Vol. 23 No.2 (Juli 2022) 189-197
e-ISSN 2548-6101 p-ISSN 1411-318X

Jurnal Teknologi Lingkungan

Journal Homepage: ejurnal.bppt.go.id/index.php/JTL

Potential Utilization of PT Vale Indonesia Tbk Slag as An Alternative Energy Source

Potensi Pemanfaatan Kerak Besi pada PT. Vale Indonesia Tbk sebagai Alternatif Sumber Energi

IRWAN RIDWAN RAHIM*, EVI APRIANTI, FAIZAL ARYA SAMMAN, SUTAMI SUPARMIN

Department of Environmental Engineering, Faculty of Engineering, Universitas Hasanuddin, Gowa, Indonesia
*irwanrr@unhas.ac.id

INFORMASI ARTIKEL

Histori artikel:
Diterima 31 October 2021
Disetujui 21 July 2022
Diterbitkan 31 July 2022

Kata kunci:
Terak nikel
Energi alternatif
Limbah
Baterai terak
Vale Indonesia

ABSTRAK

Potensi pertambangan nikel di Indonesia tersebar dari Pulau Sulawesi, Maluku, dan Papua dengan sumber daya dan cadangan biji nikel laterit sebesar 4,2 milyar ton. Dampak negatifnya adalah dihasilkan limbah dari pengolahan bijih nikel yaitu terak (slag) dalam jumlah besar dan jika tidak dilakukan pengelolaan dengan baik, maka akan mengancam lingkungan sekitar pertambangan. Penelitian ini bertujuan untuk melakukan analisis SWOT kelayakan terak nikel yang dihasilkan oleh PT. Vale Indonesia Tbk menjadi sebuah produk energi alternatif dalam bentuk baterai dengan metode mengambil sampel terak dari ke-5 lokasi pada Tempat Penyimpanan Sementara (TPS) Delaney, PT Vale Indonesia Tbk. Selanjutnya, sampel terak dihaluskan sampai mencapai ukuran 100 mesh dan diberikan empat perlakuan elektrolit yaitu kering, air distilasi, hidrogen klorida (HCl), dan natrium hidroksida (NaOH). Setiap sampel terak yang telah diberikan perlakuan selanjutnya dimasukkan ke dalam wadah (sel) dengan ukuran 10x10x2 sentimeter kemudian memasukkan plat elektroda tembaga (Cu) dan seng (Zn) pada sisi sel yang berlawanan. Eksperimen terhadap 20 sel baterai menghasilkan data tegangan rata-rata tertinggi sebesar 1,28 Volt dengan arus rata-rata tertinggi sebesar 57,34 miliAmpere. Perlakuan yang paling efektif adalah dengan penambahan natrium hidroksida (NaOH) ke dalam baterai terak. Unsur yang berpengaruh dalam menghasilkan tegangan dan arus tertinggi adalah besi (Fe) dan senyawa oksida sulfat (SO$_x$). Sel baterai terbukti dapat menyimpan energi listrik sebesar 0,1–24 kali arus dan tegangan awal melalui proses pengecasan sehingga disimpulkan bahwa baterai terak dapat dimanfaatkan sebagai sumber energi alternatif untuk alat elektronik berdaya rendah.

ARTICLE INFO

Article history:
Received 31 Oktober 2021
Accepted 21 Juli 2022
Published 31 Juli 2022

Keywords:
Nickel slag
Alternative energy
Waste
Battery slag
Vale Indonesia

ABSTRACT

Nickel mining potential in Indonesia spreads from Sulawesi Island, Maluku, and Papua with resources and reserves of nickel laterite of 4.2 billion tons. The negative impact is that large amounts of waste are generated from nickel ore processing, namely slag and if not managed properly, it will threaten the environment around the mining. This study aims to conduct a SWOT (Strenght, Weakness, opportunity, Treat) analysis of the feasibility of nickel slag produced by PT. Vale Indonesia Tbk becoming an alternative energy production in the form of batteries by taking samples of slag from five locations at the Delaney Temporary Storage (TPS) of PT Vale Indonesia Tbk. Furthermore, the slag sample was pulverized until it reached a size of 100 mesh and given four electrolyte treatments; Dry, distilled water, hydrogen chloride (HCl), and sodium hydroxide (NaOH). Each slag sample that has been treated is then put into a container (cell) with a size of 10x10x2 centimeters then inserts the copper (Cu) and zinc (Zn) electrode plates on the opposite side of the cell. Experiments on 20 battery cells resulted in the highest average voltage data of 1.28 Volts with the highest average current of 57.34 milliamperes. The most effective treatment is the addition of sodium hydroxide (NaOH) into the slag battery. The elements that influence the production of the highest voltage and current are iron (Fe) and sulfate oxide (SOx) compounds. Battery cells are proven to be able to store electrical energy of 0.1–24 times the initial current and voltage through the charging process so it is concluded that the slag battery can be used as an alternative energy source for low-power electronic devices.

1. INTRODUCTION

1.1 Research Background

Nickel mining potential in Indonesia spreads from the Sulawesi island, Maluku to Papua (Ari, 2019), with resources and reserves of laterite nickel ore of around 4.2 billion tons or one-third of the world's laterite nickel resources which reach 12.5 billion tons (Nursahan, et al., 2013). The magnitude of this potential certainly has a positive impact on the economic growth of several provinces, especially the province of South Sulawesi. Although capable of encouraging regional economic potential, nickel mining activities also produce by-products in the form of nickel processing waste, namely slag which is classified as hazardous and toxic waste. This happens because the nickel content in nickel ore feed is only 1.8 to 2.0% (Mustika, et al., 2016). In addition, the minerals obtained from processing ore used in the mining industry will not achieve 100% recovery. It can be caused by the hardness of the ore rock which causes the milled results to tend to be coarser and result in decreased recovery accompanied by lower mineral content in the concentrate (Pohan, et al., 2007).

