**COMPARATIVE ANALYSIS OF MARINE PAINT FORMULATION USING STANDARD RAW MATERIAL AS COMPARED TO LOCALLY SOURCE RAW MATERIAL**

**Abstract**

This study presents a comparative analysis of marine paint formulated using standard raw (Epicoat1004) versus locally sourced Natural Rubber Latex (NRL) as binder. The liquid latex was used with other standard chemical as binder with equal ratio as the standard binder(epoxy). Solid latex was cut into pieces then dissolve into a 500ml toluene for 90min before using as rubber latex binder for the formulation. The mixing was done sequentially, starting with addition of solvent, followed by adding the binders, pigments and finally the additives for the two different samples (commercial and organic). The properties tested were viscosity, drying time, gloss, pH value, water resistance, adhesion, storage stability, and product performance of the formulated paint. The result shows that increase in temperature of the formulation affects the viscosity of the formulation as well as the drying time leading to improper curing, standard formulation shows little or no sign of discoloration in both salt and fresh water as compared to organic formulation that shows sign of blistering and discoloration in both salt and fresh water. The stability of the two formulation shows that standard formulation (Epi 1004) had perform better than the NRL paint. Also, from the result, it was observed that Epicoat 1004 binder paint shows the following characteristics; longer drying time, provide medium gloss, superior storage resistance and adhesion to metals, while unmodified NRL takes shorter drying time, separation of solvent during storage, low gloss, and weaker adhesion to metals due to unmodified latex. Therefore, the formulated organic paint can be said to be better since it the material of production is ecofriendly and cost effective since it can be sourced locally.

**Keywords: Marine, Coating, Natural Rubber Latex, comparative, eco-friendly**

**1.Introduction**

The marine environment is one of the most challenging environment when it comes to material and surface protection, requiring specialized coatings to safeguard vessels, offshore platforms, and marine structures from corrosion, fouling, and environmental degradation (Xu et al., 2023). Marine paints play a crucial role in preserving the structural integrity (Ramansata et al., 2022) and longevity of ships by providing a protective barrier against harsh conditions such as saltwater exposure, UV radiation, and microbial growth (Sung-Hyun et al., 2020). These coatings not only enhance the aesthetic appeal of marine vessels but also contribute to their operational efficiency and durability. Marine paints are typically formulated using polymeric resins (such as epoxy, alkyd, or polyurethane), organic solvents, and a variety of organic and inorganic additives (Wu et al., 2019), including pigments, biocides, and fillers (Ayman et al., 2023). The anti-corrosive properties of marine paints prevent direct contact between metal surfaces and corrosive elements, effectively inhibiting rust formation (Musa et al 2023) and extending the lifespan of vessels (Ugwuoke et al., 2023). Traditionally, metallic chromates have been used as active anticorrosive pigments, forming a protective oxide film on metal surfaces. However, due to their toxicity, these agents are being phased out in favour of environmentally friendly alternatives (Pandey and Kiran 2021).

Recent advancements have explored the use of locally sourced raw materials such as natural resins, oils, and minerals to develop sustainable and cost-effective marine paints. This approach offers benefits such as reduced environmental impact, increased accessibility, and economic viability, while supporting local innovation (Li et al., 2023). However, other challenges including performance optimization, compatibility with existing coatings, and regulatory compliance (Wu et al,2024).

The Nigerian paint industry is characterized by heavy reliance on imported raw materials, despite the availability of local alternatives that could serve as effective substitutes. The rise in cost of imported materials due to currency fluctuations has made paint production increasingly expensive. Additionally, many synthetic materials used in marine paints are not environmentally friendly, necessitating the search for locally sourced raw materials that can provide comparable quality and performance. Developing marine paints from standard and locally sourced raw materials has the potential to revolutionize the maritime industry by promoting sustainability and economic resilience to reduce reliance on imported chemicals and incorporating indigenous resources, this approach minimizes environmental impact, stimulates local industries, and creates economic opportunities. Additionally, the development of sustainable coatings aligns with global efforts to reduce pollution and ecosystem disruption, contributing to the preservation of marine biodiversity. In previous studies, researchers investigate the use of modified natural rubber latex from hevea brasiliensis (a tropical rubber tree) for the formulation of emulsion paint (Ibrahim et al 2022) The aim of this research is to formulate and compare a five-liter marine-based paint using epi-coat 1004 and unmodified natural rubber latex as binder, and to evaluate and characterize the physio-chemical and physio-mechanical properties of the formulation.

