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Experimental Analysis of Generation of Hydrogen of Waste Mines Water: An Alternative Source of Energy

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A B S T R A C T

Introducing green hydrogen from renewable sources and storing it for a sustainable future will help them become self-sufficient in the energy sector and reduce the emission greenhouse gases. Fuel cells, electrolyzers, and renewable energy sources are used in a cost-effective manner to manufacture hydrogen compared to existing diesel 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 are high to operate the machinery. In mining industries, the availability of waste water and required more energy to operate the heavy earth moving machinery (HEMM) are the most suitable place for the generation of hydrogen. While HEMM is used to extract minerals from the earth crust, the machinery consumes fuel that increases carbon emissions, which have an adverse effect on the environment. 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. By electrolysis process and by using aluminium foil and sodium hydroxide factors like temperature, pH value, chemical like sodium hydroxide, and aluminium foil. 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

1. 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]. 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 [4]. 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 [3]. 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 decarburization 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 like dumper, truck. The limitations of batteries emit the carbon limited power and increase the weight of the machinery [3]. Hence the hydrogen is a best alternative to minimize the emission of carbon in mines. 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. According to a report by the IEA, 306 million tons of green hydrogen produced from renewable energy will be needed annually to achieve net-zero global emissions by 2050 [5].

A number of different methods can be used to produce hydrogen energy, which can be used as a gas or a liquid, converted into electricity, and used as fuel [6]. Rosenbad and Gany (2010), increasing the amount of hydrogen gas from the water by using aluminium powder and by the size of the particle of aluminium the amount of generation of hydrogen is varied [7]. The reaction starts instantaneously at the room temperature and an experimental installation is used for the measurement of hydrogen by aluminium water reaction and which result in the 100% yield of hydrogen generation and the reaction are independent of the type of water [1]. Kumar et al. (2012) experimental setup was utilizes the chemical reaction between aluminium and water to produce hydrogen by improved using 149-μm aluminium powder [4]. Zhuang et al. (2012) used aluminium, sodium hydroxide, sodium stannate solid mixture and water [8]. Jeyakumar and Das (2012) used treated mine water which consist of copper, silicon, manganese, iron, aluminium and sulphates in which electro coagulation method is used for purification in which iron anode and stain less steel cathode are used inserted in the water media the anode and cathode which absorb the impurities in the mine water [9]. Haryanth (2014) produce hydrogen by electrolysis of water variables that was applied in this work were electric current 0.5 A and 0.9 A and electrolyte additions NaOH and KOH with processing work 30 minutes the result of this work were variations of electric current at 0.9 A and electrolyte NaOH produce more amount of hydrogen [9]. Bilgin (2015) using made use of photovoltaic methods to produce the hydrogen to reduce total production cost [10].

Presently, steam methane reforming (SMR) generates almost 48% of H_2, 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 [11]. 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]. We observed that very few or rare research work was conducted on waste mine to produce hydrogen. Hence in this research work we using waste mine in NCL field to check the quality and suitability of generation of hydrogen using electrolysis process. 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 [12].

2. Methodology

The process of generating hydrogen from mine water involves the following steps shown in Figure 1.

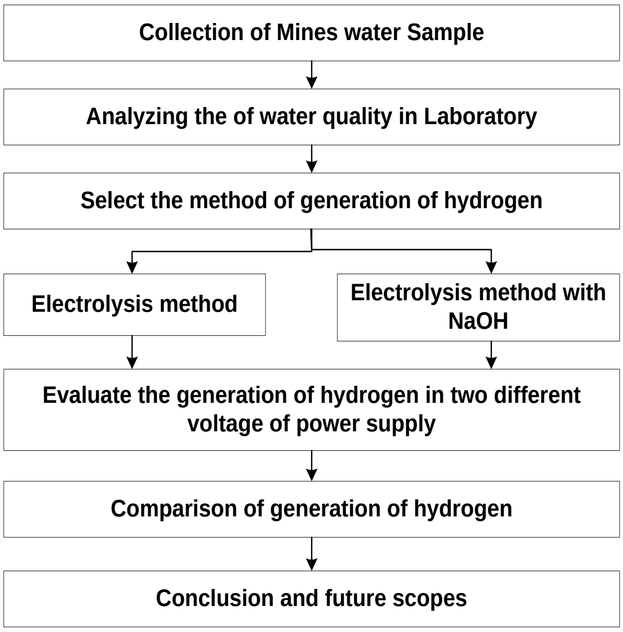

Figure 1: Flowchart of proposed methodology for generation of hydrogen

2.1 Collection of Water Sample

This study concentrated on producing hydrogen from mine water that was gathered from three different place namely Jayant, Amlori, Nigahi Project of Northern coal field Limited (NCL) Singrauli Madhya Pradesh, a subsidiary of Coal India Limited (CIL) shown in Figure 2.

(a) Jayant Project NCL (b) Amlori Project NCL (c) Nigahi Project NCL

Figure 2 Water sample collection of three different NCL mines

2.2 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			
		Amlori Project	Nigahi Project	Jayant Project	Water quality after treatment
pH	6.5 to 8.5	6.0	5.8	5.9	7
Total Dissolved Solids	500	784	780	775	490
Conductivity	<20 (µS/cm)	28	27	26	18
Alkalinity	200 ppm	300	290	295	178
Hardness	100 ppm	135	132	131	84

As per Table 1 the composition and quality of collected mine water is compared to standards required for generation of hydrogen. It is observed the quality of collected water is not within the standards. The first step is to treat mine water to remove impurities and dissolved solids that can affect the efficiency of the electrolysis process. The mine water was collected from Amlori project due to high pH Value. Treatment of coal mine water by filter beds involves the use of a specialized system that removes impurities from the water through physical and chemical processes. Filter beds are typically made up of layers of different materials that work together to remove impurities from the water. The first layer of a filter bed is typically composed of a coarse material such as gravel or crushed stone. This layer helps to remove larger particles and debris from the water through the process of physical filtration. As the water passes through this layer, the larger particles become trapped in the spaces between the rocks and are removed from the water. The second layer of a filter bed is typically composed of a finer material, such as sand or fine gravel. This layer helps to remove smaller particles and impurities from the water through the process of physical and chemical filtration. The finer particles in this layer trap smaller impurities in the water, while the chemical properties of the material help to neutralize and remove dissolved minerals and other contaminants [10]. The treated water is then stored in a tank for further to electrolysis process.