The amount of slag produced from nickel processing varies, for example at PT Aneka Tambang Pomala located in Kolaka district, Southeast Sulawesi province, slag production during the period 2011-2012 was around one million tons of slag/year (Mustika, et al., 2016). If not managed properly, slag as mining waste can have some negative impacts on the mining environment such as the use of large slag dump areas, and can pollute water bodies around the dumpsite as well as be hazardous to the environment (Rosalina, et al., 2018). Hazardous and toxic waste, abbreviated as B3 waste, shall mean any waste containing dangerous and/or toxic material, which due to its characteristics and/or concentration and/or amount, either directly or indirectly, may damage and/or pollute the living environment and/or endanger human health. *B3* waste management must apply the principle of minimization through the 4R concept (Reduce, Reuse, Recycle and Recover), one form of recycling application is the use of *B3* waste as a substitute for raw materials (Perdana and Sukandar, 2016), such as making slag as raw material for road embankments and as a concrete aggregate. Every industry needs to improve the 4R concept if it wants to implement a sustainable business, this is also by the Minister of Energy and Mineral Resources Regulation No. 26 of 2018 article 3.

In addition to increasing added value (Mustika, et al., 2016) by making embankments or concrete aggregates, slag has the potential to be developed as an alternative energy source in the form of battery electrolyte media. This is because the slag from nickel processing still contains several elements such as Mg, Al, Si, Cr, Fe, Ni, Co, and several other elements in small amounts (Juvelyn, et al., 2012), This element is also found in nickel metal hydride (Ni-MH) rechargeable batteries which consist of a mixture of metals such as titanium, manganese, aluminum, cobalt, zirconium, and vanadium (Afif & Pratiwi, 2015). While in Pinandita's 2016 research on batteries that use red clay (TLM) as an electrolyte, it could produce a current capacity of 2.44 Ah and an energy density of 1.15 Wh/gram. After measurement, it was found that several elements dominate such as sodium, magnesium, and calcium (Pinandita, 2016).

In general, the battery process in producing energy can be explained through a chemical process called Redox (Reduction - Oxidation). In moist soil, for example, it can act as an electrolyte connecting two electrodes with different potentials. The free ions were captured by the electrodes (positive and negative poles) and produced various electric voltages (Maniyar, et al., 2013). As a recap from former studies, there are many opportunities and challenges faced in managing the slag produced from the nickel mining industry, especially at PT Vale Indonesia. One of the obstacles is that slag is classified as hazardous and toxic waste (*B3*) and is considered a product that has no economic value.

1.2 Aims of Study

Seeing the potential and obstacles faced, researchers are very interested in conducting a study to increase the utilization and added value of slag produced from nickel processing by focusing on effective methods of producing slag batteries, the amount of voltage, current, capacity, and battery density as well as the ability of slag batteries in storing electrical energy.

2. PROCEDURE

2.1 Research Location and Time

This research was conducted in two places, namely where the sample was taken at the Delaney Temporary Storage (TPS), PT. Vale Indonesia is located in Sorowako, East Luwu Regency, South Sulawesi Province (Figure 1). While the place of sample testing was carried out at the Faculty of Engineering, Hasanuddin University.

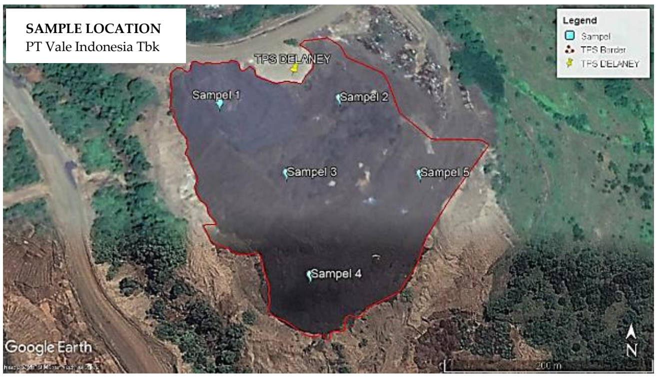
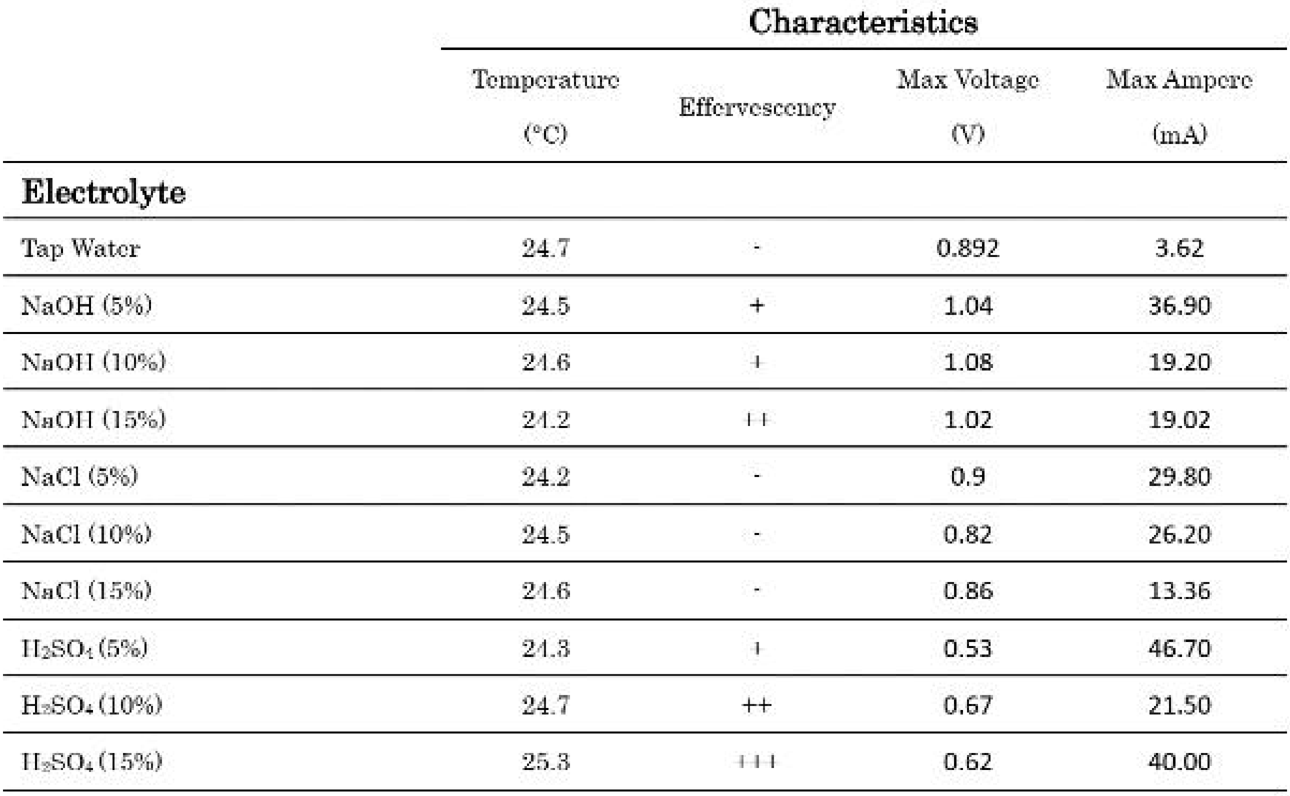


