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Optimization of Some Processing Parameters on the Quality of Emulsion Paint from Waste Polystyrene Pyrolysis Oil

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Abstract

In furtherance to our effort to reduce environmental pollution, in this study, waste polystyrene (PS) was pyrolyzed through samples preparation (granules, foams). Polystyrene is heated in the absence of oxygen. Products are collected and some physical properties of the polystyrene fuel such as viscosity, density, melting point, moisture uptake, turbidity, elongation at break and water solubility were analyzed. Fuel used as a binder to optimize some processing parameters on the properties of the paint film. Parameters namely; nitrosol, solvent (water), titanium oxide (TiO_2), and calcium carbonate ($CaCO_3$) were evaluated and optimized using polystyrene binder for the paint formulation. The result revealed that nitrosol, calcium carbonate ($CaCO_3$), solvent (water) and titanium oxide (TiO_2) have acceptable concentration of 10 – 20 g, 25 – 30 g, 70 – 90 g and 10 – 20 g respectively. The concentrations mentioned above can serve as a guide for any coating industry attempting to fomulate emulsion paint using PS as a binder. This study to a large extend addresses the optimal values of these processing parameters for emulsion paint formulation and as a guide for the paint formulation.

Introduction

Paint is any liquid, liquefiable or mastic composition which after application to substrate in a thin layer is converted to an opaque solid film. Looking around, paints and coatings are found virtually everywhere. Paint is seen on the walls of homes or offices, and on furniture, refrigerators, washing machines, and toasters with nice colourful finishes etc. There are virtually limitless products that use some kind of paint or coating on their surfaces. The wide variety of surfaces which must be protected and decorated has given rise to an infinite numbers of coating agents such as paints and varnishes. Not only to protect such surfaces, but also to decorate them or to provide special purposes like symbol in industry.

Paint is also known as the organic materials that cover the substrate of materials. The two major types of paint are; water based (emulsion) paint and Oil based paints. Oil based paint is known to contain some adorable qualities such as flexibility, gloss, low moisture uptake, and highly durable. However, due to the inorganic solvent used in dissolving the binder, and other components in the paint because of high molecular polymeric materials used as a resin, there is always an emission VOCs (Volatile Organic compounds) from the surface of the substrate, which has warranted the legislative arm to curtain the usage globally. However, emulsion paint proved to be environmentally friendly, as the organic solvent used in emulsion paint does not emit VOCs. The major setbacks of emulsion paints are poor water resistant, lack of durability due to affinity to water, and lack of luster.

The development of environmentally friendly and cost-effective paints is becoming increasingly important due to growing concerns about the environmental impact of traditional paint ingredients.

Emulsion paints which are water-based paints, are commonly used due to their ease of application, low odor, and relatively low environmental toxicity. However, achieving the desired paint properties, such as durability, consistency, and drying time, requires the use of appropriate binders, surfactants, and additives (Oyeniyi *and* Ruth., 2019).

Polystyrene pyrolysis oil, derived from the thermal degradation of polystyrene waste, has recently emerged as an innovative alternative binder in emulsion paint formulations.

Polystyrene pyrolysis oil is a renewable resource that can help reduce the environmental burden of non-biodegradable polystyrene plastic waste. As a binder, polystyrene pyrolysis oil potentially offers good film-forming properties, water resistance, and durability, which are key characteristics of high-quality paint (Hassan *et al*., 2020).

A binder that is too concentrated may lead to overly thick or difficult-to-apply paint, while insufficient binder content can result in weak adhesion and poor coverage (Mehta *et al*., 2019). In conventional emulsion paints, synthetic binders such as acrylic or vinyl are commonly used. However, there has been a growing interest in utilizing alternative, more sustainable binders, especially those derived from waste or bio-based sources. The use of waste polystyrene pyrolysis oil as a binder in emulsion paint formulations represents an innovative approach to utilizing waste plastics while reducing reliance on petrochemical-based binders.

The chemical properties of pyrolysis oil, including its viscosity, polarity, and molecular structure, may influence its compatibility with pigments and other components of the emulsion, thus affecting the overall performance of the paint (Wang *et al*., 2020). The binder concentration in emulsion paints influences several key characteristics, such as film formation, adhesion, and durability. However, an excessive binder concentration may result in a film that is too flexible or prone to cracking, while too little binder may lead to poor adhesion (Soni *et al*., 2018).

This study aims to optimize the effect of some processing parameters on the properties of emulsion paint formulated with polystyrene pyrolysis oil as a binder.

