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Production of hydrogen from industrial and domestic wastewater

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ABSTRACT

This project offers an overview of the technologies for hydrogen production from waste water. Electrolysis is a promising option for hydrogen production from renewable resources. A electrolysis cell was designed to produce a useful hydrogen gas, from the wastewater treatment process. The electrical energy efficiency of commercial water electrolysers is normally limited by internal energy losses; heat generated at economic current density levels exceeds the heat required to maintain the temperature of the electrolyte, and cooling must be used. Development of activated electrode systems and of improved electrode geometries promises to reduce these losses to the point where efficiency will be limited instead by the requirement that sufficient heat be generated internally to maintain the electrolyte temperature. The limitation on electrical energy efficiency then becomes thermodynamic. Options indicated for development of advanced technology are considered. These are then related to the approaches being taken in major worldwide programs which are working to reduce the cost of hydrogen production from wastewater.

Keyword: *Water electrolyser; Hydrogen production; packaging, liquefaction, delivery & transfer of hydrogen.*

1. INTRODUCTION

This project offers an overview of the technologies for hydrogen production. Electrolysis is a promising option for hydrogen production from renewable resources. A electrolysis cell was designed to produce a useful hydrogen gas, from the wastewater treatment process. Electrolysis is the technical name for using electricity to split wastewater into its constituent elements, hydrogen and oxygen.

Electrolyzers consist of an anode and a cathode separated by an electrolyte. Different electrolyzers function in slightly different ways, mainly due to the different type of electrolyte material involved (by using screw).

Hydrogen can be produced using the Electrolysis with an applied voltage and the hydrogen yields gradually increased with the increasing of applied voltage. All hydrogen production processes, there is a need for significant improvement in plant efficiencies, for reduced capital costs and for better reliability and operating flexibility. Electrolysis of water involves the breakdown of water. The process of electrolysis is interchange of atoms and ions. By removing or adding electrons. Which happens by an external circuit. Electrolysis of water produces pure hydrogen. During electrolysis, two electrodes are connected which act as a power source of electricity and then these electrodes are immersed in water. On negatively charged cathode hydrogen appears and on positively charged anode oxygen appears. We see that the hydrogen generated doubles the oxygen that generates. To overcome various activation barriers more energy is required while pure water's electrolysis. If not the case then the pure water's electrolysis is very slow or will not occur at all. The electrical conductivity of water is about the wastewater. A number of electrolytic cells may not have the required electro catalysts.

By adding electrolyte and by use of electro catalysts the efficiency of electrolysis is increases. Hydrogen, chemical element that exists as a gas at room temperature. When hydrogen gas burns in air, it forms water. French chemist Antoine Lavoisier named hydrogen from the Greek words for water former.

Hydrogen has the smallest atoms of any element. A hydrogen atom contains one proton, and only one electron. The proton is the center, or nucleus, of the hydrogen atom, and the electron travels around the nucleus. Pure hydrogen exists as hydrogen gas, in which pairs of hydrogen atoms bond together to make molecules.

2. EXPERIMENTAL DESIGN OF THE SYSTEM

In purpose of investigating the effect of AC voltage amplitude, AC voltage waveform, AC voltage frequency, and DC voltage on the hydrogen production, testing electrolyzing rig is built. A diagram of water electrolyzer, used in this work, is presented in Figure 1. The system consists of, DC power supply, electrode, medical drip controller tube, stainless steel screw, wires and hydrogen measurement instrument.