Figure 1. Slag Sampling Location

2.2 Materials

The used tools are a shovel, digital scales, jaw crusher 200, disk mill, thermometer, ph meter, ruler, marker, scissors, global position system (GPS), digital multimeter, solder, bucket, glue gun, sensor INA219 DC and voltage sensor, microcontroller, and ED-XRF spectrometer. The materials used in the experiment were a plastic bag, electric furnace slag, tin, zinc, and copper plates, labels, distilled water, NaOH solution, and 5% HCL concentration. The use of 15% concentration is the most effective concentration compared to a mixture with NaOH (5%), H_2SO_4 (10%), and NaCl (15%), respectively, as shown in Figure 2.



	Characteristics			
	Temperature (°C)	Effervescency	Max Voltage (V)	Max Ampere (mA)
Electrolyte				
Tap Water	24.7	-	0.892	3.62
NaOH (5%)	24.5	+	1.04	36.90
NaOH (10%)	24.6	+	1.08	19.20
NaOH (15%)	24.2	++	1.02	19.02
NaCl (5%)	24.2	-	0.9	29.80
NaCl (10%)	24.5	-	0.82	26.20
NaCl (15%)	24.6	-	0.86	13.36
H_2SO_4 (5%)	24.3	+	0.53	46.70
H_2SO_4 (10%)	24.7	++	0.67	21.50
H_2SO_4 (15%)	25.3	+++	0.62	40.00

Figure 2. Electrical Characteristics of the Tanah Merah Battery with a mixture of electrolytes Base (NaOH), Salt (NaCl) and Acid (H_2SO_4). Source: (Suparmin, et al., 2019)

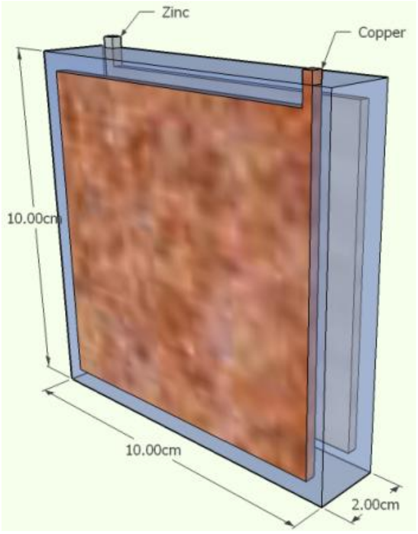


Figure 3. Slag Battery Cell Design

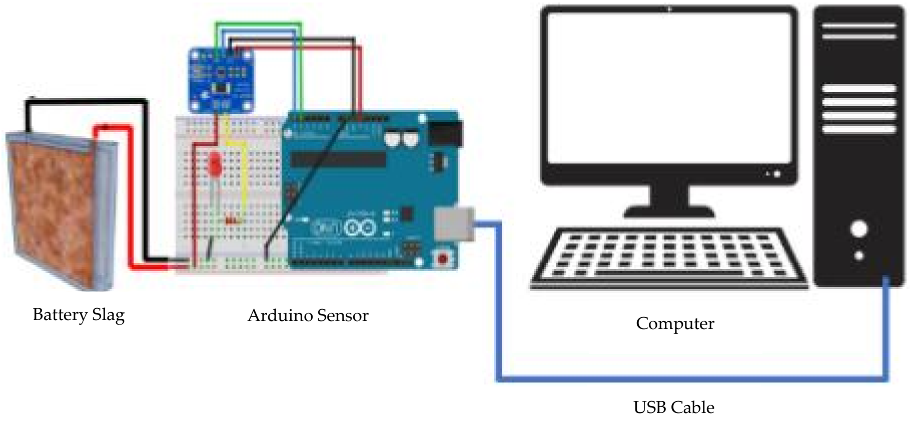


Figure 4. Slag Battery Current and Voltage Measurement Design

2.3 Experimental Process

The formation of battery cells is done by cutting mica glass (acrylic) into several parts to form cells with a size of 10x10x2 centimeters, then glued with hot glue. For the cathode and anode, copper, and zinc plates are used according to the length and width of the cell. Then each sample of slag powder (±200 mesh) was put into a cell made of mica glass with the cathode and anode on opposite sides as shown in Figure 3. There were four treatments given to the five samples, namely no electrolyte (Dry), distilled water-electrolyte, 5% NaOH Electrolyte, and finally 5% HCl electrolyte. Around 20 battery cells will be tested for voltage and electric current. The ability to store electrical energy during the charging process in about 120 minutes (2 hours) was also tested for those samples. Figure 4 is a design for measuring the current and voltage of the slag battery.

