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Integrated Wastewater Processing using Electrocoagulation Method into Oxyhydrogen (HHO) for Renewable Energy

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Abstract

Integrated wastewater is one of the contributors to wastewater that can harm the environment, thus fast industrial expansion must be followed with advancements in wastewater processing systems. Because the presence of contaminants in integrated wastewater can cause several issues for persons and the environment, integrated wastewater processing is required. One type of integrated wastewater processing is the production of hydrogen gas as a new and sustainable energy source. The electrocoagulation process may be used to convert integrated wastewater into hydrogen gas. One type of integrated wastewater processing is the production of hydrogen gas as a new and sustainable energy source. The electrocoagulation process may be used to convert integrated wastewater into hydrogen gas. In this study, oxyhydrogen (HHO) was produced from integrated wastewater utilizing two process stages: integrated wastewater processing with an electrocoagulator, followed by the process of getting HHO using an oxyhydrogen reactor. A NaOH catalyst was applied at different concentrations of 0.1 M, 0.2 M, 0.3 M, 0.4 M, and 0.5 M with an electrolysis period of 5 minutes to produce hydrogen gas. The addition of the NaOH catalyst is intended to find the optimal concentration for the production of hydrogen gas. According to the findings of the study and analysis, the optimal NaOH catalyst concentration for producing hydrogen gas is 0.5 M with hydrogen content of 346 mg/m^3.

Keywords: electrocoagulation, oxyhydrogen, integrated wastewater, renewable energy

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Limbah cair terpadu merupakan salah satu penyumbang limbah cair yang dapat mencemari lingkungan, sehingga pesatnya perkembangan industri harus diikuti pula dengan peningkatan sistem pengolahan limbahnya. Keberadaan polutan dalam limbah cair terpadu dapat menimbulkan banyak masalah bagi manusia maupun lingkungan, untuk itu pengolahan limbah cair terpadu perlu dilakukan. Salah satu bentuk pengolahan limbah cair terpadu yaitu dapat diolah sebagai bahan untuk mendapatkan gas hidrogen sebagai sumber energi baru dan terbarukan. Pengolahan limbah elektroplating menjadi gas hidrogen dapat dilakukan dengan metode elektrokoagulasi menggunakan elektroda logam. Pada penelitian ini dilakukan produksi oxyhidrogen (HHO) dari limbah cair terpadu dengan 2 tahapan proses yaitu pengolahan limbah cair terpadu dengan elektrokoagulator dan dilanjutkan proses mendapatkan HHO menggunakan reaktor oxyhydrogen. Untuk mendapatkan gas hidrogen ditambahkan katalis NaOH dengan variasi konsentrasi 0,1 M, 0,2 M, 0,3 M, 0,4 M, dan 0,5 M dengan waktu elektrolisis selama 5 menit. Tujuan penambahan katalis NaOH yaitu untuk menentukan konsentrasi optimum terbentuknya gas hidrogen. Dari hasil penelitian dan analisis, diperoleh konsentrasi katalis NaOH terbaik untuk mendapatkan gas hidrogen yaitu konsentrasi 0,5 M dengan kandungan hidrogen 346 mg/m^3

Kata Kunci: elektrokoagulasi, energi baru terbarukan, hidrogen, limbah cair terpadu

INTRODUCTION

Globally, rising air pollution from fossil fuels and market insecurity are major concerns. Fossil fuels are a non-renewable energy source that is becoming increasingly scarce. The use of fossil fuels causes air pollution and CO_2 emissions, which can harm the environment and global climate [1, 2]. As a result of this issue, numerous sorts of alternative energy sources are gradually being investigated [3].

Renewable Energy is one of the alternative energies, and one of them is hydrogen, which has extraordinary potential if maximized [4], making hydrogen a promising renewable energy [5-7]. This is due to the fact that hydrogen sources are numerous, offer high chemical energy, and are free of air [8-10]. The use of hydrogen gas as a fuel source produces no pollutants such as dust, nitrogen oxides, sulfur oxides, hydrocarbons, or carbon monoxide [11-13]. The raw material for water used to make hydrogen gas can be derived from liquid waste that has already been processed to become clean water. Environmental pollution sources, particularly water pollution in Indonesia's major cities, can be minimized [14-17].

The problem of environmental contamination, particularly the problem of water pollution in Indonesia's major cities, has manifested itself in rather alarming symptoms. Pollution is caused not only by industrial waste from factories and health care facilities that dump their waste water into rivers or the sea without first treating it, but also by the community itself, specifically water. The volume of household garbage is rising day by day as a result of population expansion and city development [18-21]. The mixture of various liquids, water, or trash is referred to as integrated liquid waste [22, 23].

