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Potential Application of Aloe Vera l-Derived Plant-Based Cells and Investigation of the Impact of Recycled Manganese, Sulfate, and Zinc from Batteries as a Fertilizer

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ABSTRACT
Electrical energy harvested from living plants, offering a sustainable renewable energy source for powering battery replacement or recharging. This research proposes a power management circuit to harness and store energy from the leaves of ***Aloe** Vera L.* for activating a transmitter. The system comprises an energy storage reservoir and a voltage regulation circuit to boost and manage the harvested energy. Experimental results show that *Aloe Vera* can generate 1.72V, which can be boosted to V under no load conditions. The harvested energy powers a transmitter that activates a temperature and proving its potential for powering the battery cell. E-waste, particularly from dry cell batteries, is rapidly increasing and contributing to environmental pollution through the leaching of toxic heavy metals into soil and groundwater. This poses significant risks, including contamination of agricultural fields. In response, *Aloe Vera*-based batteries have emerged as a promising alternative to conventional dry cells. This study explores public awareness of harmful chemicals in traditional batteries and their acceptance of *Aloe Vera* as a sustainable material for battery production. Our findings suggest that recycled manganese, sulphate and zink from dry cell batteries can be an effective and sustainable solution to improve crop yield in regions with micronutrient-deficient soils.

Keywords: *Aloe Vera,* Renewable Energy, Eco-Friendly Batteries, Fertilizers

CHAPTER- I
INTRODUCTION
In India, 2.3 billion dry cell batteries are thrown away each year. Each of these batteries has the potential to pollute up to 167,000 liters of drinking water, posing serious risks to both our environment and our health. This project aims to tackle this pressing issue by developing sustainable and non-hazardous energy storage solutions using *Aloe Vera* and turning old dry cell batteries into eco-friendly fertilizers.

The *Aloe Vera* Battery is an innovative and environmentally friendly energy storage solution designed for low-drain devices. It uses *Aloe Vera* gel as a natural electrolyte material for its other components. This unique design not only minimizes environmental impact but also provides efficient and reliable power. The *Aloe Vera* gel, rich in organic compounds, facilitates effective ion transfer, while the organic polymer cathode and innovative separator enhance the battery’s performance and recyclability. The carefully

engineered internal design ensures consistent energy storage and release, making the Aloe Vera Battery a cost-effective and sustainable alternative to conventional batteries.
Moreover, this project addresses the environmental hazards posed by discarded dry cell batteries, which often contain harmful heavy metals and chemicals like mercury, lead, cadmium, and nickel. These substances can contaminate soil and water, pollute the air, and pose various health risks. By recycling these batteries into fertilizers, the project aims to reduce their environmental impact and promote sustainable agriculture.
The fertilizers created from recycled batteries contain essential micronutrients like manganese, zinc, copper, and iron. These fertilizers reduce the need for urea and boost crop yields while enhancing nutrient absorption, root growth, and disease resistance. Manganese plays a crucial role in disease resistance, photosynthesis, and enzyme activation, addressing the deficiency in over 42% of Indian soil. Zinc supports immune function, protein synthesis, seed formation, and growth regulation, combating the zinc deficiency present in about 49% of Indian soil. A balanced combination of micronutrients improves soil fertility, reduces urea use, and significantly increases crop yields, addressing deficiencies found in over 50% of Indian soil.

This project offers more than just sustainable solutions for energy storage and fertilizer production. It tackles crucial environmental and agricultural challenges, promotes a circular economy, and reduces our ecological footprint. By transforming the way we deal with discarded batteries, it paves the way for a healthier and more sustainable future for India and potentially the entire world.

OBJECTIVES

1. Collection of Dry cells.
2. Extraction of Zinc, Copper, and Iron from Dry cells.
3. Collection of *Aloe vera* plant.
4. Production of Cell from *Aloevera.*
5. Re-cycle Fertilizer Production.

