Laboratory Studies on Small Scale Production of Three (3) Different Grades of Emulsion Paints

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Abstract
The quest to reviving the nations' economy toward local production of goods and services and gaining employment of our teaming youths revolves through encouragement and development of small scale enterprises (SMEs). In this paper, emulsion paints were formulated using different local raw material as pigments and at different pigment volume concentration (PVC) of 32%, 19%, and 10% respectively. Polyvinyl acetate (PVA) was used as binder, with dispersant and solvent (water). The effects of varying concentrations of pigments were studied and the higher concentration of pigment produce better results, as more compatibility with the binder, and deeper colour for the paints formulated were obtained. The Physico-chemical properties such as viscosity, density, drying time, opacity, and pH for the formulated paints were characterized which gives a positive yields. The results revealed that the paints could be used as both indoor and outdoor coatings that could have good value for money and long durability.

Keywords: *Grade paints, emulsion, binder, SMEs, and production*

1.0 INTRODUCTION

Paints are any liquid, liquefiable, or mastic composition that after application to a substance in a thin layer, converts to a solid film. It is most commonly used to protect, colour, or provide texture to objects and surfaces. Paint can be made or purchased in many colours and in many different types, such as water-colour, synthetic, etc. Paint is typically stored, sold, and applied as a liquid, but most types dry into a solid Stephanie, (2011). It can also be used to describe liquid material before application and coating after it has been applied and dried. The purpose of paint is to protect the surface of metals and wood from attack by rain, dust and gases in the air, it can also be applied to impart beauty and protection Crowley, (2008). Paint is a term used to describe a number of substances that consist of a pigment suspended in a liquid or paste called vehicle such as oil or water. It provides an economic protection, preservation, and decoration, aesthetic and adds functionality to structures Abidalla, (2008).
Paints composition largely determines its characteristics, usage and classification. By suitable variation of the type of proportion of the various constituents, they can be made dry, glossy or flat as desired. Other properties such as permeability to water could be varied accordingly Waldie, (1983). Paints have been manufactured since prehistoric times, but until recently they were highly expensive and thus were mainly used for artwork. It is only since the 19^{th} century that houses have commonly been painted. Today paints are used for colouring and protecting many surfaces, including houses, cars, road markings and underground storage vessels. Each of these different applications requires a different sort of paint, and it is these differences in composition that are the focus of this article. Paint is essentially composed of a binder, pigment and solvent JEPER (2014).

In this paper, the objective is to address the drastic reduction in local production of paints and possible ways to increase the gross domestic products (GDP) through paint production.

1.1 Problem Statement

Due to the changes in paint composition in the twentieth century, it becomes possible to mass produce paint from local and synthesized materials. This give rise to the problem of selecting a suitable local raw material for paint production in terms of paint quality and cost effectiveness.

1.2 Research Justifications

The justification of this work is that (i) high quality kaolin is abundant in Nigeria and if properly sourced and processed by paint industries thus will help to increase the quantity of local paint production, hence reducing the cost of paint production and conserve foreign exchange (forex) and (ii) it will provide job opportunities and reduces unemployment in the country.

2.0 BACKGROUN AND LITERATURE STUDIES

Paint is one of the oldest synthetic substances known since time immemorial. It was made more than 35000 years ago by pre-history man as they mixed clays and chalks with animal fats and used these paints to depict their hunts on cave walls. By 2500C the Egyptians had improved this technology considerably JEPER (2014).

They had developed a clear blue pigment by grinding azurite, and instead of animal fats they used gums, wax and may be also albumen (egg white) as binders and solvents for their paints. The technology improved still further during the first millennium BC as the Greeks learnt to blend paints with hot wax, rather than water, making a paint that was both thicker and easier to spread and thus making it possible to blend colors. By this time many colours were available from both natural and synthetic sources, one of the most interesting being a purple pigment made from heating yellow earth till it turned red and then plunging it into vinegar. The technology then lapsed for many years, with techniques being passed down from generation by travelling craftsmen. This continued until the eighteenth century, when paint factories began to be opened in Europe and America, and by the nineteenth century this mass production had brought prices down to such an extent that houses began to be painted. Now, in the twentieth century, the chemistry of many aspects of paint manufacture and function is understood, meaning that paint manufacture has finally moved from being a science JEPER (2014).

