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Utilization of Dry Battery Waste Carbon Rod for Whiteboard Marker Ink

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Abstract: Disposable batteries are commonly found in dry batteries (or zinc-carbon batteries) that are discarded and converted into waste. Zinc-carbon batteries have a physical component, a carbon rod that has a graphitic carbon component that has a black pigment. This black pigment is utilized as an alternative black carbon material for the manufacture of whiteboard marker ink. This research aims to utilize graphite carbon from waste batteries as a pigment in whiteboard marker ink and test the formulation of ink samples. The supporting materials in this research are glycerin, thinner, gum arabic solution, and emulsion. The best ink sample has a density value of 1.35 g/cm^3, a viscosity of 0.13 Poise, a transmittance of 72 lux, a pH of 7.67, adhesion has a dense wet nature and moderate absorbency, and non-volatility of 75% ink using a carbon mass of 6.5 grams and the ratio of thinner and glycerin is 2:5.

Keyword: battery, carbon, graphite, ink, waste

INTRODUCTION

Batteries are one of the main power sources in everyday electronic equipment, such as television remotes, wall clocks, and children's toys. Their widespread use leads to a high amount of disposable battery waste that has the potential to pollute the environment due to the content of hazardous heavy metals such as mercury (Hg), lead (Pb), and cadmium (Cd). In Australia alone, battery waste that ends up in landfills reaches 8,000 tons per year (Farzana et al., 2019).

Disposable batteries are also called primary batteries, because in this battery the chemical reaction takes place only in one direction or irreversible and if the condition is saturated then the battery is no longer functioning and must be disposed (Gonzalez-Gonzalez et al., 2022). A common type of disposable battery is the dry battery (or zinc carbon battery) which is discarded and converted into waste. Based on Government Regulation No. 22 in 2021 concerning Environmental Management, the reutilization of hazardous waste such as carbon graphite from waste batteries can reduce the impact of environmental pollution.

Commonly used zinc-carbon batteries have electrode rods containing graphite carbon and manganese dioxide (MnO_2) (Chen et al., 2021; Sundén, 2019). Graphite carbon contained in used batteries has the potential to be utilized as a black pigment in whiteboard marker ink, as an alternative to black carbon materials. Black pigments in commercial marker inks generally contain xylene, which is a volatile organic compound (VOC) that has various negative impacts such as irritation to respiratory problems (Alford & Kumar, 2021; Rengganis et al., 2017).

Ink itself is a filler media that has certain pigments or colors to be placed into other objects such as whiteboard markers. The process of making marker ink requires binding agents and wetting agents such as glycerin to increase stability and prevent the ink from drying immediately (Homann et al., 2024; Silfia et al., 2015; Wulandari & Masthura, 2023). Commercial ink has a very complex composition that contains pigments, solvents (compounds that form polar polymer ions with waterproof resins), and surfactants(Muchtar H et al., 2015). The ink standard in Indonesia in SNI 06-1567-1989 regulates each ink composition and final product standard (BSN, 1970, 1989).

This research aims to examine the potential utilization of waste batteries as raw materials in the manufacture of whiteboard marker ink, especially by utilizing carbon as a black pigment. This research also developed a method of making marker ink with an optimal formulation using waste batteries as the main component. To ensure the quality of the ink produced, an appropriate test method was identified to assess the characteristics and performance of the formulated marker ink. Furthermore, the test results will be analyzed to determine the effectiveness and stability of the developed ink formulation, so that it can be an environmentally friendly alternative in managing waste batteries.

METHOD

Material

The tools used in this research include hammer, small pliers, mortar and pestle, mesh size 12, beaker glass, measuring cup, stirrer, watch, pet drops, 1 mL Ostwald viscometer, pH paper, aluminum foil, timer, ruler, UNI-T UT383 luxmeter, 5 mL volume pipette, and oven. Furthermore, the materials used were waste batteries obtained from the environment of Bhayangkara University, Greater Jakarta, 99.7% glycerin, thinner, gom arabic, distilled water, and emulsifiers.

