

Way to Control Urine Pollution: Application of Urine for Generation of Energy by Using Fuel Cell: A Case Study of Kalyan Station

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Abstract: Anything in the universe is not a waste if we look it in a practical way. Simply saying we can reuse any waste generated in the universe. An urine; a waste can be used for generation of energy¹. Urine contains urea as a major constituent⁴. In this process urea is converted to hydrogen by electrolysis process⁴, which requires voltage of about 0.37 V¹. This produced hydrogen is used in fuel cell to produce the energy¹. Here it has been studied that, this method is more efficient to areas or places where mass amount of urine got collected, that areas or places can be made energy efficient by using this renewable source of energy. This process produces the by-products carbon dioxide and water which are ecofriendly. Thus these areas will be independent for the energy & non renewable energy can be avoid to use. This will contribute to make the green environment.

Key words: Urine, Urea, Electrolysis, hydrogen, fuel cell.

I. INTRODUCTION

All over the world fossil fuels are being exhausted day by day. And because of this we are going for alternate sources of energy like solar, wind, Biomass, geothermal energy etc., but for the generation of energy using these sources high capital cost is required & therefore so many research is going on for production of energy at low cost.

These research gives rise to a new kind of fuel called a future fuel, which is nothing but urine.

Urine is most abandoned waste found on the Earth. Urine contains more than 95% water, urea 9.3 g/L, chloride 1.87 g/L, sodium 1.17 g/L, potassium 0.750 g/L, creatinine 0.670 g/L and other different dissolved ions, inorganic and organic compounds⁵. The valuable constituent of urine other than water is urea, which is an organic source of H, C, O, and N. Despite of numerous benefits of using urea/urine for hydrogen production, there is not a single technology that directly converts urea to hydrogen⁴. Conversion of urea to valuable products before it naturally hydrolyzes to ammonia, which generates gas-phase ammonia emission & forms ammonium sulphate & ammonium nitrate in atmosphere. These gases caused many health issues. This method reduces the use of non renewable sources of energy, also reduces the hazardous effects caused due to the use of non renewable sources of energy. Thus, this method will contribute to make the green environment.

II. METHODOLOGY

The components required for generation of electricity are an electrolytic cell, water filter, an empty gas can, borax and fuel cell³. Urine is placed in the electrolytic cell. Electrolysis of urine releases mixture of hydrogen-oxygen gas. This mixture then passed into the water filter. The water filter removes impurities which might have come with the gas,

and then it passed into an empty gas cylinder which is used to store the hydrogen gas. The gas cylinder pushes hydrogen into a cylinder of liquid borax, where the moisture is removed from the hydrogen gas. Borax act as a drying agent & also helps to remove any impurities come in with the gas. The purified hydrogen gas is then used as fuel in fuel cell to generate the electricity.

The methodology is consists of following stages:

1. ELECTROLYSIS OF URINE:

Urine is the most abandoned waste found on Earth & long with water its major constituent is urea. Urea is a significant organic source of H, C, O & N having chemical formula is: CON_2H_4 or $(\text{NH}_2)_2\text{CO}$. Thus Urea is having four hydrogen atoms per molecule. During the process of electrolysis these molecules gets break down when a Power supply of 22W per gram of hydrogen gas² & a potential difference of 0.37V is applied across the electrolytic cell which is very much less than 1.23V required to break down water⁵.

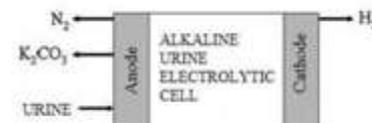


Figure 1: Schematic Representation of direct urea (urine)-to-hydrogen process.

Anode reaction: $\text{CO}(\text{NH}_2)_2 + 6\text{OH}^- \rightarrow \text{N}_2 + 5\text{H}_2\text{O} + \text{CO}_2 + 6\text{e}^-$

Cathode reaction: $6\text{H}_2\text{O} + 6\text{e}^- \rightarrow 3\text{H}_2 + 6\text{OH}^-$

Overall Reaction: $\text{CO}(\text{NH}_2)_2 + \text{H}_2\text{O} \rightarrow \text{N}_2 + 3\text{H}_2 + \text{CO}_2$

During the electrochemical process adsorption of urea takes place on the surface of nickel electrode, which allows the electrons required to break up the molecule. Pure hydrogen is liberated at the cathode, while nitrogen along with traces of oxygen and hydrogen is present at the anode. The carbon dioxide produced during this reaction is not found in the gasses as it reacts with the potassium hydroxide present in the solution to give potassium carbonate, while Nitrogen which is liberated at anode removes as a nitrate from wastewater and thus reduction of water takes place at cathode and hydrogen is produced as the final output^{4,5}.

2. PURIFICATION OF HYDROGEN:

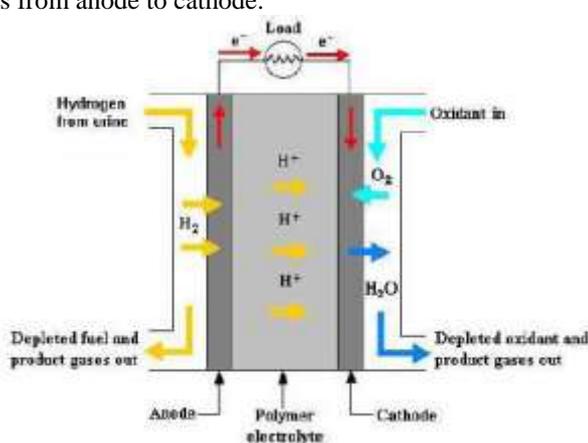
The hydrogen gas mixture from the electrolytic cell then passes into the water filter. The water filter is used to remove any impurities which might have come in with the gas and then it goes into an empty gas cylinder which act as the gas storage. The gas cylinder pushes hydrogen into a cylinder of liquid borax, which removes the moisture from the hydrogen gas. Borax act as a drying agent. Borax, also known as sodium borate, sodium tetra borate, or disodium tetra borate, is an important boron compound, a mineral, and a salt of boric acid. Powdered borax is white, & it consists of soft colorless crystals which gets easily dissolved into water³.

