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Hydrogen production by water electrolysis: Effects of the electrolyte type on the electrolysis performances with a tension generator or a photovoltaic module

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ABSTRACT

The production of hydrogen, vector of energy, by electrolysis way and by using photovoltaic solar energy can be optimized by the good choice of the electrolytes. Distilled water usually used, due to membrane presence can be substituted by used waters, which enters more and more their treatment. Used water such as those of the Cleansing National Office, and also of the factories such as those referring with ammonia, the margines, and even the urines that make it possible to produce much more hydrogen as distilled or salted water, more especially as they do not even require an additive or membranes: traditional electrolysers with two electrodes. This study seeks to optimize the choice among worn water and this, by electrolysis in laboratory or wire of the sun according to produced hydrogen flow criteria, output of electrolysis and electric power consumption. The additive used is NaCl.

KEYWORDS

Hydrogen production;
Electrolysis;
Electrolyte;
Photovoltaic.

INTRODUCTION

The water electrolysis is known for a long time to produce hydrogen. However, for the membrane electrolysers, water used must be pure.

We show here that the worn water electrolysis gives the same performances, even better ones, because it contains bacteria that produce hydrogen.

As worn water, we can cite those of the National Cleansing Office, the margines, the gas liquor of the factories of ammonia production, and also the vinegar water and the urine that is considered rich in nitrogenized substance (ammonia) according to recent research of the Ohio University USA.

The hydrogen production by water electrolysis can be profitable economically by using an electric power of renewable origin such as photovoltaic solar energy[1-2].

Our former work was based on the water salted use as electrolyte[3-7]. In this article, one will vary the nature of the electrolyte while leaning towards the worn water known by their richness with bacteria which are the hydrogen production base. The human urine will also be used in reference to work of Boot[8-10].

EXPERIMENTAL PROTOCOL

- Parameters of calculation:
- Hydrogen production flow rate: $Qv = V/t$ With:
- Absorptive power by the electrolyser: $Pa = U*I$ Useful power of the electrolyser: $Pu = PCI*Q*\rho$ With PCI: lower thermal value of hydrogen (119.910^6 J/Kg)
- ρ: density of hydrogen ($0.09\ Kg/m^3$)
- Consumed electric power: $W = Pa*t$ (J)
- Useful efficiency: $\rho = ?PCI * (V / (Pab * t)) * \rho$
- Consumed electric power per unit of volume: $W/V = Pab * t / V$ (J/cm^3)

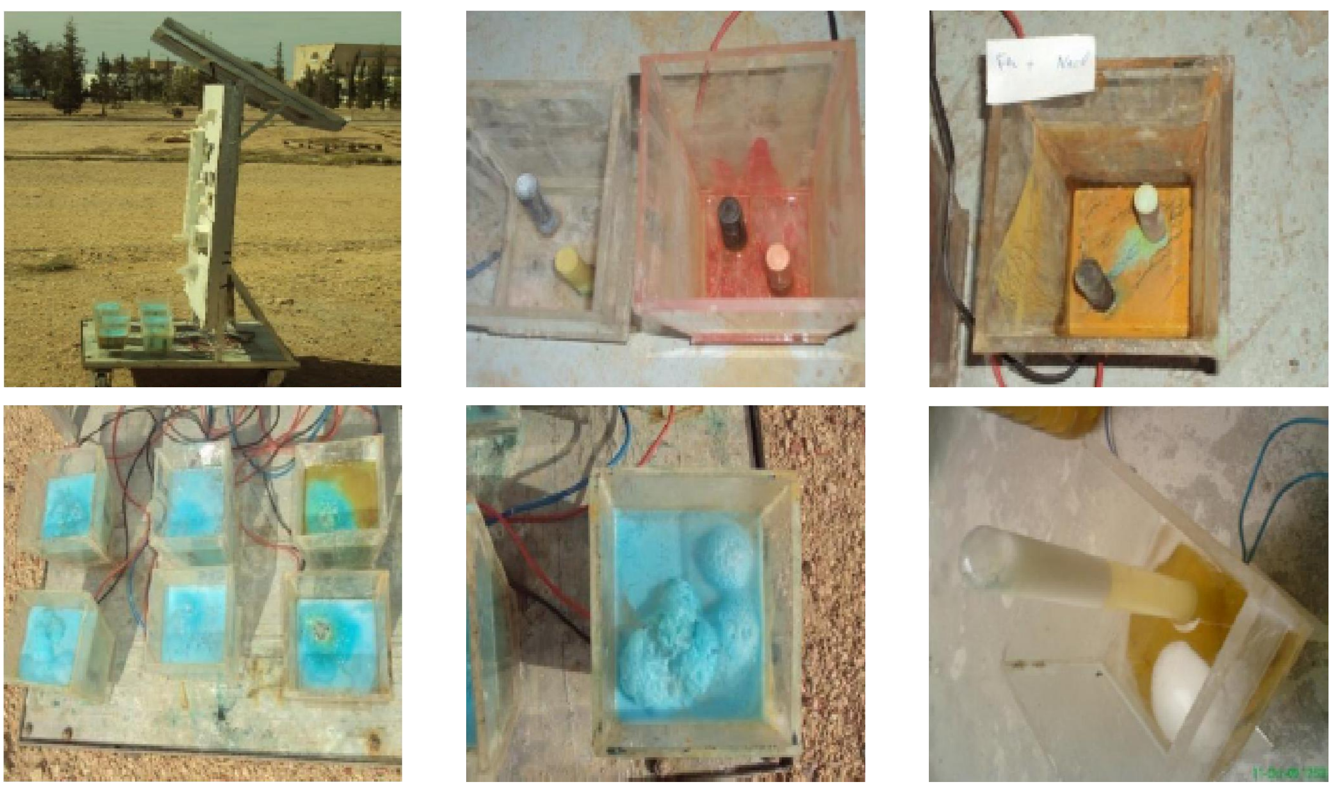
A photovoltaic module and electrolysers are used:

