity [2]. An increase in salinity in water is caused by seawater intrusion. Seawater intrusion is the infiltration or seepage of seawater into the pores of rocks, which can contaminate the water contained therein [3]. One of the impacts of seawater intrusion is the increase in salt content (salinity) of water in the coastal areas [4]. The rise in salinity decreases the quality of water consumed by the community [5] According to WHO standards, drinking water is considered safe for consumption if it has a salinity value of less than 100 ppm [6]. Therefore, seawater can cause water to be unfit for consumption by the community [7]. In addition, seawater intrusion can also cause damage and disruption to soil and building structures because it can cause corrosion to the foundation. If used for agriculture, it can reduce soil fertility [8]. Therefore, measuring the salinity level of water in coastal areas is necessary. This can be done by using accurate salinity measuring instruments, both laboratory-based and mobile.

Water salinity measurement can be done by observing the resistivity and conductivity characteristics obtained using the two-point method. The conductivity or EC method is the most effective and portable for measuring water salinity. The basic principle of water EC (Electrical Conductivity) measurement is to measure the conductivity of electricity that flows and is injected into the water. Water containing dissolved ions and cations will be more easily conductive to electricity [9]. his method is expected to make it easier for the community to determine and find out the magnitude of water salinity affected by intrusion. Overcoming this problem requires measurement of seawater intrusion based on water quality parameters, including electrical conductivity (EC) [10]. Therefore, in this study, a water salinity measuring instrument was developed using the conductivity method.

METHODS OF RESEARCH

Several work steps were created to facilitate the research process. The research steps are as follows:

a) Literature study stage. This stage was conducted to collect information related to water salinity measurement methods.
b) Design and development stage. The design and construction of the salinity measuring instrument are divided into two parts, namely, designing the hardware and software.
c) Calibration Stage. Calibration is performed using NaCl solutions with varying concentrations.
d) Testing Stage. Testing was conducted by measuring the salinity values of healthy water in coastal areas, which were indicated to have relatively high salinity due to seawater intrusion.
e) Data processing and analysis stage. This stage was conducted to obtain the performance of the developed instrument.

The design of the measurement system that was built is shown in Figure 1.

