

# RESEARCH ON DEVELOPMENT OF POWER SOURCE FOR IOT DEVICES USING LANDFILL LEACHATE

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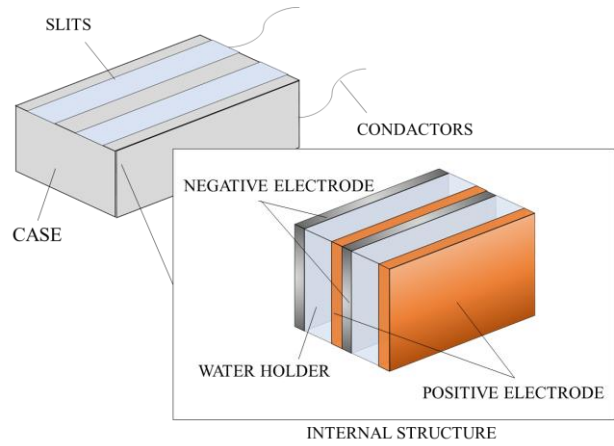
## 1 INTRODUCTION

In solid waste landfill sites, it is required to monitor landfill waste properties, leachate quality, the composition of gas generated, temperature, and the deterioration and damage of facilities to prevent environmental pollution. It is expected to build an advanced environmental monitoring system by utilizing IoT sensors, whose technological development has been advancing dramatically in recent years. Under such circumstances, securing a power source for wireless communication and installing IoT sensors that do not use a power line has become an urgent issue. Water in landfill waste is highly alkaline and has high electrical conductivity due to the dissolution of soluble salts and alkaline substances in incineration residues in rainwater. Therefore, a battery circuit is formed when metals with different ionization tendencies are immersed in the leachate. Therefore, this study aims to (1) design a garbage battery design that can be buried in landfill waste and (2) create a multilayered prototype for voltage enhancement.

## 2 METHODS

### 2.1 GARBAGE BATTERY DESIGN

Figure 1 shows the design of the garbage battery. There are slits in the case, and the leachate seeps into the battery through these slits. The advantages of this structure are (1) the retained water flows through the slits, and the electrolyte circulates, and (2) it prevents the electrodes from coming into direct contact with incineration residues, thereby reducing corrosion. The structure comprises a water holder sandwiched between a positive and negative electrode. The amount of water retained is adjusted according to the material and shape of the water holder. In the case of a pair of positive and negative electrodes, the electromotive force is approximately 1.3V. To make the voltage of the garbage battery reach the operating voltage of the microcontroller (3.3–5V), the positive and negative electrodes are stacked in layers.



**Figure 1.** The design and internal structure of the garbage battery case.

### 2.2 MULTILAYERED PROTOTYPE

This experiment used a copper plate for the positive electrode and a magnesium plate (45 mm × 15 mm × 0.5 mm) for the negative electrode. A mixture of gypsum and diatomaceous earth, with high water absorption and water retention properties, was used as the water holder. The mass ratio of gypsum and diatomaceous earth and the amount of water added were determined based on Hakiri (2019)<sup>1)</sup> and Li et al. (1991)<sup>2)</sup>, with the mass ratio of gypsum: diatomaceous earth = 10:3 and the amount of water added being 90% of the solid mass fraction. Diatomaceous earth was mixed with pure water to form a paste, poured into an acrylic case, assembled into a rectangular shape, and hardened in a drying oven at 60 °C for one day. A silicon sealant was used as a shield between the positive and negative electrodes to prevent short circuits. Prototypes with multilayer structures ranging from 2 to 4 layers with 10 mm interelectrode distance were created. Figure 2 shows the prototype of the created garbage battery.

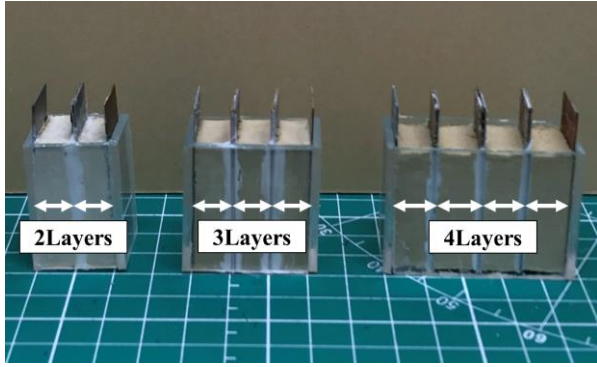


Figure 2. Multilayered prototypes.