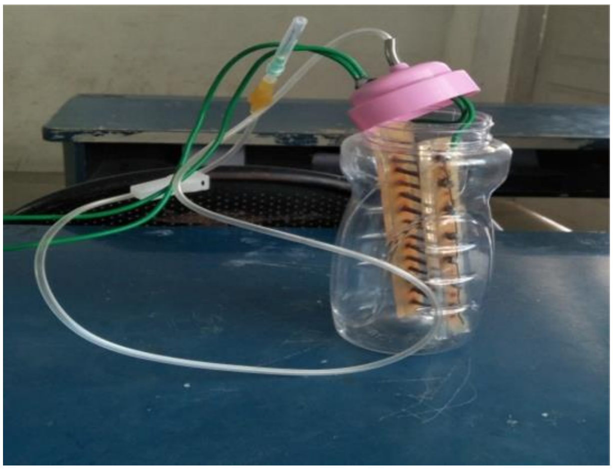


Figure 1: Water electrolyzing system

The detailed information about each element of this system can be described as following:

A) AC – DC supply

DC power supplies use AC mains electricity as an energy source. Such power supplies will employ a transformer to convert the input voltage to a higher or lower AC voltage. A rectifier is used to convert the transformer output voltage to a varying DC voltage, which in turn is passed through an electronic filter to convert it to an unregulated DC voltage.

B) Soldering

It is a process in which two or more items (usually metal) are joined together by melting and putting a filler metal (solder) into the joint, the filler metal having a lower melting point than the adjoining metal. Soldering differs from welding in that soldering does not involve melting the work pieces.

C) DC Power supply

DC power supply is used to generate regulated DC voltage. In this work, regulated power supply model XP-650 is used and its main technical data is as following: input voltage is 120 VAC or 220 VAC, output voltage 0-20 VDC or 0-40 VDC, respectively. Output current is 3A at 0-20 VDC, and 1.5A at 0-40 VDC.

D) Medical drip control

It is a process in which two or more items (usually metal) are joined together by melting and putting a filler metal (solder) into the joint, the filler metal having a lower melting point than the adjoining metal. Soldering differs from welding in that soldering does not involve melting the work pieces.

It is used to show the output of the hydrogen produced and it is connected with air tight. Hence there is no leakage while hydrogen produced in the generator. And it also used for measuring hydrogen by the help of burette.

E) Screw

Screw acts as an electrolyser which connected with positive and negative wire. The anode is now defined as the electrode at which electrons leave the cell and oxidation occurs (indicated by a minus symbol, "−"), and the cathode as the electrode at which electrons enter the cell and reduction occurs (indicated by a plus symbol, "+"). Each electrode may become either the anode or the cathode depending on the direction of current through the cell.

F) Burette

A burette is laboratory equipment used in analytical chemistry for the dispensing of variable amount of a chemical solution and measuring that amount at the same time. It is a long, graduated glass tube, with a stopcock at its lower end and a tapered capillary tube at the stopcock's outlet. Here it is used for measuring hydrogen gas.

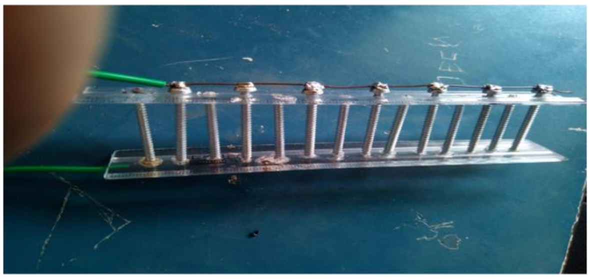


Figure 2: Electrode made of stainless steel screw

3. EXPERIMENTATION AND RESULTS

This section includes the instrumentation used in the experiments, the experimental work and setup, and the experimental results.

3.1) Instrumentation

Water electrolyser shown in Fig 1 uses a cylindrical plastic container with 30cm height, 6 cm diameter, and 0.5lit of water capacity.

The used electrodes are made of stainless steel screw shown in Figure 2. The two electrodes in which each of them is 15cm height. The gap between the screw is 1cm.

The flat plates electrodes are separated by a non-electrical conducting material. The electrolyser contains two electrodes, where each electrode is connected to power supply.

g) Hydrogen measurement instrument

The volume of gas made in a reaction can be measured. The gas may be collected over water using an upturned burette or an upturned measuring cylinder. The burette or measuring cylinder is filled with water before being turned upside down over a trough of water. As the gas bubbles in, it pushes the water out. The water level is then read off the scale on the burette. This works well for insoluble gases, such as hydrogen, or gases that do not dissolve easily in water, such as oxygen and carbon dioxide. Ammonia and chlorine are readily soluble in water and are not collected this way. Instead, they may be measured using a gas syringe, which can be used to collect and measure the volume of any gas. The volume of gas is determined by reading the scale on the side of the burette reading.