In 1866, Sherwin-Williams in the United States opened as a large paint-maker and invented a paint that could be used from the tin without preparation.

Paint is a valuable and indispensable products used in building construction all over the world. The report of Bayliss and Deacon, (2002) lamented over the challenges facing the paint industry in Nigeria and reported that the contribution of the sector to the GDP has dropped drastically. This is as a result of weakening infrastructure and the burden imposed on the manufacturing sector by the poor power supply, government policies on tariff and port operations. There is an astronomical rise in the cost of raw materials for paint making. This has also led to the high rate of adulteration of paint products. The insecurity in Niger Delta hiked the price of crude oil thereby worsening the situation. The increased demand of architectural protective coating has not improved on the performance of paint in Nigeria.

However, the report of Talbert, (2008) state that the current global paint and coating industry is doing its best to build a safer, greener and more sustainable world. He noted that industrial activity has a significant impact on economic and social development and the environment around the world. Also the global paint industry has been making the shift to more environmentally advanced technologies for more than fifty years. In addition Talbert, (2008) reported that today clean water based paint technologies are used around the world accounting for 70 percent of the total US paints and coating market while 30 percent are growing across Asia.

In 2011, South African archeologist reported finding a 100,000-year-old human-made ochre-based mixture that could have been used like paint. Cave paintings drawn with red or yellow ochre, hematite, manganese oxide, and charcoal may have been made by early homo-sapiens as long as 40,000 years ago Rasheem, and Olowu (1997).

The report of Ernest et al., (1989) state that titanium dioxide which is a major ingredient in paint manufacturing is imported. Nigeria only provides 25% of the paint industry Kaolin and lime stone (calcium carbonate). Most of the chemicals needed for paint production in Nigeria are imported with the fright rates and import duties, increasing the prices of paint raw materials. Ernest et al., (1989) noted that Nigeria paint manufacturing has been highly dependent on foreign equipment, machinery and raw material partly sue to technological backwardness and the industrialization policies particularly import substitution, of the raw materials. In recent times, the fluctuation and unstable economy has made people now to patronize locally made products, including paints produced with a high percentage of local raw materials.

2.1 Paint Composition

Today paints are used for colouring and protecting many surfaces, including houses, cars, road markings and underground storage vessels. Each of these different applications requires sort of paint, and it is these differences in composition that are the focus of this article. Paint is essentially composed of a binder, pigment, and solvent Allans and Dlant, (1984). In 2008, Talbert Rodger said that paint is a liquid engineered product made of several different ingredients that mix to create a specific product with its own unique properties. The selection of components used to manufacture paint will affect its stability (shelf life), application characteristics, handling, cleanup, disposal, and most importantly, the performance of the product on which it is applied. Paint formulations usually include; (i) resin (binder), (ii) pigments, (iii) solvents, and (iv) additives.

2.2 Paint Formulation

Proper paint formulations depend upon raw-materials selection and accurate calculation of the amounts of its constituents. Paint is a blend, in which pigments and fillers are suspended in a liquid. Therefore, paint formulations have relations to their applications. Generally paints are used to hide the original surface, proving a certain colour, resisting the weathering conditions, washability, gloss, and protecting surface from corrosion. The selection of pigments, fillers, and carrying liquids (vehicles) is necessary for a proper paint. More so, pigments should be opaque to ensure good covering power, and chemically inert to secure stability, and non-toxicity. To predict some properties of paints such as ease of painting, gloss, washability for a certain formulation, the pigment volume concentration (PVC) in paint is used as indicator. The PVC of paint, which is the volume of the paint film occupied by the pigment and pigment-extenders, is a very important concept, as it controls several paint properties, such as gloss, washability, durability, reflectance and rheological properties. It is defined and calculated using the expression from BE, (2010), Sharma, (2011).

