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AN EXPERIMENTAL STUDY USING DEVELOPED GRADES OF POLYVINYLCHLORIDE (PVC) IN IMPROVING PAINT PRODUCTION

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ABSTRACT

Research and development remains the stem in technology improvement in the modern world. Therefore an effort on studies to improve the paint products is imperative because there is the need to re-evaluate the content parameters of its constituted material elements. The suitable methods adopted in this research work are (i) preparation of organic pigments for paint production, (ii) production of emulsion paint using different grades of PVC, (iii) characterization of the paint produced and (iv) comparison of the properties of the of the formulated emulsion paint with the ASTM standard. The experimental results show that there was appropriate and consistent ration between the pigment volume concentration and the binder during the paint formulation and it also shows that viscosity increased with increase in PVC. Further studies reveal that additional pigment and the porosity of the paint increases, resulting in good deeper colour and good opacity for the paints formulated and moderate drying. The paints produced were found to have excellent viscosity which implies good flow properties. The effect of porosity (%) in respect of pigment volume concentration was stable from stage 1 to 4, having values of 167 – 620cP with the porosity ranging from 0 – 64.28%. While a drastic increase at point 4, with a progressive increase from 4 to 9. For all the drying time scale, there was steady increase progressively from the inception to the last stage of the calibrations. These evaluations occur for all the drying time durations, with the value ranges from 7.80 – 39.80 minutes.

Keywords: **ASTM standard, PVC, paint, pigment and porosity**

INTRODUCTION

Paint production has been in existence since pre-historic era about 25,000 years ago among primitive men (Hunters and Dwellers) and probably inspired by the rock formation of their cave walls to outline and colour the shapes of the animals they hunted, survived in caves in France and Spain. Early artist relied on easily available natural substances to make paint such as natural earth pigments, charcoal; berry juice, land, blood and milk weed sap. Later, the ancient Chinese, Egyptians, Hebrews, Greeks and Romans used more sophisticated materials to produce paints for limited decoration, such as painting walls. Oils were used as varnishes and pigments such as yellow and red ochre, chalk, arsenic sulphide yellow, and malachite green were mixed with binders such as gum Arabic, lime egg albumen and beeswax (Dimas and Droste 2014).

Paint is a pigmented coating material, supplied in a liquid paste or powder form, which, when applied to a substrate, forms an opaque film having protective, decorative or specific technical properties and after application dries to a solid, adherent and protective coating. It is most commonly used to protect, colour, or provide texture to objects (Kralikova et al., 2020).

Most paints consist of the same basic components: pigments, binders, liquids, and additives. Each component serves a role in determining the quality of the paint as well as its performance both during and after application.

The aim of this research is to improve the quality and performance of different grades of paints by evaluating various species of PVCs in paint production.

2.0 BACKGROUND LITERATURES

Paint is the combination of binder and volatile liquid is called the vehicle; it may be a solution or dispersion of the fine binder's particles in a non-solvent. The term coating refers to an advanced or specialized paint designed to have a specific function pertaining more to protection rather than the aesthetics of the substrate. Coating comprises varnishes, enamels, lacquers, plastisols a powder (Kralikova et al., 2020). In the review of the literatures, several authors are been depicted as presented in Table 1.

Table 1 summary review of previous investigations

Author(s)	Investigation and Capacity Frame	Research Benefits/Product Investigated	Study Remarks
Dimas and Droste (2014)	The pigment is dispersed in the aqueous phase both polymer and pigment form distinct dispersed phases and should coalesce only in the film when the water evaporates	Binder (resins) refers to substances that hold the particles of pigment together in paint . All paints include a binder of some sort because this is what keeps the pigment in place after the paint dries	The binders and solvent together are sometimes known as the vehicle, the binder may be dissolved as a solution or carried as a dispersion of microscopically small particles in a liquid
Onoja, et al., (2019)	Generally, all paints are composed of these four main ingredients; pigments, binders, solvents (liquids) and	Pigments provide color and hide, while binders work to 'bind' the pigment together and create the paint	Solvents are the liquids that suspend the ingredients and allow you to place the paint on the surfaces, and