Currently, there has been a lot of study on converting Oxyhydrogen (HHO) into fuel cells by processing existing trash, both home and non-domestic waste. Many researchers who worked on the conversion of Oxyhydrogen (HHO) into fuel cells [24, 25]. However, no one has treated liquid waste in an integrated manner by combining multiple forms of trash in one procedure. As a result, past researchers' experiments and tests on the characterization of integrated wastewater processing are required to analyze the process [26, 27]. The aim of this research is to see the effect of voltage on reaction time with variations in NaOH catalyst concentration on the production of hydrogen gas from integrated wastewater can be seen in the production process of Oxyhydrogen (HHO) into Fuel Cells, and it can be seen that the optimum voltage and catalyst concentration in the hydrogen gas production process [28-30].

MATERIALS AND METHODS

Materials

In this investigation, the following materials were used: integrated wastewater, filter granular active carbon, cartridge black carbon, filter carbon, filter silica, chemical substances such as sodium hydroxide (NaOH) as a catalyst (Merck, pellets pure), and distilled water.

Methods

This study was carried out in order to extract hydrogen gas from integrated wastewater. Using an electrocoagulator, this integrated wastewater will first be treated into clean water. The integrated wastewater is collected in the feed tank, and the pump is activated to direct the waste to the carbon and silica filters, as well as the electrocoagulation tank. When the electrode is turned on and the voltage for the electrocoagulation process is established, the electric current is automatically read [31, 32].

After the electrocoagulation process is finished, the electrode is turned off, and the tap on the electrocoagulation tank is opened to accommodate the waste in the settling tank, with pump 2 turned on to drain the waste from the settling tank to the granular active carbon filter, cartridge block carbon (CTO), and reverse osmosis (RO) to the product tank. **Figure** 1 shows the electrocoagulator.

Figure 1. Electrocoagulator

The oxyhydrogen (HHO) reactor will be fed with clean water derived from the electrocoagulation process. Before being delivered to the device, this clean water will be treated with a sodium hydroxide (NaOH) catalyst in order to speed up the electrolysis

reaction process that produces hydrogen gas. Variables such as catalyst concentration (NaOH) are changed when producing hydrogen gas from integrated wastewater in an oxyhydrogen reactor. A total of 6 liters of feed water from integrated wastewater processing was added with NaOH at each concentration without catalyst, 0.1 M, 0.2 M, 0.3 M, 0.4 M, and 0.5 M, and entered the tool oxyhydrogen reactor through a pipe at the back of the device where previously the tap on the gas flow and the pipe were opened. When all of the feed is in the reactor, the tap is closed and a holding bag is installed to retain the gas produced. The electrode is activated at the same time as the stopwatch, the measured electric current is recorded, and the pressure measurement is read and recorded. Leave the valve open until the reservoir bag is full with gas. **Figure** 2 depicts the HHO Cell Reactor [33].

Figure 2. HHO Cell Reactor

RESULTS AND DISCUSSION

Analysis of pollutant removal after electro-coagulation process

The electrocoagulation process is a hybrid of an electrochemical and a coagulation-flocculation process, in which electrocoagulation can neutralize particle and ion charges to precipitate contaminants, achieve lower concentrations than chemical precipitation, and replace and/or reduce the use of expensive chemicals (metal salts, polymers). The electrocoagulation apparatus consists of a tank with four electrodes that face each other between the cathode and anode poles. The electrodes utilized are composed of aluminum and are powered by a 12 Volt electric current with a reaction time of 30 minutes. **Table** 1 shows data on wastewater test results before and after processing with an assessed electrocoagulation instrument.

Table 1 shows that the value of pollutants in the wastewater decreased after the electrocoagulation process was completed. This is because the electrocoagulation process neutralizes the charges of particles and ions, allowing them to precipitate the contaminants in the wastewater. However, after going through the process, the pH parameter (acidity level) increased rather than decreased. The pH of the integrated liquid waste changed during the electrocoagulation process, with an initial pH assay ranging from 3.81 to 4. The water electrolysis process, which created hydrogen gas and hydroxide ions, caused the pH shift. The greater the contact period, the faster hydrogen gas and hydroxide ions develop. The pH value rises as more hydroxide ions are created [34].