### 2.3 EXPERIMENTAL PROCEDURES

Figure 3 shows the diagram of the experimental apparatus. Leachate from the incineration residue was prepared by eluting the soluble components contained in the incineration residue. Incineration residues (bottom ash: fly ash = 3:1) were sieved using a 4.75-mm sieve in a 250-ml polyethylene container, and pure water was added to bring the liquid-solid ratio to 10. The residue was shaken at 200 rpm for 6 hours using a shaker, and then solid-liquid separation was performed using a centrifuge at 2000 rpm for 20 minutes. A membrane filter with a pore diameter of 0.1  $\mu\text{m}$  was used for filtration, and the resulting filtrate was used as a simulation solution. The metal plates used for the electrodes were polished with water-resistant paper before immersion to account for the effect of voltage drop due to the oxide film. Next, 4 ml of the prepared leachate solution was gently dripped onto the water retention body, and the voltage and current were measured with a digital tester when four different resistors (1 k $\Omega$ , 4.7 k $\Omega$ , 10 k $\Omega$ , and 20 k $\Omega$ ) were incorporated.

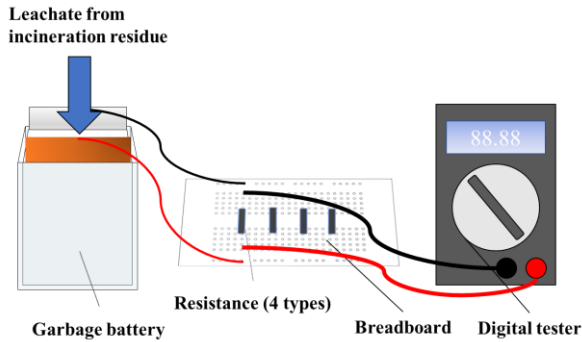


Figure 3. Experimental equipment.

### 3 RESULTS

Figure 4 shows the relationship between current and voltage for each case. The intercept of the regression line in Figure 4 is  $E$  (electromotive force), and the slope is  $-r$  (internal resistance). From the voltage  $V = E - rI$ , the

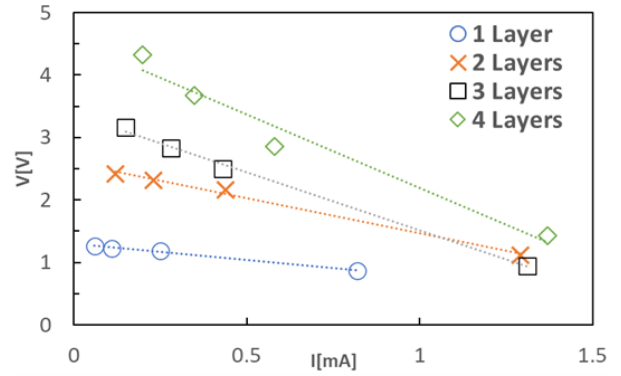


Figure 4. Relationship between voltage and current in a multilayered prototype.

Table 1. Electromotive force, internal resistance, and maximum power for each number of layers

	1 Layer	2 Layers	3 Layers	4 Layers
Electromotive Force[V]	1.29	2.59	3.37	4.55
Internal Resistance[ $\Omega$ ]	510	1,120	1,860	2,350
Maximum Power[mW]	0.82	1.50	1.53	2.20

electromotive force and internal resistance were determined. The maximum power  $P_{MAX} = E^2 / 4r$  [W] that the power source could supply was obtained from the magnitudes of the electromotive force and internal resistance obtained in the experiment. Table 1 shows the emf, internal resistance, and maximum power for each case. It was observed that the electromotive force and internal resistance increased in proportion to the number of layers. Since the operating voltage of the microcomputer envisioned for IoT monitoring of landfill sites is 3.3 V or higher, we believe that three or more layers can generate sufficient electromotive force to power the microcomputer. It was found that the multilayer structure increased internal resistance, hindering maximum power increase.

### 4 CONCLUSIONS

In this study, we designed and fabricated a "garbage battery" prototype that can be buried in landfill sites and obtained the following findings:

- (1) We designed the housing of a refuse battery and fabricated a prototype using a mixture of gypsum and diatomaceous earth as the water-holding material.
- (2) We fabricated a prototype with a multilayer structure that could satisfy the microcomputer operating voltage with three or more layers.

### 5 REFERENCES

- 1) Masahide H. et al.: Water absorbent material made from gypsum and diatomaceous earth (2019)
- 2) Lee et al.: The relationship between the pore characteristics and the suctionability of a Gypsum Mold (1991)