Procedur

a. Waste Battery Carbon Crushing

The end-of-life zinc-carbon batteries that had become waste were collected in one container. Subsequently, the batteries were crushed using a hammer and the dried carbon rods were removed using small pliers. The collected battery carbon rods were pulverized using a mortar and pestle to form a coarse solid powder. The carbon rod powder that was still in coarse solids was then filtered with a size 12 mesh to obtain fine solids powder.

b. Formulation of Whiteboard Marker Ink

Prepare the tools and materials then weigh the fine carbon powder on a watch glass using an analytical balance as much as 6.5 grams. Measure thinner and 99.7% glycerin using a measuring cup in a ratio of 2:5. Next is to make a solution of gom arabic. Weigh the gom arabic as much as 50% of the distilled water. Mix the gom arabic into the distilled water. Dissolve the mixture by heating it on a hotplate at 80°C. Ink sample formulation was carried out by dividing three types of samples, namely sample I containing all the ingredients, sample II containing all the ingredients without adding emulsifiers, and sample III containing all the ingredients without adding glycerin.

c. Ink Formulation Testing: Density

Ink density testing is carried out using a volume pipette and analytical balance, and ink formulation samples. The procedure carried out in testing ink density, namely taking samples from a beaker glass with a volume pipette. The equation is

$$Ink\ density = \frac{massa\ (gram)}{Volume\ (mL)} \quad (1)$$

d. Ink Formulation Testing: Viscosity

The viscosity test is carried out using the Ostwald Method, where the ink is measured with a viscometer and the flow time data of the ink is obtained (Astuti et al., 2022). The equation used to calculate viscosity,

$$\eta = \frac{\eta_o.(\rho.t)}{\rho_o.t_o} \quad (2)$$

Where η denotes the viscosity of ink (g/cm.s), ηo denotes the viscosity of water (g/cm.s), ρ denotes the density of ink (g/cm^3), ρo denotes the density of water (g/cm^3), t denotes the time it takes for ink to fall (s), and to denotes the time it takes for water to fall (s).

e. Ink Formulation Testing: Transmission

Transmission test or luxmeter test or light intensity level test using a luxmeter. The light intensity level is used to estimate the blackness of the ink produced. The estimation is done by measuring the light that is able to escape from the ink. placed each on a watch glass.

f. Ink Formulation Testing: pH

The pH test was conducted using universal pH paper which has a pH limit from 1-14. This test serves to measure the acidity of the ink formulation. Dip the pH paper into the ink sample. Repeat using different pH paper as test accuracy. Record each repetition of the pH test.

g. Ink Formulation Testing: Adhesion

Prepare 9 pieces of plastic sheet. Fill each sheet with ink samples. Each sample is filled on 3 cut sheets. Observe the properties, density, and absorbency of each sample. Record the properties, density, and absorbency of each sample.

h. Ink Formulation Testing: Non-Volatility

Prepare aluminum foil, cut it into 9 small pieces, and weigh each piece on an analytical balance. Record the mass of the container. Each of the 3 pieces is shaped like a bowl and filled with one type of sample. Fill the aluminum foil and weigh it on an analytical balance. Weigh aluminum and wet ink on an analytical balance. Then record the mass of the container and the wet ink. Calculate the wet ink as follows,

Mass of wet ink = (mass of container + wet ink) - (mass of container) .... (3)

Put the sample on an oven tray and warm it up using an oven to measure the mass of the material that does not evaporate. The oven is set at 110ºC for 3 hours. After 3 hours, arrange to weigh the mass of the container and dry ink again. Then record the mass of the container and the dry ink. Calculate the dry ink as follows,

Dry ink mass = (mass of container + dry ink) - (mass of container) .... (4)

Determine the volatility value with the following equation,

$$NV = \frac{mass\ of\ dry\ ink\ (gram)}{mass\ of\ wet\ ink\ (gram)} x\ 100\% \quad (5)$$

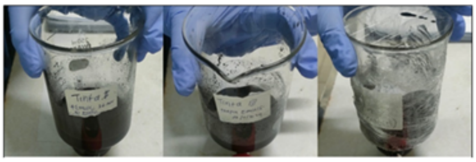
The last step of the entire formulation testing method is to calculate the standard deviation of each test result.

