International Journal of Research In Vocational Studies (IJRVOCAS)
VOL. 3, NO. 2, August 2023, PP. 34~39
Print ISSN 2777-0168| Online ISSN 2777-0141| DOI prefix: 10.53893
https://journal.gpp.or.id/index.php/ijrvocas/index

The Comparison of Hydrogen Purity on Brown's Gas Using Dry Cell Electrolyzer with/without Polyvinyl Alcohol (PVA) Separator Membrane

Nisa Rahmadina[1] , Yohandri Bow[2*] & Syahirman Yusi [3]

[1]Renewable Energy Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia
Research and Development Department, PT. Bima Shabarhum Gemilang, Palembang, Indonesia
[2]Energy Engineering Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia
[3]Business Administration Department, Politeknik Negeri Sriwijaya, Palembang, Indonesia

Email address:
yohandri@polsri.ac.id
*Corresponding author

To cite this article:

Rahmadina, N., Bow, Y., & Yusi, S. (2023). The Comparison of Hydrogen Purity on Brown's Gas Using Dry Cell Electrolyzer with/without Polyvinyl Alcohol (PVA) Separator Membrane. International Journal of Research in Vocational Studies (IJRVOCAS), 3(2), 34–39. https://doi.org/10.53893/ijrvocas.v3i2.205

Received: 07 10, 2023; **Accepted**: 07 23, 2023; **Published**: 08 25, 2023

Abstract: Global environmental issues that demand good air quality have encouraged various energy sources to develop environmentally friendly energy. Brown's Gas is produced by using an electrolysis system to separate water into Hydrogen (H_2) and Oxygen (O_2) gas. The dry cell is an electrolyzer that is widely used for both small and large-scale hydrogen production systems. A dry cell electrolyzer was designed with 12 stages of 316 stainless steel with Polyvinyl Alcohol as a polymer membrane to prevent mixing H_2 and O_2 to get a high percentage of hydrogen purity. This study compares hydrogen purity on Brown's gas using a dry cell electrolyzer with PVA with/without a PVA separator membrane. The result shows that the PVA membrane significantly impacted hydrogen purity. The hydrogen purity on Brown's gas without PVA membrane for KOH, NaOH, KCl, and Seawater was 58.37%, 56.42 %, 50.16%, and 55.22 %. Compared to using the membrane was 78.32%, 77.80%, 63.16%, and 74.0 %, with the highest hydrogen obtained was KOH electrolyte.

Keywords: Hydrogen, Brown's gas, Electrolyte, Electrolysis

1. Introduction

Currently, Indonesia's energy requirements are still dominated by fossil fuels. Dependency on fossil fuels poses three serious threats: rising prices due to high demand, depletion of oil reserves, and greenhouse gas (CO_2) pollution [1]. Global environmental issues that demand good air quality have encouraged various energy sources to develop environmentally friendly energy. Brown's gas is produced when water is separated into hydrogen (H_2) and oxygen (O_2) gas using an electrolysis method [2,3]. Both gases are then injected into the combustion chamber of the internal combustion engine. Mixing both gases with the fuel in the combustion chamber will improve the combustion process to complete combustion so that there is no residual fuel. It is more efficient because there is an additional supply of pure oxygen, and an additional explosion from hydrogen adds energy to the internal combustion engine [4]. Brown's gas is also described as an unstable state of the water, where no atomic bonds are needed to be broken before turning back hydrogen and oxygen into water. When Brown's gas is ignited in the engine combustion chamber, it is assumed that both explosion and implosion occur. The cited works claim that pulverized water aggregates with fuel particles becoming a binary mixture, with water being the core and the fuel the shell (due to density differences). The increase in heat and pressure leads the water to vaporize, with a consequent atomization of the fuel and a better mixing with surrounding oxygen [5]. One way to produce brown's gas is through the electrolysis process.