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	additives	film.	additives are ingredients that provide specific paint properties such as mildew resistance
Kralikova et al., (2020)	Pigments - provide color, hide and bulk. Pigments are finely ground particles that are dispensed into paint and provide color and hiding properties.	There are two primary types of pigment - prime pigments and extender pigments.	Titanium dioxide (TiO_2) is the most costly pigment and it contributes directly to a paint's wet hide, while providing whiteness

2.1 Various Classification of Paint

Paints are classified as follows:

2.1.1 Emulsion or Water Paint

This is a water-based paint. The pigment is dispersed in the aqueous phase both polymer and pigment form distinct dispersed phases and should coalesce only in the film when the water evaporates (Kralikova et al., 2020). Binder (resins) refers to substances that hold the particles of pigment together in paint. All paints include a binder of some sort because this is what keeps the pigment in place after the paint dries. The binders and solvent together are sometimes known as the vehicle, the binder may be dissolved as a solution or carried as a dispersion of microscopically small particles in a liquid (Chanda and Roy, 2006) depending on the type of paint intended use.

2.1.2 Pigments

Pigments - provide color, hide and bulk. Pigments are finely ground particles that are dispensed into paint and provide color and hiding properties. There are two primary types of pigment - prime pigments and extender pigments. Prime pigments are those that contribute to both wet and dry hide in paint. Titanium dioxide (TiO_2) is the most costly pigment and it contributes directly to paint's wet hide, while providing whiteness Barton, (2012).

2.1.3 Binders

Binder provides performance and support for dry paint film, binder is often a monomeric material that undergoes oxidation- polymerization or some other type of cross linking reaction. Binders are ingredients that provide a binding effect that holds the pigments together to create a dry film on the surface. Paints binder is the key ingredient that directly relates to paint's performance, including adhesion, wash ability, scrub resistance, fade resistance or gloss retention. A few binders, such as alkyl silicates and titivates, yield inorganic coatings (Onoja, et al., (2019).

2.1.3.1 Latex Binders

These are used in water-based paints. There are various types of latex binders available, such as 100% acrylic, styrene acrylic or vinyl acrylic, each providing specific performance characteristics.

2.1.3.2 Acrylic Binders

The 100% are often used in exterior paints as the benefits include adhesion (both wet and dry), fade resistance, alkali and efflorescence resistance. 100% acrylic binders are typically regarded as the best overall performing. Adhesion under wet conditions allow for greater performance in blister, cracking and peeling resistance. UV fade resistance allows the painted surface to retain its color and sheen longer Barton, (2012). Alkali resistance means the paint is less likely to "burn" over fresh concrete or masonry.

2.2 Determination of the Physical Properties of the Binder

2.2.1. Determination of Viscosity

The viscosity of the resin is mostly evaluated using BM 471 Saybolt viscometer single tube and expressed in seconds at 30^0C. The viscosity is recorded from flow time in seconds. Three different readings are taken for each sample and the average value calculated (Wiley (2012).

2.2.2 Determination of Density

The above property is determined according to (Akintreinwa et al., 2015). The density of different resins is determined by taking the weight of a known volume of each resin inside a density bottle (20 cm^3) using weighing balance, the density is calculated using the mass volume relationship. Three readings are then taken for each sample and the average value calculated.

2.2.3. Melting Point

The melting point of the different film samples is determined by using melting point block and thermometer is attached to the block and three different readings are taken for each sample and the average is calculated. The above property is determined according to standard method (Osemeahon et al., 2015).

2.2.4. Refractive Index

The refractive index of the resin samples is determined by using Abbe refractometer (Osemeahon et al., 2015). Three different reading is taken for each sample and the average is calculated and recorded.

