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# Green Emulsion Paint: Utilization of Waste Expanded Polystyrene and Rice Husk for a Sustainable Future

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## Abstract

*An emulsion paint was formulated from waste to-go boxes and rice husk as binder. A three-staged process was employed to formulate the emulsion paint. Physicochemical properties such as opacity, pH, flexibility, adhesion, tackiness, resistance to blistering, chemical resistance and drying times were carried out on the formulated emulsion paint. A reference emulsion paint was also formulated using a conventional binder composed of polyvinyl acetate (PVA) thus, the aforementioned physicochemical properties were compared to ascertain for the suitability of the polystyrene-rice husk* (PS-RH) *binder. The formulated PS-RH and PVA paints were applied on different substrates; wood, glass, wall and ceiling board to ascertain for their drying times (dry-to-touch and dry-to-hard). It was observed that the formulated emulsion paints displayed shorter surface drying times in the range of 16 to 25 minutes for PVA and 18 to 34 minutes for PS-RH across all applied surfaces. These observed drying times were comparable to SON standards for dry-to-touch of 20 minutes. The formulated PS-RH emulsion paint exhibited good adhesion, opacity, flexibility, tackiness, resistance to blistering, chemical resistance and drying times when compared to the conventional PVA binder paint and standards stipulated by the standard organization of Nigeria (SON). Results so far obtained from this study suggested that the formulated emulsion paint derived from waste to-go boxes and rice husk exhibited likened properties of a conventional binder and can serve as a viable alternative binder when employed.*

**Keywords:** Emulsion paint, Binder, Waste Polystyrene, To-go box, Rice husk.

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## INTRODUCTION

Any liquid, liquefiable, or mastic mixture that becomes an opaque solid film after being applied to a substrate in a thin coat is called paint. Painting has a reputation for being one of many crucial elements of construction (Abdulsalam, 2015; Kalu *et al*., 2023a; Uche *et al*., 2020). Its vibrant colors cover the concrete rending (plaster) and block work, providing the structure an appealing appearance that makes it aesthetically pleasing, hygienic, and livable (Asafa *et al*., 2021; Kalu *et al*., 2023a). Around the world, paint is essential for building construction (Uche *et al*., 2020). Paint with an emulsifier, coagulant, pigment, and water is called emulsion paint. Because the pigments vanish in water that has been emulsified using an emulsifying agent, it is known as an emulsion (Emmanuel *et al*., 2023). Because of its affordability, ease of use, and durability, emulsion paints are highly sought-after (Emmanuel *et al*., 2023; Uche *et al*., 2020). According to Eloho and Mpinane (Ichipi and Senekane, 2023), solid waste is any non-liquid, non-gaseous byproduct of human activity that is deemed undesirable or pointless (Ichipi and Senekane, 2023). The population growth, industrialization, and urbanization of Nigeria and other emerging nations have increased the production of solid garbage. In the last ten years, there has also been an increase in garbage and, with it, a rise in waste management issues due to factors like industrialization, displacement from rural regions, urbanization, uncontrolled consumption, and growth (Ibrahim *et al*., 2022; Ichipi and Senekane, 2023).

Solid waste management promotes economic growth and an enhanced standard of living while minimizing or completely removing harmful effects on the natural environment and public health (Ichipi and Senekane, 2023; Niyobuhungiro and Schenck, 2021). Plastic solid waste, which mostly consists of polystyrene wrapping supplies and polyethylene carry bags (both of which are polymeric materials), is a significant category of solid garbage that has presented a significant burden to society and the environment (Ichipi and Senekane, 2023). Regardless of technical advancements and understanding of sustainability, these wastes provide communities both opportunities and challenges (Niyobuhungiro and Schenck, 2021). Due to its role as an oil or film-forming element, the binder, or vehicle, is one of the most crucial constituents in paint formulation (Ayodeji *et al*., 2020). One of the convectional binders used in the formulation of emulsion paint is polyvinyl acetate (PVAc) (Ibrahim *et al*., 2022). However, it is well known that emulsion paint made with polyvinyl acetate as a binder has low water resistance and lacks shine. Thus, this study was aimed at recovering waste expanded polystyrene derived from to-go boxes and waste rice husk from the environment, employing them in the formulation of emulsion paint, whose binder can serve as an alternative and to support for the reuse of waste while converting them into usable products.