The specific objectives of this study are to:

i. Collect and pyrolyse waste polystyrene plastics to produce pyrolysis oil.
ii. Characterize the polystyrene Pyrolysis Oil produced.
iii. Formulate and characterize paint using the pyrolysis oil as a binder.
iv. Evaluate the effect of nitrosol on paint properties.
v. Study the effect of $CaCO_3$ on paint quality.
vi. Access the effect of water as a solvent in the emulsion paint
vii. Investigate the influence of pigment concentration on the emulsion paint.
viii. Evaluate the effect of pyrolysis oil concentration in the emulsion paint
ix. Compare the final quality of the emulsion paint with standard

Related Literatures

Emulsion paints, which are water-based coatings, are commonly used in various applications due to their ease of use, low toxicity, and environmental advantages. Traditional emulsion paints utilize synthetic binders, usually derived from petrochemical sources, to hold the paint's components together. However, the rising demand for more sustainable solutions has led to the exploration of alternative binders, such as those derived from waste polystyrene. One primary option is waste polystyrene, which can be converted into pyrolysis oil through a thermal decomposition process. Polystyrene pyrolysis oil is a complex mixture of hydrocarbons that can be used as a binder in emulsion paints, offering a solution to both plastic waste and the need for sustainable paint formulations. This literature review explores the role of nitrosol (sodium nitrite) as an additive in emulsion paints formulated with polystyrene oil, focusing on the effect of nitrosol, solvent (water), calcium carbonate, and pigments concentration of emulsion paint from waste polystyrene pyrolysis oil. Polystyrene pyrolysis oil in emulsion paint is a common plastic that is difficult to recycle, contributing significantly to environmental pollution. Pyrolysis of waste polystyrene provides a pathway to convert this waste into a usable resource.

Polystyrene pyrolysis oil has been explored as a binder in emulsion paints because of its chemical composition, which includes aromatic hydrocarbons and other organic compounds that can potentially improve certain paint properties. However, polystyrene pyrolysis oil tends to have high viscosity and hydrophobic characteristics, which can make it challenging to incorporate into water-based emulsions without modification. Studies such as those by Hossain *et al*. (2019) and Ogbuji *et al*. (2020) highlight the potential of polystyrene oil as a binder in emulsion paints. They reported that polystyrene oil-based paints exhibited good water resistance, hardness, and flexibility but were prone to stability issues due to phase separation. One approach to improving the stability of polystyrene oil-based emulsion paint is by adding additives that enhance the dispersion of the oil and improve emulsion properties.

MATERIALS AND METHODS

Materials

Polystyrene wastes of disposable food containers, packaging materials, insulation, and various consumer products due to its lightweight and insulating properties. These plastics were virtually free of other non-plastic contaminants except for additives added during manufacturing and were collected around homes and dumping sites of Jambutu Yola North LGA of Adamawa state and employed as raw materials for the pyrolysis process.

Methods

Pyrolysis of Polystyrene Waste (PS)

The polystyrene plastic wastes were collected from landfills, washed, detached of label, dried, and shredded into smaller sizes to increase their surface area and the shred plastic wastes will be introduced into a pyrolysis plant. The resulting liquid (plastic fuel/oil) will be collected using an appropriate container and were sealed up for further analysis.

Characterization of the Pyrolysis Oil Binder

Viscosity Determination of the PS Binder

Viscosity measurements was carried out using the VIBRO Viscometer Model SV-10. 30 mL of the sample was measured in a beaker and placed in such a way that the viscometer sensor was fully submerged into the beaker. The viscosity reading was automatically detected and recorded.

Density Determination of PS Binder

The density was determined according to AOAC (2000). The densities of the resin were determined by taking the weight of each resin concentration inside a density bottle using weighing balance. The density was calculated using the mass volume relationship. Three readings were taken for each sample and the average value was calculated.

Melting Point Determination of PS Binder

Melting point of each resin concentration was determined by using Stuart melting point machine (Model SMP 10). Triplicate determinations were made and average value was taken.

Refractive Index Determination of PS Binder

The refractive index of the resin was determined by using Abbe refractometer (Olutanti, *et al*., 2011). Three readings were taken for each sample and average value was determined.

Moisture Uptake Determination of PS Binder

The moisture uptake of resin films was determined using Memmert desiccators. 3 g of different samples were put into the desiccators containing a saturated solution of 1 g Sodium Chloride. The wet weight of each sample was monitored until maximum weight. The difference between the wet weight and dry weight was noted as moisture uptake by resin (Olutanti, *et al*., 2011).

Turbidity Determination of PS Binder

Turbidity of the binder were measured using Labtech Turbidity meter (Model AVI-654). The result of each of the samples were reported in NTU. Triplicates determinations were made and average value was calculated.