2.2.5. Determination of Moisture Uptake

The moisture uptake of the different resin films is determined using desiccators. Known weight of each of the samples was introduced into desiccators containing a saturated solution of sodium chloride. The wet weight of each sample is then monitored until maximum weight is obtained. The difference between the wet weight and the dry weight of each sample is then recorded as the moisture intake by resin (Osemeahon et al., 2015).

2.2.6. Turbidity

The turbidity of the binder is determined by using DR/89 Colorimeter, the above property is determined according to (Osemeahon et al., 2015).

2.2.7. Water Solubility

Water solubility of PS is determined by mixing 1ml of the resin with 5ml of distilled water at room temperature (30^0C). A clear transparent solution indicates water solubility while a cloudy solution or white precipitate results in the case of insolubility in water Osemeahon and Archibong, (2014).

More details about this research studies can be found from the full report (Idris and Muhammad, 2023).

Some comparisons of different types of resins are presented in Table 2 as shown.

Table 2 Some physical properties of PS films in comparison with other paint binders

Types of Resin	Density (g/cm^3)	Refractive Index	Melting Point (^0C)	Moisture Uptake %)	Viscosity (m. Pa.s)	Turbidity (NTU)	Consulted and Reviewed Literatures
EBDE	1.04	ND	179	ND	38.0	ND	Sarkodie et al., 2019
XASO	0.912	1.467	ND	ND	900	ND	Sarkodie et al., 2019
DMU	1.1840	1.4210	261.4	3.00	10.30	112	Akinterinwa et al., 2015
DMU/PS	1.0583	1.4245	205.70	0.61	149.45	597	Akinterinwa et al., 2015
DMU/PS	1.1953	1.4295	181.42	0.26	35.60	611	Osemeahon et al., 2015
TMU/PS	1.0990	1.425	262	1.02	19.70	1100	Osemeahon & Archibong, 2014
TMU/PS	1.0990	1.4250	262	1.01	19.70	878	Osemeahon & Archibong, 2014
UF/CS	1.166	1.417	130.00	0.6	11.1	ND	Dimas et. al., 2014
AESO	ND	ND	ND	ND	13,000	ND	Adamu et al., 2014
PS (diff. solvent)	0.82	1.454	164	2.00	200	1000	Osemeahon et al., 2013
PS (gasoline solvent)	0.84	1.464	168	2.00	500	1000	Osemeahon et al., 2013
RSOMAR	0.95	ND	ND	ND	3.11	ND	Wiley, (2012)
MAGPP/ER	ND	ND	ND	200	ND	ND	Sharma (2011)
Innovative	ND	ND	ND	0.25	ND	ND	Yousefi et al., 2011
TMU/NR	0.5708	1.3501	260	ND	220	ND	Osemeahon & Barminas, 2007
Commercial	ND	ND	ND	2.00	451	ND	Talbert R. (2008)

Legends:

AESO	*Acrylate epoxidized soybean oils*
CS	*Cs Epoxy resin*
DMU	*Dimethyl Urea*
EBDE	*Epoxy resin*
MAGPP/ER	*maleic anhydride–grafted polypropylene*
NR	*Nissin Resin*
PS	*Polystyrene*
RSOMAR	*Resin rsomar*
TMU	*Trimethylol Urea*
UF/CS	*Urea-formaldehyde*
XASO	*Ximenia Americana seed oil*

2.3 Polyvinyl Chloride (PVC or Vinyl)

Polyvinyl Chloride (PVC) is one of the most widely used polymers in the world. Due to its versatile nature, PVC is used extensively across a broad range of industrial, technical and everyday applications including widespread use in building, transport, packaging, electrical/electronic and healthcare applications.

3.0 MATERIALS AND METHODS

3.1 Materials and Reagents:

Water, calcium carbonate, kaolin, natrosol, formalin, calgon, yellow oxide and polyvinyl acetate (PVA) are the materials/reagents that were used in the course of this experiment. The materials are analytical grade and were obtained from Monday Market in Maiduguri, Borno state. All other equipment used was obtained from Chemical Process Engineering Laboratory, University of Maiduguri, Nigeria.

