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Hydrogen Production by Electrolysis of Wastewater: An Experimental Analysis

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A B S T R A C T :

They can lower greenhouse gas emissions and become energy self-sufficient by storing hydrogen from renewable sources for a sustainable future. This cost comparison highlights the significance of renewable energy sources by contrasting them with diesel over the next 20 years. We can determine the ideal location by determining when wastewater is easily accessible and power is needed to run the equipment or vehicle. Since fossil fuels are running out owing to geopolitics and depletion levels, alternative fuels are being examined in addition to geopolitics. This article describes an experimental analysis that used aluminum foil and electrolysis to extract hydrogen from mine water. The hydrogen concentration was monitored in 500 units every 10 minutes.ml of water over a period of 180 minutes. After 3 hours at 24 V, it observes 15 grams of hydrogen and 34 grams at 54 V. In second experiment we used aluminium foil, which acted as a catalyst for the reaction. In every 10 minutes for 180 minutes, hydrogen is produced with a chemical process (NaOH and Al) using 27V and 54V. It represents the hydrogen generation from electrolysis process with 27Vand 54V after 3 hour 52 gm and 90gm respectively. Possible - Researchers found a cheap and easy way to make hydrogen from aluminium foil and sodium hydroxide. Aluminium foil and sodium hydroxide can make hydrogen with little energy and cost, according to a study. Hydrogen can be made This research can help make a better and greener energy system, using less oil and gas and less harming the environment.

Keywords: Green hydrogen, Fossil fuels, Wastewater, Hydrogen, Mine water, Electrolysis

1. Introduction

They can lower greenhouse gas emissions and become energy self-sufficient by storing hydrogen from renewable sources for a sustainable future. This cost comparison highlights the significance of renewable energy sources by contrasting them with diesel over the next 20 years. We can determine the ideal location by determining when wastewater is easily accessible and power is needed to run the equipment or vehicle. Since fossil fuels are running out owing to geopolitics and depletion levels, alternative fuels are being examined in addition to geopolitics. This article describes an experimental analysis that used aluminum foil and electrolysis to extract hydrogen from mine water. The hydrogen concentration was monitored in 500 units every 10 minutes.[1-3]. In addition, hydrogen has the highest specific energy of any conventional fuel and is a plentiful element in pure form on Earth. The ability to generate hydrogen from a range of primary energy sources, such as solar, wind, biomass, coal, and nuclear energy, is another benefit. [4]. India follows by the Paris Agreement, which calls for it to cut emissions to net zero by 2070 and raise GDP emissions intensity by 33–35% by 2030 relative to 2005 levels. [2]. Without decarbonizing the mining industry, it is not possible. For the production of electrical batteries for mobile devices, the alternative fuel source of electrical energy requires the mineral resources lithium and cobalt. Due to battery limits, the vehicle's weight increases and carbon emissions are limited. [3]. Therefore, hydrogen is the ideal substitute to reduce carbon emissions. The Union Cabinet started the national hydrogen mission on January 4, 2021. [4]. Future plans to manufacture green hydrogen have been being developed by state-run companies such as Indian Oil Corporations Ltd, NTPC Ltd, and GAIL India Ltd, as well as private companies such as Reliance Ltd, Adani Group, and Larsen & Turbo Ltd. Currently, about 48% of H2 is produced via steam methane reforming (SMR), with the remaining 48% coming from partial oxidation and coal gasification, both of which are chemical processes. Just 4% of hydrogen is created by other processes besides electrolysis. [4]. Researchers have been studying hydrogen fuel as a possible future energy source for the past few years. [5].

Sea level rise has about tripled over the past century as a result of 0.8°C global warming. [1]. The majority of countries rely on environmentally damaging and inefficient fossil fuel-based processes, and the demand for energy is constantly rising [2]. The increase of greenhouse gases is the main cause of climate change. Sea level rise is causing significant hardship for many nations worldwide, particularly island regions. [1, 2]. It can be produced using any primary energy source, with renewable energy being the most appealing, and emits virtually no pollutants other than water. Currently, only 4% of the hydrogen produced worldwide comes from water electrolysis. [2].