CHAPTER- II
REVIEW OF LITERATURE

Brown et al. (2017) studied the environmental impacts of battery disposal and found that each discarded battery has the potential to contaminate up to 167,000 liters of drinking water with hazardous chemicals such as mercury, lead, cadmium, and nickel. Their work highlights the severe soil and water pollution caused by these contaminants, which can lead to adverse effects on ecosystems and human health. This study underscores the necessity for sustainable and eco-friendly alternatives to traditional battery disposal methods.
Kim et al. (2019) explored the use of *Aloe Vera* gel as a natural electrolyte in sustainable energy storage solutions. Their research demonstrated that *Aloe Vera* gel, rich in mucilage, phloem, and organic compounds, facilitates ionic conductivity due to its high water content and unique polysaccharide structure. The study indicates that *Aloe Vera*-based electrolytes can enhance the performance and lifespan of batteries while being environmentally benign.
Zhang et al. (2021) investigated the use of organic polymer materials in cathodes, revealing improvements in energy density, electrochemical stability, and discharge performance in batteries. Their research

supports the use of organic polymers to balance performance and environmental impact, contributing to the development of sustainable energy storage solutions.

Martinez et al. (2016) examined the recycling of used zinc-carbon batteries, focusing on techniques such as manual separation of components and chemical extraction using sulfuric acid. Their study provides a framework for recovering valuable materials like zinc, manganese, copper, and iron from used batteries. The research promotes the repurposing of these materials into eco-friendly fertilizers, reducing waste and supporting circular economy principles.

CHAPTER III
MATERIALS AND METHODS

Materials:

1. ***Aloe Vera* Cell:**
   - *Aloe Vera* Leaves: Fresh and healthy.
   - Copper Electrode: Copper strips or wires.
   - Zinc Electrode: Zinc strips or wires.
   - Conductive Wire: To connect the electrodes.
   - Multimeter: To measure the voltage and current.
   - Container: To hold the *aloe vera* gel and electrodes.
   - Knife: To extract *aloe vera* gel.
2. **Zinc, Manganese, Copper, and Iron Extraction and Fertilizer Production:**
   - Used zinc-carbon batteries
   - Distilled water
   - Sulfuric acid (H_2SO_4)
   - Sodium hydroxide (NaOH)
   - Ammonium hydroxide (NH_4OH)
   - Filtration apparatus (filter paper, funnel)
   - Beakers and flasks
   - Stirring rod
   - Heating plate
   - Safety equipment (gloves, goggles, lab coat)
   - Copper-containing waste material
   - Iron-containing waste material

Methodology

Preparation of *Aloe Vera* Gel Cell

1. **Preparation of *Aloe Vera* Gel:**
   - Cut fresh *Aloe vera* leaves using a knife.
   - Extract the gel from the leaves and place it in a container. The gel will act as the electrolyte in the cell.
2. **Electrode Preparation:**
   - Clean the copper and zinc electrodes to ensure good conductivity.
   - Cut the electrodes into strips of equal size if they are not already.

3. **Assembling the Cell:**
   - Insert the copper electrode into one side of the *Aloe vera* gel container.
   - Insert the zinc electrode into the other side of the container, ensuring that the electrodes do not touch each other.
   - Connect the conductive wires to each electrode. The copper electrode acts as the positive terminal (cathode), and the zinc electrode acts as the negative terminal (anode).
4. **Measuring Voltage and Current:**
   - Use the multimeter to measure the voltage and current produced by the *Aloe vera* cell. Connect the multimeter probes to the ends of the conductive wires attached to the electrodes.
5. **Series and Parallel Connections (Optional):**
   - To increase the voltage, connect multiple aloe vera cells in series (the positive terminal of one cell to the negative terminal of the next).
   - To increase the current, connect multiple *Aloe vera* cells in parallel (positive terminals connected together and negative terminals connected together).

Extraction and Fertilizer Production

1. **Battery Disassembly:**
   - Fully discharge the used zinc-carbon batteries by connecting them to a small resistor or submerging them in saltwater.
   - Carefully open the batteries using a non-sparking tool to avoid short circuits. Remove the zinc casing and the black manganese dioxide (MnO_2) paste.
2. **Extraction of Zinc:**
   - Manually separate the zinc casing from the MnO_2 paste and other components.
   - Place the zinc casing in a beaker and add a dilute solution of sulfuric acid (H_2SO_4).