$$\text{Pigment volume concentration (PVC \%)} = \frac{\text{volume of pigment}}{\text{volume of pigment} + \text{volume of binder}} \times 100 \qquad (1)$$

The volume of pigment (VOP) in the paint is determined from the expression: weight of pigment + extender / S.G of pigment+ extender. The value for non-volatile constituents in the

paint is obtained from the product of weight % of resin used in the paint and its total solids content. The P.V.C values for various coatings are as follows: flat paints, 50-70%; semi-gloss paints, 35-45% and gloss paints, 25-35% Sharma, (2011). Generally, the paint gloss decreases as the PVC increases. This is due to the fact that when the volume of pigment increases relative to the non-volatile vehicle, gloss decreases until the gloss of the paint becomes flat Sharma, (2011). The viscosity of paint, which is also controlled by the PVC, is an important quality parameter as it affects the flow and application properties of the paint and was also determined in this study.
The various types of paints are: (i) oil, (ii) varnish, (iii) enamel, (iv) latex, and (v) shellac etc.

2.3 Properties of a Good Quality Paint

a) Adhesive: This implies to stickiness' of the surface which bring other properties into work.
b) Film Integrity: Dries film of paint must have all film properties as claimed by the manufacture. There should be no weak spot in the film as a result of imperfect film drying.
c) Ease of Application: It must be easily applied in accordance with the method prescribed.

2.4 Process Description of Paint Production

The production of paints and surface coatings is a fairly simple mixing process that consists of dispersing and stabilizing pigment particles in a binder (resin) and a vehicle (solvent). Ideally, no chemical reactions take place during the manufacturing process. Most paint manufacturing facilities formulate paint in batch operations that can range in size from 10 to 10,000 gallons. The four major steps involved in the manufacturing of paints and surface coatings are: (i) preassembly/premixing, (ii) grinding/milling/dispersion, (iii) product finishing/blending, and (iv) product filling/packaging. There are some variations in unit operations depending on the type of paint or coating being formulated such as: (a) destabilization of water-based resins during milling and dispersion must be avoided when producing water-based paints; and (b) powder coatings require an additional grinding step after product finishing reducing the coating to a powder.
A number of important secondary operations are required in the manufacturing of paint. Much of the waste generated by the paint manufacturing industry is a direct result of these secondary operations which include: (i) equipment cleans out, (ii) emissions control, (iii) solvent recovery; and (iv) waste water treatment. Figure 1 depicts the schematic diagram of paint production.

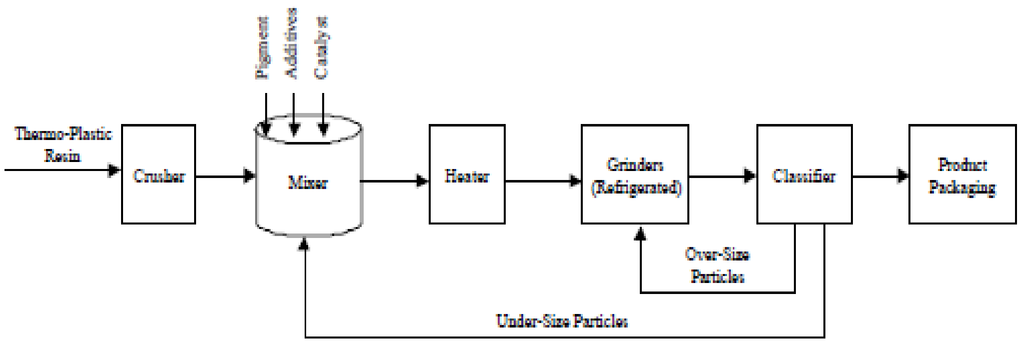
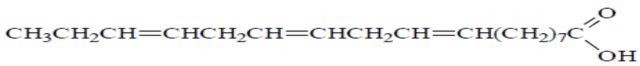