Table 1 Various types of hydrogen

Grey Hydrogen	Blue Hydrogen	Green Hydrogen
Process: SMR or Gasification **Source:** Methane or Coal	**Process:** SMR or Gasification with CCS of 80-90% **Source:** Methane or Coal	**Process:** Electrolysis with emission of water vapour **Source:** Renewable energy (Electrical Energy)

As emissions regulations in Table 1 are driven by decarbonization targets, green hydrogen has a great deal of potential to contribute to the decarbonization of the mining industry in the years to come. The green hydrogen obtained by electrolyzing water to separate the hydrogen from it using renewable energy sources [2]. Currently, hardly 0.1% of the worldwide hydrogen market is made up of green hydrogen [6]. Nevertheless, these techniques can be costly and energy-intensive. [7]. Therefore, it can be used as a source to produce hydrogen gas by employing two distinct methods of hydrogen generation: (i) electrolysis at two different power supply voltages, and (ii) using aluminum foil and sodium hydroxide (NaOH) as a catalyst to increase hydrogen emission, which may be a more affordable and accessible option. Therefore Since India complies with the Paris Agreement to minimize its emissions, the attention shifts to green hydrogen since it only releases water vapor when it burns [9, 10].

2. Hydrogen Generation Over potential

Adsorbed hydrogen generation is a commonly acknowledged step in the hydrogen evolution reaction process, as illustrated in Figure 1 [15]

$$H^+ + e^- \rightarrow H_{ads}$$

After that, either chemical desorption or

$$2H_{ads} \rightarrow H_2$$

Regarding electrochemical desorption

$$H^+ + e^- + H_{ads} \rightarrow H_2$$

Adsorbed status is shown by the subscript advertising. The Tafel equation is typically used to measure the excess potential of hydrogen.

$$\eta_{cathode} = 2.3\frac{RT}{\alpha F}\log\frac{i}{i_0}$$

The exchange current density of the reaction, or the rate constant of the reaction, depends on the type of electrode (cathode) material in this equation.

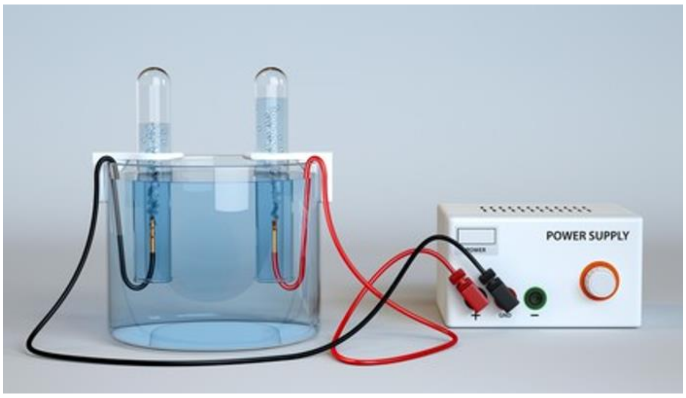

Figure 1. Electrolysis process of water

3. Research Methodology

The following procedures, which are depicted in Figure 2, are involved in producing hydrogen from wastewater. This project's objective was to turn wastewater collected in Satna, Madhya Pradesh, into hydrogen. Water quality is a key factor affecting how well electrolysis-based hydrogen generation works. For optimal electrolysis performance, the AWWA standard values for the water quality characteristics given below are often recommended [9].

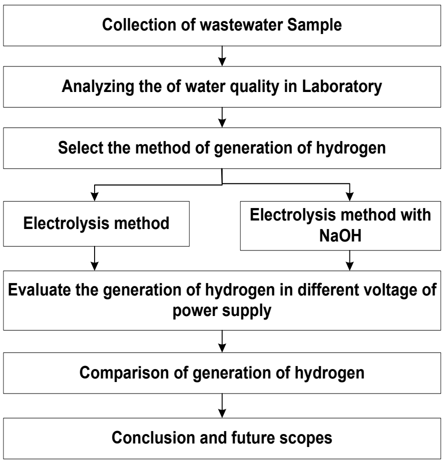

Figure 2. Flow diagram for the suggested approach

A conductivity of less than 20 micro-Siemens per centimeter (µS/cm) is recommended for water used in electrolysis. Increased energy consumption and decreased efficiency are some outcomes of elevated conductivity levels. If the pH is too low, the electrolysis process can be less successful and generate less hydrogen. Electrolysis water should contain fewer than 500 parts per million (ppm) of total dissolved solids (TDS). Increased TDS levels may cause impurities, corrosion, and electrode fouling, all of which could reduce the effectiveness of the electrolysis process. Water used in electrolysis must have an alkalinity level of less than 200 parts per million. elevated levels of alkalinity Elevated alkalinity levels can cause the electrode surfaces to scale and foul, which reduces efficiency. The hardness of the water used in electrolysis should be less than 100 parts per million. Due to scaling and fouling of the electrode surfaces, high hardness levels might decrease efficiency.