The chemical process of electrolysis turns electrical energy into chemical energy[6]. The electrolysis process separates water molecules into hydrogen and oxygen gas, one of which is by passing an electric current through the electrode to the place of the electrolyte solution that has been added to a catalyst. The electrolysis reaction is a non-spontaneous redox reaction that can occur when electrical energy is present. In electrolysis that produces H_2 and O_2, the gas begins to emerge after using an electric current of more than 4 amperes [5,6]. There are two kinds of electrolyzer, wet cell electrolyzer and dry cell electrolyzer. In comparison to wet cell electrolyzer, dry cell is an electrolyzer that is widely used for both small and large-scale hydrogen production systems. The advantage over other electrolyzers is that the electrolyte and electrode materials are less expensive and simpler to obtain, while maintaining high energy efficiency, high gas purity, and a compact vehicle-friendly form [4]. In this research, we added Polyvinyl Alcohol as separator membrane to increase the hydrogen purity composition.

Polyvinyl alcohol is the most commercially crucial water-soluble plastic in use. In addition, it can be easily incorporated with a variety of natural substances and has properties compatible with various applications. Incorporating natural fibers and fillers can further enhance mechanical properties without compromising degradability. Given its water-soluble properties, the enormous potential benefits of this material must be weighed against the practical considerations of its long-term life cycle under variable environmental conditions. PVA is an extensively used thermoplastic polymer non-toxic, harmless, and non-pathogenic to living tissues. This polymer is extensively studied due to its application in cross-linked products and nanofillers. PVA is a biodegradable polymer, and the presence of hydroxyl groups on its carbon atoms accelerates its degradation through hydrolysis. In addition, PVA is water-soluble and possesses hydrophilic properties [7,8].

This electrolyzer used NaOH, KOH, and KCl as artificial electrolytes compared with Seawater, which comes from nature. Each electrolyte facilitates the decomposition of water into hydrogen and oxygen because the catalyst ions can affect the stability of water molecules into H^+ and OH^- ions, which are more straightforward to electrolyze due to a decrease in activation energy [3,5]

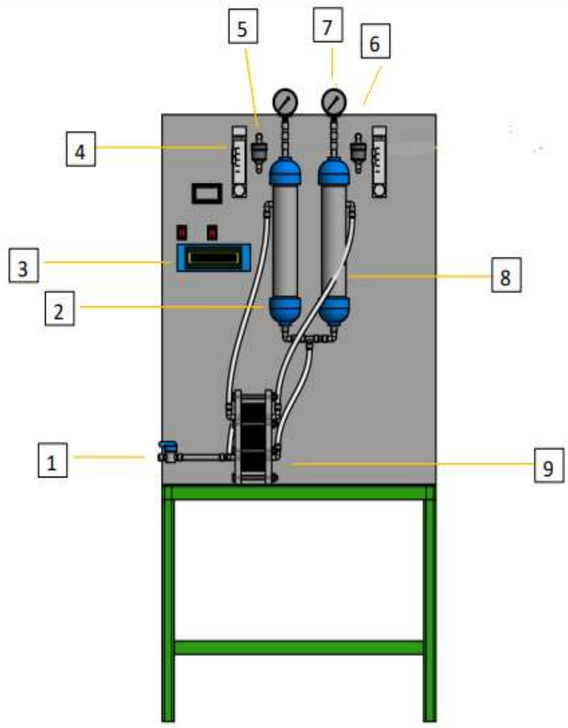

Figure 1. Set of Brown's gas Production

2. Methodology

2.1. Material Preparation

The electrolyte used in this research were NaOH, KOH, KCl, and Seawater. Seawater was taken in Mutun Beach, Lampung. Meanwhile, NaOH, KOH, and KCl electrolytes were made in Laboratorium Polytechnic Negeri Sriwijaya with the percentage of molarity that can be seen in Table 1.

Table 1. *Molarity of Electrolytes*

Electrolytes	Molarity (%)
KOH	0.8
NaOH	0.8
KCl	0.8
Seawater	39.2

The electrolyte used as catalyst, is a very specific substance that functions to accelerate the reaction by lowering the activation energy without altering the reaction equilibrium. The catalyst for water electrolysis employs a strong base electrolyte solution to facilitate the transfer of electricity between cells. Similar with strong acids, the utilised strong alkaline electrolyte solution corrodes metals[11].