3. GENERATION OF ELECTRICITY USING HYDROGEN:

A fuel cell is an electrochemical device which combines hydrogen and oxygen to generate electricity, heat and water. The hydrogen is obtained from electrolytic cell by hydrolysis of urine. The demand of oxygen is fulfilled from surrounding air. As fuel cell is an electrochemical device & therefore it works without combustion which helps in creating emission free environment. Also the fuel cell does not contain any moving parts & therefore it is a reliable source of electricity, heat and water⁵.

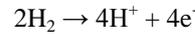
Basically, the fuel cell is a device which consist of two main parts.

1. Electrodes – used for catalyzing the electrochemical reactions
2. Electrolyte – acts as a bridge for the transfer of hydrogen ions from anode to cathode.

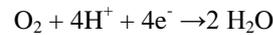


In this case ,PEM – polymer electrode membrane acts as an electrolyte. PEM helps proton to transfer from anode to cathode, but the flow of electrons is not allowed through it. The hydrogen is passed in to the fuel cell & it gets oxidized at the anode (negative electrode) which gives rise to two H⁺ ions (protons) and 2 electrons for every hydrogen molecule. This process is called as electrochemical reaction.

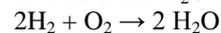
The chemical reactions is as given below:



As there is high resistance for the electrons to flow through PEM, the free electrons follows the least resistant path & thus flows through the load from anode to cathode producing electric current. On the other hand, the protons produced due to oxidation at anode are passed through the Proton Exchange Membrane (also called as Polymer electrolyte membrane) to the cathode side of the fuel cell. Oxygen enters into the fuel cell in large number at the cathode terminal and combines with the hydrogen ions and the electrons to produce water by the reduction reaction as shown below:



In this reaction oxygen acts as oxidizing agent & it gets reduced. In short, hydrogen and oxygen molecules are the reactants and H₂O is the byproduct of the reaction as below:



Fuel cell provides platform for electrochemical reactions and acquires and employs the electrons to generate electricity. This rapid combination of elements also generates heat which indicates that the process is not 100% efficient. The average operating temperature of PEM Fuel cell is about 80°C (176°F)⁵. Theoretically maximum voltage that can be attained from the fuel cell is 1.23 volts⁵. But, it is the ideal electrochemical potential of the reduction half-cell reaction which occurs at the cathode. But because of the internal resistance, diffusion losses, and voltage losses clearly indicate that 1.23Volts can not be attained. Practically the potential difference obtained across the fuel cell is 0.6 – 0.7volts⁵. Thus the efficiency of a typical fuel cell lies in the range of 50-55%⁵.

III. OBSERVATIONS

World population = 7.432 billion⁶

India population = 1,321,146,871⁷

Maharashtra Population = 121,362,092⁸

Voltage required for electrolysis of Urine (Urea) per molecule= **0.37 V**

Voltage required for electrolysis of water per molecule = **1.23 V**

Power required for electrolysis of 2grams of hydrogen = 22W²

Power required for electrolysis of 1grams of hydrogen = 11W

Approx. daily single person urine production =1-2 lit

Let be taken as 1.5lit

So total urine production in Maharashtra = 121,362,092*1.5 = 182043138 lit

Amount of hydrogen produced per litre of urine= **2 grams**

Hence, total potential of hydrogen from urine = 182043138* **0.002** = 364086.28 kg per day

Efficiency of fuel cell is about 50-55 %.

IV. CASE STUDY OF KALYAN STATION

Number of passengers travelling on this station per day = 360,000.⁹

If 50% of the total passengers availing toilet facility = 180,000.

Amount of Urine excreted at one time per person = 200ml.¹⁰

Total amount of urine produced per day = 180,000 * 200ml = 36,000 lit.

As From one litre of urine we can get enough amount of six hours of electricity. That is from one liter of urine we can produce 8.64KW of electricity which is sufficient for house hold purpose¹.

Therefore the Total electricity generated per day will be = 36000 * 8.64KW = 311,040 KW.

MERITS OF THIS METHOD:

1. Fuel cell works with high efficiency of energy.
2. There is no emission of gases & pollutants within permissible limits.
3. I is having low maintenance cost.
4. Fuel cell generators are noise free, vibration free, thermal pollution free etc.
5. Fuel cell systems are modular, & therefore the parts are exchangeable.
6. This system saves fossil fuel.

DEMERITS OF THIS METHOD:

1. Installation cost of this system is high.
2. External source of energy is required for electrolysis process.
3. Hydrogen posses' explosive risk.

CONCLUSION:

It is concluded that, 311,040 KW of electricity is produced by using 36000 lit of urine collected per day. Further it is required to calculate economical feasibility of this process for treatment of urine in mass to understand & implementation of this method for generation of electricity.

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