3.2 Equipment:

Table 3 presents the equipment used in carrying out the experimental studies.

Table 3 Some of the equipment used in the study

S/No.	Equipment	Name of company and place of manufacture	Equipment type
1.	Reaction pot	Pentagon plastics industries Ltd, Nigeria	4 litres plastic reaction pot
2.	Digital weighing balance	MXBAOHEN Gus Instrument Co, China	Multi-functional Precision Balance
3.	pH meter	Hamma Co. Ltd, Italy	Precise pH meter
4.	Stirrer	Duran Pyrex, China	A glass rod stirrer
5.	Beaker	Duran Pyrex, China	
6.	Stop watch	Flott and Co. ltd, USA	Digital professional chronograph timer
7.	Viscometer	Koehler instrument company inc., USA	Saybolt viscometer
8.	Measuring cylinder	Duran Pyrex, China	1000mL measuring cylinder
9.	Conical flask	Technico, England UK	250mL conical flask
10.	Brush	Up keep home services, USA	Paint brush
11.	Ceiling board	Locally made	Ceiling board

3.3 Methods

3.3.1 Reaction of water and calcium carbonate

1 Litre of clean and neat water (H_2O) was first measured in a measuring cylinder at room temperature and was poured into the reaction pot. The water serves as a solvent in the reaction. Calcium carbonate, $CaCO_3$, a whitish substance in a powdery form occurring in nature, which is used in the production of paint to give the paint body (coverage) or hiding capacity, 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 stirred thoroughly for 5 minute.

3.3.2 Addition of Calgon

Calgon, 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, 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 on-going. After adding the measured calgon, the mixture was stirred for 5 minutes.

3.3.3 Formulation of paint using PVA as a binder and yellow oxide as the pigment

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 to give the paint sticking ability to the surface. The right higher concentration of PVA presence in paint formation provides more durability of the paint. Yellow oxide is a synthetic pigment consisting essentially of hydrated ferric oxide and similar in colour to yellow ochre but more intense. The level of concentration of pigment in a particular paint also has a direct impact on the durability of the paint's film.

The mixture of water, calcium carbonate and calgon was first divided into four different portions. Eight different mixtures of pigment and binder were also formulated using different grades of pigment volume concentration. The mixtures were agitated continuously in a container to ensure homogeneity.

The pigment binder mixture was measured in a bowl using a weighting balance to be and was poured into the mixture in the reaction pot and the mixture in the reaction pot was stirred thoroughly for another 5 minutes and deformer was added into the mixture to subside the foam or bubbles formed.

3.3.4 Addition of preservative and thickener

Formalin (formaldehyde) is a colourless 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 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 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 forming of bubbles.

3.4 Characterization of the Paint Formulations

3.4.1 Determination of pH

The pH of the paints sample formulations were determined by using a digital pH meter (Wapler et al., 2014). The pH electrode was standardized with buffer solution pH of 7 and rinsed with distilled water. The electrode was then dipped into the paint sample and the pH of the paint sample recorded.

3.4.2 Adhesion Test

The method described by (Wapler et al., 2014) was adopted. A coat of paint film was applied with film applicator on a metal panel and allowed to dry for 48 hours. Two set of lines, one crossing perpendicularly over the other was drawn with a sharp nail on the paint film. An adhesive tape was pressed firmly with the thumb covering all the interactions of the perpendicular line. The adhesive tape was held at its loose ends and forcibly removed from the panel. Removal of more than 50% of the square lines of the paint film indicates poor adhesion. Triplicate determinations were made at 27^0C for each sample formulation and average value was recorded.

3.4.3 Measurement of Viscosity

Viscosity of paint sample formulations were determined according to procedure previously described (Wapler et al., 2014). Saybolt viscometer was used. Paint sample (25 ml) was introduced into cup of the instrument at 27^0C and stop watch was used to take the time taken for 20ml of the paint sample poured into the Saybolt viscometer cup to drain out and recorded, three replicates of the procedure was carried out for each sample produced and the average was recorded.

