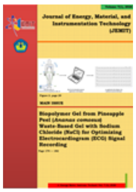
JOURNAL OF ENERGY, MATERIALS, AND INSTRUMENTATION TECHNOLOGY

Journal Webpage https://jemit.fmipa.unila.ac.id/



Analysis of Utilization of Alumina and Carbon Concentrations in Salt Bridges in Electrochemical Cells $Zn|Zn^{2+}_{(Aq)}||Ag^{+}_{(Aq)}|Cu(Ag)$ with Electrolyte Seawater and *Zinc Acid* as Alternative Energy Sources

Mayang Shavira[a], Gurum Ahmad Pauzi[b], Sri Wahyu Suciyati, and Amir Supriyanto

Department of Physics, Faculty of Mathematics and Natural Sciences, University of Lampung, Indonesia 354145

Article Information

Article history:
Received January 16, 2023
Received in revised form July 9, 2024
Accepted July 9, 2024

Keywords: *seawater, salt bridge, electrical characteristics, zinc acid, voltaic cell.*

Abstract

This study was conducted to analyze the comparison of variations in the salt bridge in a two-compartment voltaic cell with a Cu(Ag)-Zn electrode on the resulting electrical characteristics. The Cu(Ag)-Zn pair is used to generate voltage and current in the cell with seawater electrolyte and zinc acid. The two compartments are lined with a salt bridge made of Al_2O_3 *(aluminum oxide), and Carbon, NaCl (seawater) dissolved in Tiga Roda white cement. The voltaic cell consists of 4 cells arranged in series, each cell filled with ±200 ml of seawater (cathode part) and ±200 ml of acid zinc solution (anode part). The voltaic cell was measured with a multitester every 1 hour for 3 days. Based on the research that has been done, it can be concluded that the variation of the carbon salt bridge with a concentration of 12 grams has the greatest electrical characteristic value.*

Informasi Artikel

Proses artikel:
Diterima 16 Januari 2023
Diterima dan direvisi dari 9 Juli 2024
Accepted 9 Juli 2024

Kata kunci: *Air laut, jembatan garam, karakteristik elektrik, larutan acid zinc, sel volta*

Abstrak

Penelitian ini dilakukan untuk menganalisis perbandingan variasi jembatan garam pada sel volta dua kompartemen dengan electrode Cu(Ag)-Zn terhadap nilai karakteristik elektrik yang dihasilkan. Pasangan Cu(Ag)-Zn digunakan untuk menghasilkan tegangan dan arus dalam sel dengan elektrolit air laut dan acid zinc. Dua kompartemen dibatasi dengan jembatan garam yang terbuat dari Al_2O_3 *(aluminium oksida), dan Carbon, NaCl (air laut) yang terlarut dalam semen putih tiga roda. Sel volta terdiri dari 4 sel yang tersusun secara seri yang setiap sel terisi dengan ±200 ml air laut (bagian katode) dan ±200 ml larutan acid zinc (bagian anode). Sel volta diukur dengan multitester setiap 1 jam sekali selama 3 hari. Berdasarkan penelitian yang telah dilakukan diperoleh kesimpulan bahwa variasi jembatan garam carbon konsentrasi 12 gram memiliki nilai karakteristik elektrik yang paling besar.*

1. Introduction

The use of voltaic cells is the result of applying electrochemical cells to produce renewable energy technologies (Harahap, 2016). A voltaic cell in one cell causes electron transfer to occur quickly causing corrosion due to the potential difference in an electrolyte environment (Bardal, 2003 and Wibowo, 2016). Therefore, a method is needed to inhibit corrosion in voltaic cells by controlling the rate of electron transfer by coating zinc Zn (Ansari et al, 2017 and Prabhu et al, 2012). Zn zinc coating can use the salt bridge principle in electrochemical cells, one of which is by separating seawater electrolyte Zn electrodes and Cu electrodes in two different cells. If the seawater cells are separated, no electricity will occur, so that in electrochemical cells a salt bridge is needed so that the ions in the solution are balanced and a chemical change occurs into an electrical change (Chang, 2003). The salt bridge has the function of balancing cations and anions in solution. The requirements for a salt bridge are that it can be passed by ions and only a little through the solvent (Arizal et al, 2017). The results of research conducted by Akbar et al (2017) made a voltaic cell with the help of a salt bridge using bacteria as a catalyst to generate electric current and Haq et al (2018) made a voltaic cell with the help of a salt bridge for power generation applications using salt energy as an

---

* Corresponding author.
E-mail address: (a)mayangshavira23@gmail.com (b)gurum@fmipa.unila.ac.id

electrolyte. The results of this study indicate that the presence of a salt bridge in a voltaic cell causes the flow of electrons in a balanced solution to produce an electric current.