## MATERIALS AND METHOD

### Materials

Waste to-go boxes, Rice husk, Calgon, Genepour, Bermocoll, Troystan, Dispersant, Butanol, Ammonia, $TiO_2$, $Al_2(SiO)_3$, $Na_2CO_3$, Kaolin, $CaCO_3$, Distilled water, Nicofoam, Anti-skinning agent.

### Method

### Sample collection

Waste to-go boxes were collected from the vicinity of Gombe State University, Gombe, Nigeria. While, Rice husk was collected from a local rice milling plant located in Gombe metropolis.

**Sample Preparation**

The waste to-go boxes were washed with distilled water, dried chopped into pieces, while, the rice husk was similarly treated and ground to fineness using a hand grinder.

**Preparation of PS binder solution**

The procedure described by Titus *et al.* (2024) was used, and the solvent was gasoline. To produce the PS binder solution, 40g of weighted polystyrene (PS) was introduced in a 10ml gasoline and was left undisturbed to allow for dissolution at room temperature, this was followed by blending with ground rice husk shell liquid at 1:1 ratio, well stirred and formulated to yield a viscous PS-RH emulsion paint binder which was ready for application.

**Formulation of PS modified paint**

Emulsion paint was essentially formulated using the methodology detailed in Titus *et al.* (2024). The three major steps for the production process employed was:

**I. First Stage**

The additives reflected in Table 1 were introduced at the initial stage. This stage's main goal is to create an atmosphere that is conducive to particle dispersion and wetting. The blend was agitated for 15 minutes.

**II. Second Stage**

Pigments and extenders were distributed throughout the mills in the second step, which is often referred to as "mill base." Following dispersion, the mixture was agitated for further fifteen minutes at a very high-speed using the mill base stage stirrer.

**III. Third Stage**

The binder and the remaining additives from the first stage were combined at the end. This phase is referred to as "Letdown." At this point, the mixture was stirred for an additional 15 minutes at a moderate speed. Table 1 enumerated below lists the specifics of the compositions that were adopted.

**Table 1** Emulsion Paint Formulation Composition

| *Stage* | Reagents | Quantity (g) |
|---|---|---|
| First | Water | 32.7 |
| | Anti-foam | 0.2 |
| | Drier | 0.2 |
| | Calgon | 1 |
| | Genepour | 1 |
| | Bermocoll | 1 |
| | Troystan | 1 |
| | Dispersant | 0.2 |
| | Butanol | 1 |
| | Ammonia | 0.2 |
| | $TiO_2$ | 10 |
| | $Al_2(SiO)_3$ | 2 |
| Mill base | $Na_2CO_3$ | 0.2 |
| | Kaolin | 1 |
| | $CaCO_3$ | 15 |
| | PS-RH | 30 |
| | Water | 3 |
| Letdown | Dispersant | 0.1 |
| | Nicofoam | 0.1 |
| | Anti-skinning agent | 0.1 |
| | **Total** | **100** |

**pH determination of the emulsion paint**

The pH of the paint samples was determined using a pH meter. The electrode was dipped into paint samples to obtain the reading (Kalu *et al*., 2023b). The electrode was rinsed with distillated water after its pH was adjusted with a buffer solution at pH 7.

**Adhesion test of the emulsion paint**

Using a film applicator, paint film was put to a metal surface and allowed to dry for 48 hours. Two sets of lines were drawn on the paint film, one of which crossed across the other perpendicularly, using a pointed nail. An adhesive tape was firmly applied over the whole perpendicular line interaction with the thumb. The adhesive tape was forced to loosen its ends and was removed from the panel. The paint film's square lines were missing more than half of the time, indicating poor adhesion. (Kalu *et al*., 2023b; Kalu *et al*., 2023c; Titus *et al*., 2024).

**Resistance to blistering of the emulsion paint**

A day after the film was placed to a glass panel and allowed to dry, 2 ml of distilled water were added to it in the form of circular drops. The appearance of blistering, wrinkling, swelling, or cracking within 30 minutes was indicative of poor water resistance. The quality evaluation record consisted of the three duplicate determinations for each sample (Kalu *et al*., 2023a; Titus *et al*., 2024).