**2. Materials and Methods**

The method was experimental formulation. The formulation was done in two batches, 80% formulation of marine paint from standard binder (epic oat 1004) and 80%organic binder (NRL) was formulated with the same type of solvent, pigment and additive. With 20% mixture for drying and curing to be applied before application.

**2.1 Preparation of Natural Rubber Latex**

Solid latex was cut into small pieces and dissolved in 500mL toluene. The mixture was stirred intermittently and allowed to soak for 1 hour and 30 minutes at room temperature. After complete dissolution, the resulting rubber latex binder was use for the formulation and was stored in an airtight container to prevent evaporation

**2.2 Production of 80% standard and organic marine paint for 5-litre formulation.**

The paint formulation was carried out in two batches, one was the formulation of standard paint, using standard materials. The second batch was the formulation of organic paint using rubber latex. 1000mL of toluene was mixed with 1200mL of Epicote 1004 for 10 minutes. Then, 400 g of zinc phosphate, 400 g of red oxide, 200 g of talc, 200mL of bentonite, and 600mL of IPA was added sequentially. The mixture was homogenized using an EK-HM165 portable mixer for 20 minutes to ensure uniform dispersion.

 The same procedure and materials were repeated for the formulation of the organic paint except that the Epicote 1004 was replaced with the same quantity of rubber latex.

**2.3 20% Composition of Drying and Curing Formulation**

 210mL of Versamid was mixed with 130mL of toluene and 660mL of IPA using an EK-HM165 portable mixer for 10 minutes to achieve homogeneity. This formulation serves as a drier and curing agent for both standard and organic marine paints before application. Table 1 shows the composition and materials used for the paint production

**Table 1 Percentage composition for standard and organic formulation/drying and curing ingredient**

|  |  |  |
| --- | --- | --- |
| Standard ingredient | % composition | Mass/volume(ml/grams) |
| Toluene | 25 | 1000 |
| Epicote1004 | 30 | 1200 |
| Zinc phosphate | 10 | 400 |
| Red oxide | 10 | 400 |
| Talc | 5 | 200 |
| Bentonite | 5 | 200 |
| IPA | 15 | 600 |
| Organic ingredient |  |  |
| Tolune | 25 | 1000 |
| NRL (Natural rubber latex) | 30 | 1200 |
| Zinc phosphate | 10 | 400 |
| Red oxide | 10 | 400 |
| Talc | 5 | 200 |
| Bentonite | 5 | 200 |
| IPA | 14 | 560 |
| Ammonia | 1 | 40 |
| Drying/curing Ingredient |  |  |
| Versamid | 21 | 210 |
| Toluene | 13 | 130 |
| IPA | 66 | 660 |

**2.4 Metal Panel Preparation:** A 52 cm × 48 cm metal plate was cut into four pieces (13 cm × 12 cm each). The surfaces were smoothed using sandpaper and cleaned with cotton wool. The cleaned surfaces were then coated with the formulated paint and allowed to dry under normal conditions for 24 hours.

**2.5 Evaluated Properties of the Formulation**

**2.5.1 Viscosity**

20mL of both standard and organic marine paint samples were measured into separate 50mL beakers Using Brookfield NDJ-5C viscometer, the viscometer was powered on and stabilized, then viscosity readings were taken at different intervals following the ASTM testing standard. The recorded values were used to assess the flow properties of both formulations.

**2.5.2 Drying time**

 12 cm × 13 cm metal panels were smoothed with sandpaper and cleaned with cotton wool. The formulated paint was applied using a brush and allowed to dry under normal conditions. The set-to-touch time and tack-free time methods were used to record the drying and curing times for both standard and organic paint samples, following industrial standards.

**2.5.3 Gloss:** This measures the level of shine of the formulated paint according to ASTM D523 and ASTM C834 standard for standard and organic formulated paint respectively

 **2.5.3 Water resistance test**

To evaluate water resistance, two different formulated paint samples were applied to flat metal panels, dried, and cured. The panels were then immersed in fresh and salt water for 1 to 21 days to observe any chemical or physical changes such as swelling, blistering, or absorption. This test assessed the stability of the paint under prolonged water exposure.

**2.5.4 Adhesion test**

An adhesive tape and a magnifying glass were used to evaluate the adhesiveness of both paint samples on the substrate. The tape was firmly placed on the painted panels and quickly removed at a 180° angle to assess the paint's adhesion performance.

**2.5.5 Storage stability test**

A multi-sample analytical centrifuge was used to assess the long-term stability of the formulated paint. 5 mL of each sample was measured into 10 mL test tubes, inserted into the centrifugal chamber, and powered on. The centrifuge was set at different speed intervals (1000–4000 rpm) for 10 minutes, and the behavior of both samples was observed and recorded.

