**Water battery cell of carbon - PMMA with Cu - Zn electrodes for green energy**

F I Mustafa*, A K Al-Sudani, H H Al-Qazzaz  
Solar Energy Research Center, Renewable Energy Directorate  
Ministry of Science and Technology, Baghdad, Iraq  
E-mail: falah_im@yahoo.com

**Abstract.** Water battery cell is a green energy, and it is a new innovation in the field of renewable green energy as well as that input is zero energy. It produces electricity without generating any negative carbon effects on the environment. Furthermore, it is a costless innovation, and the principle of work is based on using the tap water as a fuel source for the battery. That is mean, the battery doesn’t need power charging process (zero input), and it depends on the electrochemical analysis of water into positive and negative ions. The water battery cell (WBC) consists of 8 cells connected in series to produce a suitable voltage value. Each cell is based on Zn and Cu metal electrodes with carbon- PMMA layer sandwiched between them. The (WBC) was tested in different media such as normal and hot water between 25°C to 60°C temperature water to ensure the strength of the innovation. The (WBC) has tested by recording the current, voltage and power values in each water solution media with load and without load (LED lamp). The maximum electrical power record of the battery is 65 mW when using tap water without load and 10 mW with load at 25°C, then 43 mW when using hot tap water with load at 60°C. The load represents 4 red LED lamps of 10 mA and 1.6 V each, 4 yellow LED lamps of 10 mA and 1.8 V each, 4 green LED lamps of 10 mA and 1.8 V each were used as a load separately.

1. **Introduction**

Water cell like in shape as a galvanic cell whose electrodes are zinc and copper submerged in zinc sulfate and copper sulfate, respectively, and it is known as a Daniel cell. They are known as two half cells, and it is often used due to its simplicity. The anode is the zinc metal which is oxidized (loses electrons) to form zinc ions in solution, and copper ions accept electrons from the copper metal electrode and the ions deposit at the copper cathode as an electrodeposit. This cell forms a simple battery as it will spontaneously generate a flow of electric current from the anode to the cathode through the external connection [1].

Basically, to make a water battery cell that combine any two different kinds of metal can be placed in a conducting solution to make a battery. Familiar water batteries include sheet of metals from copper and zinc strips into water, using lemon solution to make battery. The aluminum-copper-coke battery will produce about three quarters of a vol t. Another easy battery to make zinc-air battery. In this battery, the strip of zinc is oxidized by dissolved oxygen in salty water. Three of the copper-zinc-coke batteries produce about 3 volts, and can replace the 3-volt lithium battery in this small clock/calender/calculator. This power generates electricity without affecting the environment and reduce the pollution and fight the carbon emissions to the environment.
2. Theory
Metal atoms are held together by electrical attractions between the nuclei and the electrons around the atoms. When you place a strip of metal in a glass of water, the water molecules interact with the metal atoms on the surface of the strip. Water molecules are polar, meaning the one side is a slightly positive, and the other side is a slightly negative. This is because the two hydrogen atoms are not on opposite sides of the oxygen atom, but are instead about 105° apart. The hydrogen side is positive, and the oxygen side is negative as shown in the figure 1.

![Figure 1. Water molecular direction in the cell](image)

At the interface between the water and the metal, some of the metal nuclei are attracted to the negative side of the water molecules. This attraction makes it easier for a metal nucleus to leave one or more of its electrons behind in the metal strip, and migrate away from the strip into the water. The strip is left with a very small negative electric charge, because it now has one less positive nucleus in it. This tiny charge does not pull very much on the metal ion that has left the strip. In fact, that ion (a metal atom with one or more electrons missing) is quickly surrounded by water molecules, whose negative side is attracted to the positive metal ion. This blanket of water molecules spreads out the positive charge over a larger area, making it even less attracted to the metal strip. This is a very temporary effect, and the metal ion usually gets attracted back to the strip very quickly. But since there are enormous numbers of atoms at the surface of the metal strip, and an enormous number of metal ions are in the water at any given time, the metal strip ends up with quite a few more electrons than metal nuclei. This gives the strip a slight negative charge.

Some metals hold on to their atoms more tightly than others. This means that some metal strips will become more negative when placed in water than others do. If one metal strip has more extra electrons than another one does, those electrons will flow from the first strip to the second, until they both have the same charge. But to flow, the electrons need a conductive path. We give them that path when we connect two strips of different metals with a wire. The electrons then flow through that wire, creating an electric current [2].