Rizki's research (2019) has succeeded in making electrochemical cells in voltaic cells without the aid of a salt bridge with electrodes in the form of Cu(Ag)-Zn plates to determine the electrical characteristics of seawater. The drawbacks of this study were that the resulting electrical characteristics decreased due to the release of the Zn electrode due to corrosion, which was then corrected by Anjarwati's research (2019) who designed a voltaic cell with the help of a salt bridge using Cu(Ag)-Zn electrodes in the form of Cu (copper) fibers and adding NaCl and KCl salt bridges in an electrochemical process. In this study, a voltaic cell system with two compartments was used which was limited by a variation of the Al_2O_3 salt bridge (aluminum oxide) and a variation of the carbon salt bridge added with NaCl (seawater) and Tiga Roda white cement. Each cell has a pair of Cu(Ag)-Zn electrodes, the cathode compartment (Cu(Ag)) contains seawater while the anode compartment (Zn) contains zinc acid solution. The use of zinc acid solution in this study is expected to restore the quality of the oxidized anode electrode. So to find out this, an analysis of variations of the salt bridge was carried out on the electrical characteristics and corrosion rate of the two-compartment voltaic cell system with Cu(Ag)-Zn electrodes.

2. Research Methods

The tools used in this study included: seawater electrolyte media made of acrylic, cells made of acrylic material with a thickness of 3 mm, a height of 16 cm, a width of 7.5 cm and a length of 14 cm, zinc metal with a size of 4 x 5 x 0.002 cm, Ag-electroplated Cu fibers with a length of 100 cm, 20 LEDs in series, and a multimeter. The materials used in this study were: seawater, NH_4Cl, $ZnCl_2$, distilled water. The salt bridge materials are Al_2O_3 (aluminum oxide) 102 grams and 12 grams carbon, NaCL (sea water) and white cement brand three wheels. This research was carried out in several stages, namely the process of electroplating Ag on Cu, making salt bridges, making zinc acid solutions, designing and manufacturing voltaic cell systems as well as testing tools and data collection.

2.1. Ag Electroplating on Cu

The electroplating process uses a carbon rod as the anode and Cu fibers 2.5 mm in diameter and 100 cm long as the cathode. In the Ag electroplating process on Cu, 300 ml of 0.02M silver plating solution ($AgNO_3$) was used as the electrolyte solution. Before electroplating the Cu fibers were cleaned using 1% HNO_3 solution to reduce the fat content attached to the Cu fibers. Then the Cu fibers were cleaned again using 96% ethanol to remove the HNO_3 content that was still attached to Cu. Furthermore, electroplating was carried out with a voltage of 2 volts for 5 minutes.

2.2. Construction of the Salt Bridge

At this stage, the process of making a salt bridge is a mixture of Al_2O_3 (aluminum oxide) + NaCl (seawater) + Tiga Roda white cement and carbon + NaCl (seawater) + Tiga Roda white cement. The first step to make this salt bridge is to mix 102 grams of Al_2O_3, 58.5 grams of NaCl and 50 grams of Tiga Roda white cement, then stir until the three ingredients are mixed. Then the mixture of materials is printed directly in the cell to avoid leaks, then dry it and wait for it to harden. The purpose of making this salt bridge is to maintain the neutrality of the electric charge in the solution.

2.3. Preparation of *Zinc Acid* Solution

The process for making zinc acid pH 5 is mixing 150 grams of ammonium chloride, 40 grams of zinc chloride with 1 liter of distilled water (Ansari, et al. 2017). Then check the pH of the solution using universal pH paper.