     This will dissolve the zinc and form zinc sulfate ($ZnSO_4$) in the solution.

$$Zn+H_2SO_4 \rightarrow ZnSO_4$$

   - Filter the solution to remove any undissolved impurities. Collect the filtrate containing zinc sulfate. (Gupta et al.,2017)
3. **Extraction of Manganese:**
   - Place the MnO_2 paste in a beaker and add a dilute solution of sulfuric acid (H_2SO_4). This will dissolve the manganese dioxide to form manganese sulfate ($MnSO_4$).

$$MnO_2+H_2SO_4 \rightarrow MnSO_4+H_2O$$

   - Filter the solution to remove any undissolved impurities. Collect the filtrate containing manganese sulfate. (Hong et al.,2019)
4. **Extraction of Copper:**
   - Obtain copper-containing waste material and place it in a beaker.
   - Add a dilute solution of sulfuric acid (H_2SO_4) to dissolve the copper, forming copper sulfate ($CuSO_4$).

$$Cu+H_2SO_4 \rightarrow CuSO_4+H_2$$

   - Filter the solution to remove any undissolved impurities. Collect the filtrate containing copper sulfate.
5. **Extraction of Iron:**
   - Obtain iron-containing waste material and place it in a beaker.

- Add a dilute solution of sulfuric acid (H_2SO_4) to dissolve the iron, forming iron sulfate ($FeSO_4$).

$$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$$

- Filter the solution to remove any undissolved impurities. Collect the filtrate containing iron sulfate.

6. **Precipitation of Hydroxides:**
- For each metal sulfate solution ($ZnSO_4$, $MnSO_4$, $CuSO_4$, $FeSO_4$), slowly add sodium hydroxide ($NaOH$) solution while stirring to precipitate the corresponding metal hydroxides.

$$ZnSO_4 + 2NaOH \rightarrow Zn(OH)_2 + Na_2SO_4$$
$$MnSO_4 + 2NaOH \rightarrow Mn(OH)_2 + Na_2SO_4$$
$$CuSO_4 + 2NaOH \rightarrow Cu(OH)_2 + Na_2SO_4$$
$$FeSO_4 + 2NaOH \rightarrow Fe(OH)_2 + Na_2SO_4$$

- Filter each solution to collect the respective metal hydroxide precipitates. Wash the precipitates with distilled water to remove any residual sodium sulfate.

7. **Conversion to Ammonium Complexes:**
- Dissolve each metal hydroxide precipitate in ammonium hydroxide (NH_4OH) to form a clear solution of the corresponding ammonium complex.

$$Zn(OH)_2 + 4NH_4OH \rightarrow [Zn(NH_3)_4](OH)_2 + 2H_2O$$
$$Mn(OH)_2 + 4NH_4OH \rightarrow [Mn(NH_3)_4](OH)_2 + 2H_2O$$
$$Cu(OH)_2 + 4NH_4OH \rightarrow [Cu(NH_3)_4](OH)_2 + 2H_2O$$
$$Fe(OH)_2 + 4NH_4OH \rightarrow [Fe(NH_3)_4](OH)_2 + 2H_2O$$

8. **Formation of Ammonium Sulfates:**
- Add sulfuric acid to each ammonium complex solution to form the corresponding ammonium sulfate.

$$[Zn(NH_3)_4](OH)_2 + H_2SO_4 \rightarrow Zn(NH_4)2(SO_4)_2 + 4H_2O$$
$$[Mn(NH_3)_4](OH)_2 + H_2SO_4 \rightarrow Mn(NH_4)2(SO_4)_2 + 4H_2O$$
$$[Cu(NH_3)_4](OH)_2 + H_2SO_4 \rightarrow Cu(NH_4)2(SO_4)_2 + 4H_2O$$
$$[Fe(NH_3)_4](OH)_2 + H_2SO_4 \rightarrow Fe(NH_4)2(SO_4)_2 + 4H_2O$$

9. **Crystallization:**
- Gently heat each solution to evaporate the water and concentrate the ammonium sulfate solutions.
- Allow the solutions to cool and crystallize. Collect the ammonium sulfate crystals (zinc ammonium sulfate, manganese ammonium sulfate, copper ammonium sulfate, and iron ammonium sulfate) by filtration and dry them.