Figure 3: Hydrogen measuring instrument

The electrodes are immersed in water where the process of splitting water into hydrogen and oxygen occurs when electrical current generated by the pulse generator or the power supply is passed between two electrodes.

3.2) Experimental work and setup

At the beginning of each experiment, the electrolyser is filled with water and the electrodes are fully immersed in water. The terminals of power supply are connected to the electrodes. In the following sections, the experimentation is divided into two parts. In the first part, a pulse generator and a power amplifier are used to generate alternating current, with variable amplitude, waveform and frequency, to operate the electrolyser, and in the second part a DC power supply is used to generate different DC voltage values to operate the electrolyser.

4. PRODUCTION OF HYDROGEN

The main aim of this experiment is to test the production of hydrogen from domestic and industrial waste water.

4.1) Reduction at cathode

$2\,H^{+}\,(aq) + 2e^{-} \rightarrow H_2\,(g)$

At the positively charged anode, an oxidation reaction occurs, generating oxygen gas and giving electrons to the anode to complete the circuit:

4.2) Oxidation at anode

$2\,H_2O\,(l) \rightarrow O_2\,(g) + 4\,H^{+}\,(aq) + 4e^{-}$

The same half reactions can also be balanced with base as listed below. Not all half reactions must be balanced with acid or base. Many do, like the oxidation or reduction of water listed here. To add half reactions they must both be balanced with either acid or base. The acid-balanced reactions predominate in acidic (low pH) solutions, while the base-balanced reactions predominate in basic (high pH) solutions.

Cathode (reduction):

$2\,H_2O\,(l) + 2e^{-} \rightarrow H_2\,(g) + 2\,OH^{-}\,(aq)$

Anode (oxidation):

$4\,OH^{-}\,(aq) \rightarrow O_2\,(g) + 2\,H_2O\,(l) + 4\,e^{-}$

Combining either half reaction pair yields the same overall decomposition of water into oxygen and hydrogen:

4.3) Overall reaction

$2\,H_2O\,(l) \rightarrow 2\,H_2(g) + O_2(g)$

The number of hydrogen molecules produced is thus twice the number of oxygen molecules. Assuming equal temperature and pressure for both gases, the produced hydrogen gas has therefore twice the volume of the produced oxygen gas. The number of electrons pushed through the water is twice the number of generated hydrogen molecules and four times the number of generated oxygen molecules.

4.4) The standard potential

The standard potential of 1.23 Volts corresponds to the higher heating value HHV of hydrogen. Consequently, the over-potential is a measure of the electrical losses of the functioning electrolyser. The losses depend on the current density or the hydrogen production rate. As shown in Figure 4, at 1.76 Volt 1.43 energy units.

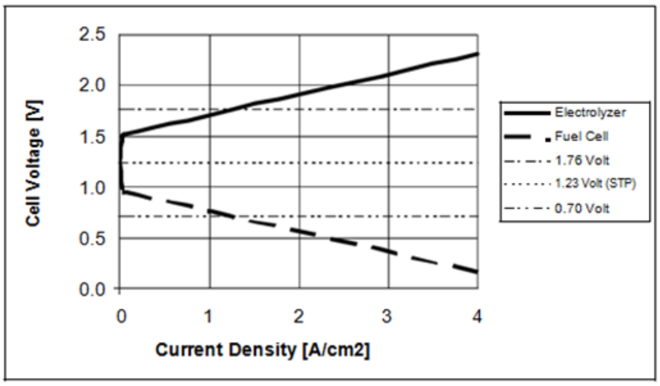
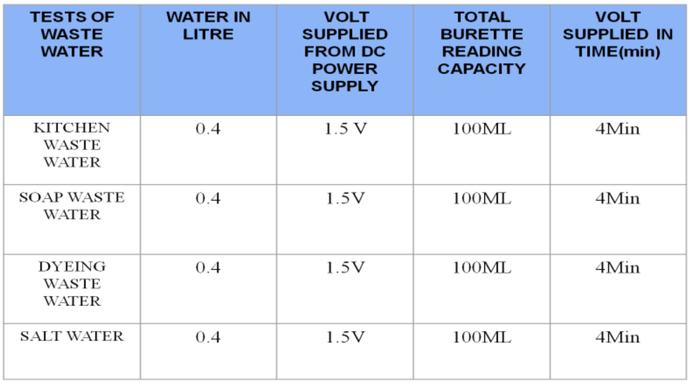