3.4.4 Opacity Test

The opacity of the paint samples produced was evaluated according to (Wapler et al., 2014) method; the 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.

3.4.5 Determination of Drying Time

The drying time of the paint samples produced was evaluated according to (Wapler et al., 2014) method; 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.

3.4.6 Dry to Touch and Dry to Hard Test

The dry test of the paint samples was evaluated according to (Wapler et al., 2014) method. Sample of paint were applied on a ceiling board primed with white paint with the aid of the brush and allowed to dry. Dry to touch was taken when the paint was no longer sticking to the finger while dry to hard was taken when the film resist finger print.

3.4.7 Re-coating test

The entire paint samples produced were similar to that of standard in having good re-coating properties. The second and third coats were applied on the first coat smoothly and with ease with the aid of a brush. There were no undesirable film properties such as peeling of underlying coat, sagging, flaking and cracking (Kralikova et al., 2020).

3.4.8 Stability Test

Phase separation by visual analysis. The paint solution was stored for 27days at room temperature and the stability test was observed.

4.0 RESULTS AND DISCUSSIONS

4.1 Results

The results of this experiment are presented in Table 4 which itemised the comparison between the physical properties of the formulated paint at different PVC grades. The viscosity, porosity, drying time to touch and hardness were classified, opacity, adhesive tests and recoating tests were carried out and the results were summarized in Table 4.

Table 4 shows the comparison between the physical properties of the formulated paint at different PVC grades.

S/No.	Parameters	Pigment-Volume Concentration (%)									ASTM
		0	10	20	30	40	50	60	70	80	
1.	Viscosity(cP)	167	272	263	365	415	472	524	601	620	620
2.	Porosity (%)	0.00	0.17	1.48	39.84	47.80	54.31	58.21	63.43	64.28	
3.	Drying Time (min.)	7.80	8.20	8.70	8.40	8.90	9.40	9.50	10.40	11.20	15.3
4.	Dry to touch (min)	19.60	19.90	21.40	22.10	23.00	25.60	37.40	27.90	39.80	45.8
5.	Dry to hard (hours)	9.30	9.80	10.20	12.40	13.10	14.70	15.10	15.30	15.90	15.3
6.	Opacity	Fail	Fail	Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass
7.	Adhesion Test	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
8.	Recoating Test	Fail	Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

4.2 Discussion of Results

Pigment volume concentration or PVC as we like to shorten it to, simply gives us an idea of how much pigment there is in the paint compared to the amount of binder. It is useful to know this because the binder has the very important job of binding all the pigment and other raw materials into the paint. There needs to be enough binder left over to enable the paint to stick (or adhere) properly to whatever it has been applied over If a paint has no pigment at all it will usually be very glossy and have a PVC of zero. An example is clear gloss paints. Flat paints have a very high pigment loading and have high PVCs (probably in the range 55% up to 80%). Primers and undercoats vary from 30% to about 50% PVC as do semi-gloss, satin and low sheen paints. Gloss coloured paints can vary from 3% to about 20% PVC depending on the colour of the paint. Generally, the darker the colour of the gloss paints the lower the PVC. As a general rule, the lower the PVC of paint is, the better its exterior durability will be. This assumes the paint is formulated on a durable binder in the first place. PVC is always expressed as a percentage. The lower the PVC the less pigment there is in paint and the glossier it is likely to be.
Pigment volume concentration in coating dispersions the pigment volume concentration is the amount of a particular pigment in a polymer dispersion coating. The point at which there is just enough binder in the dry film to completely fill the interstitial spaces between the pigment particles is known as the critical pigment volume concentration (CPVC). Below the CPVC, the pigment particles are embedded in a matrix of polymer and the coating is relatively impermeable. Above the CPVC the coating becomes progressively more porous, there are voids in the coating filled by air and the coating becomes discontinuous. At CPVC many properties of the coating like opacity, gloss and porosity change drastically (Wapler et al., 2014).