Figure 1 Schematic diagram of paint production. Source: Paint Manufacturing Wastes Listing Determination Listing Background Document Dec 15, 2000

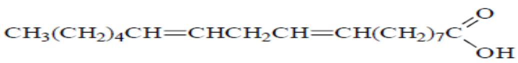
2.5 Paint Technology

2.5.1 Binder

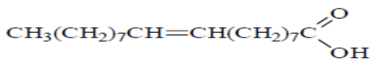
The advancement in paint technology was very little until the twentieth century. More recently as the 1960s 'drying oils' were the commonest paint binders. Drying oils are substances that, when spread out in a film, will dry to form a continuous skin. Linseed oil is the most common example of a drying oil, which dry in 2 to 3 days while other oils, such as soya bean oil, may take up to 10 days. Linseed oil is a mixture of triglycerides of long chain carboxylic acids. Some of the major component carboxylic acids are:



linolenic acid
(*cis, cis, cis* -9, 12, 15 - octadecatrienoic acid $C_{18}H_{30}O_2$

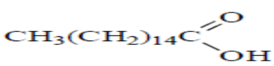


Linoleic acid
(*cis, cis* -9, 12 - octadienoic acid $C_{18}H_{32}O_2$)

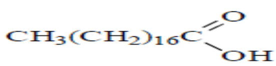


Oleic acid
(*cis,* -9, - octadeconoic acid $C_{18}H_{24}O_2$)

X-Polymers-D-Paints and Pigments-3



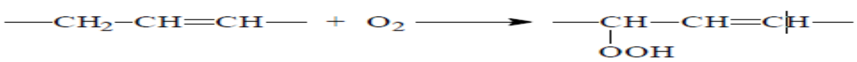
Palmitic acid
(hexadecanoic acid
$C_{16}H_{32}O_2$



Stearic acid
(octadecanoic acid
$C_{18}H_{36}O_2$

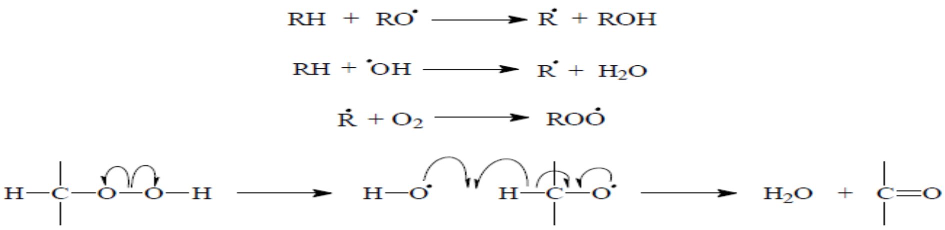
Many common drying oils contain these compounds and others, including eleosteraric and recinoleic acids, in various ratios. The drying process is a complex one of polymerization, probably catalyzed by peroxides as described by Farmer in 1912. The theory is that drying progresses as follows:

1. Double bonds are oxidized by atmospheric oxygen to give hydroperoxy groups:

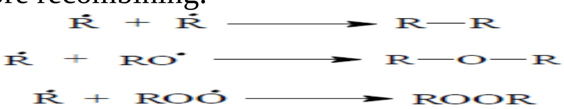


2. These peroxides then decompose to give radicals:

3. The radicals then initiate various polymerization reactions:



4. Before recombining:



2.5.2 Quality Control

Paint manufacturers utilize an extensive array of quality control measures. The ingredients and the manufacturing process undergo stringent tests, and the finished product is checked to insure that is of high quality. A finished paint is inspected for its density, fineness of grind, dispersion, and viscosity. Paint is then applied to a surface and studied for bleed resistance, rate of drying, and texture.