TABLE 1 represents the characteristics of the worn water used, such as the pH, the resistivity and initial salinity, before and after the sodium chloride addition.

We can notice that the sodium chloride addition has a weak effect on the pH, however the resistivity is strongly reduced.

TABLE 1 : Characteristics of the liquids before and after the addition of NaCl

	Liquids in initial state characteristics (before the addition of NaCl)			Salted liquids characteristics (after the addition of NaCl)	
Liquids	**pH**	**Resistivity (mS)**	**initial Salinity (g/l)**	**pH**	**Resistivity (mS)**
Water of tap, (Gabès, Tunisia)	6,97	4,67	2,5	6,9	-
Olive pucker	4,56	45,13	8,7	-	-
Margine	4,97	46,3	9,5	4,91	17,4
Urine	5,61	49,6	33,5	5,03	4,7
Vinegar of pink	5,33	4,8	2,6	4,62	3
Cleansing water	6,98	8,31	4,6	7,32	5,2
Gas liquor (NH_4OH)	7,9	120,3	-	7,37	7,9
Water of kitchen	4,18	8,5	4,7	8,34	10,3
Milk water	4,01	6,25	3,4	3,78	6,2



Chemical characteristics of worn water used

INFLUENCE OF NACL ADDITIVE ON THE ELECTROLYSIS OF VARIOUS WORN WATER

We use NaCl as additive for handling reasons facility, abundance on the market and low cost.

First size: Released hydrogen flow

These experiments are carried out under a value of 6 V and an ambient temperature of 21°C.

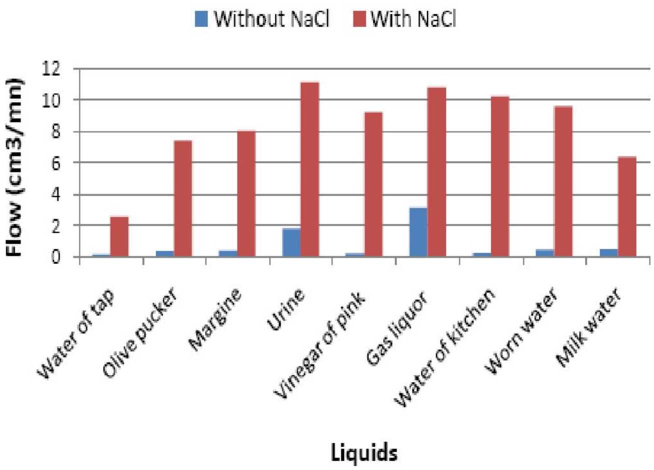


Figure 1 : Salinity effect on hydrogen flow produced by electrolyse worn water.

In the initial state of each liquid (worn water) used, we can notice that the gas liquor and the urine are distinguished because they have release hydrogen flows higher than the other liquids. With the addition of the NaCl additive, all the salted liquids see their hydrogen flow increasing in a significant way. The urine and the gas liquor remain among the best as well with as without additive salt.

Second size: Electric power consumed

The electric power is mainly consumed to produce hydrogen. Thus these two sizes are almost proportional according to Figures 1 and 2. However the variation remains enormous between the two configurations with and without additive.

This variation will be reduced in Figures 3 and 4 concerning, respectively, the efficiency of production and specific energy consumed.