3. RESULTS AND DISCUSSION

The battery voltage and current were tested twice, namely before and after charging with a measurement duration of 300 seconds (5 minutes). The following is a graph of the voltage comparison of one of the samples:

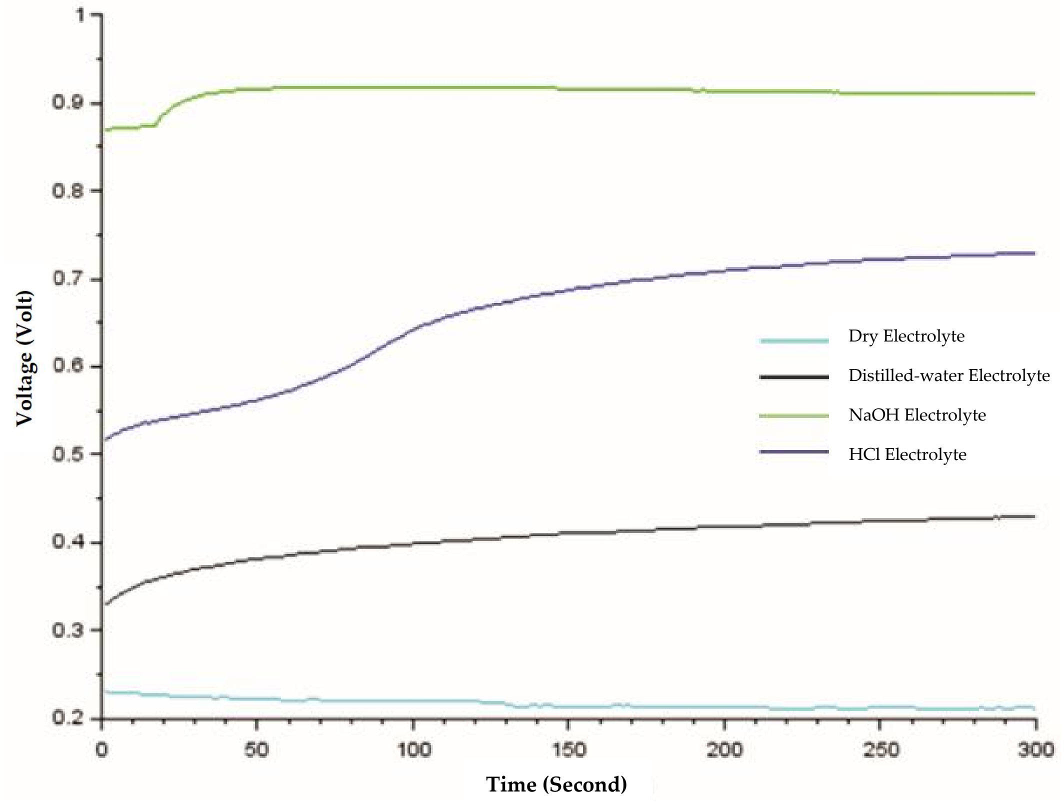


Figure 5. Slag Battery Voltage Graph of Samples Originating at Location 5 Before Charging

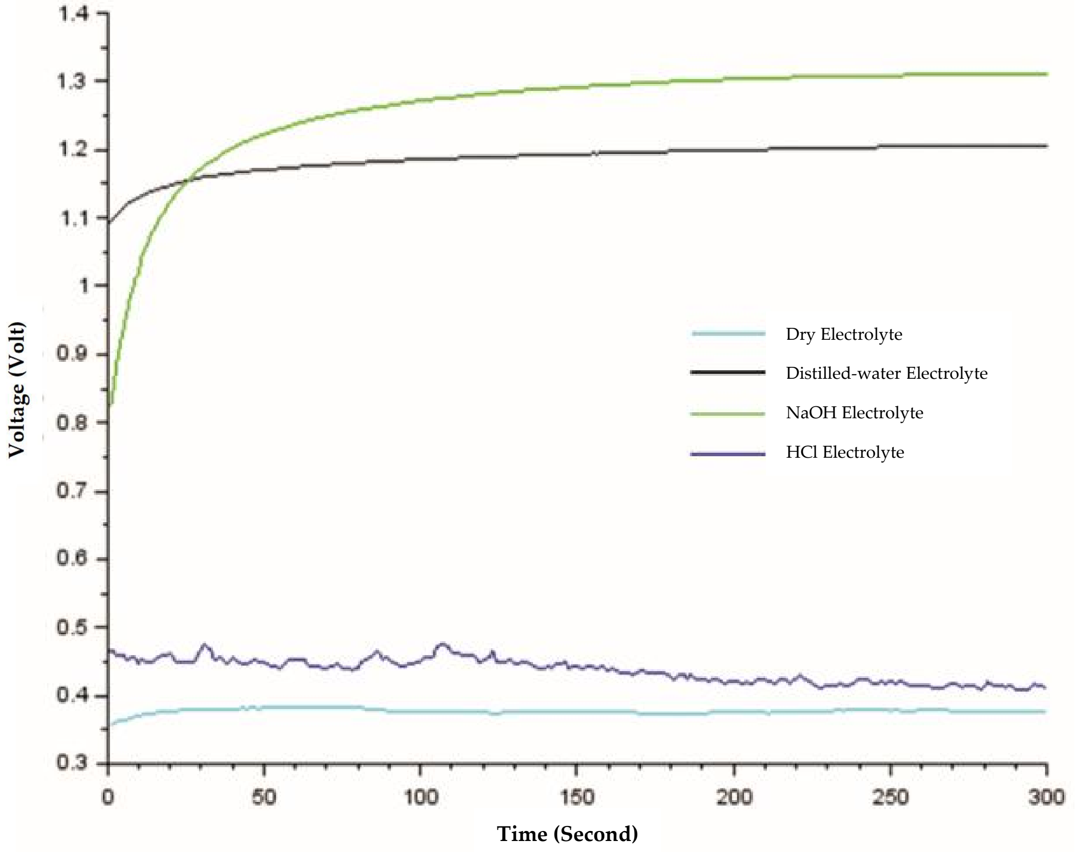


Figure 6. Slag Battery Voltage Graph of Samples Originating at Location 5 After Charging