Elongation at Break (Tensile test) Determination of PS Binder

The elongation at break was measured using Intron Tensile machine based on ASTEMD 638. The binder film of dimension 5 cm long, 2 cm wide and 0.2 cm thick for each of the sample was brought to rapture at a clamp stand with a full load of 150 g each. Three runs were carried out for each sample and the average elongation was evaluated in percentage.

Water Solubility Determination of PS Binder

The water solubility was determined by mixing 2 ml of the resin in the required 20ml of distilled water. The transparence or cloudiness of the sample which showed either their solubility or insolubility in water (Osemeahon and Dimas, 2014).

Formulation of PS Modified Paint

Basically, emulsion paint was formulated in respect to the method reported by Akinteriwa*et al*., (2015). The method splits the production process into three main stages as follows:

First Stage

At the first stage, additives such as dispersants, defoamer, thickener, anti-skin, drier, wetting agents, stabilizer, pH adjuster and preservatives were added. The basic purpose of this stage is to provide a favourable environment for wetting and dispersion of particles. A volume of 185 ml of distilled water was introduced into a litter tank and the overhead stirrer switched on after the addition of 12.7 g of the additives as shown in Table 1 below. This mixture was stirred using a high-speed stirrer for 15 minutes.

Second Stage

In the second stage, also known as "Millbase", pigments and extenders were dispersed in the mills. Immediately after dispersion, the stirrer speed in the Millbase stage was increased to a very high speed and the mixture was stirred for another 15 minutes. In Millbase, binder was not added to avoid its structural deformation under high mechanical forces.

Third Stage

Finally, binder plus the rest of the additives used in the first stage were mixed with 15 ml of water. This stage is called "Letdown". In this stage, the mixture was stirred at moderate speed for another 15 minutes. Energy losses in the Millbased were minimized by adding thickness before the dispersion stage of the production process. The details of the formulations are in the

Table 1: Emulsion paint formulation recipe of PS as a binder

Stage	Materials	Quantity (g)
First	Water	185
	Anti-foam	0.2
	Drier	0.2
	Calgon	1.16
	Genepour	1.16
	Bermocoll	2.5
	Troystan	1.14
	Dispersant	0.2
	Butanol	5
	Ammonia	10
	TiO_2	50
	$Al_2(SiO)_3$	11.2

Millbase	Na2CO3	0.58
	Kaolin	2.52
	$CaCO_3$	123
Letdown	Binder	200
	Water	15
	Dispersant	0.2
	Nicofoam	0.2
	Anti-skinning agent	0.2
	Total	609.46

Characterization of the Formulated Emulsion Paint

Viscosity Test of the Emulsion Paint

Viscosity measurements was carried out using the VIBRO Viscometer Model SV-10. 30 mL of the sample was measured in a beaker and placed in such a way that the viscometer sensor was fully submerged into the beaker. The viscosity reading was automatically detected and recorded.

pH and Opacity Test of The Emulsion Paint

The pH of paint samples was determined by using phywe pH meter model 18 195.04. Opacity was determined by using the standard Mohest Chart. The paint samples were applied on the Mohest Chart and allowed to dry for 24 hr. The opacity was evaluated by comparing the dried sample film with the hiding power chart. Three determinations were made for each sample and mean value assessment recorded.

Drying time and Flexibility Test of the Emulsion Paint

Dry time was evaluated by applying the paint sample on a glass panel with the aid of bar applicator, and allowed to dry. Dry to touch was taken when the paint film is no longer sticking to the finger and dry to hard taken was when the film resisted fingerprint. Triplicate evaluations were made for each sample and mean value assessment recorded. For flexibility test, paint sample was applied on a freshly degreased and chromate aluminium with the aid of paint applicator. The film was allowed to air dry under room temperature (27^{o}C) for 7 days. The panel with the film was bent through 1800^{o}C with a smooth action taking 1 – 2 seconds. The panel was removed and examined for cracking or loss of adhesion. Any crack or loss of adhesion indicates inflexibility or brittleness. Triplicate determinations were made at 27^{o}C for each sample for quality assessment.

Adhesion Property of the Emulsion Paint

Adhesion property of paint was carried out by applying a coat of paint film with film applicator on a degreased metal panel and allowed to dry for 48 hours. Two sets of lines, one crossing perpendicularly over the other was drawn with a crosshaten tester on the apint film. Adhesive tape was pressed firmly with the thumb covering all the interactions of the perpendicular line. The adhesive tape was at its loose end and forcibly removed from the panel. Removal of more than 50% of the square lines of the paint film indicates a poor adhesion. Triplicate determinations were made at 27^oC for each sample for quality assessment.

Stickiness (Tackiness) Test of the Emulsion Paint

This was carried out quantitatively 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 quality assessment recorded.