The concentration of catalyst (electrolyte) in water will impact the solution's conductivity. The greater the volume of the electrolyte, the greater the conductivity of the catalyst molar, indicating that the solution has a greater capacity to conduct electricity or that electricity flows more readily through the solution.

2.2. Electrolysis Process

Electrolysis of water yields a mixture of hydrogen, oxygen, and their respective ions [12]. The potential difference between the electrodes is determined by the quantity of gas produced per unit time. The reactions occurring at the electrodes are detailed below:

At cathode : $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$ (1)

At anode : $4OH^- \rightarrow O_2 + 2H_2O + 4e$ (2)

Overall reaction : $2H_2O \rightarrow 2H_2 + O_2$ (3)

The electrolyte was poured into the feed tube using a funnel, then flowed into the electrolyzer through the funnel and directed into the reservoir tube. Once the reservoir tube was half-filled, the watt meter display was turned on, and the desired voltage was adjusted using a potentiometer. Gas will be generated inside the electrolyzer with PVA serving as a separator membrane, allowing the flow of ions while separating the generated gases and preventing the mixing of O_2 and H_2. As seen in Figure 1. with the description 1. Electrolyte outlet 2. H_2 reservoir tube, 3. Watt meter display, 4. Flowmeter, 5. Gas filter, 6. Electrolyte reservoir tube, 7. Pressure gauge, 8. O_2 reservoir tube, 9. Dry cell electrolyzer

Hydrogen production via electrolysis of water combined with renewable energy is a promising strategy for future energy sustainability [13]. The high cost and energy required for water electrolysis prevents its widespread applicability on a large scale. Action is required to intensify water electrolysis and reduce energy consumption to satisfy the demand for sustainable hydrogen production [14]. The electrolyzer developed in this research was a Dry Cell Electrolyzer. It consists of cells connected in a horizontal stack with a separating gasket of heat-resistant 2 mm thick rubber silicon material [15]. The electrode material used in this design is stainless steel 316 due to the lower-cost compared with other material that has good conductivity [16]. It ensures the electrolyte flow, and Polyvinyl Alcohol is used as the separating membrane between the electrode arrays**.**

It can be seen in Figure 2. A neutral plate divides each cell, with one electrode functioning as the anode and the other as the cathode [17]. The electrolyte solution enters the electrolyzer through channels beneath the front plate, then flows inside. At the cathode, hydrogen is produced, while at the anode, oxygen is produced. Different outlets for gas output and the electrolyte mixture, which ultimately exits the electrolyzer, are located on the front plate's upper surface [17] Acrylic with dimensions of 14 x 14 x 10 cm is used to provide space.

3. Result and Discussion

3.1. The Effect of Using PVA Separator Membrane in Dry Cell Electrolyzer

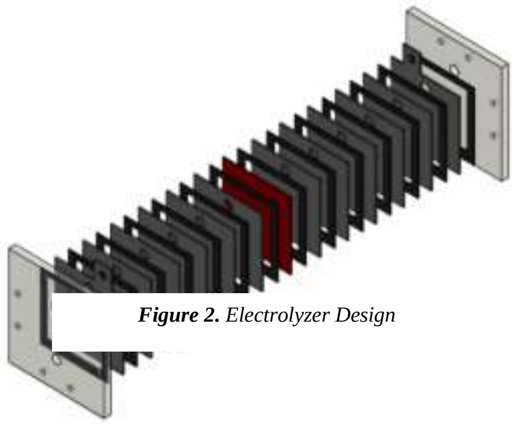

Figure 2. *Electrolyzer Design*

The oxidation-reduction reaction that creates gas occurs during the electrolysis of water using KOH, NaOH, KCl and Seawater as the electrolytes. When electrodes are energized, the electrolysis process occurs, causing the compounds in the electrolyte to disintegrate and produce ions. Although the electrolysis procedure of this chemical reaction is effective and efficient, it necessitates a large electric current [18]. When electric current is applied, the electrodes (cathodes and anodes) will be connected to one another [19]. When water is electrolyzed with the electrolyte, utilizing an electric current that passes through the water, the water components (H_2O) are broken down into hydrogen (H_2) and oxygen (O_2). By reducing two molecules, hydroxide ions (OH^-) and gas H_2 are produced.The characteristics of hydrogen, such as its higher calorific value, higher laminar flame speed, and lower petrol ignition energy, support its use as a potential alternative fuel for use in engines. Therefore, having high hydrogen purity composition is important.