3.1 Comparison of Voltage and Electric Current of the Four Electrolyte Treatments

The following is a graph of the voltage and electric current produced by the slag battery samples from location 5 at TPS Delaney PT. Vale Indonesia with dry electrolyte, distilled water, 5% NaOH, and 5% HCl:

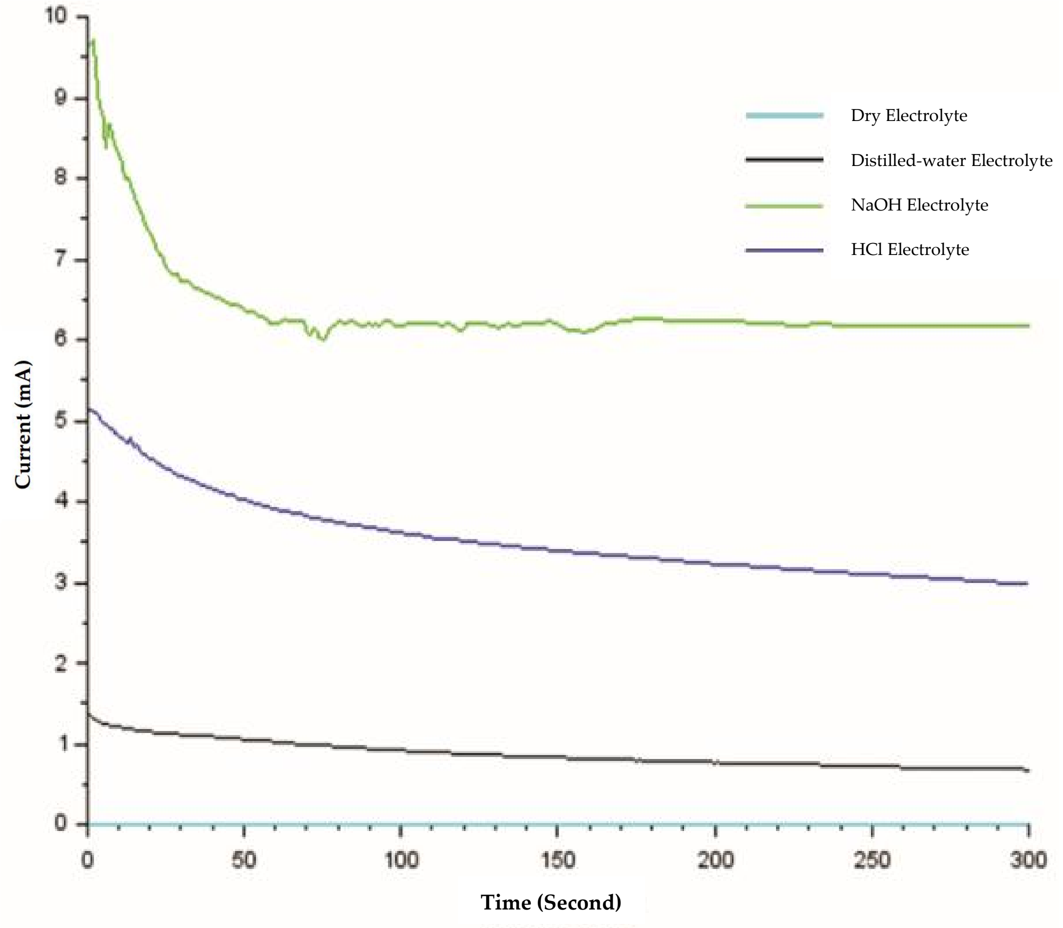


Figure 7. Graph of Battery Slag Flow from Samples Originating at Location 5 Before Charging