4.2.1 Viscosity

Viscosity is a measure of the fluid resistance to flow and is defined as the ratio of shear stress to shear rate. The shear stress is the force per unit area, while the shear rate is defined as the rate of change in velocity. The unit of viscosity is poise (P) or Pascal-seconds (Pa-s). For coating colours, the viscosity is usually expressed in centipoises (1 cP = 1 mPa-s) (Jonsson et al., 2009). Viscosity can also be explained as the measure of the internal friction of a fluid. Friction becomes apparent when layers of the fluid move in relation to each other. The greater the friction, the greater the amount of force required to cause this movement, which is called 'shear'. Highly viscous fluids require more force to move than less viscous materials (Jonsson 2009). In general, the viscosity increased with PVC. This could be due to the difference in shape and flow properties of the different pigment types. The amount of PVA was adjusted for each step increase in PVC, which might also affect the viscosity. From the laboratory results obtained, paint formulated at 80% PVC having a viscosity of 620cP satisfied the ASTM standard viscosity for paint production. Figure 1 shows the effect of PVC on viscosity of the developed paint.
However, the opacity and recoating test show failed text between 0 – 10%, but at 20% only opacity gives a failed test results, while adhesive and recoating test show a pass test at 20%. In addition, from 30 – 80% all the three (3) show pass pigment-volume percentage.

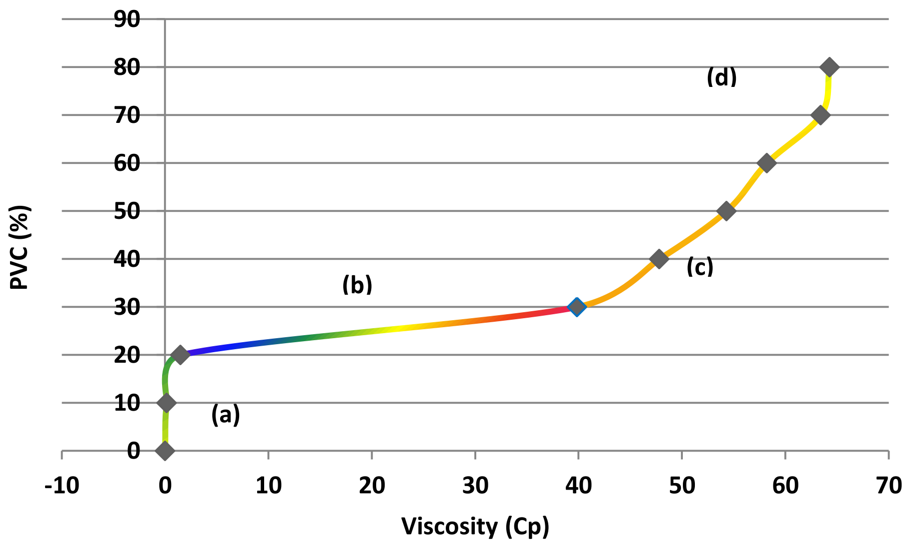

Figure 1: Effect of pigment-volume concentration on viscosity

From Figure 1, the performance curve for various non-corrosive fluids are classified in four (4) ranges of a, b, c and d. Figure 1 show the effect of pigment-volume concentration on viscosity.

4.2.2 Porosity

For a given pigment particle system, it is essentially the binder that affects the porosity and contact parameters (Gerstner et al. 2009). When platy clay is added to the system, the barrier performance of the coatings is further improved. Above the CPVC, pores start to appear in the coating film and the dried coating film becomes porous and permeable. Usually pigments with a broad particle size distribution give a dense coating because the fine particles are located to the space in between the coarser particles. The porosity will be lower in this case. At the other hand pigments with narrow particle size distributions, having small percentage of fines, give a porous coating. The porosity results of the pigments are presented in Table 4. The porosities were very low at 0% PVC. This could due to the reason that latex forms a uniform solid surface after application and drying. Increasing the pigment concentration slightly increased the porosity till the critical pigment volume concentration was reached. The critical pigment volume concentration was close to 30% (Table 4). At CPVC, a sudden increase in porosity was observed. This was due to the pores that started to appear after CPVC. Further addition of pigment above CPVC showed a higher increase in porosity. This could be due to the platy structure, which gives a better coverage. The calcium carbonate particles, when aligned, pack more densely. Figure 1 shows the effect of PVC on porosity.