As depicted in Figures 1 and 2, a dry cell electrolyzer is one in which a portion of the electrode is not submerged in electrolytes, and electrolytes only occupy the spaces between the electrodes. The primary advantage of dry cell types is the lack of electrolyzed water, the only water confined between the cell plates. Due to the circulation of heated and cold water within the reservoir, the amount of heat generated is minimal. Because less energy is converted into heat, the electric current utilized is relatively reduced [4]. The weakness of this type is the purity of the hydrogen that has a high percentage of O_2 gas.

Therefore, adding separator membrane could level up the value of dry cell electrolyzer to get higher hydrogen composition on brown's gas produced.

A PVA membrane's use influenced the Brown's gas composition, as shown in Table 2. It can be seen clearer by Figure 3.

Table 1. *Brown's gas Composition*

Mol of Gas (%)	S1*	S2*	S3*	S4*	S5*	S6*	S7*	S8*
H_2	58.3	56.4	50.1	55.2	78.3	77.8	63.1	74.9
O2	33.1	33.8	43.2	33.8	13.3	8,.3	28.5	13.9
N_2	5.1	5.9	3.7	5.7	5.1	4.16	4.5	7.9
CO_2	3.3	3.2	2.8	1.8	3.1	9.1	3.4	3.1
CO	0.0	0.5	0.0	3.4	0.0	0.0	0.3	0.0

* S1 is KOH electrolytes without membrane
* S2 is NaOH electrolytes without membrane
* S3 is KCl electrolytes without membrane
* S4 is Seawater without membrane
* S5 is KOH electrolytes with membrane
* S6 is NaOH electrolytes with membrane
* S7 is KCl electrolytes withmembrane
* S8 is Seawater with membrane

The PVA membrane, with its low oxygen transfer coefficient of (1.50×10^{-4} cm s^{-1}) [20][28] effectively separates the gases produced in each chamber. By acting this way, the product (hydrogen), which is required in some applications like PEM hydrogen fuel cells, can be refined without incurring additional costs [21].

This is in line with the result of this research that shows a significant increase in hydrogen purity. As seen in Figure 3. shows the highest hydrogen composition is utilized KOH electrolytes. S5 utilised KOH electrolyte without separator membrane got 58.3% hydrogen composition and 78.3% for S3 without separator membrane. Followed by NaOH 56.4% with separator membrane and 77.8% without separator membrane. Seawater as the natural electrolytes and also could be utilized as renewable energy is at medium yield with 55.2% and 74.9% with and without separator membrane. The lowest hydrogen composition is S3, KCl without separator membrane.

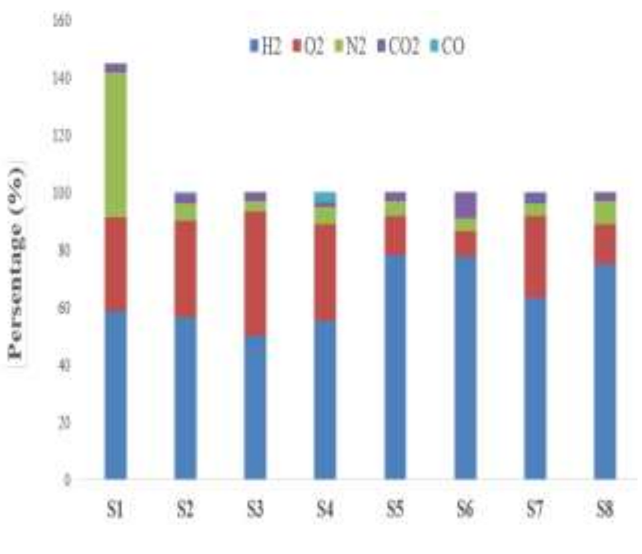

Figure 3. *Comparison of Brown's gas composition*

Membranes made of polyvinyl alcohol (PVA) are one class that has been gaining popularity [22]. It is imperative to evaluate the progress made in this field to choose acceptable and realistic research directions if the research activities in creating PVA membranes are to be increased.