2.3 Generation of Hydrogen through Electrolysis Process

The conversion from water to hydrogen and oxygen in a basic alkaline electrolysis occur by following reactions.

Anode: $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$

Cathode: $4H_2O + 4e^- \rightarrow 2H_2 + 4OH^-$

Electrolyte: 25% KOH 80^0C

Hydrogen will be stored in the storage tank oxygen will be bi-product. Electrolysis is a process shown in Figure 3 that uses an electric current to drive a non-spontaneous chemical reaction. It involves the use of an electrolytic cell, which contains two electrodes (an anode and a cathode) and an electrolyte (a solution containing ions). When a voltage is applied across the electrodes, electrons flow from the anode to the cathode, creating an electrical current.

Figure 3. Model of green hydrogen generator using electrolysis process

In this research work, the 500 ml of water was placed into one container, which tightly sealed with caps made of outlet pipes for collecting generated oxygen and hydrogen from the anode and cathode. The generated gases are then collected, where the amount of hydrogen measured. The Electrolysis process has been tested for two times with DC supply 27 V and 54 V (adding 3 and 6 battery in series) at atmospheric temperature.

$$H_2O(s) + \text{Energy} \longrightarrow H_2\ (g) + O_2\ (g)$$

In equation shown the water is charged with an electrical current during electrolysis, which separates water into its oxygen and hydrogen components [11]. The atomic components of oxygen and hydrogen are separated from the chemical bond (charge splits). The cathode, which is negatively (-) charged, and the anode, which is positively (+) charged, the two poles where the resultant ions originate. At the cathode, hydrogen ions gather and react with it to form hydrogen gas. At the anode, oxygen immediately begins a parallel reaction.

3. Results and Discussion

The result of the experiment study investigated the potential of hydrogen generation from mine water using electrolysis process at two different voltages in atmospheric temperature shown in Figure 4.

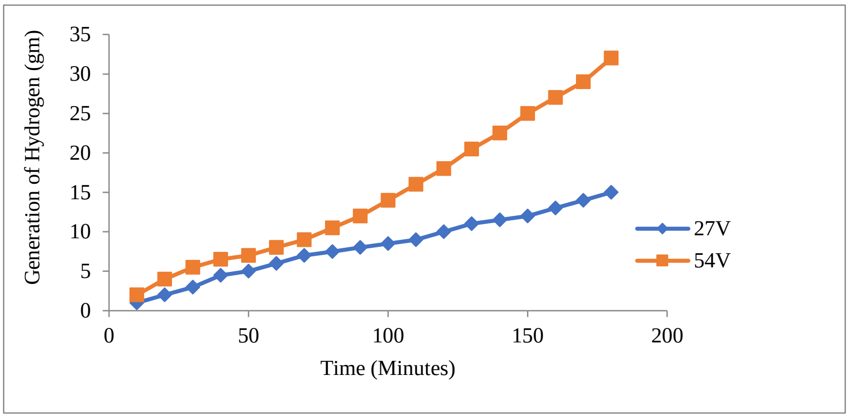

Figure 4. Relationship between hydrogen generation with time at 27V and 54V

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 as shown in Figure 4. In the second experiment, we added NaOH to water to change the pH value. 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.

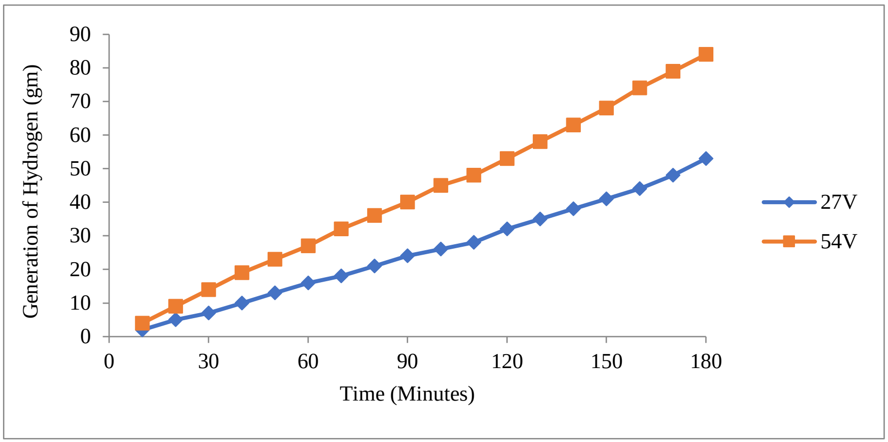

Figure 5. Relationship between hydrogen generation to time at 27V and 54V using NaOH foil as a catalyst

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 5. 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.

4. 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 from mine water. 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 mining activities while providing a sustainable and cost-effective source of energy. The results of the study suggest that hydrogen generation from mine water using aluminium foil as a catalyst can be a cost-effective and sustainable method for producing hydrogen gas. This method particularly useful in mining 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. The project on hydrogen generation by aluminium foil from mine water has the potential for several future scopes to 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 and it is possible to exploring other water sources.

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