In terms of the paint's aesthetic components, colour is checked by an experienced observer and by spectral analysis to observe if it matches a standard desired colour. Resistance of the colour to fading caused by the elements is determined by exposing a portion of a painted surface to an arc light and comparing the amount of fading to a painted surface that was not so exposed. The paint's hiding power is measured by painting it over a black surface and a white surface. The ratio of coverage on the black surface to coverage on the white surface is then determined, with 98 being high-quality paint. Gloss is measured by determining the amount of reflected light given off a painted surface.

Tests to measure the paint's more functional qualities include one for mar resistance, which entails scratching or abrading a dried coat of paint. Adhesion is tested by making a crosshatch, calibrated to 0.07 inch (2.0 ml), on a dried paint surface. An excellent paint can sit for six months with no settling and rate a ten. Poor paint, however, will settle into an immiscible lump of pigment on the bottom of the can and rate a zero. Weathering is tested by exposing the paint to outdoor conditions. Artificial weathering exposes a painted surface to sun, water, extreme temperature, humidity, or sulfuric gases. Fire retardancy is checked by burning the paint and determining its weight loss. If the amount lost is more than 10%, the paint is not considered fire-resistant.

3.0 MATERIALS AND METHODOLOGY

3.1 Raw Materials/Reagents

The raw materials used are listed as follows: Water, calcium carbonate, kaolin, natrosol, formalin, calgon, yellow oxide, polyvinyl acetate (PVA) and titanium dioxide.

3.2 Instrumentations and Equipments

The instrument and equipments used are shown in Table 1 below:

Table 1: Instrumentation and equipment used

S/NO	Equipment	Model	Manufacturer
1	Reaction pot	4 litres	Pentagon plastics industries Ltd
2	Weighting balance (scale)	A-110C	ATOM
3	Measuring bowl	1 litre	Pentagon plastics industries Ltd
4	Brush	6111 plus	Oven-Nouvelle
5	viscometer	01v11	P.G Ltd U.S.A
6	pH meter	000622470	Hamma Co. Ltd, Italy
7	Beaker	500ml	Technico England
8	Plastic rod	1meter	Pentagon plastics industries Ltd
9	Measuring cylinder	1000ml	Technico England
10	Conical flask	250ml	Technico England
11	Ceiling board	7v2.5meter	Xinging ceiling decoration material.
12	Stop watch	Nokia 200	Nokia phone

3.3 Methodology

3.3.1 Manufacture of Emulsion Paint

Production steps or process for sample 1

Clean and neat water (H_2O) was measured in a measuring cylinder at room temperature to be at 0.8 litres and was poured into the reaction pot. The water serves as a solvent in the reaction as shown in Figure 2 below.

Figure 2: The pouring of water (H_2O) into the reaction pot. (Friday, April 22, 2016, 2:45pm).

Calcium carbonate in a whitish substance in a powdery form occurring in nature, it is used in the production of paint to give the paint body (coverage) or hiding capacity. The calcium carbonate was measured in a measuring bowl using weighting balance to be 1250g and was poured into the reaction pot that already contains water and was stir thoroughly for 5 minute as shown in Figure 3.

Figure 3: The pouring of calcium carbonate ($CaCO_2$) into the reaction pot. (Friday, April 22, 2016, 2:450pm).

Calgon is also a whitish substance in powdery form that look just like salt and it is used in paint production in order to make the dissolving of calcium carbonate in water faster for it not to form bubbles in the paint. The calgon was measured in a measuring bowl using weighting balance to be 2.5g and was poured into the reaction pot while the stirring of water and calcium is still ongoing. After adding the measured calgon, the mixture was stirred for 5 minutes as shown in Figure 4.

Figure 4: The paint produced in a reaction pot. (Friday, April 22, 2016, 3:25pm).

Polyvinyl acetate (PVA) is a whitish substance in semi liquid form, that is, it is more viscous than water and it is used in paint production. It gives the paint sticking ability to the surface. The right higher concentration of PVA presence in paint formation provides more durability of the paint. The PVA was measured in a bowl using a weighting balance to be 150g and was poured into the mixture in the reaction pot and the mixture in the reaction pot was stirred thoroughly for another 5 minutes. Deformer is a substance in a liquid form and is inevitable. It is used in paint production to subside the foam or bubbles formed when PVA was added into the mixture.