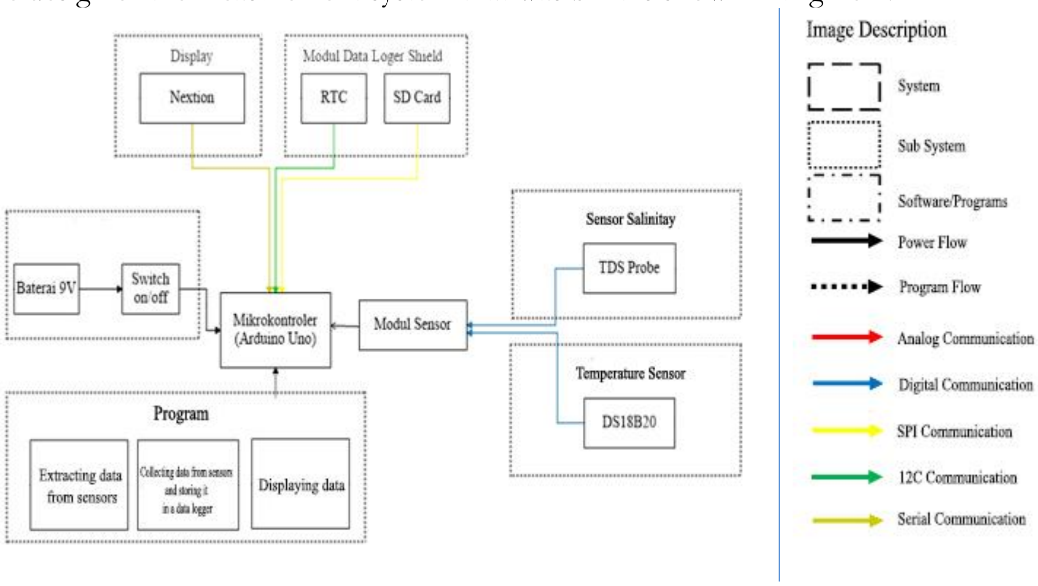

Figure 1. Measurement System Design

The design of the measurement system that was built is shown in Figure 1. In general, this system is divided into four subsystems. These subsystems include the program subsystem, the power supply subsystem, the sensor subsystem, the storage subsystem, and the display subsystem. The sensor subsystem comprises the EC-based salinity sensor and the DS18B20 temperature sensor. The software subsystem is built using the Arduino IDE application. The program creates commands or functions executed by each subsystem, such as taking data from the sensor, storing it in the data logger, and displaying data on the display. The power supply subsystem is needed as a source of energy or power for the system. This sub-component regulates the output voltage from the battery and controls the on/off of the measurement system using a switch button. The sensor subsystem consists of several sensors that measure several physical parameters. The measurement results are then sent to the microcontroller to be displayed on the display and stored on the SD Card.

The method used is the conductivity method, one of the main parameters in determining the quality of inorganic water [11]. his is because the concentration of dissolved ionic substances, such as salt, influences the conduction of electric current through a solution. There are several methods for measuring solution conductivity, one of which is using a two-electrode configuration. If the electric current injected through both electrodes is direct current (DC), corrosion will occur on both electrodes due to the accumulation of ions on the electrode surface. Therefore, to avoid this, alternating current (AC) with a specific frequency is used to prevent the formation of an oxide layer on both electrodes.

The next step is to carry out the calibration process to obtain the correlation between the salt solution concentration values and the output voltage measured by the developed conductivity sensor. The salt solution concentrations used vary at values of 10ppm, 50ppm, 100ppm, 500ppm, and 1000ppm. These salt solutions are made by dissolving several grams of salt or NaCl in several liters of distilled water. For example, to obtain a 1000ppm salt solution, 1000mg of NaCl is dissolved in one liter of distilled water. Then, a dilution process is carried out to get salt solutions with lower concentrations. Subsequently, the relationship between the salt concentration of each solution and the output voltage measured by the developed measurement system is obtained. It is known that salinity measurements using the conductivity method are influenced by the temperature of the solution. The higher the temperature of the solution, the greater the measured salinity value for the same solution. Therefore, a temperature compensation parameter is required for the measured salinity value. This can be achieved if temperature measurements are conducted simultaneously in real-time. Hence, an accurate and responsive temperature measurement system is needed. This study uses the DS18B20 waterproof digital temperature sensor, which can accurately measure temperature and respond quickly. Thus, the next step is calibrating the DS18B20 temperature sensor by comparing its measurements with those obtained using a mercury thermometer.

The calibration results include an equation relating the salt solution concentration values to the output voltage of the developed measurement system. This equation is entered into the program code to convert the measured output voltage into dissolved salt concentration or salinity values. The conversion results are stored in the data logger system and displayed as real-time numbers and graphs on the TFT LCD screen. An equation relating temperature changes to shifts in the measured salinity value for the same solution is also obtained. This equation is used to compensate for changes in the measured salinity by the developed measurement system after the calibration process carried out in the previous step.

Next, field testing was conducted by collecting salinity data from several wells around the coastal area using the developed measurement system. The testing was carried out in the coastal region of Kuta, Central Lombok, NTB. Eight wells located at varying distances from the shoreline were used as samples. The testing was done by taking one liter of healthy water and then measuring its salinity and temperature using the developed measurement system. Subsequently, a contour map of groundwater salinity distribution was created based on the measured salinity data from each well. The expected outcome of this testing is a decrease in the measured salinity value as the distance of the wells from the shoreline increases.

RESULTS AND DISCUSSION

The developed salinity measurement system is portable, so the system consists of a plastic box measuring 14.5 cm × 9.5 cm × 5 cm that already contains all the sensor components, microcontroller, battery, and display, as shown in Figure 2.

