# CONCEPTIONAL BASICS FOR DESIGNING A PHOTO-MICROBIOLOGICAL ELECTROLYSER AS BIOFUEL CELL : GREEN ENGINE

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**Abstract:**

The main condition that all countries have agreed on about the future of the earth activities is to keep it clean and free of pollution. For using energy and still keeping the earth clean, the final solution is to use alternative fuels. Hydrogen, as an alternative fuel, would be a good choice in this respect. Hydrogen could be produced by photoelectrolysis of water via a microbial cell, which is used to activate the photoelectrolyser(s). The above-mentioned combination of microbial fuelcells and photoelectrolysers is called "Green Engine". This paper will discuss theoretical aspects of making such an engine.

**Introduction:**

The main condition that all countries have agreed on about the future of the earth is to keep it clean and free of pollution. For using energy and still keeping the earth clean, the final solution is to use alternative fuels. These fuels must satisfy at least three requirements:

- Being clean, meaning that no by-products harmful to the environment will be produced
- Being abundant
- Being economic

Hydrogen, as an alternative fuel, would be a good choice in this respect. Using hydrogen as alternative fuel rests mainly upon the fact that it is both abundant and not harmful to the environment (its oxidation gives water). The only problem seems to be the fact that hydrogen may not be produced so easily.

Among methods for producing hydrogen, one is Photoelectrolysis, ie, electrolysis of water by the sun in a device called Photoelectrolyser (Pe). Main problem with Pe is that it must be pre-activated so that it can absorb light and decompose water into hydrogen and oxygen. In this respect, a microbial cell would be used to activate the Pe for the above-mentioned purpose. Theoretical aspects of such combination of microbial cell and Pe, called “Green Engine”, will be discussed here based on microbial and electrochemical basic concepts.

**1.Microbial concept of a Green Engine:**

Sulphur-oxidising bacteria (SOB) are a family of bacteria that require oxygen for their growth (aerobic bacteria). SOB can produce sulphuric acid with very low pH values down to one even [1]. A type of these bacteria known as Colourless SOB produce sulphuric acid by either of the reactions given below [2]:

$$H_2S + 2O_2 \longrightarrow H_2SO_4$$

Or

$$2S^0 + 3O_2 + 2H_2O \longrightarrow 2H_2SO_4 \qquad (1)$$

Colourless SOB can be found everywhere in the nature and be isolated from almost every aquatic system. A genus of SOB known as *Thiobacillus Ferrooxidan* is capable of producing 10% concentrated sulphuric acid with pH less than 2.5 [2,3].

Sulphate reducing bacteria (SRB) that grow anaerobically (no oxygen) are known for their capability of reducing sulphate ($SO^{-2}_4$) to sulphide ($S^{-2}$) where in absence of metallic ions such as iron they produce $H_2S$ gas [4]. SRB may be found everywhere from soil [5] to seawater [6]. Both SRB and SOB are examples of corrosion-enhancing bacteria whose annual destructive effects on national economy of Australia alone, in the form of corrosion, are estimated to be A$6b [7].

**2.Electrochemical concepts of Green Engine:**

It is known in electrochemistry that when two dissimilar metals are placed into an electrolyte, an electrochemical galvanic cell with a certain voltage is produced. For instance, if two electrodes of copper and zinc are placed in an aqueous solution with $SO^{-2}_4$ (eg, sulphuric acid), they would produce a voltage difference of about 1.1 volts; in case of using other types of electrochemical cells voltages more than 1.2 volts may be reached [8].

**2.1.Photoelectrolysis of water:**

A photoelectrolyser is a device that by using sunlight dissociates water into hydrogen and oxygen for which 62.3 Kcal must be consumed, Figure.1.

