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Electrolysis Analysis of Sewage Water for the Generation of Hydrogen: A Clean Source of Energy

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ABSTRACT :

To reduce greenhouse gas emissions used hydrogen from renewable sources and storing it for a sustainable future will help them become self-sufficient in the energy sector. Fuel cells, electrolyzes, and renewable energy sources are used in a cost-effective manner to manufacture hydrogen compared to existing other power generation. This cost comparison illustrates the importance of renewable energy sources for a sustainable future when compared to diesel for the next 20 years. As a result, we identify the best suitable location when waste water is readily available and power requirements to operate the machinery or vehicle. In sewage water, the availability of waste water in suitable place to generation of hydrogen and minimized the pollution of particular area. In addition, the demand for fossil fuels has increased due to geopolitics, and the depletion levels of fossil fuels have led to consideration of alternative fuel sources. In this article an experimental analysis was performed to produce hydrogen from mine water using electrolysis process and by using aluminium foil. The experiment was conducted on 500 ml of water, with time duration of 180 minutes and measure the hydrogen for every 10 minutes. It observes that the amount of hydrogen after 3 hour at 24 V is 15 gm and at 54V is 34 gm. In second experiment we used aluminium foil, which acted as a catalyst for the reaction. The hydrogen production with chemical process (NaOH and Al) ant 27V and 54V in every 10 minutes duration 180 minutes. It represents the hydrogen generation from electrolysis process with 27Vand 54V after 3 hour 52 gm and 90gm respectively. A study concludes that aluminium foil and sodium hydroxide can provide a low-cost, low-energy hydrogen production solution by using aluminium foil and sodium hydroxide. The results of this research can contribute to the development of a sustainable and clean energy system, reducing the dependence on fossil fuels and mitigating the environmental impact of energy production.

Keywords: Carbon emissions, Fossil fuels, Hydrogen, Mine water, Electrolysis

Introduction :

The energy demand continuously increasing and the majority of nations rely on fossil fuel-based processes, which are inefficient and harmful to the environment [1]. Over the twentieth century, sea level rise has roughly tripled due to global warming of 0.8°C [2]. Climate change is primarily caused by the rise in greenhouse gases. Several countries, especially island areas, are suffering a lot due to sea level rise all over the world [1, 2]. In order to meet these demands, alternative, sustainable and clean energy sources like solar, wind, hydraulic, and green hydrogen are becoming more and more popular [3]. Hydrogen as an important energy carrier has wide applications and great potentials. With ever increasing energy costs and concerns with climate change associated with carbon dioxide emissions from the use of fossil fuels, hydrogen has in recent years become very popular as it is perceived as a clean fuel that emits almost no pollutants other than water and can be produced using any primary energy sources, with renewable energy being most attractive. Presently water electrolysis represents only 4% of the world hydrogen production [2].

In this context, hydrogen energy, which is considered a future energy source that plays a key role to reduce greenhouse gases emissions and energy storage problems significantly [3]. Moreover, hydrogen is an abundant element on earth, in pure form, and has the highest specific energy of any conventional fuel. Additionally, hydrogen has the advantage of being produced from a variety of primary energy sources, including solar, wind, biomass, coal, and nuclear energy [4]. India complies with Paris agreement to reduce its emissions by net zero by 2070, and increasing the GDP emissions intensity by 33-35% by 2030 compared to 2005 levels [2]. It is not feasible without decarbonization of mining sector. The electrical energy is alternative fuel source which needs lithium and cobalt mineral resources for manufacturing of electrical batteries for mobile equipment. The limitations of batteries emit the carbon limited power and increase the weight of the vehicle [3]. Hence the hydrogen is a best alternative to minimize the emission of carbon. The national hydrogen mission has been launched by union cabinet on 4th January 2021 [4]. In order to produce green hydrogen in the future, businesses like Reliance Ltd, Adani Group, Larsen & Turbo Ltd, and state-run firms like Indian Oil Corporations Ltd, NTPC Ltd, and GAIL India Ltd have been developing plans. Presently, steam methane reforming (SMR) generates almost 48% of H2, while partial oxidation and coal gasification generate the remaining 48%, both processes based on chemical processes. In addition to electrolysis, only 4% of hydrogen is produced by other methods [4]. During the past few years, researchers have been researching hydrogen fuel as a potential future energy carrier [5]. Green hydrogen has a significant potential to play a significant role in decarbonizing the mining industry in the coming years as decarbonization targets drive emissions regulations. The green hydrogen obtained by electrolyzing water to separate the hydrogen from it using renewable energy sources [2]. The green hydrogen currently only makes up 0.1% of the global hydrogen market. Cost reductions in renewable energy production increase the viability of adopting green hydrogen in mining [6]. However, these methods can be expensive and require significant amounts of energy [7]. Mining industry generates huge amount of waste water, which will be stored in sumps, with very less potential usage [8]. So, it can be used as the source to generate hydrogen gas. The present research work focuses on, conducting two different techniques of the generation of hydrogen using (i) By Using electrolysis process at two different voltage of power supply and (ii) By using aluminium foil and sodium hydroxide (NaOH) as a catalyst to increase the emission of hydrogen that are potentially cheaper and more accessible alternative in coal mines. Hence India complies with Paris agreement to reduce its emissions decarbonization should not emit carbon, so, the focus moves towards the green hydrogen as it emits only water vapor during combustion [9, 10].