Formalin is a colorless liquid but have choky smell, it is used in paint production to preserve the paint for some period of time. Both the formalin and deformer was measured in a

measuring bowl using weighting balance at 12.5g and 5g respectively and was poured into the mixture and was stirred up to 5 minutes. Nitrosol is a whitish substance in powdery form that looks just like salt and it is used in paint production to thicken the mixture in the reaction pot. The nitrosol was measured in a measuring bowl to be 10g using the weighting balance; the measured nitrosol was first poured into a conical flask and mixed with 0.20 liters of water. The mixture of nitrosol and water in the conical flask was shaken for 30 seconds and then poured at once into the mixture in the reaction pot and was stirred for 10 minutes to avoid the forming of bubble was noticed.
The mixed nitrosol (Thickener) was poured into the reaction pot and was thoroughly mixed with water into the reaction pot. The resultant mixture (forming paint, nitrosol and water) in a conical flask was stirred for 10 minutes; the paint is readily produced as shown in Figure 4 above.

3.3.2 Drying Time

25ml of the paint produced was painted on a ceiling board initially primed with white paint and allowed to dry at room temperature by taking the drying time using a stopwatch.

3.3.3 Opacity Test

A ceiling board was primed with white paint and dried at room temperature. 25ml of the different paint formulations was poured into a beaker; the brush to be used was dipped into the paint sample produced before it was dipped into the 25ml beaker to prevent the brush from taking too much of the paint, it was used to paint the ceiling board and the area of the painted surface was taken to find the opacity of the paint.

$$\text{Opacity}\left(\frac{m^2}{l} = \frac{area\ of\ painted\ surface}{volume\ of\ paint\ applied}\right) \quad (2)$$

3.3.4 Viscosity Test

50ml of the paint produced was poured into a beaker and the viscosity was determined using viscometer. The same procedure was also used to determine the viscosity of other paint samples.

3.3.5 pH Test

50ml of the paint produced was poured into a beaker and the pH was determined using pH meter. The same procedure was also used to determine the pH of other paint samples.

4.0 RESULTS AND DISCUSSIONS

The results obtained during the course of this research work on the production of emulsion paint using local raw material were presented and discussed as follows.

4.1 Paint Formation

The different grade of emulsion paints were formulated using different local raw materials as pigment. During the formulation, PVA was used as the binder, which gave good compatibility with the pigment in each case. The paints were formulated using different pigment volume concentration (PVC). The emulsion paint produced with 10% PVC showed more levelness and gave a deeper coloured paints in all the cases. However, the lower the PVC used the more the compatibility and the deeper the colour obtained. The paints showed good flow property which made them easy to apply and was also found to possess high opacity.

4.2 Experimental Results

The various laboratory results carried out on the different emulsion paint produced are shown below.

4.2.1 Characterization of the Physico-Chemical Properties of the Formulated Paints

4.2.1.1 Viscosity

Viscosities of the emulsion paint samples at different PVC.

Table 2: The viscosities results of paint samples produced.

S/No	Paint Samples	Viscosity in poise (P) (1Pa.s = 10P)
1.	A	0.93
2.	B	0.94
3.	C	1.13
4.	Commercial paint	0.94337

From Table 2 above, it was observe that the formulated emulsion paint sample C has a high viscosity when compared with samples A and B. However, the entire sample paints shown a moderate viscosity which indicated good flow property.

4.2.1.2 Density

The densities of the formulated emulsion paints were obtained in the laboratory at room temperature and the results were presented in Table 3 below. These densities of the emulsion paint samples were as a result of different PVC used.

Table 3: The densities of paint samples produced.

S/No	Paint Samples	Density (ρ) (kg/l)
1.	A	1.01
2.	B	1.12
3.	C	1.15
4.	Commercial paint	1.01326

Density of emulsion paint depends on the materials used in the production of the emulsion paint as can be seen in Figures 2-4 above. Sample C have density of 1.15kg/l which is higher than sample A and sample B with densities of 1.01kg/l and 1.12kg/l respectively. Sample B have higher density than sample A.