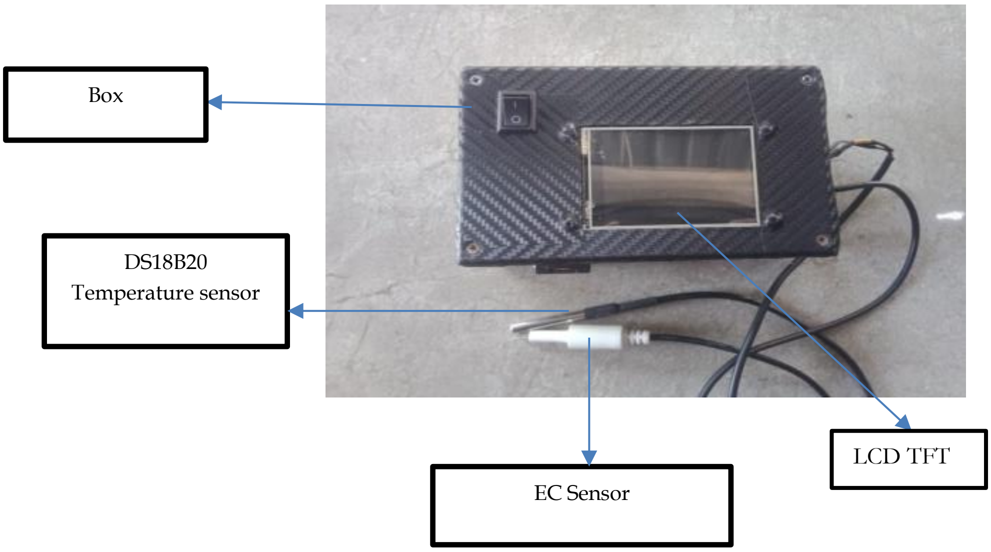

Figure 2. Image of the salinity measurement system design implementation results

Figure 3. TFT displays images showing salinity and solution temperature measurement results in real-time numbers and curves

The EC sensor calibration process compared the output value read when the sensor electrode was inserted into a solution with different NaCl concentrations. Therefore, the first thing that was done was to make NaCl solutions with different concentrations, namely 100 PPM, 500 PPM, 100 PPM, 50 PPM, and 10 PPM. The calibration results of the built-in device are shown as the relationship between the concentration value of the NaCl solution and the sensor output voltage at a temperature of 29.62°C, as shown in Figure 3.

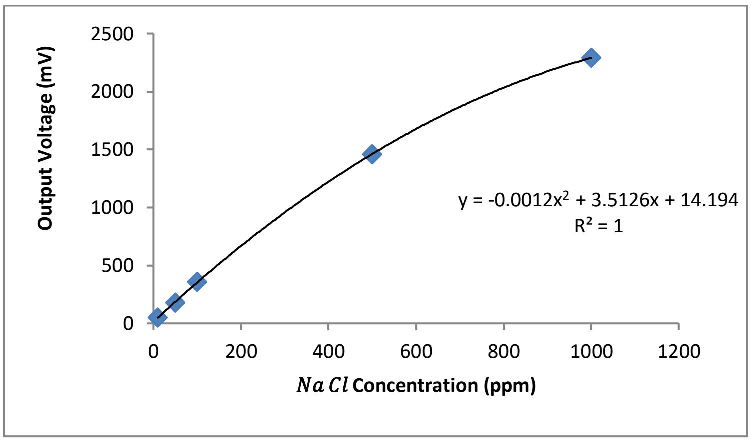

Figure 4. Graph of calibration results showing the relationship between salt solution concentration and the output voltage measured by the developed measurement system

Based on Figure 3, the relationship between the concentration value of the solution and the output voltage value of the EC sensor is obtained by a regression equation that is approximated by a 2nd-order polynomial, namely:

$$y = 0{,}0012x^2 + 3{,}5126x + 14{,}194 \quad (1)$$

The transfer function shown in equation 1 produces a correlation coefficient (R2) value of 1, indicating that the possible deviation during measurement is minimal. Meanwhile, the sensitivity value of the sensor is obtained from the gradient of the regression equation with a value of -0.0024x + 3.5126 mV/ppm, where the sensitivity indicates how sensitive the sensor is to the measured quantity. The higher the sensitivity value of the sensor, the more sensitive the sensor is to its input, and therefore the better the quality of the sensor. Meanwhile, equation 2 can be used to obtain the estimation error value.

$$S_{x,y} = \sqrt{\frac{\sum(Y-\hat{Y}_t)^2}{n-2}} \quad (2)$$

Therefore, the error value of the estimate is 1.45, which means that the deviation of the regression value from the actual value is 1.45. Transfer function obtained in the calibration process is entered into the programming logarithm of the developed salinity measurement system to obtain the solution's salinity value in ppm units based on the sensor's output voltage.

