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Road Transport System Run by Hydrogen as a Fuel Generated through Urine

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Abstract: *One of the main disadvantages of hydrogen fuel cell cars is the way hydrogen is produced. In this paper our main aim is to eliminate this disadvantage of hydrogen fuel cars. We are suggesting the use of human urine collected from various working places like railway stations, airports etc. which is taken to a refilling station. Urine's major constituent is urea. Electrolysis of urea give pure hydrogen. The process needs a voltage of about 0.37V and hydrogen produced is supplied to fuel cell which will convert the hydrogen and oxygen into water and in this way it produces electricity at a voltage of about 1.23V. The efficiency of fuel cell is about 60%. Vehicle is having fuel cell installed which will provide power to run the vehicle. The calculation are performed for the Delhi region and based on the calculations, it can be inferred that this system is more efficient than petrol in terms of cost and also produces waste products like carbon dioxide and water which are eco-friendly. This paper provides a new way to run our cars and an alternative to meet the increasing demand of diesel/petrol. Cost effectiveness of such a vehicle is amusing.*

Key words: *Electrolysis, Fuel cell, hydrogen, electrochemical process.*

1. INTRODUCTION

Urea is the main component of human and livestock urine, as well as a key ingredient of fertilizers. There is, as a result, an abundance of urea-rich wastewater. If this wastewater is left untreated and then discharged into rivers, creeks, and lakes, the urea will naturally hydrolyze into pollutants such as ammonia and nitrates. One way to utilize this waste is hydrolysis. Hydrolysis of urine, having urea as its main constituent, releases pure hydrogen. This hydrogen collected need not require any further purification process. This hydrogen can directly be used in hydrogen fuel cell which can run our vehicle.

Advantages of using hydrogen: Firstly, if used in a car, it would take comparatively less to fill it up than a car running on standard fuel due to the hydrogen fuel cell efficiency. Efficiency of hydrogen is more than that of conventional petrol/diesel engines. Secondly, Hydrogen fuel is exponentially cleaner than its standard fuel competition. Even when combusted in combination with hydrocarbon fuels, it is virtually harmless to the environment, as the only emission produced is water. Another problem of increasing air pollution by exhaust gases is being tackled by using hydrogen as fuel. Also, switching to hydrogen fuel would mean that we had to depend a lot less on foreign oil sources, lessening the need for international importation of fuel. Once the relevant technology has caught up and hydrogen fuel performance is optimum, it will be a hugely practical fuel method for people living in cities, built-up areas and other locations with high pollution or close-proximity constructions. Solutes found in urine may be classified as ions or organic molecules.

Ions are atoms or groups of atoms that have either, lost some outer electrons, hence have a positive electric charge, or have gained some outer electrons (to the atom or group of atoms), and hence have a negative electric charge. Even in the cases of ions formed by groups of atoms (they are ions due to the few lost or gained electrons), the groups are formed from only a small number of particles and therefore tend to be relatively small.

Organic molecules are electrically neutral and can be relatively large (compared with the 'simpler' ions - below). These include:

- *Urea:* Urea is an organic (i.e. carbon-based) compound whose chemical formula is: CON_2H_4 or $(NH_2)_2CO$. It is also known as carbamide. Urea is derived from ammonia and produced by the

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deamination of amino acids. The amount of urea in urine is related to quantity of dietary protein.

- *Uric acid:* Uric acid is an organic (i.e. carbon-based) compound whose chemical formula is: $C_5H_4N_4O_3$.Due to its insolubility, uric acid has a tendency to crystallize, and is a common part of kidney stones.
- *Other substances/molecules*: Example of other substances that may be found in small amounts in normal urine includes carbohydrates, enzymes, fatty acids, hormones, pigments, and mucins.

2. GENERATION OF HYDROGEN FROM URINE

Urine's major constituent is urea, which incorporates four hydrogen atoms per molecule. Electrolysis process is used to break the molecule apart, developing an inexpensive new nickel-based electrode to selectively and efficiently oxidize the urea. To break the molecule down, a voltage of 0.37V and a power supply of 22KW per gram of hydrogen gas is to be applied across the cell as available in [2]. Now if we produce hydrogen by electrolysis of water, 1.23V is needed to split water. The calorific value of hydrogen is 142KJ/Kg which is much more than standard fuel.Thus voltage requirement for electrolysis of urine is much less as available in [3].