2. Hydrogen Generation Over potential :

The mechanism of the hydrogen evolution reaction is widely accepted to be a step involving the formation of adsorbed hydrogen shown in Figure 1 [15]

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

Which is followed by either chemical desorption

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

For electrochemical desorption

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

Where the subscript *ads* represents the adsorbed status. The over potential of hydrogen is generally measured by the Tafel equation

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

In this equation, i_0, the exchange current density of the reaction, which can be analogized as the rate constant of reaction, is a function of the nature of the electrode (cathode) material.

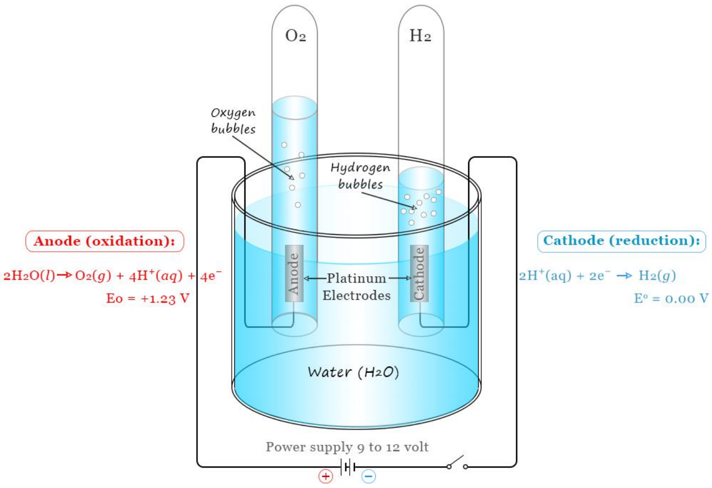


Figure 1. Electrolysis process of water

Research Methodology :

The process of generating hydrogen from mine water involves the following steps shown in Figure 2. This study concentrated on producing hydrogen from sewage water that was gathered from Satna Madhya Pradesh. Water quality is an important factor that affects the efficiency of hydrogen generation through electrolysis. Here are AWWA standard values for water quality parameters that are typically recommended for optimal electrolysis performance [9].

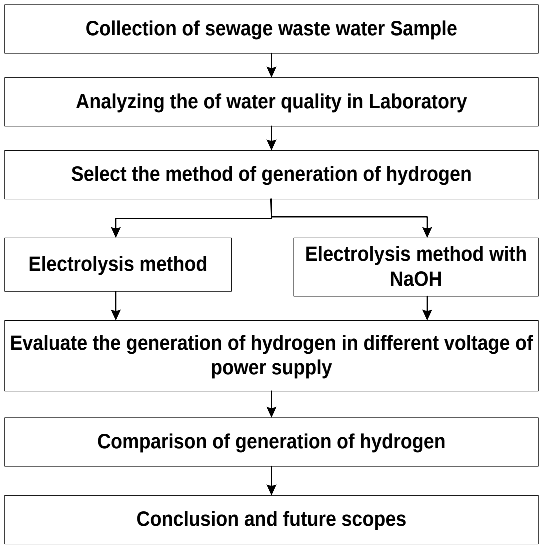


Figure 2. Flow chart of proposed methodology

- **Conductivity -** The recommended conductivity level for water used in electrolysis is less than 20 micro-Siemens per centimeter (µS/cm). Higher conductivity levels can increase energy consumption and reduce efficiency.
- **pH value** - The recommended pH level for water used in electrolysis is between 6.5 and 8.5. If the pH is too low, it can affect the efficiency of the electrolysis process and reduce hydrogen production.
- **Total Dissolved Solids (TDS)** - The recommended TDS level for water used in electrolysis is less than 500 parts per million (ppm). Higher TDS levels can lead to electrode fouling, corrosion, and impurities that can reduce the efficiency of the electrolysis process.
- **Alkalinity** - The recommended alkalinity level for water used in electrolysis is less than 200 ppm. High alkalinity levels can cause scaling and fouling of the electrode surfaces, reducing efficiency.
- **Hardness** - The recommended hardness level for water used in electrolysis is less than 100 ppm. High hardness levels can cause scaling and fouling of the electrode surfaces, reducing efficiency.