Resistance to Blistering Test of the Emulsion Paint

Resistance to blistering was determined thus; undiluted paint sample was applied to a glass panel with an applicator to give a wet film thickness of about 120 μm, which was allowed to dry for 24 hours. At the end of this period 4 ml of distilled water in the form of circular drop was placed on the film. The presence of blistering, wrinkling, swelling or cracking within a period of 30 minutes indicates poor water resistance. Quality assessment recorded was the mean triplicate determinations of each sample.

Water Resistance Test of the Emulsion Paint

This was carried out by applying the paint sample on a smooth brick and placed inside a bowl of water for seven days. At the end of the seven days, the sample was removed from the water, poor water resistance was indicated by the presence of paint particles in the water.

Chemical Resistance Test of the Emulsion Paint

The chemical resistance of the paint films was carried out thus; three flexible aluminium panels (150 mm x0.3) was used as the test panels. A coat of paint with paint applicator was applied on the panel. One liter glass beaker was filled with 0.1 M NaOH solution to a depth of 150 mm and the test pieces immersed for 48 hours to the depth of approximately 120 mm. the test piece was removed, washed with running water and stood to dry for 2 hours. The above procedure was repeated using 0.1 M NaCl respectively. Poor chemical resistance was indicated by the presence of any surface defects such as cracking, blistering, peeling or changes in color.

RESULTS AND DISCUSSION

Optimization of Some Processing Parameters on the Properties of the Film

Table 2: Effect of nitrosol concentration on chalking film

S/N	Concentration (g)	Results
1.	10 g	P
2.	15 g	P
3.	20 g	P
4.	25 g	F
5.	30 g	F

P = Pass, F = Fail

In table 2 above shows concentration between 10 to 20 g of the ingredient nitrosol. Concentration above 20 g caused over loading or incompatibility issues, leading to chalking. The results indicate that nitrosol concentration between 10 to 20 g yield positive result for chalking resistance, while concentration above 20 g leads to negative result (Chalking). Concentration can increase the resistance to flow within the material (Yin et al., 2013).

Table 3: Effect of nitrosol concentration on drying time of paint film

S/N	Concentration (g)	Results
1.	10 g	6 hours
2.	15 g	5 hours 30 minutes
3.	20 g	5 hours 30 minutes
4.	25 g	5 hours 20 minutes
5.	30 g	5 hours 10 minutes

The results presented in table 3 above shows Nitrosol thickening properties influence paint drying behaviour, potentially reducing drying time. The data suggest that highesr nitrosol concentrations can lead to faster drying time which may be beneficial for certain applications. In the context of coating industry, the viscosity of the nitrosol affect the application and final appearance of the coating (Osemeahon et al., 2013). The faster rate of drying at higher concentrations can be attributed to increased in viscosity due to progressive decrease in solvent concentration in the paint formulation.

Table 4: Effect of Concentration of $CaCO_3$ on Chalking of paint film

S/N	Concentration (g)	Results
1.	10 g	P
2.	15 g	P
3.	20 g	P
4.	25 g	F
5.	30 g	F

P = Pass, F = Fail

In Table 4 above shows that lower $CaCO_3$ concentration (10 to 20 g) exhibit good results for chalking potentially indicating good durability. Higher $CaCO_3$ concentrations (25 to 30 g) shows chalking suggesting a poor paint product. This result can be explained on basis of good or poor coverage of the binder on the pigment. The pigment volume concentration is a crucial factor when considering optimization of processing ingredients in paint formulation (Edga and Lopez, 2023). Above 20 g there is poor coverage of the pigment by the binder hence excess pigments leading to chalking (Liu., et al, 2018). This result provides us with the optimal value of $CaCO_3$ needed for our paint formulation.

Table 5: Effect of Concentration of $CaCO_3$ on The Drying Time of Paint

S/N	Concentration (g)	Results
1.	**10 g**	9 hours 30 minutes
2.	**15 g**	7 hours
3.	**20 g**	6 hours 30 minutes
4.	**25 g**	6 hours 20 minutes
5.	**30 g**	6 hours 10 minutes

In Table 5 above shows $CaCO_3$ influence paint film formation and drying behaviour. Changes in $CaCO_3$ affect paint rheology, impacting drying time. The data suggest that higher $CaCO_3$ concentrations lead to faster drying time, which may be beneficial for certain application. The result indicates that increasing $CaCO_3$ concentration generally increases viscosity thereby decreasing drying time (Basta A., et al., 2019).