2.4. Design and Manufacture of the Voltaic Cell System

Before the research was carried out, a two-compartment voltaic cell media design was made using the SketchUp 2020 application as a manufacturing reference as shown in Figure 1, Figure 2, and Figure 3. In this study, the voltaic cell system was composed of 4 cells made of acrylic material with a thickness of 3mm . Each cell contains a pair of Cu(Ag)-Zn electrodes with different compartments bounded by a salt bridge. The salt bridge used is a mixture of Al_2O_3 (aluminum oxide) + NaCl (seawater) and carbon + NaCl (seawater) dissolved in Tiga Roda white cement. In each voltaic cell, the electrolyte used in the cathode compartment (Cu(Ag)) contains ±200 ml of seawater, while the anode compartment (Zn) contains ±200 ml of *zinc acid* solution pH 5. The electrolyte used will be replaced every 24 hours. The voltaic cell system in this study is connected in series using a connecting cable.

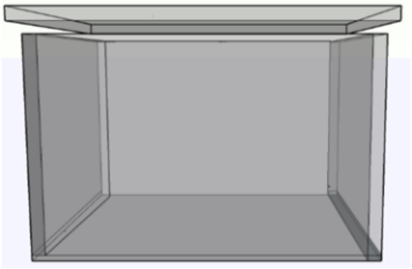


Figure 1. Single voltaic cell design

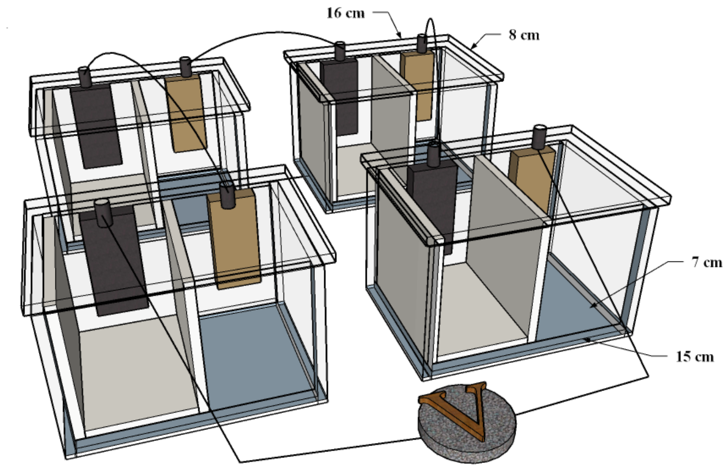


Figure 2. Voltaic cell arrangement design

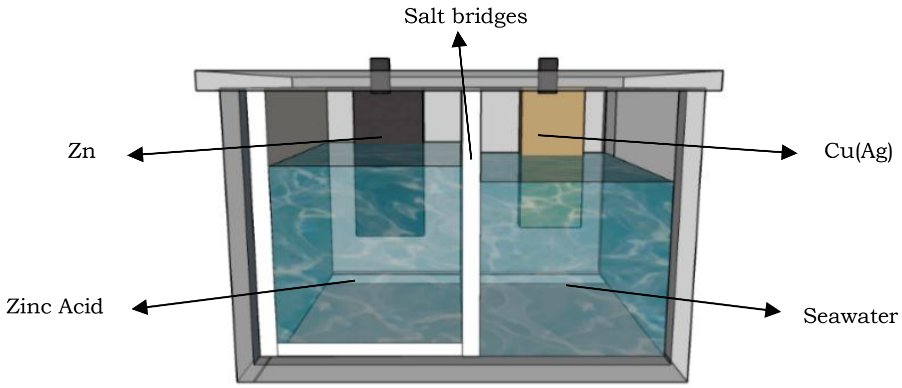


Figure 3. Compartment cells with salt bridges

2.5. Tool Testing and Data Retrieval

Tool testing is carried out by connecting a voltaic cell to a multitester that has been connected to the load (20 LEDs). Electrical energy analysis is carried out by collecting data in the form of no-load voltage (volts), load voltage (volts), current (A), light intensity (lux), calculation of internal resistance (R_{in}) (kOhm) using Equation 1 and calculating the power generated using Equation 2. Data collection is done every 1 hour for 72 hours. In this system, a simple circuit is used to measure the resulting electrical characteristic values as in Figure 4.

(a)

(b)

Figure 4. Circuit to measure the values (a) OCV and (b) CCV

$$R_{in} = \frac{OCV - CCV}{I} \tag{1}$$

$$P = CCV\,I \tag{2}$$

Open circuit voltage is a measurement of electrical variables when a load that has been used for some time is removed. Meanwhile, close circuit voltage is a measurement of electrical variables that have been used for some time when the load is installed. In Equation (1) R_{in} = internal resistance (Ω), *OCV* = open circuit voltage (volts), *CCV* = closed circuit voltage (volts) and I = current strength (amperes). In Equation 2 P = power (watts), *CCV* = close circuit voltage (volts) and I = current strength (amperes).

