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Study of Making of Hydrogen Gas by Using Waste and Sewage Water

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Abstract: *In recent years, the intensification of human activities has led to an increase in waste production and energy demand. The treatment of pollutants contained in wastewater coupled with energy recovery is an attractive solution to simultaneously reduce environmental pollution and provide alternative energy sources. Hydrogen represents a clean energy carrier for the transition to ad carbonized society. Hydrogen can be generated by photosynthetic water splitting where oxygen and hydrogen are produced, and the process is driven by the light energy absorbed by the photocatalyst. Alternatively, hydrogen may be generated from hydrogenated pollutants in water through photocatalysis, and the overall reaction is thermodynamically more favorable than water splitting for hydrogen. This review is focused on recent developments in research surrounding photocatalytic and photoelectrochemical hydrogen production from pollutants that may be found in wastewater. The fundamentals of photocatalysis and photoelectrochemical cells are discussed, along with materials, and efficiency determination. Then the review focuses on hydrogen production linked to the oxidation of compounds found in wastewater. Some research has investigated hydrogen production from wastewater mixtures such as olive mill wastewater, juice production wastewater, and waste-activated sludge. This is an exciting area for research in photocatalysis and semiconductor photo electrochemistry with real potential for scale-up in niche applications.*

Keywords: Hydrogen gas, Waste water, sewage water, Green Hydrogen gas, photocatalytic, photoelectrochemical cell

I. INTRODUCTION

The current society is based on a linear production route, where the extraction of raw matter follows its industrial conversion into products and its disposal as waste. This linear practice creates long-term problems because resources are limited and inefficiently used. The impact of this approach includes climate crisis, water pollution, and reduction of biodiversity. Therefore, it is necessary to adopt different strategies conforming to the circular economy concept, where products and materials are in the economy as long as possible. Wastewater has a great potential for resource recovery, being a source of nutrients such as phosphorus and nitrogen, materials including precious metals, and also a potential source for energy recovery. Conventional wastewater treatment plants are energy-intensive, however, energy can be extracted from wastewater in diverse forms, including electricity, heat, or fuels, such as methane or hydrogen. Biogas production by anaerobic digestion is one of the most utilized methods for energy recovery from wastewater . In this process, bacteria degrade the organic waste in the absence of oxygen to produce biogas, a gas mixture mostly composed of methane and carbon dioxide. Anaerobic digestion has been and is widely used in wastewater treatment plants around the world.

II. METHODOLOGY

As there are various method of make hydrogen from that we use this following method

1. Photocatalysis
2. Photoelectrochemical cells

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2.1 Photocatalysis

In photocatalysis, a semiconductor is irradiated with photons with energy equal to or greater than the bandgap energy, resulting in the excitation of electrons from the valence band (VB) to the conduction band (CB). The photo-excited electron leaves a positively charged hole in the VB. These charge carriers are referred to as electron-hole pairs. The charge carriers can recombine in the semiconductor bulk dissipating energy as heat or light or they can migrate to the surface of the semiconductor. At the surface, they can undergo charge transfer processes driving redox reactions with chemical species which are adsorbed at the surface of the photocatalyst.

Photocatalysis has been widely studied for the degradation of organic pollutants and extensive information can be found in previous reviews . The organic pollutants can either undergo direct oxidation by holes, indirect oxidation by reactive oxygen species including hydroxyl radicals, or they may be transformed by a reductive route involving CB electrons. The most common electron acceptor in photocatalytic oxidation reactions is molecular oxygen since it is abundant in the air and is reasonably soluble in aqueous solutions. The oxygen is reduced by the CB electrons to form the superoxide radical anion (O2•-). Subsequent reduction reactions lead to H2O2, •OH, and eventually H2O.

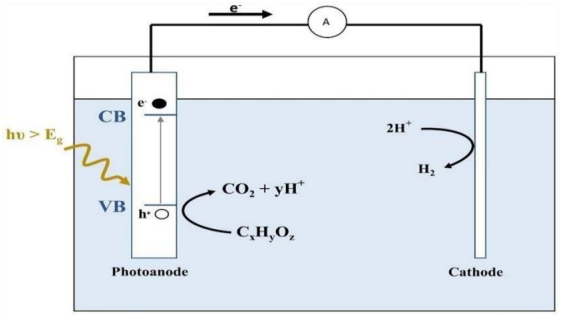

Fig. photocatalytic process

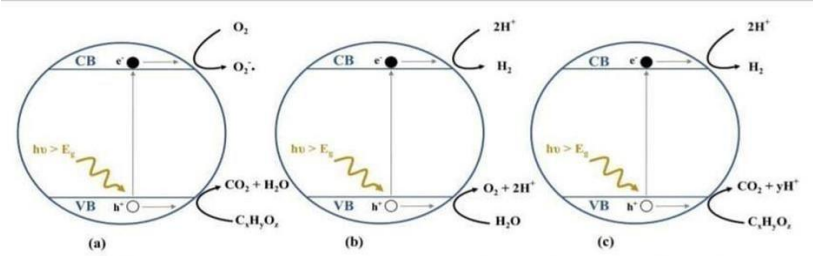

Figure 1. Schematic representation of photocatalytic process. (a) Photocatalytic degradation of organic pollutants with oxygen as the electron acceptor. (b) Photocatalytic water splitting. (c) Photocatalytic oxidation of pollutant with H_2 evolution as the reduction reaction.