4. Water Quality Analysis of Collected Water Sample :

The collected samples are tested by the accurate laboratory tested with the test method IS 3025. The Bureau of Indian Standards developed the IS 3025 standard as a guide for the sampling and testing of water and wastewater in India. It provides instructions for various tests and analyses to guarantee consistent and dependable results and covers a variety of biological, chemical, and physical parameters. All reported metrics (conductivity, pH, TDS, alkalinity, and hardness), according to the data given, are in compliance with the established requirements. The range of reported concentrations is shown in Table 1.

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

Figure 3. Water sample collection

Figure 4. Treatment of water sample

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

Sodium hydroxide (NaOH) is a necessary component in the generation of hydrogen by aluminium foil due to its role as a reactant in the chemical reaction that occurs. In this process, aluminium (Al) reacts with sodium hydroxide in the presence of water to produce hydrogen gas (H_2) and aluminium hydroxide (Al $(OH)_3$). The balanced chemical equation for this reaction:

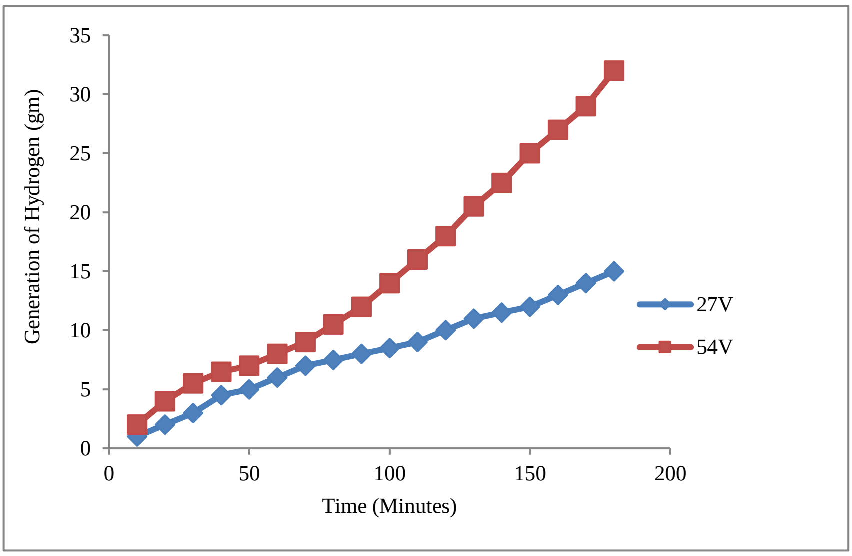
$$2Al + 2NaOH + 6H_2O \rightarrow 2Na\,[Al\,(OH)_4] + 3H_2$$

Sodium hydroxide is necessary to initiate the reaction by providing the hydroxide (OH-) ions required for the reaction to occur. The hydroxide ions react with the aluminium to produce aluminium hydroxide and hydrogen gas. Additionally, sodium hydroxide serves as a catalyst in this reaction, as it facilitates the transfer of electrons from the aluminium to the hydrogen ions. This allows the hydrogen gas to be produced more efficiently. Finally, the sodium hydroxide helps to maintain a basic pH environment, which is necessary for the reaction to occur. The basic environment helps to prevent the aluminium from forming an oxide layer on its surface, which would hinder the reaction. Hence we observed that sodium hydroxide is necessary in the generation of hydrogen by aluminium foil as it provides the hydroxide ions needed for the reaction, serves as a catalyst, and helps to maintain a basic pH environment.

6. Results and Discussion :

The result of the experiment study investigated the potential of hydrogen generation from mine water using electrolysis process at two different voltage in atmospheric temperature shown in Figure 5.