3. Results and Discussions

The data produced at a carbon concentration of 12 grams for OCV in the first hour was 4.15 Volts, while in the 72nd hour it was 3.53 Volts. Based on this data, it is known that OCV decreased after the first hour. This decrease occurred because the electrode had not initially been oxidized and after the first hour it began to oxidize and there was still a lot of dissolved oxygen in the solution, resulting in a maximum OCV value. In the next hour the electrode used began to oxidize so that the electron activity on the electrode began to be hampered so that the OCV value decreased. For CCV in the first hour it is 3.28 Volts. The stability of the CCV value in the 12 gram carbon salt bridge variation occurred at the 16th to the 20th hour, the 30th to the 34th hour, the 37th to the 41st hour, and the 52nd to the 41st hour. -57. Based on this data, it can be seen that the CCV value has decreased, this happens because CCV is directly proportional to the E value (OCV).

The current value obtained in the first hour was 3.91 mA, the value at the 72nd hour was 2.31 mA. This situation is caused because the value of the current produced is directly proportional to the value of V (CCV). The greater the CCV value, the greater the electric charge that can be moved so that the resulting current (I) value will be greater. The light intensity value produced in the first hour is 22 lux, while in the 72nd hour it is 7 lux. This situation is caused because the light intensity value produced is directly proportional to the current value (I), the greater the current value, the greater the light intensity value produced.

The resulting internal resistance value is 0.281 kΩ. The R_{in} value on the carbon salt bridge has increased due to corrosion on the electrode which becomes an obstacle in the cell. The longer the corrosion occurs, the greater the Rin value will be. This is also in accordance with the OCV, CCV and I values obtained based on Ohm's Law, namely the resistance value is inversely proportional to the voltage and current values. And for the maximum power value produced, namely 12,825 mWatt, the power value after 72 hours is 6,214 mWatt. The 12 gram Carbon salt bridge has a large Power value, this situation occurs because the Power value is the result of multiplying the CCV and I values. The higher the CCV and I values, the greater the resulting Power value.

3.1 Realization of the Voltaic Cell System

Realization of a two-compartment voltaic cell system made from seawater electrolyte and zinc acid solution to produce electricity can be seen in Figure 4. In this study the electrical characteristics of the voltaic cell (voltage, current and light intensity) were measured using a multitester and luxmeter to test the resulting electrical characteristics.

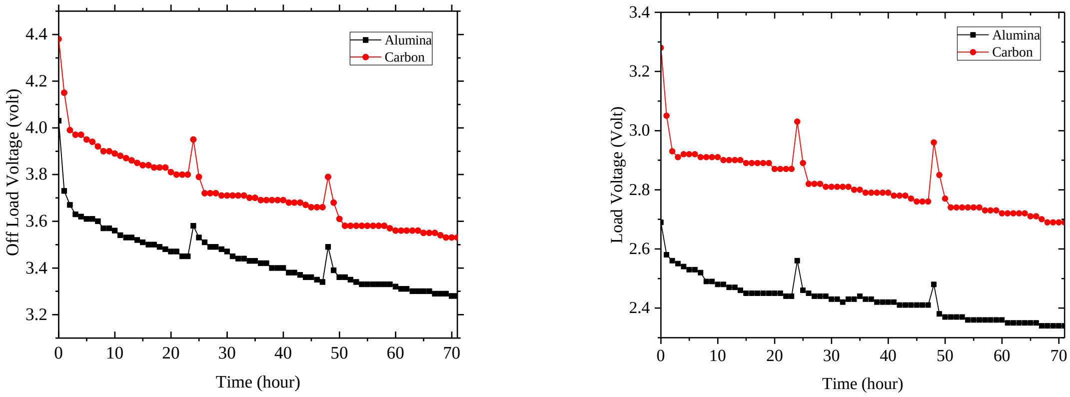
(a)

(b)

Figure 5. (a) Realization of the voltaic cell system (b) Array of LEDs used

3.2 Data Comparison of Electrical Characteristics of Alumina and Carbon

1. Open Circuit Voltage (*OCV*) and *Close Circuit Voltage* (*CCV*). The OCV and CCV values of the alumina and carbon salt bridges can be seen in Figure 6 (a) and (b).