Tabel 1. Results Data Before and After Integrated Wastewater Treatment

No	Parameter/unit	Before	After
1	Smell -	Smells	Odorless
2	Color Scale TCU	76	6
3	pH -	3.81	4
4	TDS mg/L	714	430
5	TSS mg/L	38.5	18.0
6	Conductivity/µS	89.34	76.01
7	Turbidity/NTU	92	1.52
8	BOD mg/L	6.83	2.71
9	COD mg/L	20	9
10	PO_4 mg/L	0.029	0.015
12	Pb mg/L	<0.0045	<0.0045
13	Cr mg/L	1.29	0.03

The electrocoagulation process used in integrated liquid waste processing transforms the color of the waste from hazy white to somewhat clear or even translucent. As seen in **Table** 1, there is a decrease in turbidity (level of turbidity). The presence of metal ions causes the color of integrated liquid effluent. Integrated liquid waste that has been electrocoagulated but still has a slightly cloudy color indicates the presence of other heavy metals, including total Cr, Pb, and organic substances in waste water, *jumputan* dyes, because these compounds cannot be precipitated because their positive properties are the same as colloids from wastewater. However, the output of this method is clear in color, as evidenced by the lower amount of heavy metals such as Cr (chromium), Pb (lead), and PO_4 (phosphate), as shown in **Table** 1. The Cr value, which was initially 1.29 mg/L, has fallen to 0.3 mg/L, and the PO_4 value has decreased to 0.015 mg/L from 0.029 mg/L, but the analysis of the lead content in integrated liquid waste was unreadable due to the high lead content in waste water. 0.0045 mg/L is

a very small amount. **Figure** 3 show wastewater before and after the electrocoagulation process.

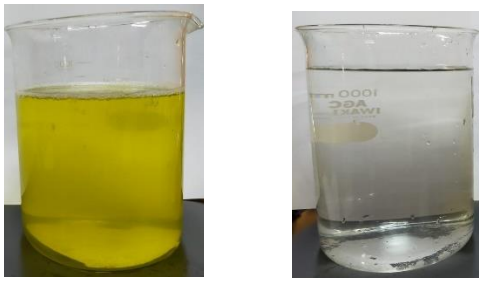

Figure 3. Wastewater before and after electocoagulation process.

The integrated wastewater processing process causes the reduction in Chemical Oxygen Demand (COD) in integrated wastewater because organic material molecules are destabilized by coagulants and the electric field in the solution during the process. The physical links between organic molecules will be disrupted, allowing these molecules to be absorbed by the coagulant flocs and subsequently settle once a sufficient weight is reached. The presence of hydrogen and oxygen gases created during the process induces flotation of some of the dissolved organic and other dissolved materials, including hydroxide floc, which collects part of the organic waste that does not deposit on the cathode rod. Floating flocs will settle only when they have gained enough weight.

The high current and voltage applied during the liquid waste processing process reduces Total Suspended Solid (TSS) in integrated liquid waste because the high current and voltage generate flocs that can bind pollutants in the waste. Some of the ensuing flocs will settle, while others may float to the surface of the water with gas bubbles. TSS is a contaminant that is suspended in the environment. If a substance is hanging, it is in solid form and has a specific size. TDS, on the other hand, is a solid dissolved in solution, either in the form of organic or inorganic compounds.

The reduction in Total Dissolve Solid (TDS) value from 714 mg/L to 430 mg/L led the conductivity value to fall from 89.34 Ms to 76.01 µS. This is because raising TDS increases water conductivity since water conductivity is dependent on the amount of non-organic material ions and dissolved salts. Because the TDS value has reduced, the conductivity value will likewise decrease [35]. The weakness of the electrocoagulation process in processing wastewater lies in the use of electrodes where electrodes that have been used must often be washed or rinsed for subsequent use.

Relationship between catalyst concentration and measured electric current

Based on data from trials using an Oxyhydrogen (HHO) Cell Reactor at a voltage of 12.2 volts, it will produce an electric current that flows differently in each variation. This is because the higher the concentration of catalyst added, the stronger the electric current will flow, because a higher percentage of catalyst can reduce resistance in the electrolyte, so that electron transfer can be faster in electrolyzing the electrolyte. This is proven in **Figure** 4.

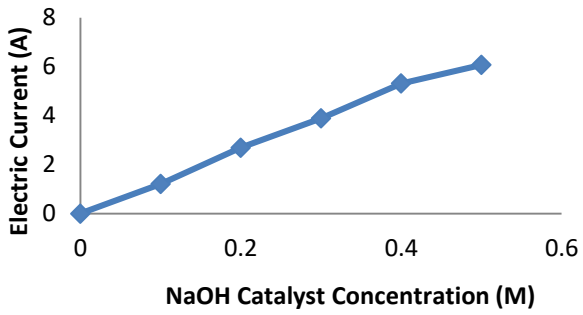

Figure 4. The effect of catalyst concentration on the measured electric current

Figure 4 indicates that a higher catalyst concentration generates more electron transfer during electrolysis, increasing the rate of hydrogen gas generation, as evidenced by the larger current magnitude. Based on the data collected, it can be seen that with a higher concentration of the electrolyte solution, there are more reactants, resulting in more electron charge transfer and a higher electric current, resulting in a higher power produced because power is directly proportional to current. According to the graph above, the effect of catalyst concentration on power produced is as follows: the higher the catalyst concentration, the easier it is to transfer electrons during the electrolysis process, causing more electron charge to react, the higher the current produced, and the lower the resulting power. Large amounts of oxyhydrogen gas (HHO) are generated.