**Drying time of the emulsion paint**

The drying times of the paint samples were evaluated. A ceiling board primed with yellow paint and left to dry at room temperature was painted with 10 ml paint sample that was formulated. Using a stopwatch, the drying times of every sample were noted (Igwe *et al*., 2017; Kalu *et al*., 2023a; Titus *et al*., 2024).

**Flexibility test of the emulsion paint**

Paint samples were applied to the aluminum panel mix using a paint applicator which was followed by drying at room temperature (27 °C) for seven days. The panel was then be put back into its original condition after being bent through $180^0$. The panel was examined for adhesion loss and cracking; any break or loss of adhesion indicated rigidity or fragility (Kalu *et al*., 2023c; Titus *et al*., 2024).

**Tackiness of the emulsion paint**

In order to ascertain whether or not the paint is sticky, this was also measured on the film of each paint formulation by hand-feeling. According to Kalu *et al*. (2023a) and Titus *et al*. (2024), a dried film's stickiness suggests strong bonding between the paint and the applied substrate and void of contaminants that might lower the adhesive property (Kalu *et al*., 2023a).

**Chemical resistance of the emulsion paint**

Three flexible aluminum test panels (150 mm x 0.3 mm) were used to evaluate the chemical resistance of the paint layers. With a paintbrush, a coat of paint was applied to the panel. The test pieces were placed in a one-liter glass beaker filled with 0.1 M NaOH solution until it reached a depth of 150 mm. The beaker was left submerged for 24 hours at a depth of about 120 mm. After being removed, the test material was cleaned with running water and allowed to air dry for two hours. The previous procedure is repeated using 0.1 M HCl and 0.1 M NaCl, respectively. Poor chemical resistance was indicated by any surface imperfections, such as blistering, peeling, cracking, or color changes (Kalu *et al*., 2023a; Titus *et al*., 2024; Victor *et al*., 2018).

**Opacity of the emulsion paint**

The opacity test, which was performed by brushing paint on a ceiling board, measured how much high-quality paint covered a specific surface area and how much low-quality paint required a large volume to cover the same surface. The emulsion paint samples that were produced passed the opacity test, demonstrating their capacity to stabilize pigment dispersion (Kalu *et al.*, 2023b; Titus *et al.*, 2024).

**Results and discussion**

**Results**

The results derived from the formulated waste polystyrene-rice husk emulsion paint samples in comparison to polyvinyl acetate analyzed in this work were reported as follows:

**Table 1** Physicochemical Properties of Paints Formulated from PVA and PS-RH Binders

| Parameter | PVA | PS-RH | SON Standard |
|---|---|---|---|
| pH | 7.51 | 8.12 | 7.0 – 8.5 |
| Flexibility | Pass | Pass | Pass |
| Opacity | Pass | Pass | Pass |
| Adhesion | Pass | Pass | Pass |
| Tackiness | Fail | Pass | Pass |
| Resistance to blistering | Pass | Pass | Pass |

**Table 2** Comparison of drying times of paints formulated from PS-RH and PVA on applied substrates

| Parameter | Wood | | Glass | | Wall | | Ceiling board | |
|---|---|---|---|---|---|---|---|---|
| | Dry-to-touch | Dry-to-hard | Dry-to-touch | Dry-to-hard | Dry-to-touch | Dry-to-hard | Dry-to-touch | Dry-to-hard |
| PVA | 17 | 22 | 21 | 25 | 17 | 20 | 16 | 20 |
| PS-RH | 20 | 34 | 19 | 31 | 19 | 18 | 18 | 22 |

**Table 3** Chemical Resistance of PVA and PS-RH Films in different solvent media

| Samples | 0.1 M NaCl | 0.1 M HCl | 0.1 M NaOH |
|---|---|---|---|
| PVA | No effect | No effect | No effect |
| PS-RH | No effect | No effect | No effect |

**DISCUSSION**

**pH of the paint samples**

All the paint samples produced were alkaline with the pH favorably falling within that of the SON specification range (Titus *et al.*, 2024; Uche *et al.*, 2020) as seen from Table 1. The pH of the PVA paint was however higher than that of the PS-RH and this could be attributed to the OH group from the PVA (Titus *et al.*, 2024). Depending on the nature of the inhabitant microbes in a particular environment, paint pH can be used to inhibit microbial activities in the film (Kalu *et al.*, 2023a).