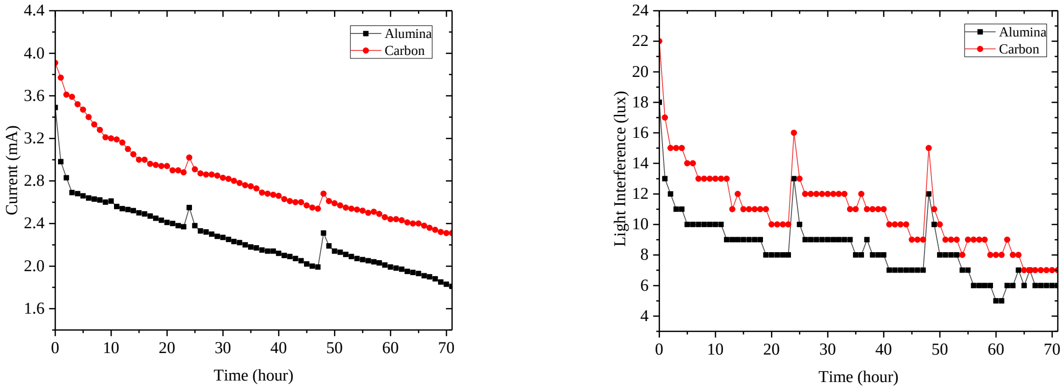


(a) (b)

Figure 6. (a) Comparison of *OCV* values on alumina and carbon salt bridges (b) Comparison of *CCV* values on alumina and carbon salt bridges

The graphs in Figure 5 (a) and (b) show that the Open Circuit Voltage (*OCV*) and Close Circuit Voltage (*CCV*) values of the carbon salt bridge are greater than those of the alumina salt bridge. In Figure 5 (a) the *OCV* of the carbon salt bridge produces a value in the first (maximum) hour of 4.15 volts and at the 72nd hour which is 3.53 volts, while the alumina salt bridge produces a value of 4.03 volts and at the 72nd hour the 72nd is 3.28 volts. In Figure 5 (b) the *CCV* of the carbon salt bridge produces a value in the first hour of 3.28 volts, while the alumina salt bridge produces a value of 2.59 volts.

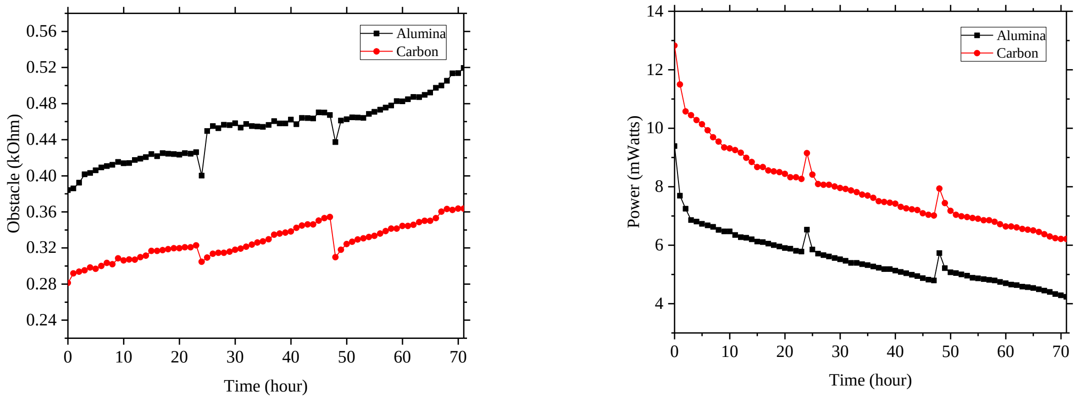
2. Current and Light Intensity. The graph in Figure 6 (a) shows a comparison of the current values of the alumina salt bridge and the salt bridge. The current value of the carbon salt bridge for the first hour is 3.91 mA and at the 72nd hour it is 2.31 mA, while for the alumina salt bridge the value for the first hour is 3.49 mA and at the 72nd hour it is 1.81 mA. The graph in Figure 6 (b) shows the light intensity obtained by the carbon salt bridge in the first hour, namely 22 lux and at the 72nd hour, it was 7 lux, while for the alumina salt bridge, it was 18 lux and at the 72nd hour, it was 6 lux.