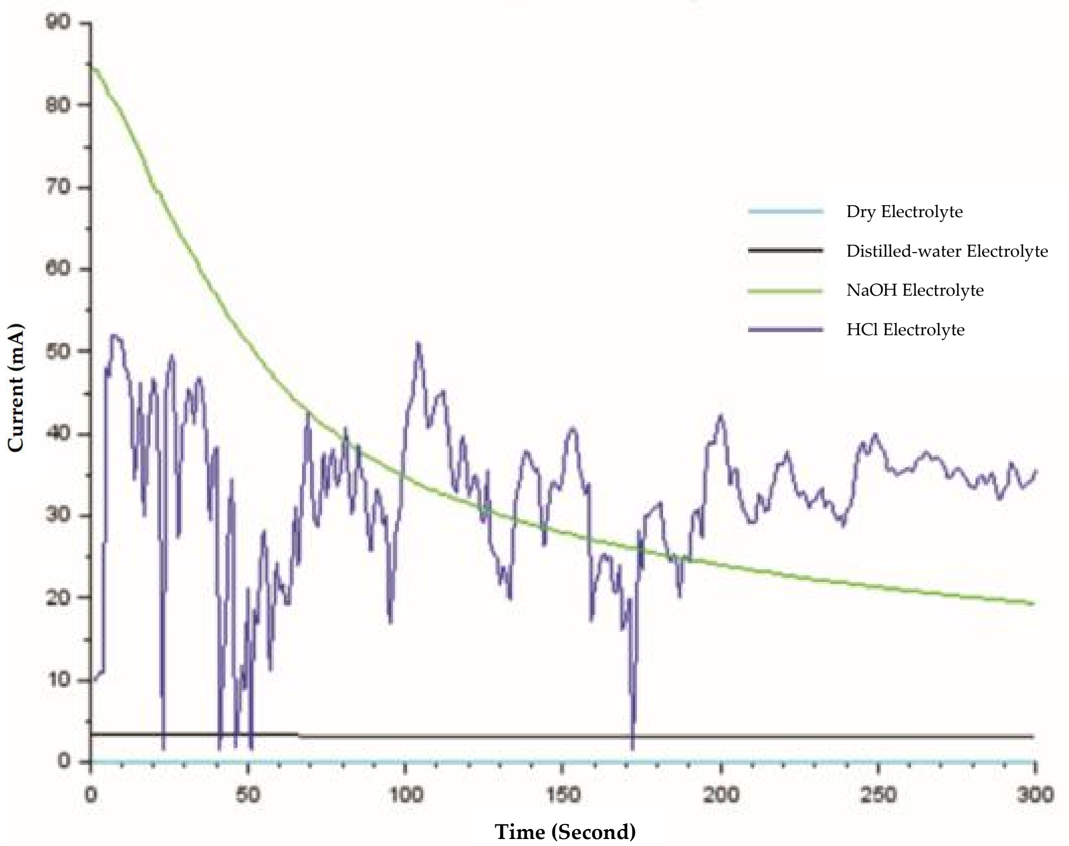


Figure 8. Graph of Battery Slag Flow from Samples Originating at Location 5 After Charging

3.1.1 Voltage

Figure 5 and Figure 6 are graphs of the electrical voltage before and after charging the slag battery from location 5. From Figure 5 and Figure 6, the highest average voltage from the addition of 5% NaOH electrolyte was 0.91 Volt before charging and 1.26 Volt after charging, with the ability to increase the voltage (save electrical energy) by 72%. After that, it was continued with the addition of distilled water, HCl, and dry electrolyte with a voltage capability of 1.18; 0.43; and 0.37 volts after charging.

3.1.2 Current

Figure 7 and Figure 8 are graphs of the electric current before and after charging the slag battery from location 5. From the graph above, the highest current from the addition of 5% NaOH electrolyte with an average current value of 6.38 milliampere (mA) before charging, and 35 mA after charging, with the ability to increase the current by 18% after charging then followed by the treatment of electrolytes HCl, and distilled water of 32 and 3.21 mA. The dry cell treatment did not produce an electric current at all. The generated average power during the 5-minute measurement of 20 battery samples, can be seen in Figure 9.