The NaCl addition increases the electrolyte conductivity and consequently the current passage and thus the consumed electric power and the produced hydrogen flow and this, whatsoever the type of electrolyte.

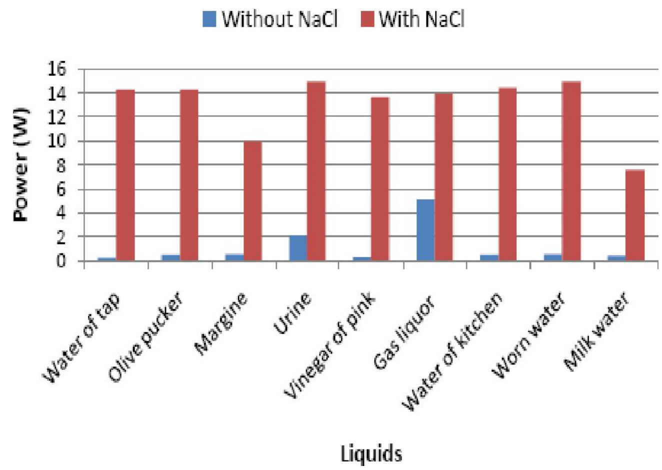


Figure 2 : Salinity effect on the electric power consumed to produce hydrogen by worn water electrolysis.

Third size: Electrolyser efficiency

The calculated efficiency is proportional to the quotient flow / electric power.

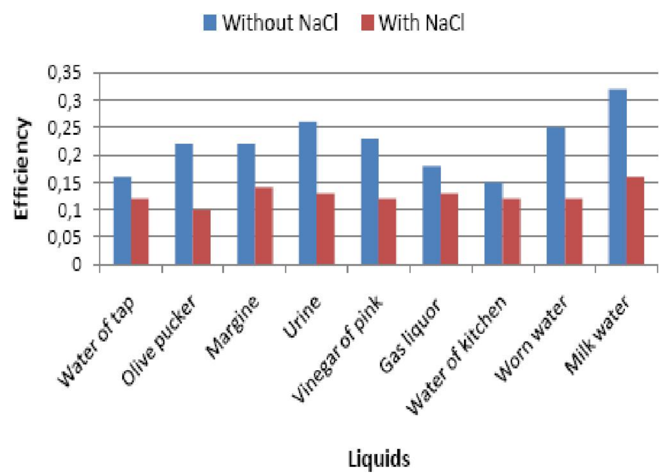


Figure 3 : Salinity effect on the produced hydrogen efficiency by worn water electrolyse.

We can only notice a small difference on the results indicated in this Figure 3. In fact, it is noted that the efficiency of the liquids without sodium chloride is larger than that of the liquids with NaCl. This will be explained by the low electric power dissipated for the liquids without NaCl that for the liquids salted even those which have significant flows.

Fourth size: consumed specific electric power

By this measured size of consumed specific electric power, we wanted to alleviate the great variations which exist between the two configurations with and without additive, observed in Figures 1 and 2.

If it is true that the addition of NaCl does not have

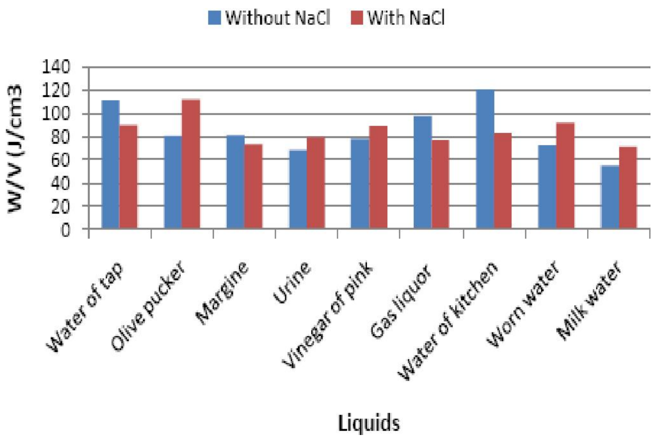


Figure 4 : Salinity effect on the consumed specific electric power to produce hydrogen by worn water electrolysis.

spectacular effect for all the electrolytes as in the case of flow and power consumption, we can however note that the addition of NaCl generates a decrease in the specific energy consumed in the case of the water of tap, margine, gas liquor, cooking worn water and an increase in this energy to let us pucker olive, urinates, vinegar of pink, *cleansing* water and milk water.

SIZES OF PERFORMANCE OF THE ELECTROLYSIS OF THE WORN WATER SALTED (200G/L OF NACL) WITH THE SUN WIRE

Our initial goal in fact is certainly to produce hydrogen by solar electrolysis using a photovoltaic module to be profitable economically and in favour of the natural environment.