The aluminum-air cell belongs to the category of metal-air cells and zinc-air batteries operating in alkaline electrolytes have been developed for industrial and commercial applications. The energy densities of the industrial batteries are 150-300 W h/kg and 175-400 Wh/liter. The theoretical data for the following table 1 provides the reduction potentials of the indicated reducing agent at 25 °C. [3-4].
Table 1. Metal reduction potentials at 25 °C

| Oxidizing agent | Reducing agent | Reduction potential (V) |
|-----------------|----------------|-------------------------|
| Li⁺ + e⁻ = Li   | −3.04          |
| Cu²⁺ + e⁻ = Cu⁺| +0.16          |
| Zn²⁺ + 2e⁻ = Zn | −0.76          |
| Al³⁺ + 3e⁻ = Al | −1.66          |

2.1. COPPER, ZINC, AND SALT

A different chemistry happens when we have salt instead of acid in the water. Salt breaks up in water to make positive sodium ions and negative chloride ions. These ions reduce the energy needed for water to split into hydroxide ions (OH⁻) and hydrogen ions H⁺ (the hydrogen ions quickly find another water molecule and create hydronium ions, H₃O⁺). At the zinc strip, the zinc ion combines with four hydroxide ions to form one ion of zincate (Zn(OH)₄²⁻), leaving two electrons behind on the zinc strip. The chloride ions from the salt then combine with the hydronium ions left over when the hydroxide ions were taken away by the zinc, and form hydrochloric acid.

Over on the copper strip, four electrons combine with oxygen dissolved in the water and two molecules of water to form four hydroxide ions. The sodium ions from the salt combine with these hydroxide ions to make sodium hydroxide. The hydrochloric acid and the sodium hydroxide combine back into salt. So the salt is merely in the picture as a way to move charges through the water. It is not used up.

We can summarize what happens at the zinc strip (called the anode this way):

\[
\begin{align*}
\text{Zn} + 4\text{OH}^- &\Rightarrow \text{Zn(OH)}_4^{2-} + 2e^- \\
4\text{Cl}^- + 4\text{H}_2\text{O} &\Rightarrow 4\text{HCl} + 4\text{OH}^- \\
\text{Zn(OH)}_4^{2-} &\Rightarrow \text{ZnO} + \text{H}_2\text{O} + 2\text{OH}^- 
\end{align*}
\]

At the copper strip (called the cathode) we have:

\[
\begin{align*}
\text{O}_2 + 2\text{H}_2\text{O} + 4e^- &\Rightarrow 4\text{OH}^- \\
4\text{Na}^+ + 4\text{OH}^- &\Rightarrow 4\text{NaOH}
\end{align*}
\]

The water battery cell can have called a zinc-air battery. The oxygen from the air is combining with the zinc [5]. The copper electrode is just there to conduct the electrons, and does not participate in the chemistry. It can be replaced with a carbon rod. You may notice that after a short while, the oxygen in the battery is used up, and the current (and thus the brightness of the LED) begins to drop. Stirring the salt water helps to put more oxygen in the water, and the LED gets bright again [6-11].

3. Experiments and characterization techniques

The (WB) consists of 8 water cells of (9*5cm²) connected in series, as shown in the figure 2, and each cell consists of Zn- Cu electrodes, and a thin layer of carbon- PMMA material sandwiched between the electrodes with thickness about 2mm. The Cu or the positive electrode is a thin plate of pure Cu of (5*9cm²) surface area, and a thickness of 0.2 mm. The Zn or the negative electrode is a thin plate of pure 80% Zn metal and the surface area is about (5*9cm²) with the thickness of 0.3 mm. The carbon- PMMA was prepared by dissolving 2.5g of carbon powder and 2.5g of PMMA polymer in 8 ml of acetone as solvent. The paste was mixed carefully till forming a homogenous thin layer. This layer was rolled and pressed between the two electrodes.
Figure 2. shows the WB and the measuring tools.

After finishing the preparation of the 8 cells, we packed them inside a suitable plastic prepared box and connected them in series by copper wires. A Fluke multi-meter was used to measure the current (ampere), voltage (volt), and power characteristics by multiply current with voltage (watt). The PH-208 meter was used to test the PH of all solutions. A heat controlled plate heater of Chemat Technology was used to test the performance of the WB under the 60-degree centigrade water and all temperature measurements have tested and recorded by thermometer data logger with sensor type K.

4. Results and discussion

Each cell of the 8 cells consists of Cu plate as a cathode and a Zn plate as an anode. A Thin layer of carbon- PMMA was sandwiched between the electrodes. The carbon- PMMA layer was used to accelerate water analysis into positive and into negative ions to release electrons to generate electricity. The cells were connected in series by using copper wires to get a suitable voltage values and then the cells were put inside 600ml of tap water to start the electrical tests. The WB was tested inside 600ml of 25°C tap water and it was tested inside 600ml of 60°C tap water to ensure the normality of the electrical performance in a hot environment. We test the WB without using load (open circuit voltage and short circuit current and theoretical power). The WB was also tested under load to record the values of current, voltage, and real power. The cathode and anode voltage values depends on the oxidation and reduction reactions of the electrodes (REDOX reactions). The difference between the cathodic and the anodic voltages will modify the whole voltage of the cell. The whole electrical current of the cell is highly affected by the ionic content and the dissolved minerals inside the electrolyte (tap water). The tap water consists of the following elements: ((Ca++, Na+, Mg++, K+, Cl-, Al+++, Fe++, SiO2, CO3, SO4) [4].

These ions could react with the metal sheets to release more electrons; as a result, they will increase the value of the total current of the cell. The first case, we tested the WB in 25°C tap water without load and with load. All the voltage, current, and power values were recorded each 5 minutes for 45 min. Figure 3. shows the electrical performance of the WB.