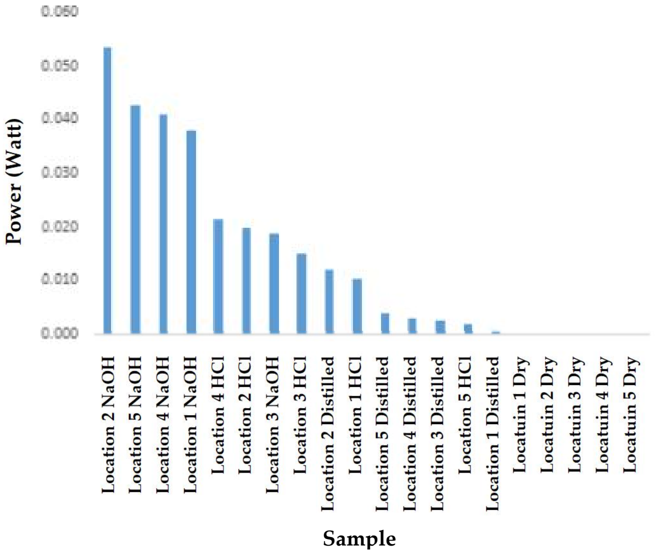


Figure 9. 20 Cell Slag Battery Average Power Graph

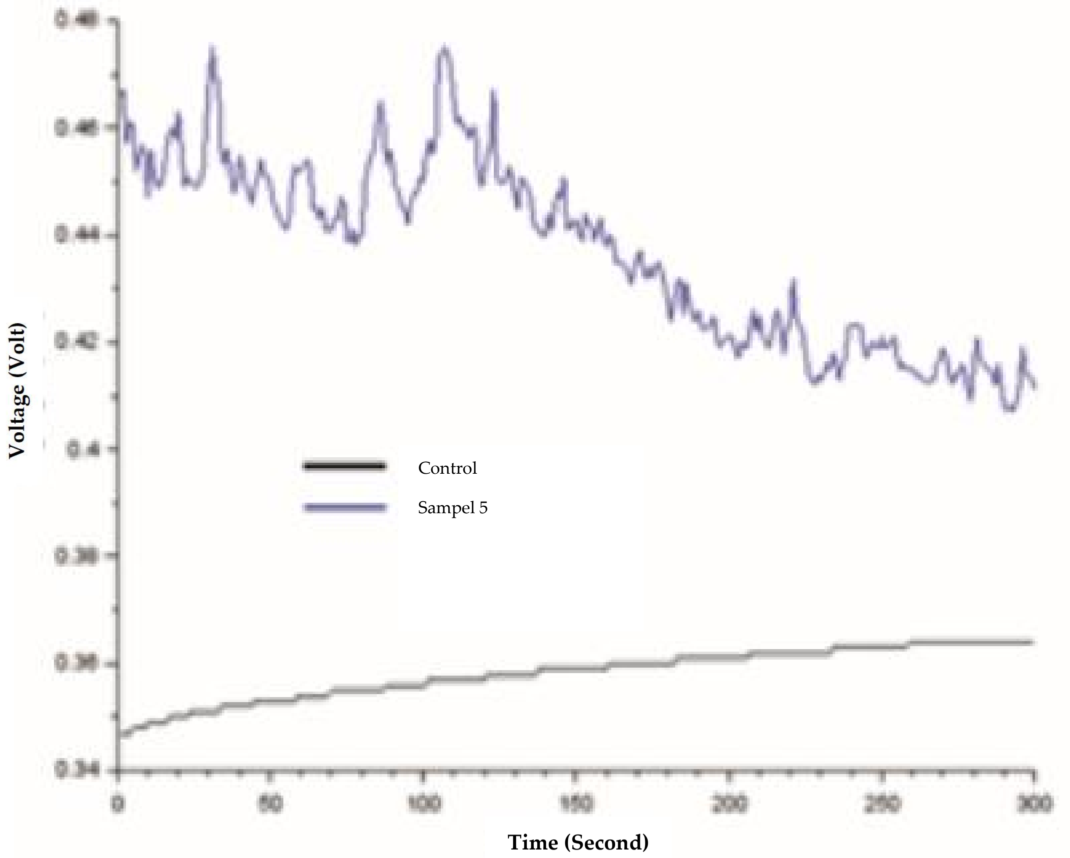


Figure 10. Comparison Graph of Control Voltage and Battery Slag After Charging

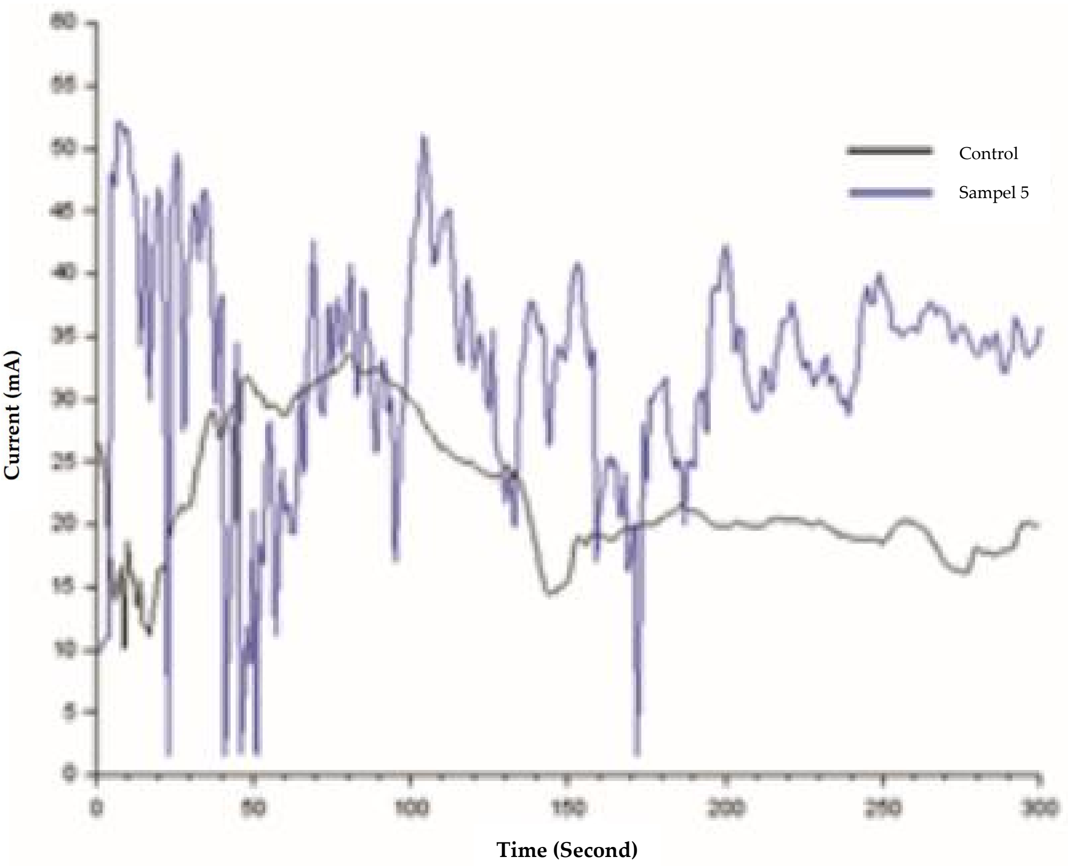


Figure 11. Comparison Graph of Control Current and Battery Slag After Charging

3.2 Voltage and Current Comparison of Slag and Control Batteries

To see the effect of adding slag to battery cells in alkaline (NaOH) and acid (HCl) electrolytes, a current and voltage test was carried out on cells without slag (only electrodes + electrolyte) in this case called a control cell, then the current will compare to voltage. The slag batteries origin from sample 5th are shown in Figure 10.

3.2.1 Voltage

Figure 10 is a comparison graph of control voltage and slag battery after charging.

3.2.2 Current

From the graph above (Figure 11), the slag addition as a mixture of HCl electrolytes into the battery provided a significant increase in voltage and electric current of 81% of the control voltage while the increased current was approximately 69%. While on NaOH electrolyte can increase the voltage by 72% and the electric current by 25% from the addition of slag.

3.3 Battery Cell Capacity and Density

Based on the cell measuring at the highest power for 5 minutes, further measurements were carried out to determine the capacity and density of the slag battery from the 2nd sample shown in Table 1.

Table 1. Battery Cell Capacity and Density Slag Sample 2 NaOH

Variable	Quantity
Total Capacity	2592 mAh
Hourly Power	15.12 Wh
Density	0.271 W/gr
Working hours	7 hours

3.4 Slag Battery Elemental Composition

An elemental test was carried out using Energy Dispersive X-Ray Fluorescence (ED-XRF) to find the influencing elements for the production of voltage and electric current from the slag battery. Figure 12 is a diagram of the elemental composition of one of the battery samples. According to Figure 12, the types of elements can be divided into two parts based on their concentration. The first element has the largest percentage and is generally found in slag such as iron in the form of Fe_2O_3 by 88.04%, silicate in the form of SiO_2 by 5.87%, sulfur oxide in the form of SO_3 by 2.9%, manganese in the form of MnO by 1.26%, and copper in the form of CuO by 0.88%. The elements with a very small percentage are generally below 1% such as nickel in the form of NiO by 0.56%, niobium in the form of Nb_2O_5 by 0.01%, and other elements less than 0.03% such as Ga, Mo, Sn, and In.