4.2.3 Drying Time

Drying time of the paint samples produced at different pigment-volume concentration was taken into consideration. Drying time of paint usually depends on the environment temperature and humidity. The laboratory result revealed that the paint produced displayed shorter surface drying times than that of the standard paints. The effects of pigment-volume concentration on porosity are depicted in Figure 2.

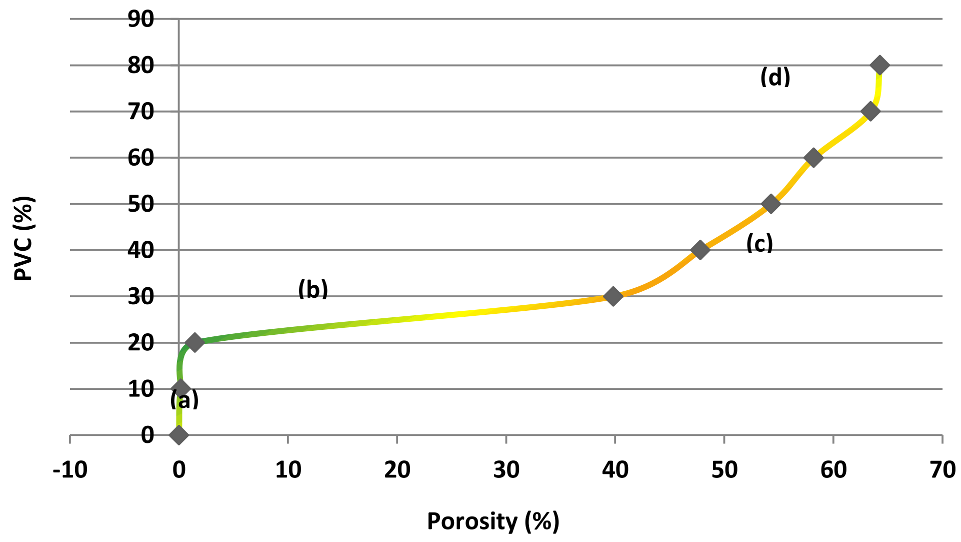

Figure 2 Effect of pigment-volume concentration on porosity

4.2.4 Dry to touch and dry to hard test

Touch-dry and hard-dry are respective stages in coating dry- film formation. The touch-dry time is the period of particle coalescence and cohesion as the solvent evaporates, while hard-dry is the period of optimum adhesion and cohesion of the film to a stage desired. At 60,70 and 80% pigment-volume concentration of the formulated paint sample produced exhibits relatively longer touch dry time this may be due to the change in the morphology of the composite resin with change in PVC. This change tends towards the disruption of the existing macrostructure and hence the change in density of the composite resins Barton, (2012)

4.2.5 Opacity Test

The opacity of the formulated paints produced at different pigment-volume concentration as obtained in the laboratory using ceiling board and brush. The opacity result on formulated paint produced at 0% PVC was the less. The less opacity, also the higher PVC the higher the opacity. The binder which has high values of refractive index has the ability to scatter light more significantly and contribute more to opacity.

4.2.6 Adhesion Test

Almost all the formulated paint was similar to that of standard in having good re-coating properties. Each sample were applied on the coat smoothly and ease with the aid of a brush(except for a sample at 70 and 80 PVC). There were no undesirable film properties such as peeling of underlying coat, sagging, flaking and cracking on each sample.

