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Using of produced water associated with oil and gas production as a source of hydrogen: solar electrolysis cell application

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Abstract In frame of the growing global concerns regarding to the high extent of environmental pollution and its serious consequences on the future of the planet. The seek out for a proper source of clean energy is considered to be a top priority. Where a substantial reduction in a present reliance on fossil fuels is achieved. This objective can not be factual without intensive efforts to find out the appropriate alternative, which are the sustainable and environmentally friendly energy alternatives. The use of hydrogen as an alternative fuel is gaining more and more acceptance as the environmental impact of hydrocarbons becomes more evident. The using of enormous amount of a polluted produced water associated oil and gas production activities to generate the hydrogen by solar hydrolysis cell, is considered to be a multi advantages alternative, where the volume of polluted and environmentally risky water been reduced and a significant volume of hydrogen been gained.
This work is an attempt to design of a hydrogen generating station by water electrolysis whose energy resources are solar. The electricity supply is done by photovoltaic cells. The novelty of this work is the using of produced water to generate a clean energy (hydrogen), and in the same time reducing the threats caused by the disposal pits of the vast volume of the produced water at oilfields, which is the biggest challenge to the oil industry and the environment. In this work, the produced water has been electrolyzed by using solar energy. Standard chemical analyses methods have followed to determine the pollutants constitutes in this water. A pilot plant of solar hydrogen production unit has been built consisting of; solar photovoltaic cells, water electrolyzer, and hydrogen and oxygen gas storages. The hydrogen production rate is given for various values of the solar radiation during the year in-site of the oil production field in Libya.

Keywords: hydrogen from solar energy, water electrolysis, photovoltaic, produced water.

1. Introduction

Produced water is water trapped in underground formations that is brought to the surface along with oil or gas production. It is by far the largest volume by-product or waste stream associated with oil and gas production. Therefore produced water is the principal source of many pollutants carried by it and impact the round environment causing a serious threats to the ecosystem [1].

Produced water can have different potential impacts depending on where it is discharged. For example, discharges to small streams are likely to have a larger environmental impact than discharges made to the open ocean by virtue of dilution that takes place following discharge. Regulatory agencies have recognized the potential impacts that produced water discharges can have on the environment and have prohibited discharges in most onshore or near-shore locations [2], see Fig. 1 and 2.

It contaminates the soils and causes the outright death of plants, wildlife, and the consequent erosion of topsoil. In addition, impacted soil lead to wide spread contamination of surface waters and shallow aquifers [3].

The volume of produced water from oil and gas wells dose not remains constant over time. The water-to-oil ratio increases over the life of a conventional oil or gas well. For such wells, water makes up a small percentage of produced fluids when the well is new. Over time the percentage of water increase and the percentage of product declines.

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Fig. 1. Discharging pipes of produced water into surface pit at an oilfield

Fig. 2. Surface pit of a large amount of produced water at an oil field

Lee et al. [4] report that U.S. wells produced an average of more than 7 bbl of water for each billion barrel of oil. For crude oil wells nearing the end of their productive lives, water can comprise as much as 98% of the materials brought to the surface. Wells elsewhere in the world produced an average of 3 bbl of water for each billion barrel of oil [5]. Katib and Verbeek [5] found that for 1999, an average of 210 million bbl of water was produced each day worldwide. This volume is about 77 billion bbl of the produced water for the entire year. The development of effective produced water management strategies posses a big challenge to the oil and gas industry today.

The developing of a novel technique to consume the enormous amount of produced water that usually disposed into surface pits, to produce a clean energy (hydrogen), can have a positive response on the environment and the availability of the renewable energy. Hydrogen can be used as a non-toxic energy storage and transport medium [6, 7]. Make hydrogen while the sun shines. Then use the stored hydrogen to produce heat and electricity on demand, day or night. Therefore, in this work, the produced water has been electrolyzed by using solar energy. Standard chemical analyses methods have followed to determine the pollutants constitutes in this water. A pilot plant of solar hydrogen production unit has been built consisting of; solar photovoltaic cells, water electrolyzer, and hydrogen and oxygen gas storages.

2. Experimental

2.1. Samples collection and produced water analyses

Five samples of produced water have been collected from different sampling points and depths at the pit of produced water disposal. The samples were analyzed in order to characterize the constituent content. The main parameters that have been determined were pH, electrical conductivity (EC), cations and anions content. The analyses were made according to standard methods.

2.2. Solar-hydrogen system

A pilot plant of solar electrolysis cell has been built consisting of one solar electric module (100 Watt), water electrolyzer, hydrogen, and oxygen gas storages (Fig. 3).

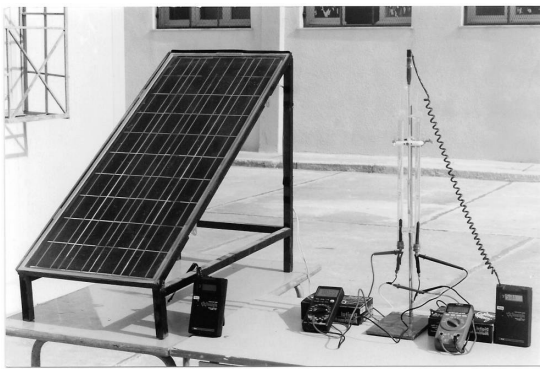

Fig.3. The solar electrolyzer system (pilot plant).

3. Results and discussions

The results of produced water analyses are presented in Fig. 4, 5 and Table 1.