Moreover, the measured solution value is also affected by the temperature of the solution. [12](Yolanda, 2023). Therefore, it is necessary to calibrate the measurement results against temperature changes. The temperature correction factor will be obtained in the calibration process. In this study, calibration is carried out to get the temperature correction factor by measuring the concentration of the same solution at different temperatures using the built measurement system. The calibration results show the relationship between the solution temperature and the measured concentration value shown in Figure 4.

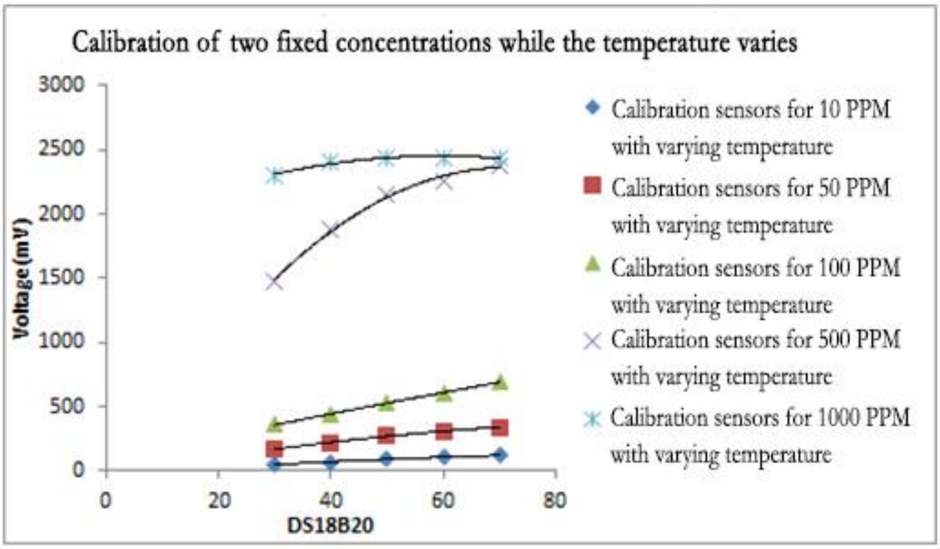

Figure 5 Graph of the Effect of Temperature on the Output of the EC Sensor

Figure 4 shows the measured solution concentration increases as the solution temperature increases. After the calibration process of the built measurement system was carried out, field testing was then carried out to measure the concentration value of the salt solution of healthy water from residents on the coast of Kuta Village, Central Lombok.

CONCLUSION

Each subsystem functions appropriately so that the integrated system can work according to its purpose: to measure, store, and display data from the sensor. Furthermore, the relationship between the concentration of its output voltage is also affected by temperature, where the higher the temperature, the higher the measured output voltage will be. It can be seen from each concentration that the trend or relationship between the change in output voltage and temperature has different trends. Furthermore, when field tests were conducted to measure salinity in several wells near the coast in the village of Kuta, Central Lombok, it showed that the further away from the beach, the smaller the salinity value of the healthy water will be.

REFERENCES

[1] M. Khairul Annam, Yohanna Lilis Handayani, and Lita Darmayanti, "Pemetaan Salinitas Sumur Dangkal Berdasarkan Jumlah Konsentrasi Garam Di Kecamatan Tebing Tinggi Dan Tebing Tinggi Barat Kabupaten Kepulauan Meranti," *JOURNAL OF INFRASTRUCTURE AND CIVIL ENGINEERING*, vol. 02, no. 01, pp. 25–33, 2022.