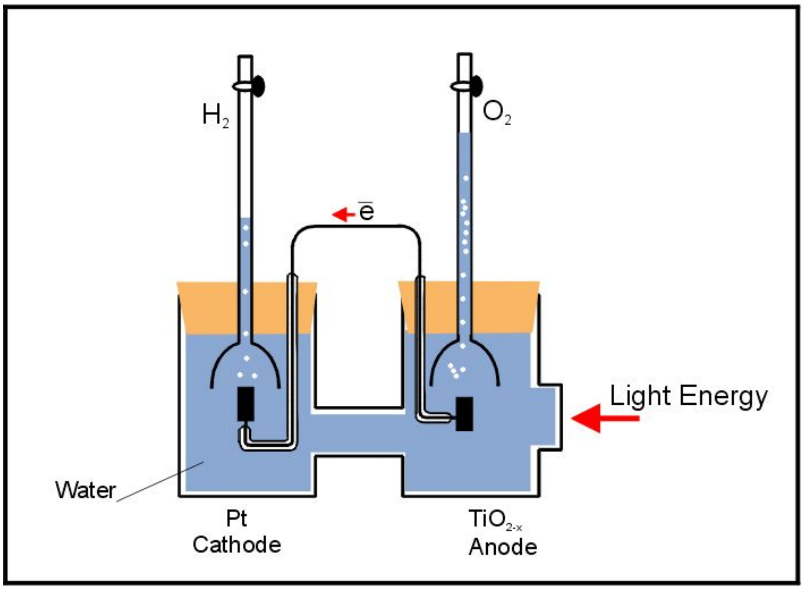


Figure.1: Basic drawing of a photoelectolyser (Pe)

A part of this consumed energy is deposited in hydrogen molecules, as water cannot absorb the ultraviolet radiation that accounts for 50% of the sunlight [8]. To solve this problem, an n-type semi-conductor known as photoanode is used. The photoanode absorbs sunlight and gets excited so that emits electron. The cathode for decomposition of water molecules and hydrogen production will use these electrons:

(2) Cathode: $2H_2O + 2e^- \longrightarrow H_2 + 2OH^-$

At the same time, as photoanode has sent off electron and lacks it now, it will attract the soluble hydroxyl ions that are oxidised and oxygen is given off:

(3) Anode: $2OH^- \longrightarrow \frac{1}{2} O_2 + 2e^-$

Photoanodes are made up of materials such as Titanium Oxide ($TiO_{2-x}$). It is very important to note that $TiO_{2-x}$ photoanodes must be "pre-excited" by an external voltage shock of about 0.2 V to become active and ready for electron emission. At IBARAKI national industrial chemistry laboratories in Japan, researchers have found out that [9] if sodium carbonate is added to the water and $TiO_2$ + 0.3% platinum is used as the catalyst, the best result is achieved: with only 0.3 gr of that catalyst, hydrogen with a rate of 0.2 ml.$H_2$/hour will be produced. One tone of such catalyst would produce 75000 litre hydrogen gas (or 100 litre of liquid $H_2$) which is enough for running a car for a distance of 300 Km. The energy efficiency of an advanced electrolyser is 75% [10] where using hydrogen in running an electrical engine-by a fuel cell, for instance- would yield an efficiency of 60% which is much better than internal combustion engines being only 35% [9].

**3.Activating a Pe by a microbially activated cell:**

In absence of metallic ions, colourless SOB to produce sulphuric acid constantly and naturally may use the $H_2S$ produced by SRB as a source. The acid would be used as electrolyte in an appropriate electrochemical cell (like a galvanic cell or an oxygen aeration cell) to produce a voltage of about 1.2 volts. Such a voltage would be high enough to run at lease six Pe`s simultaneously. If we take a galvanic cell having copper and zinc as electrodes and sulphuric acid as the electrolyte, for a copper sulphate and zinc sulphate concentrations of 10 mol/lit. and 0.1 mol/lit. , respectively, and a $Zn^{+2}/Cu^{+2}$ ratio of 0.01, the output voltage of the cell would be 1.16 volts. This means that as long as polarisation is not taking place and the bacteria are alive and active, at least six Titanium oxide photoanodes corresponding to six Pe`s could be running (remember that each photoanode would require a "push" of 0.2 volt whereas the available voltage from an electrochemical cell with microbial electrolyte would be about 1.2 volts).