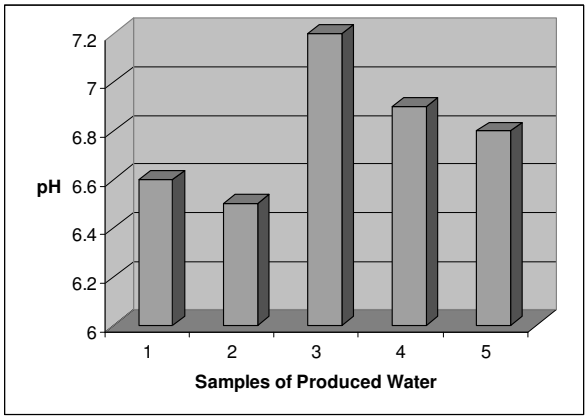

Fig. 4. pH of produced water.

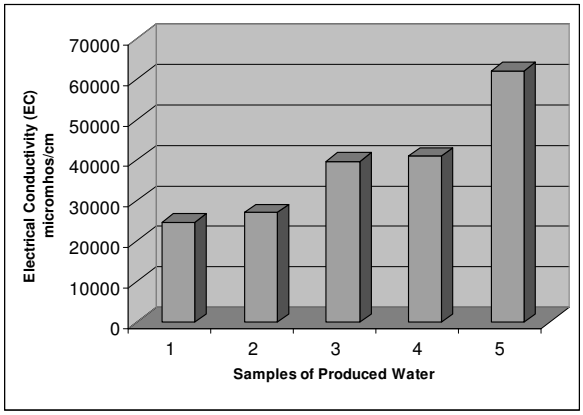

Fig. 5. Electrical conductivity of produced water.

A typical produced water sample has been formed by mixing an equal volume of produced water taken from each sample. The properties of the typical sample of produced water are presented in Table 2. The typical sample has been charged to the solar electrolysis cell to be used as a source of hydrogen production.

Figure 6 shows the variation of monthly hydrogen production from the pilot plant of solar electrolysis cell. The results showed that the pilot plant with one solar cell module (0.5 m^2) produced a total of 48.5 m^3 of hydrogen per year.

Table 1. Ions concentrations in produced water, mg/L

Ion/ Sample	**1**	**2**	**3**	**4**	**5**
Cl^-	8588	10221	16354	16013	6235
SO_4^{--}	1560	1276	1716	1671	1502
HCO_3^-	756	771	273	464	1537
CO_3^{--}	0	0	0	0	0
Na^+	5800	6500	9500	9500	5050
K^+	180	210	300	300	150
Ca^{++}	328	400	880	840	60
Mg^{++}	182	224	437	389	85

Table 2. Properties of typical sample of produced water.

Property, units	Value for typical sample
Cl^-, mg/L	10080
SO_4^{--}, mg/L	1514
HCO_3^-, mg/L	718
CO_3^{--}, mg/L	0
Na^+, mg/L	7100
K^+, mg/L	188
Ca^{++}, mg/L	412
Mg^{++}, mg/L	246
pH at 25^0C	6.88
EC [micromhos/cm]	44000

This means that for a small plant with solar cell modules of 10×10 m^2, can produced a total of 9700 m^3 of hydrogen per year.

4. Conclusions

1. Renewable energies are emissions-free way to produce hydrogen by electrolysis, and, conversely, hydrogen offers a way for renewable to generate transportation fuel and reliable power.

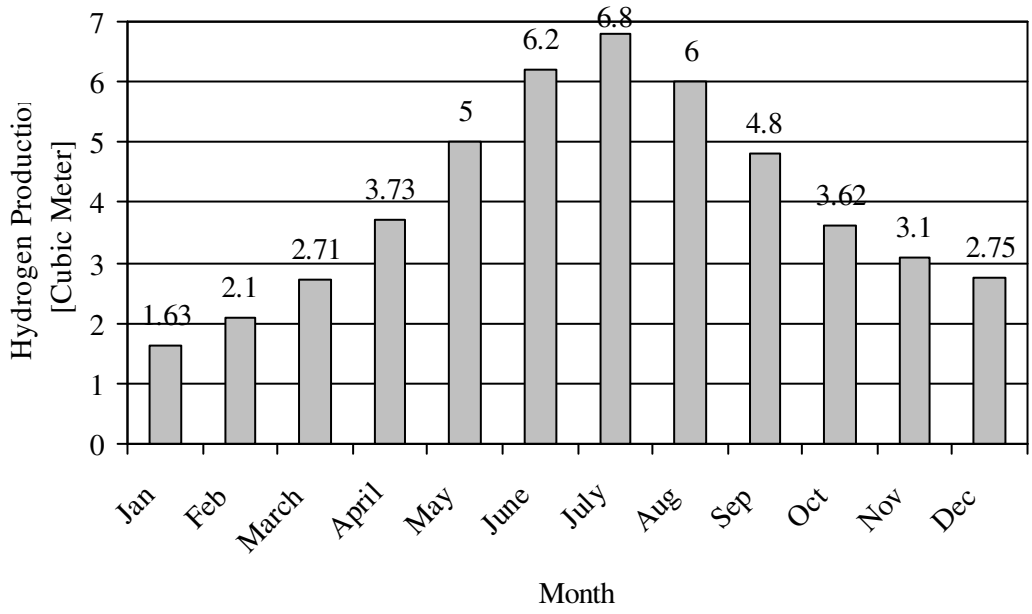

Fig. 6. Average of monthly production of hydrogen along one year of the pilot plant with one solar cell module (100 Watt)

2. A laboratory plant of a solar hydrogen production unit has been built consisting of solar electric modules, water electrolyzer, hydrogen, and oxygen gas storages.
3. Huge amount of produced water has been used in this novel work to generate a clean energy (hydrogen), and in the same time reducing the vast volume of the waste water associated oil and gas production.

5. References

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