Figure 3. Wastewater

Figure 4. Wastewater sample collection

4. Water Quality Analysis of Collected Water Sample

Increased hardness levels can cause the electrode surfaces to scale and foul, which lowers efficiency. The IS 3025 standard was created by the Bureau of Indian Standards to serve as a reference for water and wastewater sampling and testing in India. It covers a range of biological, chemical, and physical factors and offers guidelines for different tests and analysis to ensure reliable and consistent results. Based on the provided data, all reported measures (hardness, alkalinity, pH, TDS, conductivity, and pH) meet the standards. Table 1 displays the range of reported concentrations.

Table 1. Water quality of collected water sample of coal mine

Water quality Parameter	Permissible limit per AWWA	Concentration reports
pH	6.5 to 8.5	6.0
Total Dissolved Solids	500	784
Conductivity	<20 (µS/cm)	28
Alkalinity	200 ppm	300
Hardness	100 ppm	135

5. Necessity of Sodium Hydroxide in Generation of Hydrogen by Aluminium Foil

Due to its function as a reactant in the chemical reaction that takes place, sodium hydroxide (NaOH) is an essential component in the production of hydrogen by aluminum foil. This process creates hydrogen gas (H_2) and aluminum hydroxide (Al $(OH)_3$) when aluminum (Al) and sodium hydroxide react with water. The reaction's balanced chemical equation:

$$2Al + 2NaOH + 6H_2O \rightarrow 2Na\,[Al\,(OH)_4] + 3H_2$$

By supplying the hydroxide (OH-) ions needed for the reaction to begin, sodium hydroxide is required to start the reaction. Aluminum hydroxide and hydrogen gas are the products of the reaction between the hydroxide ions and the aluminum. Sodium hydroxide also acts as a catalyst in this process by promoting the electron transfer from the aluminum to the hydrogen ions. This makes it possible to manufacture hydrogen gas more effectively.

6. Results and Discussion

As seen in Figure 5, the experiment's findings examined the possibility of producing hydrogen from mine water by employing an electrolysis procedure at two distinct voltages and ambient temperatures.

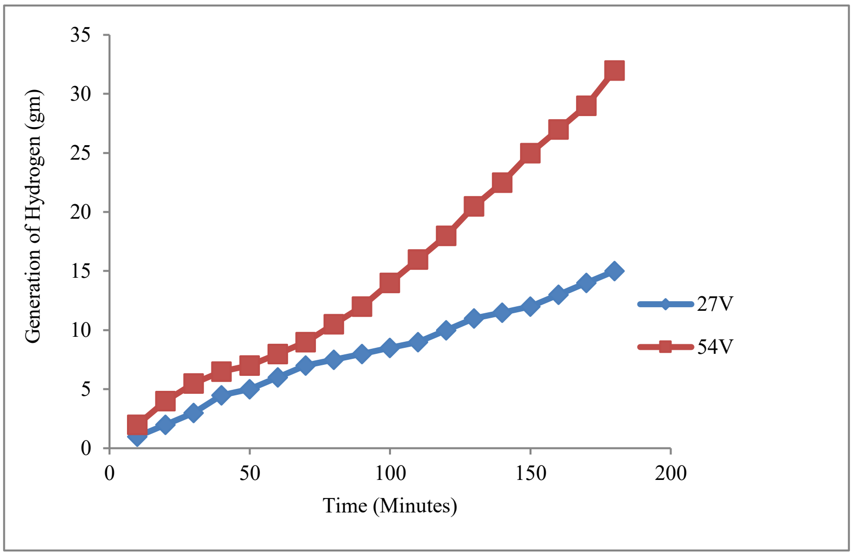

Figure 5. Hydrogen production as a function of time at 27V and 54V

During the 180-minute experiment, which involved measuring the hydrogen every ten minutes, 500 milliliters of water were used. After three hours at 24 V, it shows that there is 15 g of hydrogen and 34 g at 54 V. In the second experiment, we altered the pH of the water by adding NaOH. To alter the pH of the water in the second experiment, we added NaOH. The experiment's findings demonstrated that as pH levels rose, so did the amount of hydrogen gas produced. At pH 14 and 80°C, the greatest rate of hydrogen generation was noted. Because water molecules tend to dissociate more readily and release more hydrogen ions at higher pH values, this is the case. Likewise, as the temperature rises, more water molecules ionize, increasing the rate at which hydrogen is produced. The outcomes showed that aluminum foil worked very well as a catalyst to produce hydrogen from mine water. By taking electrons from the water molecules, the aluminum foil functioned as a reducing agent, encouraging the creation of hydrogen gas.