3.2. Variation of Electrolytes Utilised

Electrolytes can make the non-conductive nature of pure water, thus affecting the voltage required for electrolysis processes at a specific current density. The electrolyte concentration affects the quantity of hydrogen that can be produced [23][29]. Higher electrolyte concentration leads to increased surface reactions between the electrolyte, resulting in enhanced ionic conductivity, ion mobility, and current intensity. Consequently, the hydrogen reaction rate and the amount of hydrogen generated in an electrolysis cell are higher [16,6]. The current measured with 12 Voltage can be seen in Figure 4.

The difference in electrical resistance between the Potash and Soda electrolyzers can be attributed to the higher ionic conductivity of K^+ compared to Na^+..

Brown's gas production rate gradually increased with the applied voltage increase due to the uniform charge density increase, ions exchange on the electrode surface and the reaction kinetics acceleration. The decline between theoretical and experimental brown's gas flow rates increased with the applied voltage increase because of the higher losses [24]. Previous research utilising additives such as NaCl, KOH, and NaOH significantly increases the flux of hydrogen production [25][27]. Compared to NaOH, KOH has a higher ionic conductivity. KOH is extremely corrosive, restricting the types of materials that can be utilised. Nickel is relatively less expensive and less corrosive, so it can be utilised with KOH [21-23].

KCl as the weak electrolyte in theory also shows the in line result that has the lowest current measured to produce hydrogen either using separator membrane or not.

Based on variations of the electrolytes used with the same concentration except for the Seawater because it has naturally based NaOH, KOH, KCl, and Seawater, the hydrogen purity data was collected. The purity of hydrogen gas produced using a membrane separator was 58.57 % when using a membrane separator and 78.33 % when not using a membrane separator, as shown by the experiment results. Compared with KCl and Seawater (NaCl) results, the two bottom lowest hydrogen purity is in line with the current measured in the electrolysis process.

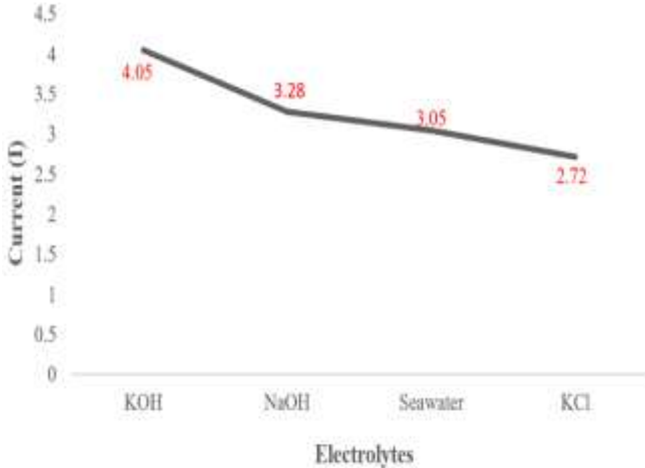

Figure 4. *The Current Measured*

4. Conclusion

In this study, the purity of hydrogen production comparison using a dry cell electrolyzer with PVA as a separator membrane showed a significant result. The highest hydrogen purity obtained using the PVA separator membrane was 78.32 % with KOH electrolytes and the lowest hydrogen purity is 50,1 with KCl electrolytes.

Acknowledgements

This research was supported by the Renewable Energy Engineering Master Program at Politeknik Negeri Sriwijaya

References

[1] K. Praveen and M. Sethumadhavan, "On the extension of XOR step construction for optimal contrast grey level visual cryptography," *2017 Int. Conf. Adv. Comput. Commun. Informatics, ICACCI 2017*, vol. 2017-Janua, pp. 219–222, 2017, doi: 10.1109/ICACCI.2017.8125843.

[2] A. Ronzino *et al.*, "The energy efficiency management at urban scale by means of integrated modelling.," *Energy Procedia*, vol. 83, pp. 258–268, 2015, doi: 10.1016/j.egypro.2015.12.180.

[3] D. Irtas, Y. Bow, and Rusdianasari, "The Effect of Electric Current on the Production of Brown's Gas using Hydrogen Fuel Generator with Seawater Electrolytes," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 709, no. 1, 2021, doi: 10.1088/1755-1315/709/1/012001.