4.2.1.3 Drying Time

The Drying time of the formulated emulsion paints at different PVC were obtained in the laboratory at room temperature using a stop watch and were presented in the Table 4 below. Drying time of the emulsion paint samples at different PVC were taken into consideration.

Table 4: The drying time results on paint samples produced.

S/No	Paint Samples	Time (Minutes)
1.	A	20 - 25
2.	B	20 - 25
3.	C	20 - 25
4.	Commercial paint	20 - 30

Drying time of paint depends on the environment, mainly on temperature and humidity. The laboratory result revealed that the emulsion paint produced had the drying surface time of 20 to 25 minute as shown in the Table 4 above, which is in conformity with the standard. The paint film applied on a ceiling board by a brush became hard dry in not more than 25 minute from the time of the application. The drying time test was carried out at the laboratory under normal room temperature.

4.2.1.4 pH

The pH of the formulated emulsion paints at different PVC was obtained in the laboratory using the pH meter and was presented in Table 5 below.

Table 5: The pH obtained for the samples produced.

S/No	Paint Samples	pH
1.	A	7.9
2.	B	7.9
3.	C	7.9
4.	Commercial paint	7.0 – 9.0

The paints mixed readily with a minimum amount of foaming to a smooth and homogeneous state. The pH values of the paints were also normal (between 7.0 and 9.0). Table 5 above shows the pH measurement which is the amount of the relative acidity or alkalinity of the samples of emulsion paint produced, the pH is in the range of 7.0 - 9.0 which are in conformity with the national institute of standard (NIS). The pH test was carried out at the laboratory under normal room temperature.

4.2.1.5 Opacity

Table 6 represent the opacity of the formulated emulsion sample paints at different PVC as obtained in the laboratory using ceiling board and brush. The opacity result on sample A paint produced was higher than that of A and B.

Table 6: The drying time results on paint samples produced.

S/No	Paint Samples	Time (Minutes)
1.	A	10
2.	B	9.5
3.	C	9.0
4.	Commercial paint	20 - 30

Small quantity of high quality paint covers a given surface area whereas a paint of low quality requires a large volume to give coverage to the same surface. The samples of the paints were prepared for laboratory investigation, following the National Institute of Standards, NIS 267: 1989. The panels used, were also in accordance with NIS 273: 1990. The opacity test of the samples of the emulsion paint produced was carried out at room temperatures.

4.3 Comparison of Formulated Grade Paint with Commercial Paint

Table 7 represent table of comparison of formulated grade paints with NIS and commercial paint worldwide. The information on commercial paint was sourced from the reference journal of Sharma (2002).

Table 7: Comparison of formulated paint samples with commercial grade

S/No	Properties	Formulated Sample paint	Commercial

					paint
		A	B	C	
1.	Density (ρ)	1.01	1.12	1.15	1.01326
2.	Viscosity (μ)	0.93	1.04	1.13	0.94337
3.	pH	7.9	7.9	7.9	8.0
4.	Drying time (min)	20 - 25	20 - 25	20 - 25	20 – 30
5.	Opacity	10	9.5	9.0	10

4.4 Discussion of Results

4.4.1 Viscosities

From Table 7, in comparing the viscosities of all the formulated paint samples, it was observed that the PVC had some influence on the viscosity. The 32% PVC had the highest viscosity in all the cases. The higher the pigment volume concentration (PVC) the higher the viscosity of the paint obtained. The low viscosity paint produced showed good leveling, with high opacity. The gloss of the paints was also higher. The paints were associated with having low spattering when coated on cardboard substrate. The low viscosity of the paints formulated accounts for high tendency of its movement and easy application. They also smooth out faster. These results compared revealed that the paint performance has influence on the value of viscosity. The formulated paint sample viscosity readings were taken at room temperature.