Table 6: Effect of $CaCO_3$ Concentration on Adhesion of Paint Film

S/N	Concentration (g)	Results
1.	**10 g**	G
2.	**15 g**	G
3.	**20 g**	G
4.	**25 g**	VG
5.	**30 g**	VG

G = Good, VG = Very Good

In Table 6 above shows $CaCO_3$ interact with the binder enhancing adhesion properties. Changes in $CaCO_3$ concentration influence film properties, such as cohesion and adhesion. The data suggest that increasing $CaCO_3$ concentration leads to improve adhesion with optimal results achieved at higher concentration (25 to 30 g). The result indicate that lower $CaCO_3$ concentrations (10 to 20 g) exhibit good adhesion. Higher

$CaCO_3$ concentrations (25 to 30 g) shows very good adhesion, suggesting improved bond strength within 25 – 30 g of $CaCO_3$ (Ali M. A., et al., 2019).

Table 7: Effect of Concentration of $CaCO_3$ on blistering of Paint Film

S/N	Concentration (g)	Results
1.	10 g	VG
2.	15 g	VG
3.	20 g	VG
4.	25 g	G
5.	30 g	G

G = Good, VG = Very Good

The Table 7 above shows that lower $CaCO_3$ concentrations (10 to 20 g) exhibit very good blistering resistance. Higher $CaCO_3$ concentration (25 to 30 g) shows fair blistering resistance, suggesting decreased performance. The data suggest that optima blistering resistance is achieve at lower $CaCO_3$ concentration (10 to 20 g). Higher concentration may compromise blistering resistance (Ichan L., et al., 2018). This result is attributable to differences in Pigment volume concentrations.

Table 8: Effect of Water Concentration on Chalking of Paint Film

S/N	Concentration (g)	Results
1.	70 g	P
2.	90 g	P
3.	110 g	F
4.	130 g	C
5.	150 g	C

P = Pass, F = Fail, C = Chalking

The results in Table 8 above shows water concentration affect the paint film, influencing chalking behaviour. Changes in water concentration may impact film properties, such as cohesion and adhesion. The data suggest that optimal chalking resistance is achieved at lower water concentrations (70 to 110 g). Higher water concentration may compromise paint durability. This result can be attributed to dilution effect on the concentration of the binder thereby making the binder film too weak to Cohens the pigments (Osemeahon et al, 2013).

Table 9: Effect of Water Concentration on the Drying Time of the Paint Film

S/N	Concentration (g)	Results
1.	70 g	9 hours 30 minutes
2.	90 g	9 hours 40 minutes
3.	110 g	9 hours 40 minutes
4.	130 g	9 hours 55 minutes
5.	150 g	10 hours

The Table 9 above shows that higher water content leads to longer drying time due to increased solvent. Changes in water concentration affect film formation kinetic. It also increases the time required for solvent evaporation and the increase in drying rate. Increasing water concentration generally increase drying time (He Q., et al., 2013).

Table 10: Effect of Water Concentration on the Adhesion of the Paint Film

S/N	Concentration (g)	Results
1.	70 g	G
2.	90 g	G
3.	110 g	P
4.	130 g	P
5.	150 g	P

G = Good, P = Poor

In Table 10 above shows that water concentration affect adhesion. This is because it affects the pigment binder ratio, influencing adhesion properties. Changes in water concentration impact film properties, such as cohesion and adhesion. The data suggest that optimal adhesion is achieved at lower water concentration (70 to 90 g). Higher water concentration compromised adhesion properties. The result indicates that lower water concentration (70 to 90 g) exhibit good adhesion. Higher water concentration (110 to 150 g) shows poor adhesion, suggesting poor binding ability of the binder due to its dilution performance (Stark A., et al., 2017).

Table 11: Effect of Water Concentration on the Blistering Property of the Paint Film

S/N	Concentration (g)	Results
1.	70 g	F
2.	90 g	F
3.	110 g	P
4.	130 g	P
5.	150 g	P

F = Fail Blistering, P = Pass Blistering

The result presented in table 11 regarding the effect of water concentrations on the blistering property of the paint film shows high water concentrations (110 – 150 g) increases blistering in the paint film (Samsin K. et al., 2009). This is because excess water can be trapped beneath the paint film during application or due to high humidity. When the moisture evaporates, it creates pressure leading to the paint film bubbling up and forming blisters.