**3 Results and Discussions**

**3.1 Viscosity:** The flow properties of the formulated paint for critical applications was measured and observed that the viscosity for different spindle and speed at different temperature was tested and result shown in Table 2 and Table 3 according to (ASTM D2196) for standard formulation and (ASTM D2939) for organic formulation. The industrial standard base on application ranges as follows; High viscosity ≥50000cp typically for thicker coating, medium viscosity ≥ 1000cp common for brushing and rolling, Low viscosity < 1000cp mostly for spray application. The tested viscosity values for both formulations fall within medium viscosity range which can be adjusted based on the manufacturers type of formulation and application. The result shows that average tested viscosity for standard and organic marine paint was 32100cp and 12100cp and was observed to be within the medium viscosity standard for both formulations.

**Table 2: Viscosity Measurement of Standard Formulated Paint**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SPINDLE NO | SPEED (rpm) | Temperature (oc) | VISCOSITY (mPa-s) | AVERAGE SPINDLE VISCOSITY (mPa-s) |
| 111 | 123060 | 27.027.627.8 | 530004220022900 | 39100 |
| 222 | 123060 | 27.728.128.3 | 466003020015400 | 30700 |
| 333 | 123060 | 28.628.428.4 | 456001630010900 | 24200 |
| 444 | 123060 | 292929.1 | 474003780017900 | 34400 |
| Mean viscosity |  |  |  | 39100+30700+24200+34400=32100 |

**Table 3: Organic Viscosity Test Values of the Formulated Paint**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SPINDLE NO | SPEED (rpm) | VISCOSITY(mPa-s) | TEMPERATURE | AVERAGE SPINDLE VISCOSITY (mPa-s) |
| 111 | 123060 | 1200090006500 | 2727.627.8 | 9200 |
| 222 | 123060 | 18600128009500 | 27.728.128.3 | 13600 |
| 333 | 123060 | 17000112008300 | 28.628.428.4 | 12200 |
| 444 | 123060 | 17300136009700 | 292929 | 13500 |
| Mean Viscosity |  |  |  | 9200+13600+12200+13500=12100 |

**3.2 Drying Time:** This was to determine how quickly the paint will dry under normal condition according to industrial standard. According to ASTM C679 standard, a set to-touch time and a tack-free-time was used to determine the drying time of the formulation as shown in Table 4

**3.2.1 Set-to-touch-time**: The time taken for the two formulated painted samples to dry sufficiently such that it does not stick to finger was observed and recorded, the standard formulation took 3-5hours to dry while organic formulation took about 1hr 30minute to dry. According to ASTM C679 standard, 2-12 hours for organic formulation while standard formulation can take 1-8 hours comparing the result of the formulation from Table 4 the set-to-touch time for standard was within the standard range while organic formulation was far from the range which could be as a result of incompatibility of unmodified latex with other component of the formulation.

**3.2.2 Tack-free-time:** This is the time it takes for the painted film to dry and cure completely that it does not adhere to light object place on it ,the tack-free -time for both formulation was between 24-48hrs and 1-3hrs for standard and organic respectively which according to ASTM C679 standard, the tack-free depends on the product data which could depend on the type of formulation and environmental condition but basically it ranges from 1-12 hours for organic while standard is from 4-24 hours according ASTM C679, the ranges for tack free time for the standard formulated paint was close to ASTM C679 value if environmental condition and nature of the formulation was to be considered. From the observation after tack free time, there was some stains from organic painted panel when touch with light object compared to standard painted panel that leaves no stain when touch with lighter object which shows standard formulation perform better than unmodified latex formulation.

**Table 4 Drying Time for Standard and Organic Formulation**

|  |  |  |
| --- | --- | --- |
| Paint type | Set-to-touch time (hours) | Tack-free time (hours) |
| Standard | 3-5 hours | 24-48 hours |
| Organic | 1hr 30min | 1-3 hours |

**3.2.4 Gloss:** The gloss value for each formulation was recorded and observed, the result shows that the standard painted panel shows a shinning but not reflective surface compared to latex which shows a dull or rough surface on visual observation. table 4 shows the gloss values for standard and organic which ranges from high gloss to low gloss, High gloss (20°) for highly reflective surfaces, medium gloss (60°) used on different surface, Low gloss (80°) used for matt or rough surfaces. The gloss values for standard formulated paint fall within the range of medium gloss while the latex formulated paint falls within low gloss as shown in Table 5