$$\sigma = \frac{\sqrt{\sum_{i=1}^{n=a}[x_i - \bar{x}]^2}}{n} \quad (6)$$

RESULT AND DISCUSSION

1. Whiteboard Ink Formulation

Whiteboard marker ink components generally have refillable and erase-able characteristics, making them more effective for daily use (Po et al., 2018). Dried zinc-carbon battery carbon waste is used as a component as well as black pigment in the manufacture of whiteboard marker ink. In the pre-formulation stage, the author conducted a pre-formulation study by mixing battery carbon and thinner solvent to determine its solubility and compare with commercial inks that were not physically suitable. Furthermore, the author found the right ingredients for binders, adhesives, and homogenization of material components with each other such as glycerin, gum arabic, water, and emulsion. As a result of the initial formula in Figure 1, the physical form of the ink is like commercial ink and this result can be continued with characteristics and quality testing.



Sample I	Sample II	Sample III

Figure 1. Testing Ink Formulation Results

2. Marker Ink Formulations

Whiteboard marker ink components generally have refillable and erase-able characteristics, making them more effective for daily use. The dried carbon waste of zinc-carbon batteries is used as a component as well as black pigment in the manufacture of whiteboard marker ink. In the pre-formulation stage, the author conducted a pre-formulation study by mixing battery carbon and thinner solvent to determine its solubility and compare with commercial inks that were not physically suitable. Furthermore, the author found the right ingredients for binders, adhesives, and homogenization of material components with each other such as glycerin, gum arabic, water, and emulsion. As a result of the initial formula in Figure 1, the physical form of the ink is like commercial ink and this result can be continued with characteristics and quality testing.

3. Density Testing

Table 1. Ink Density (in g/cm^3)

Sampel/Percobaan	1	2	3	$\bar{x}$	σ
Sampel I	1.46	1.33	1.26	1.35	0.08
Sampel II	1.27	1.18	1.13	1.19	0.06
Sampel III	1.09	1.12	1.14	1.12	0.01

Density or density in this research was determined by weighing the mass of the known volume. This is used because of the limited volume of each sample that has been made. Through this method, Table 1 shows the density results for the three samples with an average density of 1.352 gr/cm^3 in sample I, 1.191 gr/cm^3 in sample II, and 1.118 gr/cm^3 in sample III. The standard deviation of each sample is less than 1 indicating that the value of each data is close to the average density data.

The average density value of each sample was compared with the density regulated by SNI 06-1567-1989 which is still valid according to the Regulation of the National Standardization Agency of the Republic of Indonesia Number 7 of 2019 concerning

"Conformity Assessment Scheme for Indonesian National Standards in the Chemical Sector" which is 1 gr/cm^3. Of the three samples tested, the third sample which has an initial formulation without glycerin has a density that is close to the density value regulated by SNI.

4. Viscosity Testing

Table 2. Ink Viscosity (in Poise)

Sampel/Percobaan	1	2	3	$\bar{x}$	σ
Sampel I	0.13	0.14	0.13	0.13	0.01
Sampel II	0.12	0.12	0.12	0.12	0.01
Sampel III	0	0	0	0	0

Viscosity is a measure of the viscosity of a fluid component, the fluid used in this test is a marker ink sample. The viscosity measurement in this study uses the Ostwald Method with the reference ratio used is water (Rahayu & Fatimah, 2021). Water is used as a universal reference so that it is used in viscosity testing with a comparison of water time of 3.75 seconds, density of 0.992 g/cm^3, and water viscosity of 0.007972 Poise at 30^{o}C (Data Observation, 2025). Each sample was inserted into the Ostwald viscometer and measured for 46.33 seconds in sample I and 47.67 seconds in sample II.

Based on the tests that have been carried out, the average viscosity value of each sample is obtained, namely sample 0.1342 Poise, sample II 0.1220 Poise, and sample III 0 Poise. Sample I has a greater viscosity value than sample II, meaning that sample I has a thicker physical fluid. The standard deviation on the viscosity gain is found to be less than 1 so that the data distance is close to the average.