Table 12: Effect of Concentration of TiO_2 on Chalking Behaviour of the Paint Film

S/N	Concentration (g)	Results
1.	10 g	P
2.	15 g	P
3.	20 g	P
4.	25 g	F
5.	30 g	F

P = Pass Chalking, F = Chalking

The Table 12 above shows that TiO_2 concentration affect pigment loading, influencing chalking behaviour. TiO_2 is known for its UV resistance properties, which contribute to improve chalking resistance. The data suggest that higher TiO_2 concentration (25-30 g) may provide poor chalking resistance in emulsion paint formulation.
The results indicate that lower TiO_2 concentrations (10-20 g) exhibit good chalking resistance. Higher TiO_2 concentrations (25-30 g) show negative result, suggesting poor chalking resistance (Awasthi L., et al., 2019). This development is attributable to the poor pigment volume concentration (PVC) in the paint formulation. This reduced ration of binder concentration leading to incomplete coverage of pigment by the binder.

Table 13: Effect of TiO_2 Concentration on Adhesion of the Paint Film

S/N	Concentration (g)	Results
1.	10 g	P
2.	15 g	P
3.	20 g	F
4.	25 g	F
5.	30 g	F

P = Pass, F = Fail

The Table 13 above shows that TiO_2 concentration affect the pigment binder interaction, influencing adhesion properties. High TiO_2 concentrations leads to increased pigment loading potentially compromising adhesion. The data suggest

optimal adhesion is achieved at lower TiO_2 concentrations (10-15 g). Higher concentration compromised adhesion properties.
The result indicates that lower TiO_2 concentrations (10-15 g) exhibit positive adhesion result. Higher TiO_2 concentrations (20-30 g) show negative adhesion results, suggesting decreased performance.

Table 14: Effect of TiO_2 Concentration on the drying time of Paint Film

S/N	Concentration (g)	Results
1.	**10 g**	8 hours
2.	**15 g**	7 hours 50 minutes
3.	**20 g**	7 hours 40 minutes
4.	**25 g**	7 hours 20 minutes
5.	**30 g**	7 hours

The Table 14 above shows that higher TiO_2 concentration leads to increased pigment loading affecting drying behaviour. Changes in TiO_2 concentration influenced film formation kinetics. The data suggest that higher TiO_2 concentration can lead to lower drying time, potentially impacting production efficiency.
The results indicate decreased TiO_2 concentration generally increased drying time (Taha, M., et al., 2022).

Table 15: Effect of TiO_2 Concentration on Blistering of Paint Film

S/N	Concentration (g)	Results
1.	**10 g**	P
2.	**15 g**	P
3.	**20 g**	P
4.	**25 g**	F
5.	**30 g**	F

P = Pass, F = Fail

The Table 15 above shows that high TiO_2 concentrations lead to increased pigment loading, affecting film properties and low blistering resistance. Changes in TiO_2 concentration influence incomplete coverage of pigment which allows moisture into the paint film, impacting blistering behaviour.
The results indicate that lower TiO_2 concentrations (10-20 g) exhibit good blistering resistance. Higher TiO_2 concentration (25-30 g) show poor blistering resistance, suggesting decreased performance (Solomon J., et al., 2002). Formulation of emulsion paint with this binder will require maximum inclusion of 20 g of TiO_2.

Effect of PS Binder Concentration on the Properties of the Emulsion Paint

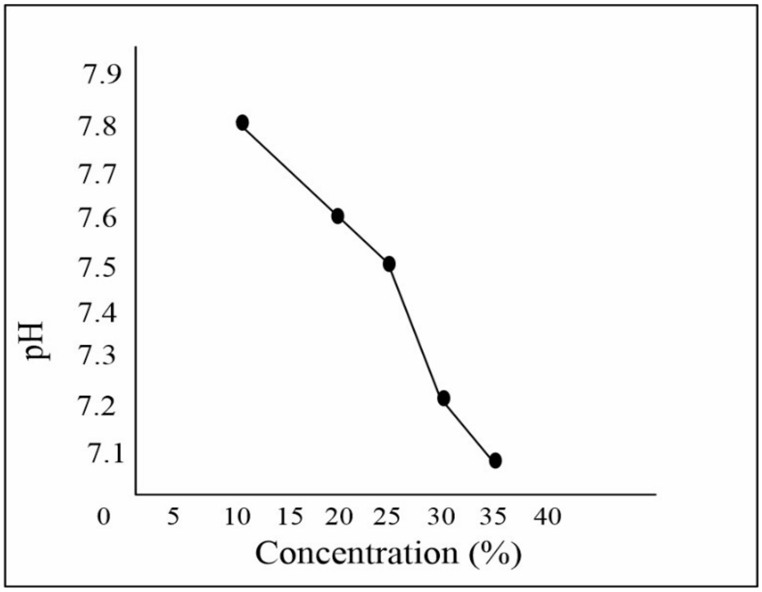

Figure 1: Effect of PS Binder Concentration on the pH of an Emulsion Paint

The results presented in figure 1 regarding the effect of PS Binder concentration on pH of an Emulsion Paint are quite revealing. The study demonstrates that the pH of the emulsion film is directly proportional to the concentration of dissolved PS (Osemeahon et al, 2013). Specifically, an emulsion blended with 35% PS exhibited the highest pH.