4.4.2 Densities

In comparing the densities obtained from the formulated paint samples as shown in Table 7 above, that is, 1.15, 1.12, and 1.01 kg/l for 32%, 19%, and 10% PVC respectively, indicates that the densities of the paint changes with the pigment volume concentration (PVC); such that the higher the PVC, the higher the densities of the paint in each case. However, this may be due to the influence of the pigment, additive and other paint ingredients. However, the commercial paint showed a higher density 1.0136, a small value-increase compared to all the formulated sample paints.

4.4.3 Drying Time

More so, the drying time of paint depends on the environment, mainly on temperature and humidity. The laboratory results carried out at the Chemical Engineering laboratory, University of Maiduguri of the emulsion paint produced at room temperature revealed that the emulsion paint had the drying surface time of 25 minute which is in conformity with the emulsion paint drying time of not more than 24 hour of the National Institute of Standard (NIS). The paint film applied on a brushed tinplate pane became hard dry in not more than 25 minute from the time of the application. It is clear from the above results that there is no considerable change in the dry time value of different types of pigment used in the production of emulsion paint. In other words, the pigment has little or no effect on drying time of emulsion paint as can be seen in Table 7 above. From Table 7, it shows that the drying time of sample A which is produced with titanium dioxide (TiO_2) as the pigment, sample B which is produced with yellow iron oxide as the pigment, and sample C which is produced with no pigment all dry within the same time i.e. within 20 - 25 minute.

From the laboratory result carried out, it also shows that kaolin ($Al_2Si_2O_5(OH)_4$) also has little or no effect on drying time of emulsion paint as can be seen in Table 7 above.

Practically, it is observed that small quantity of high quality paint covers a given surface area whereas a paint of low quality requires a large volume to give coverage to the same surface.

The formulated samples of the paints were prepared for laboratory investigation, following the National Institute of Standards, NIS 267: 1989. The panels used, were also in accordance with NIS 273: 1990. The opacity test of the samples of the emulsion paint produced was carried out at room temperatures BCES, (2014*)*.

The different grade of emulsion paint produced in these research work has shown from the laboratory result carried out in the Chemical Engineering laboratory, University of Maiduguri in Table 7 above, that the emulsion paint produced has good opacity and was able to cover well at not more than two coats which is according to the standard. From the laboratory results carried out, it also shows that pigment has great effect on opacity (coverage). The result shows that sample A which is produced with 12.5g of titanium dioxide (TiO_2) had the opacity of 10 m^2 which is higher than that of sample B which is produced with 5g of yellow ion oxide, and that of sample C.

4.4.4 Brush Ability

The paint brush easily and possess good leveling property when applied at a spreading rate of approximately 10 m^2 per litre to a cream faced, gypsum plaster board. This complies with the Standard Organization of Nigeria (SON). Due to the addition of formalin in the emulsion paints produced as preservative, it observed to have a shocking smell.

5.0 CONCLUSION

In conclusion, the study shows that there was a good compatibility between the pigment and the binder during the paint formulation, which accounts for the deeper colour and good opacity for the sample paints formulated. Characterization of the physico-chemical properties of the paints indicated good properties associated with the paints such as, good opacity, moderate drying, and moderate pH. The formulated sample paints were also found to have moderate viscosity which accounts for good flow properties. These results have revealed that the paints formulated could be used as both indoor and outdoor coatings.

Recommendations

We recommend that all building contractors and owners should make painting a compulsory thing that must be done on their buildings for beautification and protection since paints are use as protective coating in buildings. The emulsion paint with PVC of 10% should be use as exterior due to the durability and strength to withstand rain, while both the emulsion paint with PVC of 19% and 32% is use as interior decorative paint.

List of Symbols and Abbreviations

NIS = National Institute for Standards
GDP = Gross domestic products
PVA = Polyvinyl acetate
PVC = Pigment volume concentration
SMEs = Small scale enterprises
SON = Standard Organization of Nigeria

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