**Table 5 Gloss values for standard and organic formulation**

|  |  |  |
| --- | --- | --- |
| Test method | Standard formulation | Organic formulation |
| Gloss meter 20 | 82 GU | 48 |
| Glossmeter 60 | 80 GU | 45 |
| Glossmeter 80 | 78 GU | 42 |
| Visual inspection | Medium gloss | Low gloss |

**Figure 1: Bar chat showing level of performance for drying time, pH and gloss for both formulated paint**

**3.3 water resistance:**  This was to evaluate the formulated paint ability to resist water penetration on the substrate, immersion test was conducted on the two metal painted with organic and standard paint for 21days as shown in Table 6, it was observed that between 3-7days,organic painted panels shows sign of blistering, peeling and discoloration in salt and fresh water which could be as a result of compatibility factor between other component with the unmodified latex while the standard painted panels shows no sign of discoloration after 21days of immersion which can be a good formulation compared to latex formulation according to ASTM D870 for water resistance, standard formulated paint shows no discoloration for prolong exposure to both salt and fresh water maintaining structural integrity than latex formulated paint that could not withstand prolong exposure due to unmodified latex that might become incompatible with other ingredient of the paint.

**Table 6: Evaluated Water Resistance of the Formulated Paint**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Paint** | **Duration (days)** | **Salt water sample** | **Fresh water sample** | **Paint** | **Duration (days)** | **Salt water sample** | **Fresh water sample** | **Paint** | **Duration (days)** | **Salt water sample** | **Fresh water sample** |
| **Epoxy** | 1-3 | No discoloration | No discoloration | Epoxy | 3-7 | No discoloration | No discoloration | Epoxy | 7-21 | Minor crack | No crack |
| **Latex** | 1-3 | No discoloration | No discoloration | Latex | 3-7 | No change in color | No change in color | Latex | 7-21 | Change in color | Change in color with some cracks |

**3.4 Storage Stability:**  Centrifugal stability of the formulated paints which was conducted to assess how the paint will maintain its quality over time. This was aim to evaluate the stability of the formulated paints, the analysis was conducted over a period of time, the result shows constant separation of the solvent with the organic formulation which shows inconsistency in quality as compared to standard formulation that shows no separation of the solvent with consistency in quality. according to ASTM D6930. Table 7 shows centrifugal assessment of both formulations.

**Table 7**: Centrifugal Storage assessment

|  |  |  |
| --- | --- | --- |
| Speed (rpm) | Epoxy | Latex |
| 10 min@1000rpm | No suspension | No suspension |
| 10min@2000rpm | No suspension | Little suspension |
| 10min @3000rpm | No suspension |  Other component suspended to the bottom leaving solvent on top |
| 10 min@4000rpm  | No suspension  | Solvent on top and other component suspended to the bottom. |

**3.5 Adhesion:** This was tested to ensure the formulated paint sticks well to the panel according to ASTM D3359. Observing the two painted panel with a magnifying glass, and adhesive tape, the organic panel shows sign of cracking and peeling with magnifying glass and some stains on adhesive tap which shows weaker adhesion compared to standard formulated painted panel which shows no stains and is durable compared to paint formulated with natural rubber latex binder.

**3.6 Ethical Issues**

This research work considered and addressed the following ethical issues:

i. All materials and chemical used for this research work were of good quality and Analytical grade.

ii. All laboratory precautions and instructions were strictly adhered to throughout the period of this research work to avoid irregularities, accidents and hazards.

iii. The spent reagents and the unused wastewater were properly disposed to avoid environmental hazard and pollution according to the environmental Protection Agency policies on wastewater treatment (EPA, 1997).

iv. All design calculations and experimental procedures used in this research work were in line with the scientific standards.

v. All scholarly works used in this research work were properly cited and referenced to avoid any form of plagiarism, infringement of copyright laws and impersonation.

 **4 Conclusion:**

 The comparative analysis of marine paint was carried on two marine paints samples produced using conventional Epicoat 1004 and locally sourced natural rubber latex as the binders. The physio-chemical and physio-mechanical properties of the formulation such as viscosity, drying time, gloss, adhesion, water resistance, storage stability and product performance have been investigated. The result shows that the standard formulated marine paint using epicoat1004 as binder outperform that of the organic paint in stability, water resistance and adhesive strength, whereas the organic formulated paint shows a better drying time, pH (due to the presence of ammonia), low gloss and are more eco-friendly. This aligning with sustainable development goal but faces challenges in storage and adhesion. These qualities may improve if the rubber latex is given some pretreatment or modification before being used. Due to environmental benefit from organic formulation, future research should focus on the compatibility between different standard ingredient of marine paint with unmodified NRL as binder to pave way to solutions in marine coating industries.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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