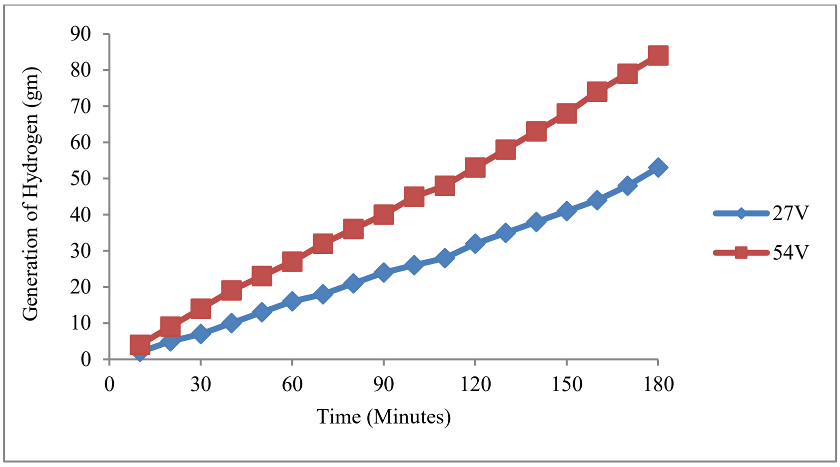

Figure 6. Hydrogen production and time at 27 and 54 volts using NaOH foil as a catalyst

As a catalyst for the process, the thin oxide layer that formed on the aluminum foil's surface made this reaction possible. Figure 4.3 illustrates the 180-minute hydrogen production process using a chemical process (NaOH and Al) and 27V and 54V every 10 minutes. It illustrates how 27V and 54V electrolysis produces 52 g and 90 g of hydrogen after three hours, respectively. It is evident that the amount of hydrogen generated grew as power and pH levels.

7. Conclusion

According to the results of experiments, hydrogen can be produced by electrolyzing mine water and then adding aluminum foil. The findings demonstrated that when temperature and pH levels rose, so did the amount of hydrogen gas produced. If effectively expanded, this approach offered a sustainable and economical energy source while also making a substantial contribution to lessening the environmental impact. According to the study's findings, creating hydrogen gas from wastewater by employing aluminum foil as a catalyst can be an economical and environmentally friendly process. In sewage areas with high water levels and a need for an environmentally safe and sustainable energy source, this technique is especially helpful. It should be mentioned that even though the current study was carried out on a modest scale, more investigation is required to ascertain whether it can be scaled up to industrial levels.

7. Future Scope

There are numerous potential future applications for the project on producing hydrogen from waste water using aluminum foil. Here are some recommendations:

- **Process scaling:** Although the current study is being carried out on a modest scale, commercialization is a possibility. The technology can be scaled up to produce hydrogen on a greater scale with more research.
- **Investigating alternative water sources:** The current study concentrated on producing hydrogen from wastewater. It would be intriguing to investigate alternative water sources, though, as brackish water, wastewater, and seawater can all be utilized to produce hydrogen.
- **Enhancing process efficiency:** By maximizing the aluminum concentration and water usage, the process's efficiency can be increased. The hydrogen yield can also be raised by optimizing additional variables like temperature, pH, and reaction time.
- **Examining the process's economic feasibility:** To ascertain whether the method can be commercialized, its economic viability must be examined. It is necessary to include the cost of producing and storing hydrogen in addition to the cost of water, aluminum, and other reagents.
- **Investigating the uses of hydrogen:** The produced hydrogen has a variety of uses, including as power generation, fuel cells, and transportation. To investigate these possible uses, more research can be done.
- **Environmental Implications:** The environmental effects of producing hydrogen from aluminum foil and mine water must be assessed. It is possible to evaluate the project's environmental implications and take steps to reduce any negative effects.

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