Figure 3. electrical performance of the WB at (25°C) tap water without using load the voltage and current values through 45 mins and the power carve of the water battery.
In this test, the maximum power of the WB was achieved as (65 mW). We can see the values of the electrical terms start to be decreased with the time due to the chemical analysis of water. The second test was done in 25°C with using load to see the difference in the electrical performance. The WB was tested inside 600ml of 60°C tap water to check the electrical performance of the WB inside a hot media. The power curve of the water battery working inside 25°C water under 4 red LEDs of 1.6 V and 10 mA each connected in parallel.

The maximum power in figure 4 is about 65 mW in 60°C water without using the electrical load. The increment that observed when using hot water is due to increasing the dynamic movement of the positive and negative ions inside the water.

**Figure 4.** shows the electrical performance of the WB in 60°C without using the electrical load

In figure 5 the WB works in 60°C water under 4 red LEDs of 1.6 V and 10 mA each. The maximum power was recorded here as 43 mW. In order to understand the differences in the electrical performance of the WB inside cooled and hot water with load and without load, figure 6 will make it clear for good understanding.
Figure 6. shows the power comparison of the water battery inside cooled and hot water with and without load.

From figure 6 the WB working inside 25°C tap water without load gave the Max power of 65mW, while the WB working inside a 60°C tap water without load gave about 64mW which are the same. The effect of increasing the temperature on the electrical performance was clearly seen on the red line in figure 6. There is a difference in the performance under an electrical load between the red and the black line which clearly reflects the positive effect of increasing temperature. To see the electrical performance against the temperature increasing. Figure 7, shows the effect of temperature on the power of the WB working inside hot water under electrical load. PH factor is very important to be recorded to see what happen to water during the chemical analysis of it. Figure 8, shows the pH value changing with time.

Figure 7. shows the power increasing with temperature increasing.
Figure 8. shows the PH variation with the time

From figure 8, we notice the increasing in the PH value with the time which means the water goes toward the base nature due to increasing the (OH-) ions in the liquid. The positive ions may generate an H₂ gas and escapes from water.

Figure 9. Cu-Zn cell electrical test (voltage, current, and power) at 25°C at (A) Deionized water. (B) Drinking water. (C) 1M NaCl solution. (D) Power curves of the cell.
5. Conclusion
Water battery (WB) was designed and tested here to open a new way of utilizing the hydropower. WB is a costless device and a very clean energy source. It is also characterized by electrochemically stable and long lifetime. The WB consists of 8 symmetric water cell connected in series. The WB was tested in different media with electrical load and without. The max power generated from the device was 65mW when working inside 600ml of 25°C tap water without connecting to an electrical load. While it produced 64mW when working inside 600ml 60°C tap water without using electrical load. The WB produced 43mW power inside 60°C tap water under the electrical load. The electrical load was 4 red LED of 1.6 V and 10 mA each. For the future steps, we will try to optimize the elements of the WB to evaluate the electrical performance of the WB.

6. Acknowledgments
This research was supported by Scientific Projects in Solar Energy Research Center, Renewable Energy Directorate Ministry of Science and Technology of 2018 year in Baghdad Iraq.

References
[1] S James N.; Bodner, George M.; Rickard, Lyman H. 2010 Chemistry: Structure and Dynamics (Fifth Edition). John Wiley & Sons. p. 564. ISBN 9780470587119.
[2] Robinson, R Anthony, and R H Stokes 2002 Electrolyte solutions. Courier Corporation.
[3] O J Murphy et al 1992 Electrochemistry in Transition, Plenum Press, New York.
[4] Burgot, Jean-Louis 2012 "Redox Reactions and Electrochemical Cells." In Ionic Equilibria in Analytical Chemistry, Springer. New York. pp. 205-227.
[5] E L Littauer and J F Cooper 1984 “Metal air batteries,” in Handbook of Batteries and Fuel Cells, edited by D. Linden (McGraw Hill, New York), pp. 30-1–30-21.
[6] Ponrouch, A Goñi, A. & Palacín, M. R 2013 High capacity hard carbon anodes for sodium ion batteries in additive free electrolyte. Electrochem. Comm. 27, 85–88.
[7] M Tamez and J H Yu 2007 “Aluminum–air battery.” J. Chem. Educ. 84, 1936A.
[8] D Rathjen and P. Doherty, 2002 Square Wheels and Other Easy-to-Build Hands-On Science Activities (Exploratorium, San Francisco), p.85.
[9] J P Hoare, 1985 “Oxygen,” in Standard Potentials in Aqueous Solution, IUPAC, edited by A.J. Bard, R. Parsons, and J. Jordan (Marcel Dekker, Inc., New York), pp.54–66.
[10] S M Park 1985 “Boron, aluminum and scandium,” in Standard Potentials in Aqueous Solution, IUPAC, edited by A.J. Bard, R. Parsons, and J. Jordan (Marcel Dekker, Inc., New York), pp. 566-580.
[11] P N Ross, “Hydrogen” in Standard Reduction Potentials, IUPAC, edited by A.J. Bard, R. Parsons, and J. Jordan (Marcel Dekker, Inc., New York), pp. 39-48.