Figure 5. Relationship between hydrogen generation with time at 27V and 54V



The experiment was conducted on 500 ml of water, with time duration of 180 minutes and measure the hydrogen for every 10 minutes. It observes that the amount of Hydrogen after 3 hour at 24 V is 15 gm and at 54V is 34 gm. In the second experiment, we added NaOH to water to change the pH value. The relationship between the amounts NaOH to change the pH value of water shown in Figure 4.2. The result of the experiment shown the production of hydrogen gas increased with increasing pH levels. The highest hydrogen production rate was observed at pH 14 and a temperature of 80°C. This because at higher pH levels, the water molecules tend to dissociate more easily, releasing more hydrogen ions. Similarly, an increase in temperature causes more water molecules to ionize, leading to a higher hydrogen production rate. The results indicated that the use of aluminium foil as a catalyst for hydrogen generation from mine water was highly effective. The aluminium foil acted as a reducing agent, promoting the formation of hydrogen gas by accepting electrons from the water molecules.

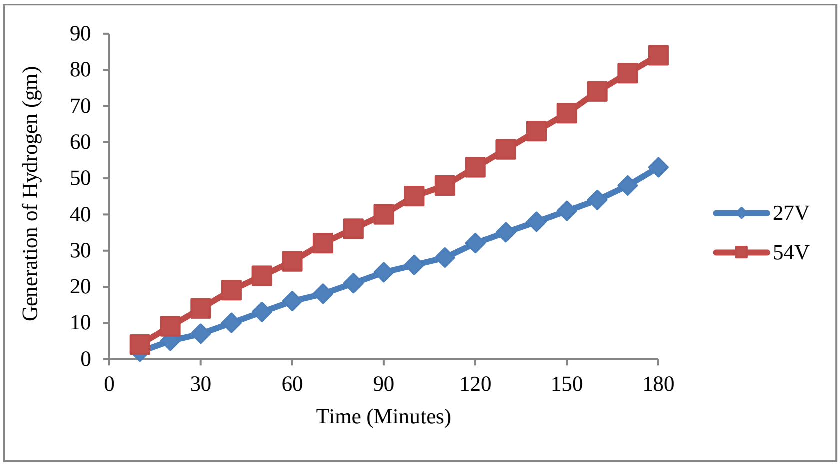


Figure 6. Relationship between hydrogen generation to time at 27V and 54V using NaOH foil as a catalyst

This reaction was facilitated by the formation of a thin oxide layer on the surface of the aluminium foil, which acted as a catalyst for the reaction. The hydrogen production with chemical process (NaOH and Al) ant 27V and 54V in every 10 minutes duration 180 minutes shown in Figure 4.3. It represents the hydrogen generation from electrolysis process with 27Vand 54V after 3 hour 52 gm and 90gm respectively. It clearly shows that with increase in power and high pH value the quantity of hydrogen generation increased.

7. Conclusion :

As a result of experiments, it is observed that electrolysis process of mine water and by adding aluminium foil can be used to generate hydrogen. The results showed that the production of hydrogen gas increased with increasing pH levels and temperature. If successfully scaled up, this method significantly contributed to reducing the environmental impact of while providing a sustainable and cost-effective source of energy. The results of the study suggest that hydrogen generation from waste water using aluminium foil as a catalyst can be a cost-effective and sustainable method for producing hydrogen gas. This method particularly useful in sewage areas where large quantities of water are present, and there is a need for a sustainable and environmentally friendly source of energy. Although the present study was conducted on a small scale, it should be noted that further research is needed in order to determine whether it can be scaled up to industrial levels.

7. Future Scope :

The project on hydrogen generation by aluminium foil from waste water has the potential for several future scopes. Here are a few suggestions:

- **Scaling up the process:** The present research work conducted on a small scale, but it has the potential for commercialization. Further research can be carried out to scale up the process to generate hydrogen on a larger scale.
- **Exploring other water sources**: The present research work focused on using mine water as a source of hydrogen generation. However, it would be interesting to explore other sources of water, such as seawater, wastewater, and brackish water, also can also be used for hydrogen generation.
- **Improving the efficiency of the process:** The efficiency of the process can be improved by optimizing the concentration of aluminium and the amount of water used. Additionally, other factors such as temperature, pH, and reaction time can be optimized to increase the hydrogen yield.
- **Investigating the economic viability:** The economic viability of the process needs to be investigated to determine if it can be commercialized. The cost of aluminium, water, and other reagents, as well as the cost of generating and storing hydrogen, must be taken into account.
- **Exploration of used of hydrogen:** The generated hydrogen can be used for a wide range of applications, including fuel cells, power generation, and transportation. Further research can be conducted to explore these potential applications.

- **Environmental Implications:** The process of generating hydrogen from aluminium foil and mine water needs to be evaluated for its environmental impact. The environmental implications of the project can be assessed, and measures can be taken to minimize any adverse effects

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