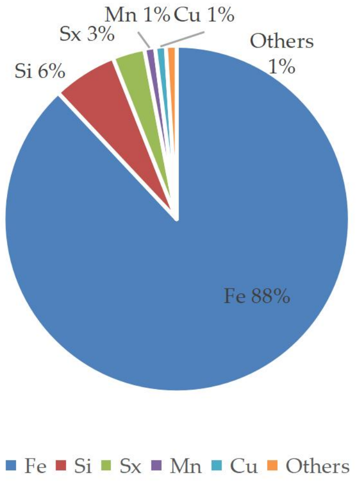


Figure 12. Elemental Composition of Slag samples from Location 2 NaOH . Electrolyte

3.5 SWOT Analysis of Feasibility of Slag Batteries as Alternative Energy Sources

The explanation of the SWOT analysis of the feasibility of slag batteries is shown below.

Strengths

Renewable energy is energy that is unlimited in quantity and can be renewed. PT Vale Indonesia, which is located in Sorowako, can produce 3,750,000 tons of slag per year (Jefriyanto, 2018) if not managed properly, its use can cause environmental problems. Sustainable, this is because it is enough to be recharged (charging) so that the power can be raised again.

Weaknesses

The energy from renewable sources will be less than conventional energy, so it will fear that it will be insufficient to meet the energy needs of the community in the future. Several things to be noted about slag batteries such as electrolytes and electrodes that can be corroded due to use.

Opportunity

The opportunity of developing renewable energy from this slag battery is to help the community as an alternative energy source. It was recorded that in 2014 there were around 64,457 families in East Luwu (Cipta Karya PU, 2016). Of these, there are around 7,780 households that do not yet have access to electricity. Assuming the use of electrical energy in homes that do not have access to electricity is 900 VA, then to use a slag battery with a density of 209 gr to produce 0.052 watt takes about 132 tons of slag to be utilized.

Threats

The perceived threat that will arise when the development of this renewable energy is carried out, namely, inadequate human resources and technology for this renewable energy project, specifically the case at PT. Vale slag is classified as hazardous and toxic waste (*B3*) and is considered a product that has no economic value through the use of slag battery innovation to the surrounding community.

4. CONCLUSION

The hazardous wastes will be more challenging if they do not dispose of safely in the environment. After conducting experimental works, the most effective method in producing slag batteries is to utilize nickel slag from PT. Vale Indonesia with 5% NaOH electrolyte treatment. The highest average voltage generated from the sample 1st battery NaOH treatment was 1.28 volts, while the highest average current generated from the sample 3rd NaOH electrolyte treatment was 74mA.The highest power produced from the sample 2nd battery with NaOH electrolyte treatment of 0.052 watts with a capacity of 2,592 mAh and a battery density was 0.271 watt/gr. Based on the SWOT analysis, innovation of the used slag battery as an alternative energy source deserves to be developed, because it can reduce the environmental impact of stockpiling slag in a Temporary Storage Place (TPS) of PT. Vale Indonesia Tbk. The conclusion is the slag battery can store energy.

ACKNOWLEDGEMENT

The author expresses his appreciation and gratitude to those who have assisted in the completion of this research, especially to Mr. Muhammad Zuhair as the coordinator of the Hadji Kalla Foundation who has provided support in the form of grants for research completion.

REFERENCE

Afif, M. T. & Pratiwi, I. A. P. (2015). Analisis Perbandingan Baterai Lithium Ion, Lithium Polymer, Lead Acid dan Nickel Metal Hydride pada Penggunaan Mobil Listrik - Review. Jurnal Rekayasa Mesin, VI(2), pp. 95-99.

Jefriyanto, W. (2018). Analisis Karakteristik Paduan Logam Oksida Fe2O3 dengan Slag Nikel. Journal Neutrino, I (1), pp. 33-38.

Juvelyn, D. S., Ruben, A. J. F., Robert, M. F. & Cesar, D. G. (2012). Characterization and Leaching Assessment of Ferronickel Slag from a Smelting Plant in Iligan City, Philippines. International Journal of Environmental Science and Development, III (5), pp. 470-474.

Maniyar, M., Patil, N., Jadhav, S. & Dhokle, S. (2013). Uninterruptable Power Supply Using Earth Battery and Solar Panel. International Journal of Emerging Technologies in Computational and Applied Sciences, pp. 107-112.

Mustika, W., Sudarsana, K. & Salain, I. M. A. K. (2016). Penggunaan Terak Nikel Sebagai Agregat dalam Campuran Beton. Jurnal Spektran, IV (2), pp. 36-40.

Ursahan, I., Isnaniawardhani, V. & Sulaksana, N. (2013). Penentuan Kawasan Pertambangan Berbasis Sektor Komoditas Unggulan Sumberdaya Nikel Kabupaten Konawe dan Konawe Utara Provinsi Sulawesi Tenggara. Buletin Sumber Daya Geologi, pp. 41-53.

Perdana, A, L. & Sukandar. (2016). Keterlindian Logam Berat Dari Pemanfaatan Limbah slag Besi Dan Baja Sebagai Agregat Campuran Lapis Permukaan Jalan. Jurnal Teknik Lingkungan,hal 1-10.

Pinandita, S. (2016). Prototipe Cell Baterai Tanah Lempung Merah (TLM) dengan Elektroda Cu dan Zn, Yogyakarta: Universitas Gadjah Mada.

Pohan, M. P., W, D., J.S, S. & A., A. (2007). Penyelidikan Potensi Bahan Galian pada Tailing PT Freeport Indonesia di Kabupaten Mimika Provinsi Papua. Jakarta, PUSAT SUMBER DAYA GEOLOGI.

Rosalina, F. Tjahyandari, D. & Darmawan. (2018). The Potential of Nickel Slag with Humic Substance Addition as Amelioration Materials on Gajrug Red-Yellow Podzolic. Sains Tanah, 15(1), pp. 61-68.

Suparmin, S., Zakir, M., Rahim, I. R., & Samman, F. A. (2019). Comparative Experimental Power Measurement of Red Soil Battery with H2SO4, NaCl, and NaOH Additive Solutions. JCREN. Makassar.