The tests in day lights took place at the time of quite sunny days. One then records the flow of produced hydrogen, the efficiency of electrolysis, the consumed electric power and the specific energy of hydrogen production.

First size: Release of hydrogen flow

These experiments are carried out during a quite sunny day until 14 H, then after midday the sky became covered.

Throughout the day, it is practically the gas liquor, the urine and the worn water of the ONAS that produce the most hydrogen. It would be thus to use them for a massive production of hydrogen. However to treat margine effluant, electrolysis can be retained, even through the production of hydrogen is slow, on the other hand, it admits a sufficient conversion efficiency and

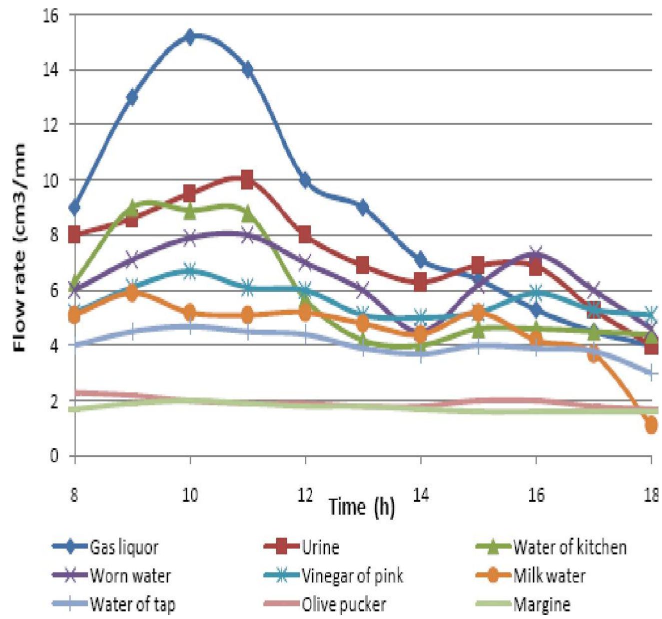


Figure 5 : Hydrogen release flow according to time (08/06/2010)

especially a rather reduced specific consumption.

Second size: Electric power

Measurements of current and the electrolyser terminal voltage give the consumed electric.

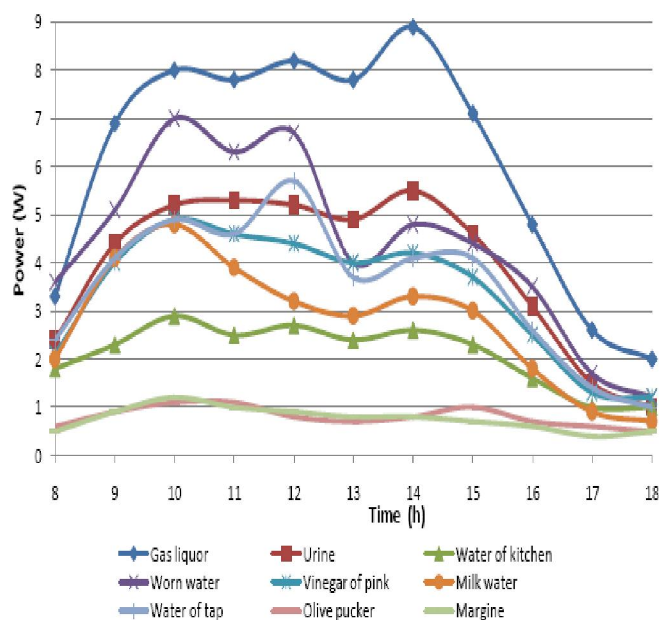


Figure 6 : Absorbed electric power according to time (08/06/2010)

The consumed power is that delivered by the photovoltaic generator, which, exposed to the sun delivers a current proportional to the sunning. The day of the experiment after midday was cloudy, which explains the fall of the power after 14 h.

According to Figure 6, gas liquor, urine and cleansing worn water deliver the most flow of hydrogen, it is them also which consume the most electric power.