5. Transmission Testing

Table 3. 5 cm Distance Ink Transmission (in lux)

Sampel/Percobaan	1	2	3	$\bar{x}$	σ
Sampel I	59	79	77	72	8.99
Sampel II	90	58	78	75	13.2
Sampel III	107	102	106	105	2.16

Table 4. 10 cm Distance Ink Transmission (in lux)

Sampel/Percobaan	1	2	3	$\bar{x}$	σ
Sampel I	218	196	196	193	22
Sampel II	108	105	112	108	33
Sampel III	258	267	265	263	34

This transmission test was previously conducted by Putro et al. (2018) who conducted transmission tests on commercial inks and obtained 56 lux. Furthermore, the research subject, namely whiteboard marker ink, measured the distance using a ruler of 5 cm and 10 cm to determine the amount of transmission from each distance. According to Table 3 and Table 4, the transmission value that is close to the commercial value is in sample I with the initial formulation given a distance of 5 cm.

6. pH Testing

Table 5. pH Ink

Sampel/Percobaan	1	2	3	$\bar{x}$	σ
Sampel I	6	9	8	7.67	1.25

Sampel II	6	7	6	6.33	0.47
Sampel III	6	5	6	5.67	0.47

Testing the pH level of the ink sample to determine the acidity of the sample.The pH measurement used is universal pH paper which has a pH interval between 1 to 14. Through the measured pH measurements, the average pH of sample I was 7.67; sample II was 6.33; and sample III was 5.67. The pH results of the three samples tested met the pH interval of whiteboard ink in the research of Dagde. K.K et al. (2019) except sample I which is out of the interval by 3%. The pH value in sample I has a more neutral pH than the other two samples which tend to be more acidic. This neutral pH is safer when exposed to hands because it is non-acidic.

7. Adhesion Testing

Table 6. Ink Adhesion Sample I

Variable	1	2	3
Characteristics	Wet	Wet	Wet
Concentration	Unconcentrated	Medium	Concentrated
Absorbence	Less Absorbency	Less Absorbency	Medium

Table 7. Ink Adhesion Sample II

Variable	1	2	3
Characteristics	Wet	Wet	Wet
Concentration	Unconcentrated	Medium	Concentrated
Absorbence	Less	Less	Less

Table 8. Ink Adhesion Sample III

Variable	1	2	3
Characteristics	Humid	Dry	Wet
Concentration	Concentrated	Concentrated	Concentrated
Absorbence	Extremely	Extremely	Extremely

Figure 1. Adhesion Test Results

Adhesion to ink samples to determine the adhesion (stickiness) of the samples used in Table 6, Table 7, and Table 8. The samples in Figure 2 have wet properties indicating that they are easier to erase and do not dry out quickly in samples I and II. The density of the samples was found to be different after being inscribed on the plastic sheet and the absorbency of each sample. Sample III has properties that tend to dry quickly, high absorbency, and high density making it less appropriate for whiteboard marker ink which is easier to erase commercially.

8. Non-Volatility Testing

Table 9. Ink Non-Volatility

Sampel/Percobaan	1	2	3	$\bar{x}$	σ
Sampel I	39%	83%	104%	75%	0,27
Sampel II	27%	67%	66%	54%	0,19
Sampel III	27%	104%	95%	76%	0,35

The NV test is to determine the percentage of non-vaporized material in the ink. This test variable can also be an indicator of VOCs that are considered dangerous because the higher the NV value, the VOC value will decrease (David E & Niculescu V. C, 2021). This NV test uses gravimetric analysis (David Harvey, 2024). In Table 9, the average value of NV in the three samples is 75.16%; 53.79%; and 75.64%. Samples I and III had NV values 28% higher than sample II which reached NV values above 75%. The NV value in one of the containers in samples I and III has an NV value above 100%, this can occur due to the mass of water that falls back into the container before the oven time is complete.

CONCLUSION

Based on the results of the research, the best sample of whiteboard marker ink from dried zinc-carbon battery carbon waste with a desintas value of 1.35 g/cm3, viscosity of 0.13 Poise, transmission of 72 lux, pH 7.67, adhesion has concentrated wetness and medium absorbency, and non-volatility of 75% ink by using a mass of 6.5 grams of carbon and the ratio of thinner and glycerin is 2: 5. This best sample has the characteristics of solid black color, ink easily absorbs into the surface, safe to use.

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