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A Study on Paper-Based Water-Activated Disposable Batteries and its Impact on Sustainable Growth

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Abstract: Growing interest in green and renewable energy sources is a result of the global search for sustainable energy alternatives. Paper-based water-activated batteries have become a promising technology in this regard. The creation, possible uses, and environmental effects of paper-based water-activated batteries are observed in this study, as well as how they might affect sustainable development. This study intends to shed light on the applicability of this novel energy storage technology in fostering a greener and more sustainable future through a thorough analysis of existing research and practical demonstrations. This paper devotes a great deal of attention to historical development and evolution as well as the escalating environmental sustainability problems.

Key words: Growth, Impact and Sustainable Storage**.**

1. Introduction

Water-activated batteries, also known as water-activated cells or magnesium-water batteries, are a type of disposable, environmentally friendly power source that generates electricity through a chemical reaction between water and a metal, typically magnesium. These batteries are often used in emergency situations, such as for powering flashlights, radios, and other portable devices in situations where access to electricity is limited.

Water-activated batteries and sustainable growth are related in a number of ways since sustainability includes social, economic, and environmental factors. The relationship between water-activated batteries and sustainable growth is best illustrated by the following main points:

Water-activated batteries are often considered more environmentally friendly than conventional batteries because they use water as an electrolyte, which is non-toxic and readily available. This can contribute to reducing the environmental impact associated with battery disposal and production. Unlike traditional batteries that use corrosive and potentially harmful chemicals, water-activated batteries use materials that are less harmful to the environment, promoting sustainability by reducing the release of hazardous substances.

1.1 Background of the Study

Water-activated batteries rely on a chemical reaction known as a galvanic or electrochemical reaction. In this case, magnesium serves as the anode, and water serves as the electrolyte. When the battery is activated by adding water, the magnesium reacts with the water to form magnesium hydroxide and release electrons. The electrons flow through an external circuit, producing electrical energy.

Water-activated batteries are considered environmentally friendly because they do not contain toxic chemicals or heavy metals like traditional alkaline batteries. They are non-toxic and can be safely disposed of in most waste streams.

2. Literature Review

"Water-Activated Paper Battery" by Seokheun Choi, published in the journal Advanced Science in 2017. This paper discusses the development of a microbial fuel cell-based paper battery that is activated by water and can be used for various applications.

"A Self-Healing, Water-Activated, and Biocompatible Zinc-Manganese Dioxide Battery" by Lushuai Zhang, et al., published in Advanced Materials in 2019. This research presents a water-activated zinc-manganese dioxide battery with self-healing properties.

"High-Performance Paper-Based Microbial Fuel Cells" by Seokheun Choi, published in the journal Nano Letters in 2015. This paper explores the use of paper as a substrate for microbial fuel cells, which can be activated using various liquids, including water.

"Flexible and Printable Paper-Based Solid-State Micro-Supercapacitor Using a Pencil Drawing Technique" by Yu Geun Choi, et al., published in Nano Energy in 2016. This work discusses the development of paper-based supercapacitors that can be activated with water-based inks.

"A Sustainable Paper Battery for Large-Scale Energy Storage" by Xiaolu Tang, et al., published in Advanced Sustainable Systems in 2019. This research presents a sustainable paper battery design that can be activated with water and used for large-scale energy storage.

"Eco-Friendly Water-Activated Primary Zinc–Manganese Dioxide Batteries with Long Shelf Life and High Power Density" by Yanbin Shen, et al., published in Advanced Functional Materials in 2019. This paper discusses water-activated primary batteries with eco-friendly components.

"Water-Activated Paper Batteries: Functional Integration of Energy Storage and Sensing" by Xian Huang, et al., published in Advanced Materials Technologies in 2018. This research explores the integration of energy storage and sensing capabilities in water-activated paper batteries.

"Flexible and Biodegradable Paper-Based Battery for Wearable Electronics" by Zhong Lin Wang, et al., published in Advanced Energy Materials in 2016. This work presents a biodegradable paper-based battery that can be activated with water and is suitable for wearable electronics.

3. Scope of the Study

The study of disposable paper batteries has a vast and evolving scope, spanning numerous opportunities for research, development, and application. Fundamentally, this field aims to transform energy storage by fusing utility and sustainability. In order to maximise performance and efficiency, researchers can explore different paper substrates, electrode materials, and electrolytes.