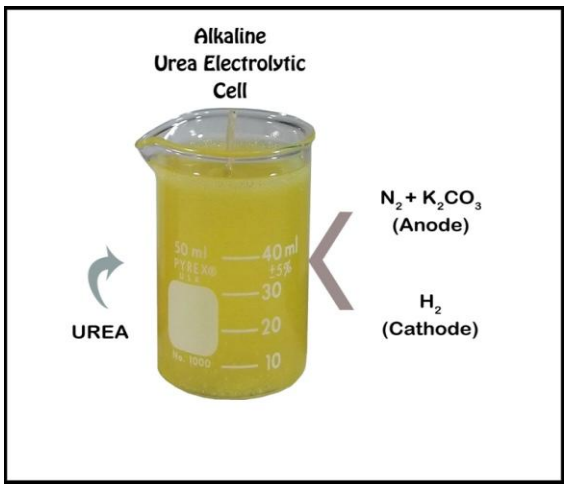

Figure 1: Schematic Representation of direct urea-to-hydrogen process

Anode reaction: $CO(NH_2)_2 + 6OH^- \text{----} > N_2 + 5H_2O + CO_2 + 6e^-$

Cathode reaction: $6H_2O + 6e^- \text{-----} > 3H_2 + 6OH^-$

Overall reaction: $CO(NH_2)_2 + H_2O \text{-----} > N_2 + 3H_2 + CO_2$

These reactions take place at room temperature and under normal pressure conditions. During the electrochemical process the urea gets adsorbed on to the nickel electrode surface, which passes the electrons needed to break up the molecule. Pure hydrogen is evolved at the cathode, while nitrogen plus a trace of oxygen and hydrogen were collected at the anode. While carbon dioxide is generated during the reaction, none is found in the collected gasses as it reacts with the potassium hydroxide in the solution to form potassium carbonate.

Fuel cell: A fuel cell is an ***electrochemical energy conversion device***. A fuel cell converts the chemicals-hydrogen and oxygen into water, and in the process it produces electricity. With a fuel cell, chemicals constantly flow into the cell so it never goes dead -- as long as there is a flow of chemicals into the cell, the electricity flows out of the cell. Most fuel cells in use today use hydrogen and oxygen as the chemicals. Batteries convert chemical energy back into electrical energy when needed. Fuel cells should do both tasks more efficiently. A fuel cell provides a DC (direct current) voltage that can be used to power motors, lights or any number of electrical appliances. The fuel cell used for running cars is known as polymer exchange membrane fuel cells (PEMFC) is available in [1].

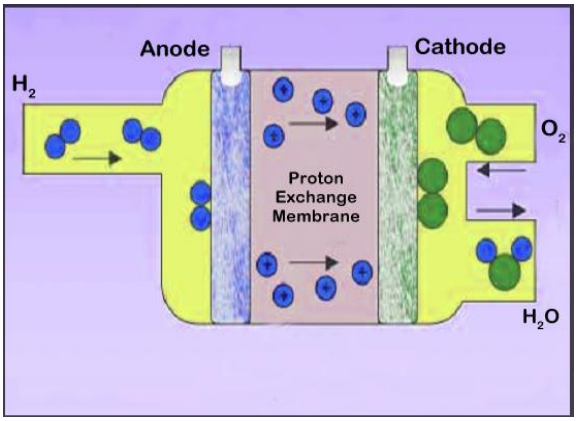

Figure 2: Working of Fuel cell (PEMFC)

Figure above, shows the pressurized hydrogen gas (H_2) entering the fuel cell on the anode side. This gas is forced through the catalyst by the pressure. When an H_2 molecule comes in contact with the platinum on the catalyst, it splits into two H^+ ions and two electrons (e^-). The electrons are conducted through the anode, where they make their way through the external circuit (doing useful work such as turning a motor) and return to the cathode side of the fuel cell. Meanwhile, on the cathode side of the fuel cell, oxygen gas (O_2) is being forced through the catalyst, where it forms two oxygen atoms. Each of these atoms has a strong negative charge. This negative charge attracts the two H^+ ions through the membrane, where they combine with an

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oxygen atom and two of the electrons from the external circuit to form a water molecule (H_2O). This reaction in a single fuel cell produces only about 0.7 volts. To get this voltage up to a reasonable level, many separate fuel cells must be combined to form a fuel-cell stack. Bipolar plates are used to connect one fuel cell to another and are subjected to both oxidizing and reducing conditions and potentials. A big issue with bipolar plates is stability. Metallic bipolar plates can corrode, and the by-products of corrosion (iron and chromium ions) can decrease the effectiveness of fuel cell membranes and electrodes. Low-temperature fuel cells use lightweight metals, graphite and carbon / thermoset composites (thermoset is a kind of plastic that remains rigid even when subjected to high temperatures) as bipolar plate material as available in [4].