Effect of PS Binder Concentration on the Viscosity of an Emulsion Paint

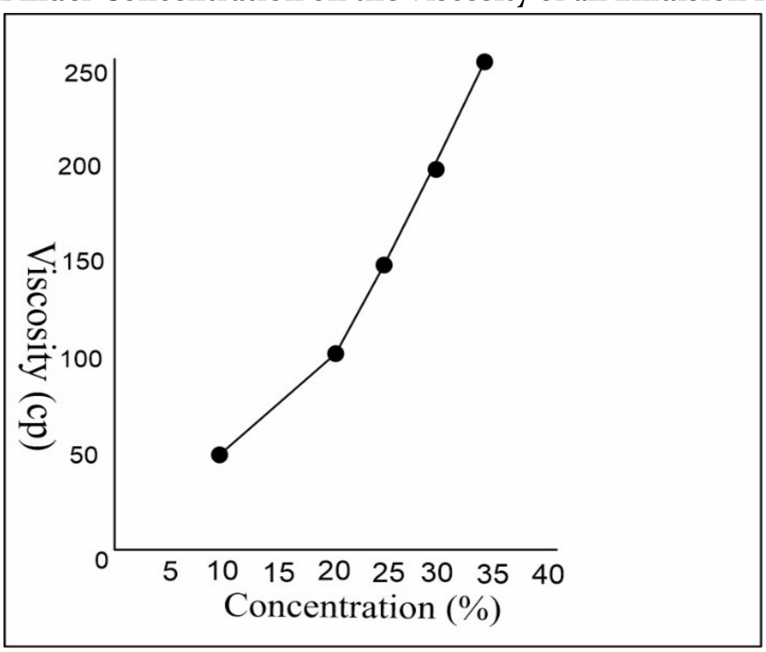

Figure 2: Effect of PS Binder Concentration on the Viscosity of an Emulsion Paint

The results presented in figure 2 regarding the effect of PS Binder concentration on the viscosity of the Emulsion Paint shows a positive correlation between PS Binder concentration and viscosity of Emulsion Paint (Yin et al, 2003). As PS Binder concentration increases, the viscosity of the Emulsion Paint also increases. This suggest that higher binder concentration leads to ticker more resistant paint.

Table 16: Effects of concentration of waste ps on the resistance to blistering of an emulsion paint

S/N	Concentration (%)	Result
1.	10 g	P
2.	20 g	P
3.	25 g	P
4.	30 g	P
5.	35 g	P

P = Pass

The Table 16. shows the effect of waste PS concentration on resistance to blistery of the emulsion paint. All the paint sample passed the blistering test, this can be attributed to the high adhesive nature of the binder (Onoja *et al.,* 2019). The ability of this paint to withstand blistering is very commendable since this goes on to address one of the short comings of emulsion paint (Osemeahon *et al.,* 2009). Resistance to the blistering by the paint sample is an indication that the paint can be used for both interior and exterior decoration (SON, 1998)

Table 17: Effect of concentration of waste ps on the adhesion of the emulsion paint

S/N	Concentration (%)	Result
1.	10 g	P
2.	20 g	P
3.	25 g	P
4.	30 g	P
5.	35 g	P

P = Pass

The Table 17 above shows that all the paint samples passed the adhesion test. This behavior can be attributed to the high-molecules weight and adhesion property of the binder used. (Onoja *et al.,* 2019). The quality and durability of a coating is directly related to the nature of adhesion (Butt 2007).

Table 18: Effect of PS Binder concentration on chalking of the emulsion paint

S/N	Concentration (%)	Result
1.	10 g	P
2.	20 g	P
3.	25 g	P
4.	30 g	P
5.	35 g	P

P = Pass

In Table 18, the effect of binder concentration on the degree of chalking of an emulsion paint. Chalking is the formalty of a white powdery substance on the paint surface due to degradation of the binder over time often accelerated by UV exposure, weathering and other environmental factors.

There was no chalking, from 10-35% concentration as the binder concentration increased, this can be attribute to higher binding ability of the binder used and improved binderpigment interaction (Singh *et al.,* 2018). And also due to the improved adhesion and cohesion of the binder (Kumar *et al.,* 2016). This property exhibited by the paint is commendable. Makes its as a good coating material.