A crucial component of sustainability is the evaluation of biodegradability, environmental effect, and electronic waste reduction as compared to traditional batteries. Determining the viability of disposable paper batteries for various applications requires evaluating energy storage capacity, discharge characteristics, and activation techniques. This includes its incorporation into flexible and wearable electronics, enabling the creation of cutting-edge, lightweight, and environmentally friendly technology.

Water-activated batteries can play a vital role in sustainable energy systems by providing energy storage solutions for intermittent renewable energy sources like solar and wind power. This helps stabilize the grid and makes renewable energy more reliable.

Water-activated batteries can be manufactured using renewable and biodegradable materials, promoting resource efficiency and minimizing the depletion of finite resources.

4. Objective of the Study

- Studying disposable paper batteries will primarily enhance the creation of environmentally responsible and sustainable energy storage technologies.
- In order to address the growing concern over the amount of electronic trash produced by conventional

batteries, these batteries are made with an emphasis on biodegradability and low environmental effect.

- These batteries' portability and light weight make them perfect for powering wearables, remote sensors, and portable gadgets, advancing technology across a range of industries.
- In cases where immediate power generation is required, such as emergencies or off-grid settings, their water-activation capability is especially useful.

1. Fabrication

A paper substrate that has been cut to a size greater than the intended battery serves as the foundation for the production of the paper battery. To make a hydrophobic area where the battery contacts can be found, melted wax is poured into one end of the paper substrate. After being submerged in 3M aq. NaCl, the paper substrate is dried. The cathode is stencil-printed and given a 10-minute drying period. the same printing process and drying circumstances are then utilised to pattern the anode, bottom current collector, and top current collector. The terminals are made by connecting the lead wires after the sample has been cut into the correct shape.

2. Battery Construction

The paper substrate of a single cell battery is placed between an air cathode and a current collector on one side and a zinc anode and a current collector on the other. Because there is no electrolyte in the battery when it is made, the anode and cathode are essentially kept separate. Water rapidly absorbs and diffuses through the paper substrate when it is introduced to the system, dissolving the NaCl that has been disseminated in the paper and activating the electrochemical cell. The airtight current collector, which is placed on this side of the device, can only be so large since the cathode requires oxygen from the surrounding air. The contact resistance is kept as low as feasible while the oxygen flow is maximised. On the other hand, to prevent undesirable electrochemical reactions with the connecting wires, the substrate is made hydrophobic on the terminal end. A 1.2 V open circuit battery was provided by the single cell battery. To generate greater open circuit potentials, multiple electrochemical cells can be printed on the same substrate and connected in series.

3. Setup and Ink Preparation

Shellac, ethanol, and graphite flakes make up 15%, 30%, and 47%, respectively, of the cathode ink. Ethanol is used to dissolve the shellac, and then graphite and PEG are added. The resulting mixture is blended in a planetary mixer at 2300 rpm for 1 minute. The anode ink contains PEG, 5.5 weight percent ethanol, 89.5 weight percent zinc powder, and 2.5 weight percent shellac. The final mixture is blended for q=1 min at 2300 rpm in a planetary mixer.

6.5wt% carbon black, 41.5wt% ethanol, 21.5wt% shellac, and 4wt% polyethylene glycol make up the present collector ink. Shellac is dissolved in ethanol, followed by the addition of carbon black, graphite, and PEG. The resultant mixture is then ball milled for 1 minute at 2300 rpm in a planetary mixer. 50 weight percent carnauba wax and 50 weight percent rapeseed oil make up the wax oleogel. In a metal dish that is placed on a hotplate and heated above the temperature at which carnauba wax melts, the oil and wax are combined and thoroughly swirled. The finished mixture is taken off the fire and chilled to room temperature. On a rotational and oscillatory rheometer, the rheology of the anode, cathode, and current collector were assessed using a plate-plate geometry with a 1mm gap.