3. BLOCK DIAGRAM

The entire process in block diagram form can be represented as follows:

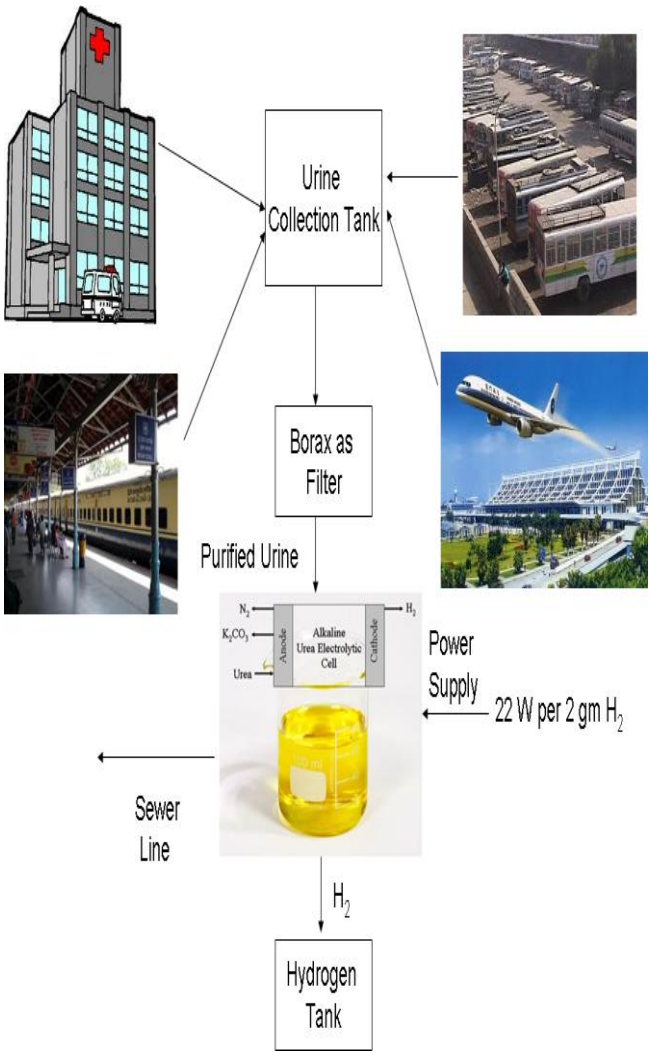

Figure 3 Block Diagram of the process

4. CALCULATIONS & RESULT

World population=7.063 billion [5]
India population= 1,224,260,000

Voltage required for electrolysis of Urine (Urea) per molecule= **0.37 V**
Voltage required for electrolysis of water per molecule = **1.23 V** [4]

Approx. daily single person urine production =1-2 lit
Let be taken as 1.5lit
So total urine production in India = 1224260000* 1.5 = 1836390000 lit
Amount of hydrogen produced per litre of urine= **2 grams**
Hence, total potential of hydrogen from urine = **1836390000* 0.002** = 3772780 kg per day
Efficiency of fuel cell is about 60 % . Hence, it is about 2-3 times more efficient than petrol and diesel internal combustion engine.

Calorific Value of hydrogen = 142 KJ/ kg. Hence, it has 3 times more calorific value than petrol (48 KJ/kg).

Hence, this results into **multiplication factor of 2*3= 6**.

Thus, petrol equivalent of hydrogen = 3772780*6 kg=**22036680 kg**

Dividing this amount with the density of petrol (0.75 kg/ltr) = 22036680 / 0.75 = **29382240 litres**
Amount of oil consumption in India= 3,182,000 bbl / day = 3182000***158.987295** =505897573 lit/day [6]

If we take the efficiency to be 60% over a period of time, amount of hydrogen collected is equivalent to **29382240*0.6 litres = 17629344 litres** taking in consideration, the profits which can be obtained.

Now considering the case of Delhi city,
Population of Delhi compared to total population of India=1.23%
Petrol equivalent which can be produced in Delhi = 17629344* 1.23% **= 216840.93 lit per day**
Cost of 216840.93 litre petrol = 216840.93*60 (price of petrol) = 1.30 crore
Now hydrogen which can be produced in Delhi = 3772780 *1.23% = **46405.194 kg per day.**

Power required for electrolysis of 2 gms hydrogen = **22 Wh**

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Power which is produced by burning = **78 Wh**
Hence, cost of electrolysis = **46405.194 * 11 kWh * 7 (per unit price)** = **3573199 /-**
Taking into account the operational cost, maintenance and efficiency, that is approx. equal to above cost = 3573199/- .
The total cost can be taken to be approx. = **70lakhs /-** (at the most)
Thus % saving in the cost = (130 – 70)* 100/130

= (60 / 130) *100 = **46.15 %**

5. CONCLUSIONS

System using hydrogen generated from urine is 46.15% more efficient than the petrol fuel. Running cost nearly turns to half as compared to petrol and thus this is a solution to the increasing demand of the oil fuel which is eco-friendly and reduces the burden on the fuels.

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