[2] Muhardi, Faurizal, and Widodo, "Analisis Pengaruh Intrusi Air Laut terhadap Keberadaan Air Tanah di Desa Nusapati, Kabupaten Mempawah Menggunakan Metode Geolistrik Resistivitas," *Indonesian Journal of Applied Physics*, vol. 10, no. 2, pp. 2089–0133, 2020.

[3] D. Radityo *et al.*, "Identifikasi Keberadaan Intrusi Air Laut pada Kawasan Pemukiman di Sekitar Pesisir Pantai Daerah Desa Sukajaya Lempasing Kecamatan Teluk Pandan," *Journal of Science and Applicative Technology*, vol. 4, no. 2, p. 110, Dec. 2020, doi: 10.35472/jsat.v4i2.366.

[4] M. Fajar Ismawan, T. Budi Sanjoto, and W. Setyaningsih Jurusan Geografi, "KAJIAN INTRUSI AIR LAUT DAN DAMPAKNYA TERHADAP MASYARAKAT DI PESISIR KOTA TEGAL," 2016. [Online]. Available: http://journal.unnes.ac.id/sju/index.php/geoimage

[5] A. W. Krisdiarto, A. Ferhat, M. Prasanto Bimantio, I. P. Stiper, and Y. Jl, "Penyediaan Air Bagi Masyarakat Pesisir Terdampak Kekeringan dengan Teknologi Desalinasi Air Laut Sederhana," 2020.

[6] D. Hastama Nugraha, M. Mahida, B. Litbang Sosekling Bidang Permukiman, P. Litbang Sosial, E. dan Lingkungan, and K. Pekerjaan Umum Jalan Laksda Adisucipto, "KESIAPAN MASyARAKAT MENERAPKAN TEKNOLOGI TEPAT GUNA PENGOLAHAN AIR MINUM (STUDI KASUS : PULAU PALU'E, NUSA TENGGARA TIMUR)," *Jurnal Sosek Pekerjaan Umum*, vol. 5, no. 2, pp. 119–129, 2013.

[7] Anis Milena Cesari Kutananda and Harmin Sulistiyaning Titah, "Kajian Desalinasi Air Laut Menggunakan Sistem Reverse Osmosis sebagai Pemenuhan Kebutuhan Air Tawar Kampung Wisata Apung, Malahing, Kota Bontang dan SDGs Poin 6," *JURNAL TEKNIK ITS*, vol. 11, no. 3, pp. 107–112, 2022.

[8] W. Riyanti, S. Y. S. Rahayu, and A. K. Fauzie, "ANALISIS PENGARUH JUMLAH PENDUDUK TERHADAP SALINITAS AIR TANAH DI WILAYAH PESISIR KARAWANG," *Barometer*, vol. 7, no. 2, pp. 69–77, Jul. 2022, doi: 10.35261/barometer.v7i2.5845.

[9] H. M. Suud, D. E. Kusbiantoro, M. G. Rosyady, and O. A. Farisi, "JURNAL REVIEW : EFEKTIVITAS PENGUKURAN KONDUKTIVITAS LISTRIK TANAH UNTUK MENDUGA KONDISI KESUBURAN TANAH PADA LAHAN PERTANIAN," *Hijau Cendikia*, vol. 7, no. 2, pp. 71–79, 2022.

[10] A. A. Hafiidh, S. Krido Saptomo, C. Arif, D. R. Santoso, and B. Waspodo, "Sebaran Intrusi Air Laut di Kabupaten Indramayu, Jawa Barat (Distribution of Seawater Intrusion in Indramayu District, West Java)," 2018.

[11] I. A. Rozaq, D. Tauhida, R. Primadasa, and F. Setiawan, "Uji Linieritas Sensor Konduktivitas Pada Prototipe Pengukur Kualitas Air Tambak," *Jurnal Zetroem*, vol. 05, no. 02, pp. 136–139, 2023.

[12] Y. Yolanda, "Analisa Pengaruh Suhu, Salinitas dan pH Terhadap Kualitas Air di Muara Perairan Belawan," *Jurnal Teknologi Lingkungan Lahan Basah*, vol. 11, no. 2, pp. 329–337, 2023.