**Adhesion of the paint samples**

The formulated emulsion paint exhibited good adhesion as there was no peeling off observed just after the adhesive tape was forcibly removed (Kalu *et al.*, 2023b; Titus *et al.*, 2024). All the paint samples produced passed the adhesion test, the quality and durability of a coating is directly related to the nature of adhesion (Igwe *et al*., 2017; Titus *et al*., 2024).

**Resistance to blistering of the paint samples**

It was recorded that the emulsion paint samples were all resistant to blistering (Table 1) and as a result, can serve for both interior and exterior coating (Kalu *et al*., 2023a; Titus *et al*., 2024).

**Flexibility of the paint samples**

The flexibility test was passed by all paint samples made with PS-RH and PVA, as indicated in Table 1. PVA typically shows more flexibility than PS-RH in terms of adaptability. Synthetic polymer PVA is well-known for its flexibility, capacity to create films, and water-soluble nature. In contrast to PVA, PS is a thermoplastic polymer that has a tendency to be more brittle and harder. It is frequently utilized in industries like packaging and disposable cutlery where stiffness is required (Igwe *et al*., 2017; Titus *et al*., 2024).

**Drying Time of the paint samples**

Drying time of the emulsion paint samples produced were observed on application on different substrates; wood, glass, wall and ceiling board as shown in Table 2. Drying time of paint depends on the environment, mainly on temperature and humidity. The laboratory result revealed that the emulsion paint produced, displayed shorter surface drying times in the range 16 to 25 minutes for PVA and 18 to 34 minutes for PS-RH across all applied surfaces, these observed drying times were comparable to SON standards for dry-to-touch of 20 minutes (Kalu *et al*., 2023b; Titus *et al*., 2024) whereas, the dry-to-hard times were found to be in the range of 20 to 25 minutes for PVA and 18 to 50 minutes for PS, these values were also in the range stipulated by SON for 120 minutes on applied surfaces (Titus *et al*., 2024).

**Opacity of the paint samples**

The opacity test was a measure to which extent high quality paint covers a given surface area where as paint with low quality requires a large volume to give coverage to the same surface, it was carried out by applying the paint on a ceiling board with a brush, the emulsion paints samples produced passed the opacity test, indicating their ability to stabilize pigment dispersion (Kalu *et al*., 2023a; Titus *et al*., 2024) as observed from Table 1.

**Tackiness**

Tackiness was done qualitatively on the dried film by hand feeling to find out if the paint film is sticky or not. Stickiness of a dried paint film is an indication that the film is tacky. Triplicate samples were used for each determination and the average assessment was noted (Kalu *et al*., 2023c; Titus *et al*., 2024; Uche *et al*., 2020). It can also be observed from Table 1 that the emulsion paints exhibited good tackiness on the applied substrate. The tackiness test was passed by both paint samples, suggesting that all of the paint samples have good adhesion potential.

**Chemical Resistance**

One of the ideal characteristics of a good coating film is paint's resistance to chemical influence and discoloration (Kalu *et al*., 2023a) A coating film's resistance to discoloration from chemicals and other compounds is assessed using a chemical resistance test. According to Table 3's results, neither the acidic nor the alkaline solutions had any effect on PVA or PS-RH film. This is likely because of the network's high cross-linked density, which lessens the exposure to environmental conditions (Kalu *et al*., 2023b; Titus *et al*., 2024; Victor *et al*., 2018) This suggest that the formulated emulsion paint is durable and can withstand acidic and basic effects, this also can invariably can impact positively to its ability to resist stain from acidic or basic chemical species.

## CONCLUSION

An emulsion paint was successfully formulated from waste to-go boxes composed of polystyrene and rice husk and compared with a conventional binder (PVA). The result revealed that PS-RH emulsion paint exhibited likened properties to the formulated PVA binder emulsion paint with comparable physicochemical properties such as flexibility, drying times, adhesion, opacity to mention but a few. In working towards an environmentally friendly society, waste to-go boxes can be converted as binder for emulsion paint formulation which encouraged the conversion or recycling of waste in our environment. It can also increase the quantity of emulsion paints in the market and lower its price. The formulated PS-RH and PVA paints samples produced exhibited similar characteristics based on their studied physicochemical properties and when compared to the standard organization of Nigeria (SON) requirements. This work may therefore, introduce a novel emulsion paint derived from waste to-go boxes and rice husk binder into the coating industry.

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