Figure4: Voltage-current characteristics of Electrolyser and fuel cell.

WASTE WATER TESTED

- Kitchen waste water
- Soap waste water
- Dyeing waste water
- Salt waste water

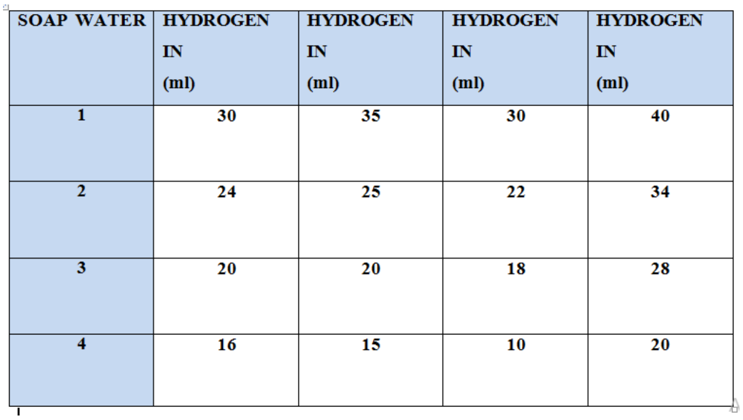
Table 1: Limits of volt, time, litre and burette capacity shown in table.



TESTS OF WASTE WATER	WATER IN LITRE	VOLT SUPPLIED FROM DC POWER SUPPLY	TOTAL BURETTE READING CAPACITY	VOLT SUPPLIED IN TIME(min)
KITCHEN WASTE WATER	0.4	1.5 V	100ML	4Min
SOAP WASTE WATER	0.4	1.5V	100ML	4Min
DYEING WASTE WATER	0.4	1.5V	100ML	4Min
SALT WATER	0.4	1.5V	100ML	4Min

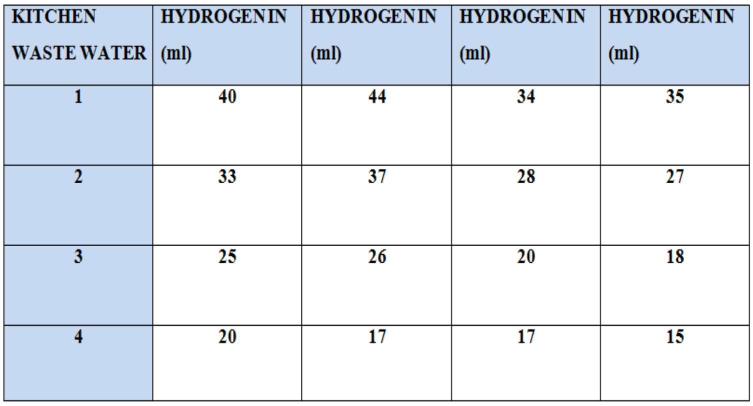
Hydrogen content present in waste water are shown below table2, table3, table4 & table5