Third size: Energetic efficiency of the electrolyser

The efficiency is deduced from the released hydrogen flow and its lower calorific value and from the consumed electric power.

$$\eta = \frac{PCI.V.\rho}{Pab.t}$$

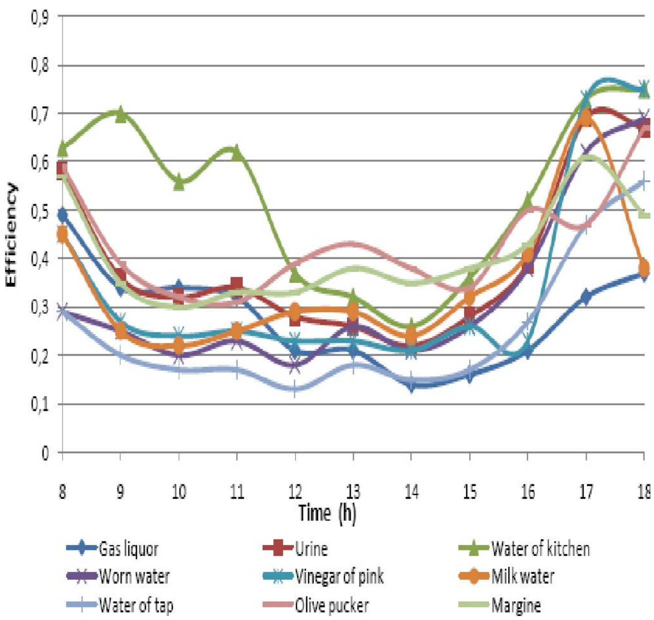


Figure 7 : Electrolysis efficiency according to time (08/06/2010)

The energetic efficiency is high at the beginning of morning and at the end of the day because received energy, being weak, is used effectively for electrolysis, the losses of powers transformed into heat with water are thus reduced.

The efficiency comparisons according to the electrolyte are almost contrary with the produced hydrogen flow and the consumed electric power; what is true for any energetic system.

Fourth size: Consumed electric power

From the flow and absorbed electric power measurements, we deduce the electric power consumed by an electrolyser to fill a volume V with test tube.

$$\frac{W}{V} = \frac{Pab.t}{V} = \frac{Pab}{Qv}\left(\frac{J}{cm^3}\right)$$

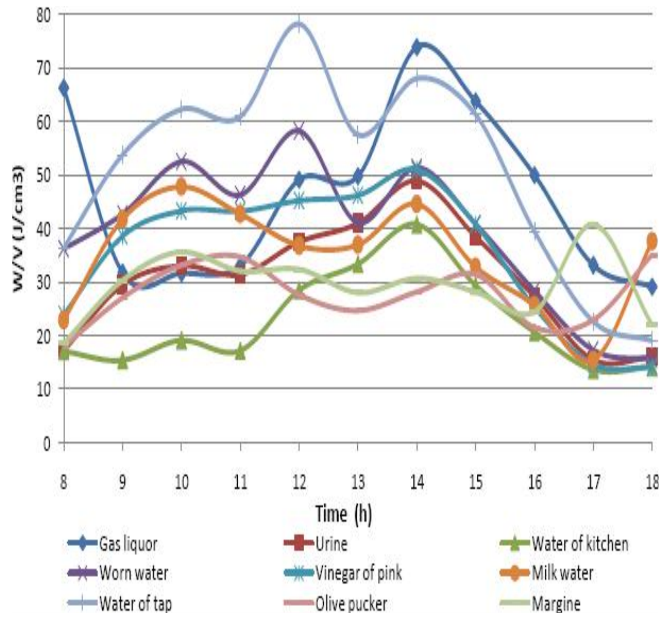


Figure 8 : Electric power consumed according to time (08/06/2010)

To have a minimal energy consumption, it is necessary that at least at least one of the following factors is weak, the consumption power and the conversion efficiency; conversely for a high energy consumption.

NOMENCLATURE

I	Electrical current (A)
U	Voltage (V)
P	Power (W)
PCI	Lower calorific value (J/kg)
Q	Flow rate (m^3/s)
V	volume of the test tube (m^3)
t	tube filling time (s)
W	electrical energy (J)
?	density of hydrogen (Kg/m^3)
Indices :	
a	absorbed
u	useful
nom	nominal
ab	absorbed

CONCLUDING REMARKS

Various measurements give sometimes conclusions that can appear contradictory as for the interest of the NaCl additive. However, our objective is to reach the best flows of production with a less consumption; it is with the manner of the vehicles that must run quickly without consuming too much!

Thus while using NaCl like additive, come to the first rank the ammonia water and urine, to the second rank worn water of cooking and from the cleansing water and the margine, finally the water out of the tap and the others.

If theoretical energy to break the water molecule is of 285 kJ / mol is 12,7 J/cm3, our found values are thus high and electrolysis still requires to be optimized for example by reducing the supply voltage by the parallel assembly of the electrolysers on the photovoltaic module.

The results of the tests to the wire of the sun show that the electric power consumed by the electrolyser follows that of the daily sunning; it is the reverse for the efficiency. We observed the same paces of efficiency for the case of the solar water heaters.

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