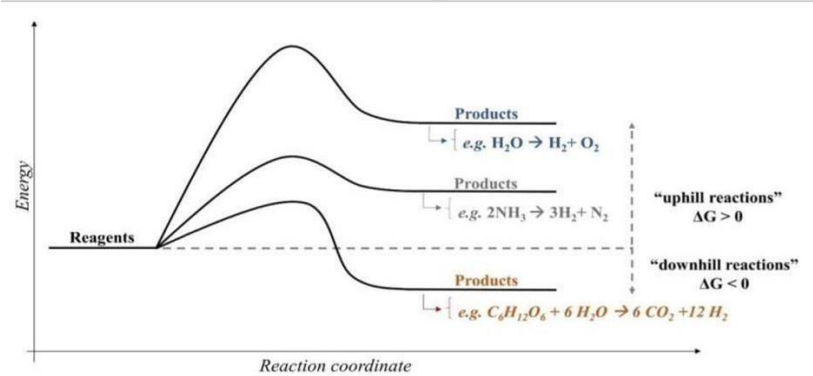

Figure 2. Thermodynamic energy diagram with examples for hydrogen production from water, ammonia, and glucose.

Fig. Schematic representation of photocatalytic process

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2.2 Photoelectrochemical cells

An approach to enhance the efficiency of photocatalysis is the use of electrochemically assisted photocatalysts in a PEC. In this configuration, the oxidation and reduction reactions are performed by two different electrode materials that are connected through an external circuit. The oxidation is driven by the holes in the (photo)anode, while the electrons travel from the photoanode through the external circuit to the (photo)cathode, where the reduction reaction takes place. This process is schematically represented in figure. When a PEC is utilized to produce a fuel (e.g. hydrogen) from solar energy it can be referred to as a photosynthetic cell. Similarly, when the PEC is employed to produce electricity from the photodegradation of substances, it can be defined as a photo fuel cell.

In systems where wastewater compounds are being oxidized in a PEC to generate H2, depending on the thermodynamics of the reaction, the system can also produce electricity and therefore is a combination of both cells; not clearly defined as one or the other. Moreover, a system without applied bias, where hydrogen is produced by a flow of current, could also be considered a photo fuel cell. PECs can be used with different configurations, i.e. semiconductor photoanode with the metallic cathode,

semiconductor photocathode with the metallic anode, or photoanode with photocathode. These cells are driven by the potential difference between the Fermi levels of the two electrodes. For a typical n-type semiconductor photoanode, the Fermi level is close to the CB while for a typical p-type semiconductor photocathode the Fermi level is close to the VB. If the PEC uses a dark anode or cathode, these potentials are ideally dependent on the oxidation and reduction reaction potentials, respectively.

III. CONCLUSION

This review has described the potential of wastewater as a source of energy recovery, using photocatalytic oxidation of pollutants coupled with hydrogen production. The production of hydrogen from pollutants and wastes is energetically more favorable than the production of hydrogen from water splitting. Using suspensions of photocatalytic particles has been the most common approach to date, while only a limited number of works have adopted the use of PECs. PEC represents a promising option since this configuration reduces the recombination losses within the system. Up to now, there has been limited research focused on the optimization of the design of photocatalytic reactors or PECs to improve the overall system efficiency. More research is needed on materials that have already shown promising results for water splitting and which might show improved efficiencies as compared to pure TiO2 for hydrogen production from wastewater. Only a few studies have investigated hydrogen production coupled to the treatment of real or simulated wastewater and more studies are needed to assess the real application. It is extremely challenging to compare the performance of the different published works. Hydrogen production rates, when given, are measured under very different operating conditions and the quantum efficiencies are sometimes not reported.

Table 2. Summary of the materials used in the H_2 production from degradation of wastewater compounds using photoelectrochemical cells.

Waste	Photoanode	(Photo)Cathode	Maximum efficiency (%)	Reference
Ammonia	TiO_2	Pt	—	[54]
	TiO_2	Pt/C	—	[56]
Urea	$Ni(OH)_2$ loaded on TiO_2 or α-Fe_2O_3	Pt	—	[55]
	TiO_2	Pt/C	—	[56]
Formamide	TiO_2	Pt/C	—	[56]
Glucose	WO_3	WC	$EQE_{(600\ nm)} = 80$	[114]
	$Ni(OH)_2$ loaded on α-Fe_2O_3	Pt	—	[62]
Phenol	TiO_2 NRs, TiO_2 NTs/Ti, CdS and CdSe	C/Cu_2O/Cu and Cu_2O	$IPCE_{(380\ nm)} = 68$	[57]
	BiO_X-TiO_2/Ti	SS	—	[118]
	Bi/$BiVO_4$	Pt	—	[120]
Ethanol	TiO_2	Pt	$IPCE_{(360nm)} = 96$	[137]
	TiO_2/WO_3	Carbon black	—	[138]
Glycerol	TiO_2	Pt	—	[145]
	TiO_2/CdS	Pt	—	[146]

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