Table 2: Result of hydrogen present in soap waste water



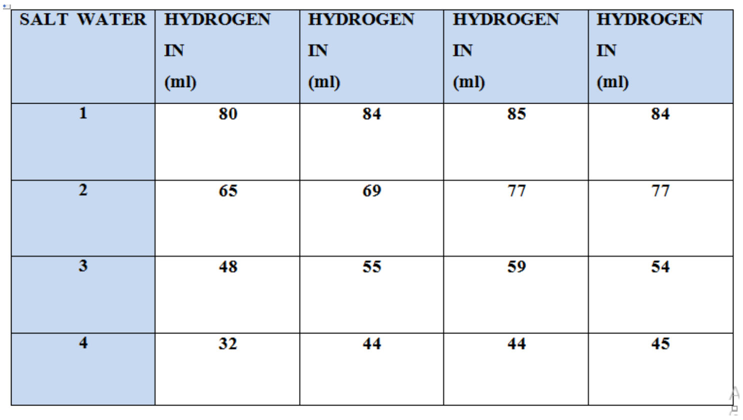
SOAP WATER	HYDROGEN IN (ml)	HYDROGEN IN (ml)	HYDROGEN IN (ml)	HYDROGEN IN (ml)
1	30	35	30	40
2	24	25	22	34
3	20	20	18	28
4	16	15	10	20

Table 3: Result of Hydrogen present in kitchen waste water



KITCHEN WASTE WATER	HYDROGEN IN (ml)	HYDROGEN IN (ml)	HYDROGEN IN (ml)	HYDROGEN IN (ml)
1	40	44	34	35
2	33	37	28	27
3	25	26	20	18
4	20	17	17	15

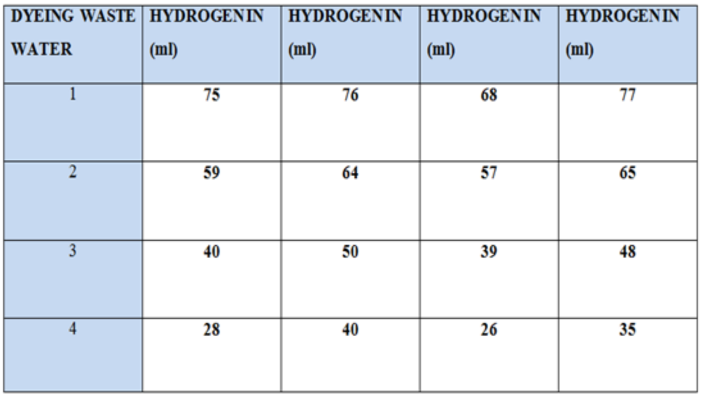
Table 4: Result of hydrogen present in dyeing waste water



SALT WATER	HYDROGEN IN (ml)	HYDROGEN IN (ml)	HYDROGEN IN (ml)	HYDROGEN IN (ml)
1	80	84	85	84
2	65	69	77	77
3	48	55	59	54
4	32	44	44	45

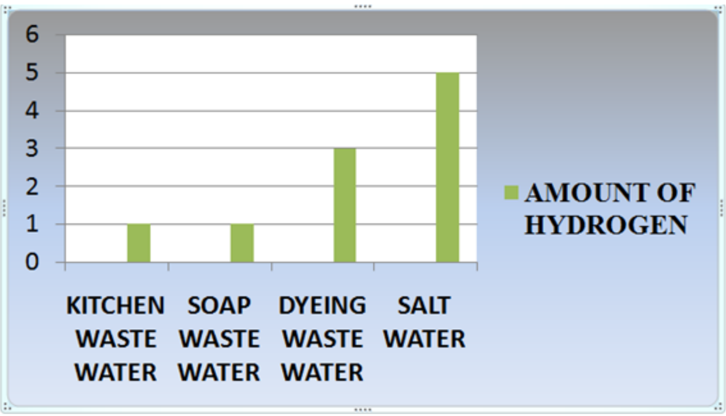
Table 5: Result of Hydrogen present in salt water

Packaging of Hydrogen



DYEING WASTE WATER	HYDROGEN IN (ml)	HYDROGEN IN (ml)	HYDROGEN IN (ml)	HYDROGEN IN (ml)
1	75	76	68	77
2	59	64	57	65
3	40	50	39	48
4	28	40	26	35

Table 6: Flow chart of overall hydrogen present in waste water sample



5. COMPRESSION OF HYDROGEN

Energy is needed to compress gases. The compression work depends on the thermodynamic compression process. The ideal isothermal compression cannot be realized. The adiabatic compression equation.