4.2.7 Recoating Test

Almost all the formulated paint was similar to that of standard in having good re-coating properties. Each sample was applied on the coat smoothly and ease with the aid of a brush. There were no undesirable film properties such as peeling of underlying coat, sagging, flaking and cracking on each sample.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Within the limit of experimental error, the study examined the effects of using different pigment-volume concentration in paint production. From the result obtained, it shows that viscosity increased with increase in PVC and also with further addition of pigment, the porosity of the paint increases.

The results equally shows that the level of concentration of pigment affect the paint performance and quality. Furthermore, the it also indicates that the level of concentration of pigment in a particular paint also has a direct impact on the durability of the paint and higher PVC paints are more durable and are easier to clean.

5.2 Recommendations

From the experiment, it is recommended that the amount of pigment present in the paint or variation in the concentration of the pigment volume presents gradual change in the qualities of the paint. It was also observed that 50% PVC is recommended for formulation in production of emulsion paint as its production will improve the quality and durability of the paint.

REFERENCE

Adamu, A.K., Yakubu, M.K., & Sunmonu, O.K. (2014*), 'Characterization of Emulsion Paints Formulated using Reactive – Dyed Starch as a Pigment'*. International conference on Biological, Chemical and Environmental Sciences.

Akintreinwa, A., Osemeahon, S. A., Nkafamiya, I. I., & Maitera, O. N. (2015). '*Synthesis and characterization of emulsion paint binder from a copolymer composite of dimethyl urea/polystyrene'*. Journal of polymer and composites. 3(2), 11-21.

Barton, F. C. (2012). *'Victrolac motion picture records'*. Journal of the Society of Motion Picture Engineers, 18(4), 452-460.

Chanda, M., & Roy, S. K. (2006). '*Plastics technology handbook'*. CRC press USA.

Dimas F. A and Droste, F.G (2014). *'Cave paintings of the early stone age: The early writings of modern man*'. Semiotica, 2014(202), 155-165.

Idris M. N., and Muhammad I. Y., (2023), '*Study Evatuation using Different Grades of PVC in Paint Production*.' Unpublished final year research Thesis submitted to the Department of Chemical Engineering, University of Maiduguri. Borno State Nigeria

Johnson E. S., Kaley, K. B., Carlisle, J., Siegel, D., & Salinas, J. (2009). *'Health concerns and environmental issues with PVC-containing building materials in green buildings'*. Integrated Waste Management Board, California Environmental Protection Agency, USA, 11.

Kralikova, Ruzena & Piňosová, Miriama & Koblasa, František & Wessely, Emil & Rusko, Miroslav. (2020). '*Environmental and Health Impact of Paint Products'*. 10.2507/31st.daaam.proceedings.005.

Onoja F e., Obidi O.F., Aboaba O.O., Makanjuola M.S. and Nwachukwu S.C.U. (2019). *'Microbial evaluation and deterioration of paints and paint-products*'. Journal of Environmental Biology'. Vol. 30(5) 835-840.

Osemeahon S. A., Nkafamiya II, Maitera O. N., Akinterinwa A. (2015). *'Synthesis and Characterization of an Emulsion Paint Binder from a Copolymer Composite of Dimethylol Urea/Polystyrene'. Journal of Polymer & Composites*. ; 3(2):11–21p.

Sarkodie, B., Achaempong, C., Asinyo, B., Zhang, X and Tawiah, B. (2019), *'Characteristics of pigments, modification and their functionalities'.* Color Research & Application 44(3), 396-410.

Wapler, M. C., Leupold, J., Dragonu, I., von Elverfeld, D., Zaitsev, M., & Wallrabe, U. (2014). *'Magnetic Properties of Materials for MR Engineering, micro-MR and Beyond'*. *Journal of magnetic resonance*, *242*, 233-242.

Wiley, (2012). *'Properties and Behavior of Polymers'*. John Wiley & Sons. Pg. 157. London UK.

Yousefi, A. A., Huaei, P.S., and Yousefi A. (2011). *'Preparation of Water-Based Alkyd/Acrylic Hybrid Resins'*. Journal of Polymer Resins, UK