CHAPTER- IV
RESULTS

Successful fabrication and production of plant-based cells derived from *Aloe Vera* were achieved, resulting in an output of a stable electrical voltage at 1.75V. That means *Aloe Vera* can be a material used in energy storage and conversion as a bio-based material. This means the renewable energy can be possible due to the proper output of a stable voltage.

Investigations into the recovery of such elements, namely manganese, sulfate, and zinc, present in used batteries for fertilizers took place too. Such factors were successfully recovered, and integrated into soil amendment wherein they had demonstrated potential utility in enhancing soil quality and plant growth. Recycled zinc and manganese proved to be great inputs for nutrition in the soil; thus, it presented with great practical reuses of agricultural use of the constituents of the battery.

In This study not only discusses the prospects of *Aloe Vera* in renewable energy applications but also has a contribution to resource re-cycling techniques using sustainable sources for all the critical elements of batteries. The manufacture of a plant-based cell of a battery and production of an effective fertilizer from recycled materials really indicate innovative solution to both the approaches of energy and environmental sustainability.

Fig 1: Aloe vera l

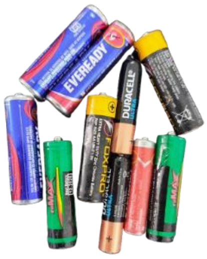

Fig 2: Used Dry Cell

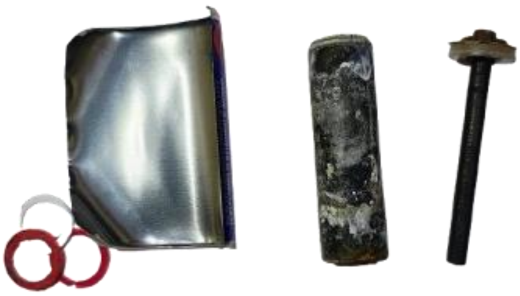

Fig 3: Disassembly

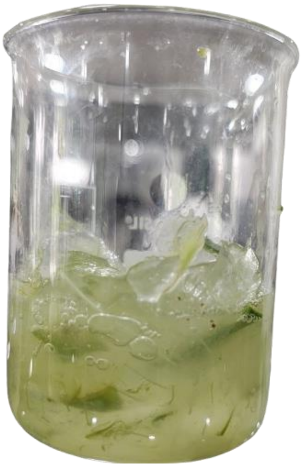

Fig 4: Aloe gel

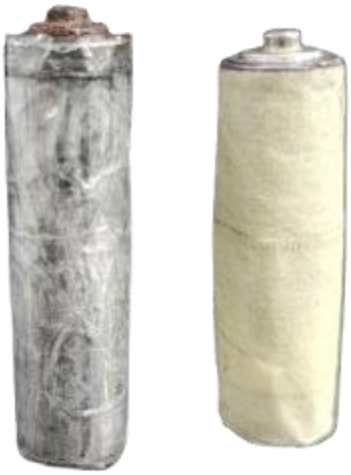

Fig 5: Aloe Cell

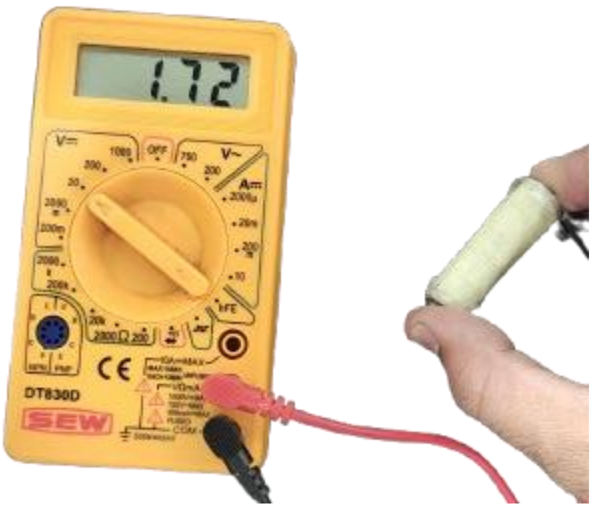

Fig 6: Out Put Voltage

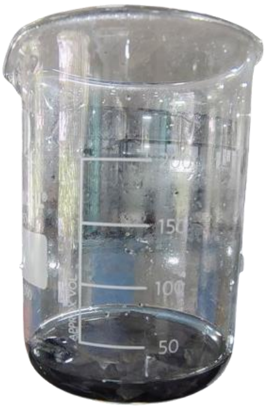

Fig 7: $ZnSO_4$ Without Filter

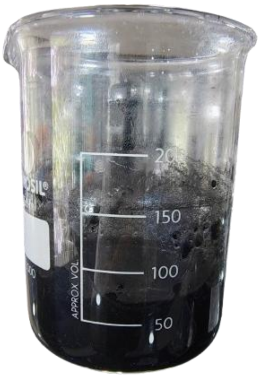

Fig 8: $MnSo_4$ Without Filter

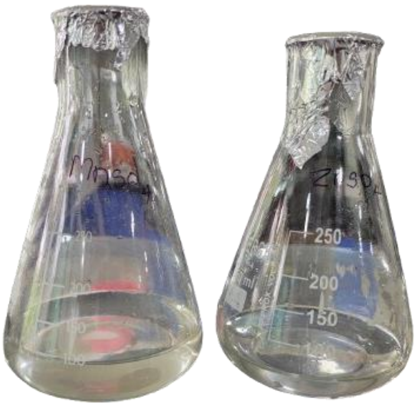

Fig 9&10: Fertilizer

CHAPTER- V
DISCUSSION

A dry battery obtained from *Aloe Vera* reached a level of 1.75V, which eventually marked a great success for plant-based cells as an environmentally friendly alternative to traditionally used batteries. *Aloe Vera*, in dry cell form, as an electrolyte, simply suggests a tremendous role in sustainable energy storage with minimal negative impacts on the environment. This development might well pave the way for further innovations in greener battery technologies.

Another sustainable approach in dealing with used batteries is through the successful recycling of manganese, sulfate, and zinc to become fertilizers. These elements proved to improve soil fertility, especially through zinc and manganese on plant growth promotion, showing that including materials recycled from used batteries must be a productive practice for agriculture.