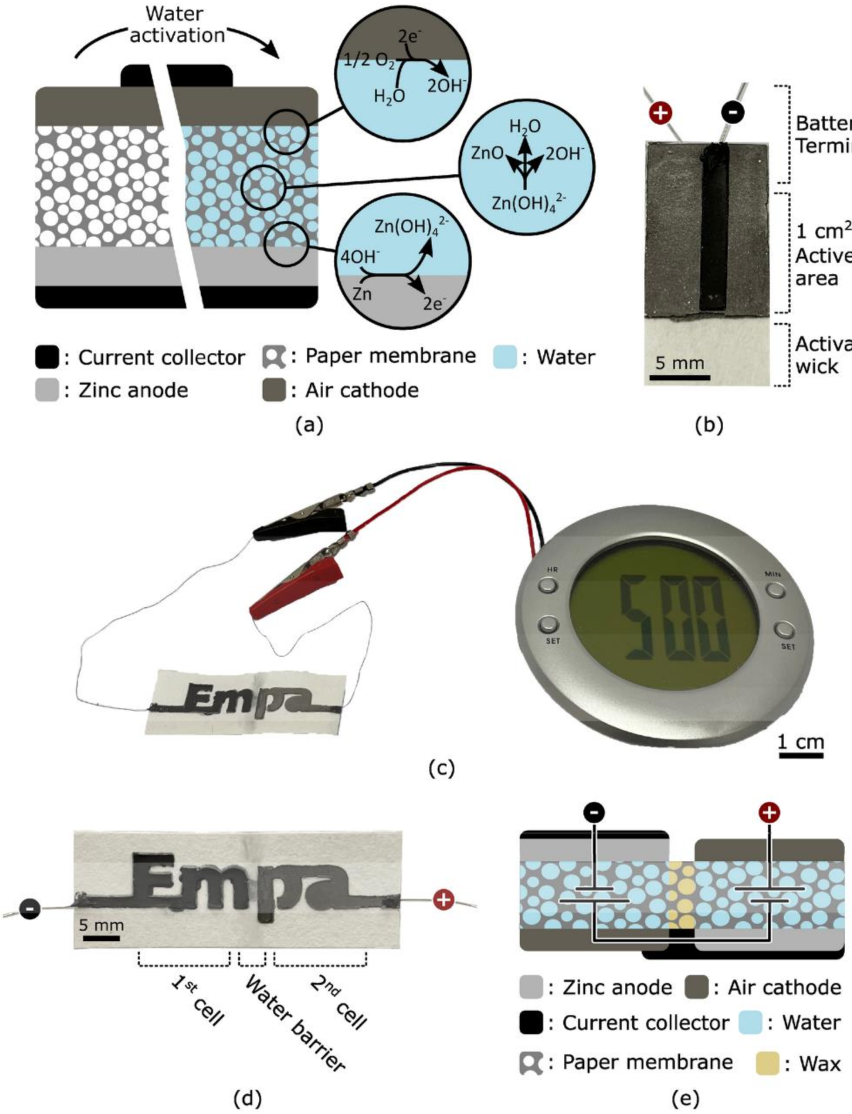

Fig 1: Conceptual Model. (Credits: Alexandre Poulin)

8. Benefits over existing batteries

1. Eco-Friendly: It is a biodegradable and non-toxic product because the majority of its contents are of organic origin.
2. Biocompatible: If inserted into a human body, they are not readily rejected by the immune system.
3. Simple to Reuse and Recycle: Because it is made of cellulose, this product is simple to reuse and recycle, even when using the current paper recycling procedures.
4. Resilient: It has a three-year shelf life (at room temperature). It can function in temperatures between -75° and +150°C when necessary.
5. It is rechargeable up to 300 times using virtually all electrolytes, including bio-salts from sweat, urine, and blood.
6. No Leakage & No Overheating: Despite harsh conditions, it does not overheat due to the low resistance.

8. Applications

1. In Electronics: Laptop batteries, mobile phones, handheld digital cameras: The weight of these devices can be significantly reduced by replacing the alkaline batteries with light- weight Paper

Batteries, without compromising with the power requirement.

2. In Medical Sciences:
   - in Pacemakers for the heart
   - in Artificial tissues (using Carbon nanotubes)
   - in Cosmetics, Drug-delivery systems
   - in Biosensors, such as Glucose meters, Sugar meters, etc.
3. In Automobiles and Aircrafts:
   - in Hybrid Car batteries
   - in Long Air Flights reducing Refueling
   - for Light weight guided missiles
   - for powering electronic devices in Satellite programs

Moreover, the electrical hazards related to recharging will be greatly reduced.