[4] P. Haug, M. Koj, and T. Turek, "Influence of process conditions on gas purity in alkaline water electrolysis," *Int. J. Hydrogen Energy*, vol. 42, no. 15, pp. 9406–9418, 2017, doi: 10.1016/j.ijhydene.2016.12.111.

[5] P. Polverino, F. D'Aniello, I. Arsie, and C. Pianese, "Study of the energetic needs for the on-board production of Oxy-Hydrogen as fuel additive in internal combustion engines," *Energy Convers. Manag.*, vol. 179, no. September 2018, pp. 114–131, 2019, doi: 10.1016/j.enconman.2018.09.082.

[6] R. Rusdianasari, Y. Bow, T. Dewi, A. Taqwa, and L. Prasetyani, "Effect of Sodium Chloride Solution Concentration on Hydrogen Gas Production in Water Electrolyzer Prototype," *2019 Int. Conf. Technol. Policies Electr. Power Energy, TPEPE 2019*, no. 3, pp. 3–8, 2019, doi: 10.1109/IEEECONF48524.2019.9102508.

[7] M. H. Sellami and K. Loudiyi, "Electrolytes behavior during hydrogen production by solar energy," *Renew. Sustain. Energy Rev.*, no. July, pp. 0–1, 2016, doi: 10.1016/j.rser.2016.12.034.

[8] A. Syakdani, Y. Bow, Rusdianasari, and M. Taufik, "Analysis of Cooler Performance in Air Supply Feed for Nitrogen Production Process Using Pressure Swing Adsorption (PSA) Method," *J. Phys. Conf. Ser.*, vol. 1167, no. 1, 2019, doi: 10.1088/1742-6596/1167/1/012055.

[9] Z. Zakaria and S. K. Kamarudin, "A review of alkaline solid polymer membrane in the application of AEM electrolyzer: Materials and characterization," *Int. J. Energy Res.*, vol. 45, no. 13, pp. 18337–18354, 2021, doi: 10.1002/er.6983.

[10] R. Nagarkar and J. Patel, "Acta Scientific Pharmaceutical Sciences (ISSN: 2581-5423) Polyvinyl Alcohol: A Comprehensive Study," vol. 3, no. 4, pp. 34–44, 2019.

[11] M. H. Lin, C. J. Huang, P. H. Cheng, J. H. Cheng, and C. C. Wang, "Revealing the effect of polyethylenimine on zinc metal anodes in alkaline electrolyte solution for zinc-air batteries: Mechanism studies of dendrite suppression and corrosion inhibition," *J. Mater. Chem. A*, vol. 8, no. 39, pp. 20637–20649, 2020, doi: 10.1039/d0ta06929a.

[12] B. Subramanian and S. Ismail, "Production and use of HHO gas in IC engines," *Int. J. Hydrogen Energy*, vol. 43, no. 14, pp. 7140–7154, 2018, doi: 10.1016/j.ijhydene.2018.02.120.

[13] E. Maican *et al.*, "Hybrid renewable energy systems for isolated farms. A review," *INMATEH - Agric. Eng.*, vol. 59, no. 3, pp. 77–92, 2019, doi: 10.35633/INMATEH-59-09.

[14] M. Wang, Z. Wang, X. Gong, and Z. Guo, "The

intensification technologies to water electrolysis for hydrogen production - A review," *Renew. Sustain. Energy Rev.*, vol. 29, pp. 573–588, 2014, doi: 10.1016/j.rser.2013.08.090.

[15] A. Budiman, M. Yerizam, and Y. Bow, "Design of Dry Cell HHO Generator using NaCl Solution for Hydrogen Production," pp. 8–15, 2021, doi: 10.24845/ijfac.v7.i1.8.

[16] H. Teuku, I. Alshami, J. Goh, M. S. Masdar, and K. S. Loh, "Review on bipolar plates for low-temperature polymer electrolyte membrane water electrolyzer," *Int. J. Energy Res.*, vol. 45, no. 15, pp. 20583–20600, 2021, doi: 10.1002/er.7182.