Table 19: Effect of PS Binder concentration on the Drying Time of the Emulsion paint

Table 19a: Dry to touch

S/N	Concentration (%)	Result
1.	10 g	5hour 18Minutes
2.	20 g	5hour 38minutes
3.	25 g	6hour 25minutes
4.	30 g	6hour 48minutes
5.	35 g	7hour

Table 19b: Dry to Hard

S/N	Concentration (%)	Result
1.	10 g	24hours
2.	20 g	45hours
3.	25 g	48hours
4.	30 g	65hours
5.	35 g	72hours

The Table 19. a and b show the effects of PS concentration on the drying time of emulsion paint at room temperature. The result obtained at various PS concentration from 10-35% was due to an increase in viscosity from low viscosity value of the paints, which is the consequence of the different level of interaction of PS binder at different concentration which result to an increase in the molecular weight. The drying time of the paint increased for both dry to touch and dry to hard from 5hrs 18 mins – 7 hrs and 24 hrs - 72hrs responsively with increased in PS concentration which is strickly recorded from 10%-35% (Lawal *et al.,* 2019). The concentration of the pigment or its ratio to the Binder decreases with increase in Binder concentration, hence time of drying time is proportionality increased (Lawal *et al.,* 2019). This implies that it will make a good binder for an emulsion paint. These results are in accordance with the work-done by (Osemeahon and Berminas, 2007).

Table 20: FTIR Spectral Analysis of PS Binder

Peaks (cm^{-1})	Functional Group
3038.1818	Aromatic C-H stretch
2865.8343	Aliphatic C-H stretch
2931.1434	Aliphatic C-H stretch
1458.4727	Benzene ring deformation
1522.2949	Aromatic C-C stretch
1204.5010	C-C stretching
1003.7010	Aromatic in-plane C-H deformation
743.3859	Out-of-plane aromatic C-H deformation

Table 21: Properties of PS Paint in Comparison with the SON Standard

S/N	Parameter	Experimental Value	SON Standard
1.	Density (g/cm^3)	0.9359	0.9 – 2.0
2.	Viscosity(cp)	3.93	3.11 – 38.00
3.	Flash point(^oC)	74	21 – 37.8
4.	Refractive Index (B×)	1.4331	1.4 – 1.6
5.	pH value	5.28	4 – 9
6.	Turbidity (NTU)	57.0	<5 NTU
7.	Elongation at Break (%)	1200	100 – 400
8.	Dispersibility	Partially disperses	Good dispersibility
9.	Moisture uptake (%)	0.006	0.1 – 5
10.	Melting (^oc)	119	60 – 160

Conclusion

The study focused on optimizing the concentration of nitrosol, $CaCO_3$, water (solvent), TiO_2 and waste polystyrene pyrolysis oil on the quality of emulsion paint.

The following test namely: chalking, drying time, adhesion and blistering were carried out on each of the processing parameters above to rule out their effect on concentration of emulsion paint.

Under the effect of nitrosol, concentration between 10 to 20 g found to enhance film properties such as cohesion and adhesion. Higher nitrosol concentration (25 to 30 g) can lead to faster drying time, leading to poor adhesion. Concentration between 10 to 20g achieved optimal thickening allowing for good adhesion. Fail blistering resistance was found at the concertation between 10 to 20 g.

For effect of $CaCO_3$, concentration between 10 to 20g exhibited pass result for chalking potentially indicating good durability. Higher concentration of $CaCO_3$ (25 to 30 g) shows chalking suggesting a poor paint product. Concentration between 25 to 30 g shows very good adhesion, optimal blistering resistance was achieved at lower concentration of 10 to 20 g.

Optimal chalking resistance was achieved at lower water concentration (70 – 110 g), higher water content between 130 – 150 g leads to longer drying time. Data also suggest that optimal adhesion was achieved at lower water concentration 70 – 90 g, concentration between 130 – 150 g improved blistering compared to lower concentration.

For TiO_2, concentration between 25 – 30 g provided better chalking resistance in emulsion paint, adhesion was achieved at lower TiO_2 concentration (10 – 15 g). longer drying time was found at the lower concentration of 10 – 15 g. Blistering resistance was exhibited at lower concentration of TiO_2 (10 – 20 g).

All the samples i.e 10 – 35 g past the blistering and adhesion test with no chalking. Result also showed prolong drying time with increase of concentration of PS and vice versa. Optimal drying time which is after 24 hours was found between concentration of 10 g.

This study identified optimal concentration of key ingredients to achieved desired paint properties. The optimized formulation demonstrated enhanced resistance to blistering, chalking, and improved adhesion. The used of waste pyrolysis oil contributed to environmental sustainability and potential cost savings.

Recommendations

1. Further optimization: Additional studies could explore further optimization
2. Industrial scale validation: Large scale trials could validate the optimized formulations performance.
3. Broader applications: The optimized formulation could be explored for various industries.

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