While the project had a successful outcome, further research may focus on increasing efficiency and storage capacity of the dry *Aloe Vera* battery and the long-term impacts of the recycling fertilizer on soil condition.

CHAPTER-VI
SUMMARY AND CONCLUSION

The project involved preparation of a dry cell using *Aloe Vera* plant tissue and analysed the possibility of using such plant based materials for energy storage. It achieved a voltage output of 1.75V. This further justifies the use of Aloe Vera as a green material for different energy applications.

Apart from energy production, the idea also dealt with recovery of manganese, sulfate and zinc from spent batteries and utilization as an effective plant fertilizer. The managed substrate was used to enhance soil quality where zinc and manganese components were especially helpful for plants. It tackles the problem of battery waste contamination effectively without the disadvantages of chemical based fertilizers.

The project proposes an innovative and eco-friendly approach of waste management through adoption of renewable energy technologies It is evident that the eco-destructive plants can be converted into energy in a safe *Aloe Vera* based dry battery but also recycling battery components is reaping benefits to farming. This tends to lay a ground work for further studies aimed at the expansion of plant based batteries and more so the use of plant waste for farming purposes. All these strategies aim at addressing the environmental problems sustainably and prudently utilizing the available resources.

FUTURE LINE OF WORK

- Battery Optimization: Improve the energy storage capacity, durability, and scalability of the *Aloe Vera* dry battery for practical use.
- Renewable Integration: Explore pairing plant-based batteries with solar or wind energy for hybrid systems that enhance sustainability.
- Long-Term Fertilizer Impact: Conduct long-term studies on the effects of the recycled fertilizers on soil health, plant growth, and crop yield.
- Exploration of Other Plants: Investigate other bio-materials with similar properties for more efficient plant-based batteries.
- Commercialization: Assess the economic feasibility and scale-up potential of both the batteries and fertilizers for real-world applications.
- Sustainability Assessment: Perform life cycle and cost-benefit analyses to evaluate environmental and economic impacts.

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