[17] A. Kovač, D. Marciuš, and L. Budin, "Solar hydrogen production via alkaline water electrolysis," *Int. J. Hydrogen Energy*, vol. 44, no. 20, pp. 9841–9848, 2019, doi: 10.1016/j.ijhydene.2018.11.007.

[18] Rusdianasari, Y. Bow, T. Dewi, and P. Risma, "Hydrogen Gas Production Using Water Electrolyzer as Hydrogen Power," *ICECOS 2019 - 3rd Int. Conf. Electr. Eng. Comput. Sci. Proceeding*, no. 4, pp. 127–131, 2019, doi: 10.1109/ICECOS47637.2019.8984438.

[19] L. Gustavo, M. Vieira, and R. Damasceno, "ScienceDirect Hydrogen production by a low-cost electrolyzer developed through the combination of alkaline water electrolysis and solar energy use," vol. 3, pp. 0–10, 2018, doi: 10.1016/j.ijhydene.2018.01.051.

[20] M. J. González-Pabón, R. Cardeña, E. Cortón, and G. Buitrón, "Hydrogen production in two-chamber MEC using a low-cost and biodegradable poly(vinyl) alcohol/chitosan membrane," *Bioresour. Technol.*, vol. 319, no. September 2020, 2021, doi: 10.1016/j.biortech.2020.124168.

[21] K. Rajagukguk, "Pengolahan Limbah Cair Tahu Menjadi Biogas Menggunakan Reaktor Biogas Portabel," *Quantum Tek. J. Tek. Mesin Terap.*, vol. 1, no. 2, pp. 63–71, 2020, doi: 10.18196/jqt.010210.

[22] D. L. Hoskins, X. Zhang, M. A. Hickner, and B. E. Logan, "Spray-on polyvinyl alcohol separators and impact on power production in air-cathode microbial fuel cells with different solution conductivities," *Bioresour. Technol.*, vol. 172, pp. 156–161, 2014, doi: 10.1016/j.biortech.2014.09.004.

[23] Rusdianasari, Y. Bow, and T. Dewi, "HHO Gas Generation in Hydrogen Generator using Electrolysis," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 258, no. 1, 2019, doi: 10.1088/1755-1315/258/1/012007.

[24] M. A. El Kady, A. El Fatih Farrag, M. S. Gad, A. K. El Soly, and H. M. Abu Hashish, "Parametric study and experimental investigation of hydroxy (HHO) production using dry cell," *Fuel*, vol. 282, no. May, p. 118825, 2020, doi: 10.1016/j.fuel.2020.118825.

[25] A. Valente, D. Iribarren, and J. Dufour, "End of life of fuel cells and hydrogen products: From technologies to strategies," *Int. J. Hydrogen Energy*, vol. 44, no. 38, pp. 20965–20977, 2019, doi: 10.1016/j.ijhydene.2019.01.110.

[26] A. N. Colli, H. H. Girault, and A. Battistel, "Non-precious electrodes for practical alkaline water electrolysis," *Materials (Basel).*, vol. 12, no. 8, pp. 1–17, 2019, doi: 10.3390/ma12081336.

[27] Rusdianasari, A Taqwa, A Syarif, and Y Bow, "Hydrogen Recovery from Electroplating Wastewater Electrocoagulation Treatment", International Journal on Advanced Science Engineering Information Technology, Vol. 3 No. 2, pp. 592-598, 2023, DOI:10.18517/ijaseit.13.2.16667

[28] Bow, Y., Rusdianasari, ., Meidinariasty, A. and Yori Pratama, M., "Effect of Stainless Steel Duplex Electrode Size on Hydrogen Production through Electrolysis Process", In Proceedings of the 4th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2021), pp. 393-397, 2023, DOI: 10.5220/0010946400003260

[29] Rusdianasari, Iskandar, I., Basuki, PD., "Utilizing on Oxyhydrogen Reactor to Produce Hydrogen Gas in a New Source of Energy from Textile Effluent:, International Journal of Research In Vocational Studies, Vol. 2 No. 3, pp. 31-36, 2022, https://doi.org/10.53893/ijrvocas.v2i3.149