The percentage of catalyst and electron transport are proportional. Sample 6 produced the highest hydrogen gas flow rate of 6.0553 ml/second due to the addition of the highest catalyst concentration of the 6 variations tested, namely 0.5 M NaOH, while samples without a catalyst produced no electric current, so no electron transfer occurred during the electrolysis process, and thus no oxyhydrogen gas was produced. This is due to the fact that the inclusion of a catalyst increases the electrolyte characteristics of the water used to feed the HHO Cell Reactor, resulting in improved electrical conductivity, indicating that feed

water without a catalyst is not an electrolyte. The varying concentrations induce different electric currents in each sample, increasing the amount of hydrogen gas produced. Figure 3 demonstrates that the higher the concentration of catalyst added to the input water, the higher the flow rate of hydrogen gas generation created, which is also connected to the strength of the electric current flowing. Sample 2 with an additional catalyst concentration of 0.1 M and an electric current flowing of 1.21 A with a hydrogen gas production rate of 1.5091 ml/second, and sample 3 with an added catalyst concentration of 0. The higher the size, 0.2 M, the greater the electric current running through it, 2.69 A, and the rate of hydrogen gas generation increases by 3.3707 ml/second.

Effect of catalyst concentration on the purity of oxyhydrogen gas (HHO) produced

The NaOH catalyst facilitates the process of breaking down water into hydrogen and oxygen because the catalyst ions can influence the stability of water molecules into H^+ and OH^- ions, which are easier to electrolyze due to a decrease in activation energy, and also improve the electrolyte properties of the feed water. **Figure** 5 depicts the influence of catalyst concentration on the purity of hydrogen gas.

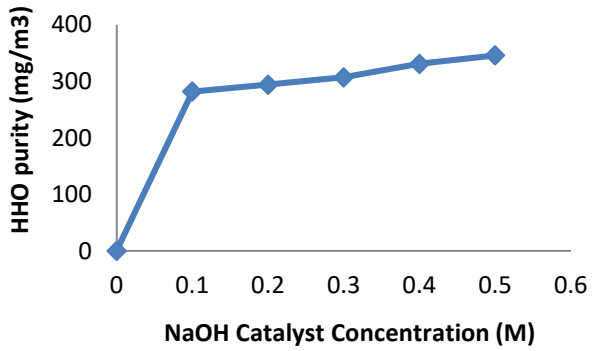

Figure 5. Effect of Catalyst Concentration on the Purity of Oxyhydrogen Gas (HHO) Produced

Figure 5 illustrates the influence of catalyst concentration on the purity of the oxyhydrogen gas (HHO) generated. The graph indicates that the generation of hydrogen gas rises with increasing NaOH catalyst concentration. Because there is no strong current flowing in sample 1 without catalyst concentration, there is no electron transfer in the electrolysis process, which is the process of breaking down water compounds into hydrogen and oxygen gas using an electric current through the water. However, oxyhydrogen gas (HHO) is created during the electrolysis process in samples 2 to 6, with purity levels ranging from 282 mg/m^3 to 346 mg/m^3. Sample 6 had the highest amount of hydrogen gas purity of all the changes in catalyst concentration applied, with a NaOH catalyst concentration of 0.5 M and a hydrogen gas generated of 346 mg/m^3 while sample 6 had the highest concentration of catalyst used. The addition of NaOH to water electrolysis acts as a catalyst, increasing the generation of HHO gas because the higher the concentration of the catalyst, the lower the resistance in the electrolyte. So that electron transport may more swiftly electrolyze the electrolyte, and so the electrolysis process at the electrode proceeds more smoothly in the creation of hydrogen gas. Hydrogen production efficiency can reach until 60% using the HHO Cell Reactor.

CONCLUSION

The research results indicate that when the greatest catalyst concentration of 0.5 M NaOH is used, the observed electric current is 6.07 A. The higher the catalyst concentration, the higher the observed electric current, the more electron transfer happens, and hence the rate of oxyhydrogen gas generation increases. The hydrogen gas generated is 346 mg/m^3 at the optimal condition of the NaOH catalyst concentration supplied at a concentration of 0.5 M.

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