- In calculators, wrist watch and other low drain devices.
- In wireless communication devices like speakers, mouse,keyboard, Bluetooth headsets etc.
- In Enhanced Printed Circuit Board (PCB) wherein both the sides of the PCB can be used: one for the circuit and the other side (containing the components would contain alayer of customized Paper Battery. This would eliminate heavy step-down transformers and the need of separate power supply unit for most electronic circuits.

9. Limitations and Disadvantages:

It would not be logical only to ponder over the miraculous properties and applications of Paper Batteries.

Things need to be discussed at the flip side as well. Following are some of them:

1. Have Low Shear strength:
2. They can be 'torn' easily. The Techniques and the Set-ups used in the production of Carbon Nanotubes are very Expensive and very less Efficient. They are electrolysis, CVD etc.
3. When inhaled, their interaction with the Microphages present in the lungs is similar to that with Asbestos fibers, hence may be seriously hazardous to human health

10. Conclusion

The energy crisis is one of the main issues plaguing the world right now. Each and every country requires power and energy. And the developing nations, like India, are considerably more affected by this issue than the developed nations are. In the current situation, where there can never be a day without power, Paper Batteries can offer an entirely novel alternative.

Flexible paper batteries have the potential versatility to power the next generation of electronics, medical devices, and hybrid cars, enabling for radical new designs and medical breakthroughs. These batteries are biodegradable, lightweight, and nontoxic. If India is to rely solely on its own energy supply, it still has a long way to go. According to literature, Indian researchers possess the scientific acumen required for such ground-breaking work. But the lack of resources and finance is what gets in the way of their progress. Of course, there is an infinitely wide range of curiosity, and our work is only a small step in that direction.

References

[1] Kumar, A., Holuszko, M. & Espinosa, D. C. R. -E-waste: An overview on generation, collection, legislation and recycling practices. *Resour. Conserv. Recycl.* **122**, 32–42 (2017). "

[2] Irimia-Vladu, M., Głowacki, E. D., Voss, G., Bauer, S. & Sariciftci, N. S.-Green and biodegradable electronics. *Mater. Today* 15, 340– 346 (2012).

[3] Muralidharan, N., Afolabi, J., Share, K., Li, M. &Pint, C. L. - A fully transient mechanical energy harvester. *Adv. Mater. Technol.* **3**, 1–7 (2018).

[4] Gogotsi, Y. & Simon, P. -True performance metrics in electrochemical energy storage.

Science (1979) **334**, 917LP – 918 (2011).

[5] Aeby, X., Poulin, A., Siqueira, G., Hausmann, M.K. & Nyström, G.-Fully 3D printed and disposable paper supercapacitors. *Adv.Mater.* **2101328**, 1–9 (2021).

[6] Chen, C. *et al.* - All-wood, low tortuosity, aqueous, biodegradable supercapacitors with ultra-high capacitance. *Energy Environ. Sci.* **10**, 538–545 (2017).

[7] Maiti, S., Karan, S. K., Kim, J. K. & Khatua, B- Nature driven bio-piezoelectric/triboelectric nanogenerator as next-generation green energy harvester for smart and pollution free society. *Adv. Energy Mater.* **9**, 1–41 (2019).

[8] Choi, J. W. & Aurbach, D.- Promise and reality of post-lithium-ion batteries with high energydensities. *Nat. Rev. Mater.* **1**, 1–16 (2016).

[9] Sun, Y., Liu, N. & Cui, Y.- Promises andchallenges of nanomaterials for lithium-based rechargeable batteries. *Nat. Energy* **1**, 16071(2016).

[10] Zhao, L. *et al.*- A fully biodegradable battery for self-powered transient implants. *Small* **14**, 1800994 (2018).

[11] Rogers, J. A. *et al.*- Materials, designs, and operational characteristics for fully biodegradable primary batteries. *Adv. Mater.* **26**, 3879–3884 (2014).

[12] Esquivel, J. P. *et al.*- A metal-free and biotically degradable battery for portable single-use applications. *Adv. Energy Mater.* **7**, 1700275 (2017).

[13] Egorov, V., Gulzar, U., Zhang, Y., Breen, S. & O'Dwyer, C.- Evolution of 3D printing methods and materials for electrochemical energy storage. *Adv. Mater.* **2000556**, 1–27 (2020).

[14] Martinez, A. W., Phillips, S. T., Whitesides, G. M. & Carrilho, E.- Diagnostics for the developing world: Microfluidic paper-based analytical devices. *Anal. Chem.* **82**, 3–10 (2010).