Isothermal compression follows a simpler equation:

$W = p_0 V_0 \ln (p_1/p_0)$

6. DELIVERY OF HYDROGEN

6.1) Road Delivery of Hydrogen

A hydrogen economy also involves hydrogen transport by trucks and ships. There are other options for hydrogen distribution, but road transport will always play a role, be it to serve remote locations or to provide back-up fuel to filling stations at times of peak demand.

Fig 5 Energy needed for the road delivery of fuels compared to their HHV energy content

6.2) ONSITE GENERATION OF HYDROGEN

One option for providing clean hydrogen at filling stations and dispersed depots is the on-site generation of the gas by electrolysis. Again, the energy needed to generate and compress hydrogen by this scheme is compared to the HHV energy content of the hydrogen delivered to local customers. Natural gas reforming is not considered for reasons stated earlier. The analysis is done for single gas station serving 100 to 2,000 conventional road vehicles per day.

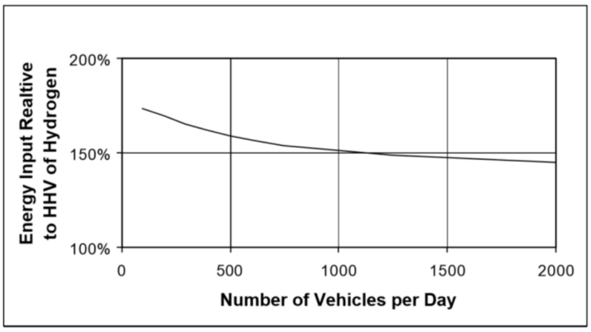


Fig 6 Energy needed for onsite generation of hydrogen by electrolysis and for compression to 200 bars at filling stations compared to the HHV energy content of the hydrogen delivered to road vehicles.

7. TRANSFER OF HYDROGEN

Liquid can be drained from a full into an empty container by action of gravity. There is no energy required, unless the liquids are transferred from a lower to a higher tank, under controlled flow rates or under accelerated conditions.
The transfer of pressurized gases obeys different laws. Figure 13 may illustrate the point. Assume two tanks of equal volume, one full at 200 bar and the other empty at 0 bar pressure.

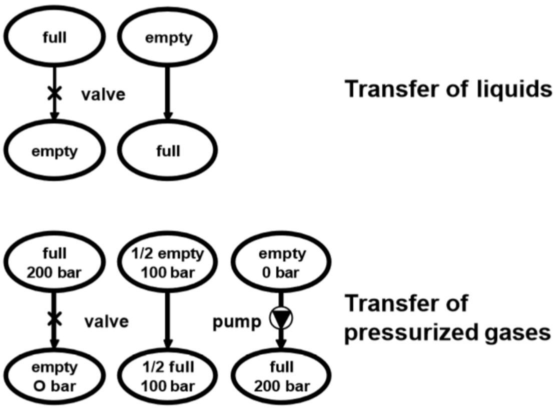


Figure 7 Schematic representation of the transfer of liquids and gases

8. CONCLUSION

Thus we have tested for four water sample. We get more hydrogen from dyeing and salt waste water, when compared to kitchen and soap waste water. The volume of gas production rate measured by reading the scale on the side of the burette.The reported results are by no means final. The readers of this study are invited to refine the analysis and to contribute further details. The energy cost of producing, packaging, distributing, storing and transferring hydrogen must have been analyzed in different contexts. The results of those studies may be used to verify, correct, or reject our numbers. For given energy demand the well-to-wheel efficiency is reduced and, as a consequence, the emission of CO2 is increased when natural gas is converted to hydrogen for daily use.

9. ACKNOWLEDGEMENT

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