Calculations show that [9] considering 300 sunny days in a year and a day-length of 12 hours, a surface area of 1 $cm^2$ would receive an energy amount of 0.033 Watts/hour from the sun so that the amount of hydrogen produced by the sun in a Pe having a photoanode area of just 1 $cm^2$ would be 0.01 litre/hour/photoanode surface area. By increasing the photoanode surface area to 4 $cm^2$, the hydrogen then-produced would be about 0.05 lit.$H_2$/hour. On the other hand, if for just one Pe, the photoanode is $TiO_{2-x}$ of the type octahedrite with a density of 3.9 $kg/m^3$ ,a titanium oxide sample of 0.3 gr would have a volume of more than 70 $cm^3$ suggesting that the anode surface area could be taken much more than 1 $cm^2$ so receiving much more sunlight and energy. In this way, six Pe`s working together would receive more energy so that more water could be decomposed and, therefore, more hydrogen would be produced. The oxygen produced in this way could be used for many applications as well.

**Summary:**

If a combined microbial cell containing SRB and SOB were used, theoretically they would produce the voltage necessary for running at least six photoelectrolysers simultaneously. This combination of electrochemical cells having microbial electrolytes with photoelectrolysers is defined as a "Green Engine", Figure.2

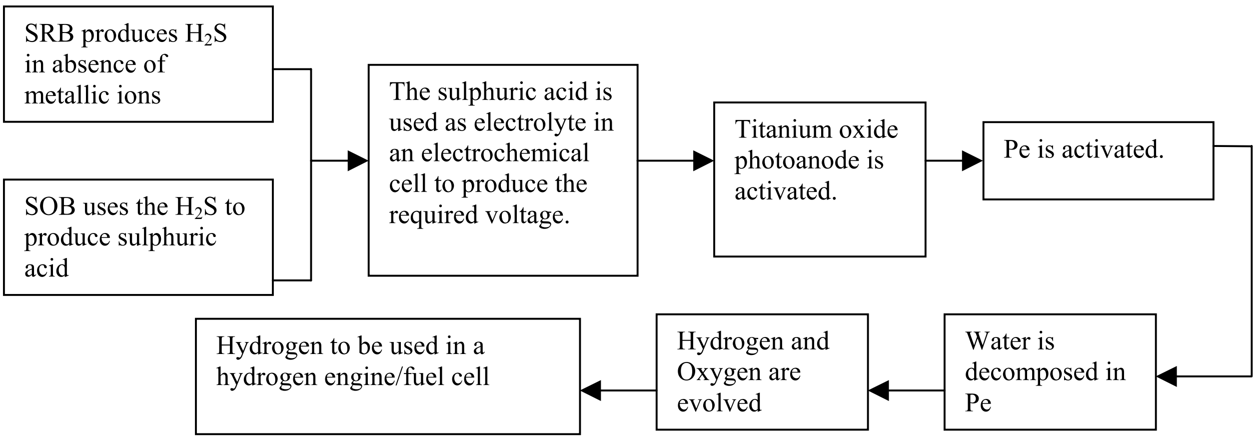


Figure.2: Components of Green Engine

The resulted hydrogen and oxygen from such an engine, could be used in many applications including hydrogen production for hydrogen engines and oxygen to lower harmful effects of fossil fuels. This paper discussed theoretical aspects of such a green engine.

**Abbreviations:**

**Pe:** Photeoelectrolyser, a device in which decomposition of water by the action of solar energy, ie, photoelectrolysis is taking place.
**SOB**: Sulphur-oxidising bacteria, a type of aerobic (oxygen-requiring) bacteria capable of producing sulphuric acid with very low pH.
**SRB**: Sulphate-reducing bacteria, a type of anaerobic (no oxygen) bacteria. These bacteria reduce sulphate to sulphide and in absence of metallic ions like iron, produce $H_2S$ gas.

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