(a) (b)

Figure 7. (a) Comparison of current values on alumina and carbon salt bridges (b) Comparison of light intensity on alumina and carbon salt bridges

3. Resistance and Power. The graph in Figure 7 (a) shows the value of the internal resistance (R_{in}) obtained by the carbon salt bridge of 0.281 kΩ, while that of the alumina salt bridge is 0.384 kΩ. The power value shown in Figure 7 (b) for the carbon salt bridge is 12.825 mWatt, while for the alumina salt bridge it is 9.388 mWatt. The carbon salt bridge has a lower resistance value and has a greater power value than the alumina salt bridge.



(a) (b)

Figure 8. (a) Comparison of resistance values on alumina and carbon salt bridges (b) Comparison of power values on alumina and carbon salt bridges

4. Conclusions

Based on the research that has been done, it can be concluded that the greater the concentration of the salt bridge, the denser the carbon and Al_2O_3 content in the salt bridge will increase the resistance of H^+ ions to pass through the salt bridge, so that the redox reaction is hampered and produces a smaller value of electrical characteristics. This study also concluded that the use of carbon salt bridges will improve the electrical characteristics of the voltaic cell and the use of zinc acid solution creates opportunities to regenerate the Zn anode.

5. Bibliography

Akbar, T. N., Kirom, M. R., & Iskandar, R. F. (2017). Analisis pengaruh material logam sebagai elektroda microbial fuel cell terhadap produksi energi listrik. *E-Proceeding of Engineering, 4*(2), 2123–2138.

Anjarwati, A. (2019). *Analisis aplikasi jembatan garam pada sel elektrokimia menggunakan elektroda Cu(Ag)-Zn berbahan elektrolit air laut* [Skripsi, University of Lampung].

Ansari, I., Indrawijaya, B., Nurohmawati, F., & Zakaria, I. (2017). Pengaruh waktu dan luas permukaan terhadap ketebalan produk pada elektroplating acid zinc. *Jurnal Ilmiah Teknik Kimia UNPAM, 1*(1), 1–7.

Arizal, F., Hasbi, M., & Kadir, A. (2017). Pengaruh kadar garam terhadap daya yang dihasilkan pembangkit listrik tenaga air garam sebagai energi alternatif terbarukan. *Enthalphy: Jurnal Ilmiah Mahasiswa Teknik Mesin, 2*(1), 1–5.

Bardal, E. (2003). *Corrosion and protection.* Springer.

Chang, R. (2003). *General chemistry: The essential concepts.* Erlangga.

Haq, S. Z. N., Kurniawan, E., & Ramdhani, M. (2018). Analisis pembangkit elektrik menggunakan media air garam sebagai larutan elektrolit. *E-Proceeding of Engineering, 5*(3), 3823–3830.

Harahap, M. R. (2016). Sel elektrokimia: Karakteristik dan aplikasi. *Circuit, 2*(1), 177–180.

Pauzi, G. A., Pratiwi, N. A., Surtono, A., & Suciyati, S. W. (2022). Analisis pengaruh variasi pH larutan acid zinc pada sel volta dua kompartemen dengan elektrode Cu(Ag)-Zn. *Journal of Energy, Material, and Instrumentation Technology, 3*(1), 21–30. https://doi.org/10.23960/jemit.v3i1.88

Prabhu, R. A., Venkatesha, T. V., & Praveen, B. M. (2012). Electrochemical study of the corrosion behavior of zinc surface treated with a new organic chelating inhibitor. *ISRN Metallurgy*, 2012, Article 940107. https://doi.org/10.5402/2012/940107

Rizki, K. C. (2019). *Analisis pengaruh elektroplating perak (Ag) pada tembaga (Cu) terhadap karakteristik elektrik air laut sebagai sumber energi listrik terbarukan* [Skripsi, University of Lampung].

Wibowo, A. (2016). Analisis sifat korosi galvanik berbagai plat logam di Laboratorium Metalurgi Politeknik Negeri Batam. *Jurnal Integrasi, 8*(2), 144–147.

Wicaksono, D., Bhakti, T. L., Taruno, R. B., Subroto, M. R. S., & Mustikasari, A. (2021). Sistem sensor untuk pemantauan kadar oksigen terlarut berbasis galvanic pada kolam budidaya ikan air tawar. *Jurnal Teknologi dan Sistem Komputer, 9*(2), 83–89.