Production of Emulsion Paint Using Polystyrene Waste/Cashew Nutshell Liquid Copolymer as A Binder Compiled

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Abstract: - **This study investigated the applicability of Cashew nutshell liquid/Polystyrene (CNSL/PS) as a new binder in emulsion paint. In our continuous desire to find suitable methods of recycling polystyrene (PS) waste from our environment and the used of local resources; the quest to reviving the nations' economy toward local production of goods and services and environmental friendly ways of recycling of waste by gaining employment for our teaming youths revolves through encouragement and development of small scale enterprises (SMEs). CNSL/PS was formulated from extraction extracts of cashew nut and blending with polystyrene waste dissolved in gasoline at different concentrations (5 – 35%). Physical properties of the paint samples produced was investigated and the results revealed improvement in the properties of CNSL/PS compared to that of pure PS. The results obtain were also compared with that of SON.**

Paint

Paint can be defined as a mixture of pigments, binders and solvent that forms a continuous film that can be decorative or protective. 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 nonsolvents. 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 encomprises varnishes, enamels, lacquers, plastisols and powder (Lowel, 1990). However, the term paint is often used nonspecifically to cover all of these categories as though it were synonymous with coatings. When a liquid paint is applied to a surface, the volatile portion of the vehicle evaporates leaving the nonvolatile binder-pigment combination as residual film which may or may not require chemical conversion to an insoluble state. Small amount of additives are often included to improve application, pigment settling, drying characteristic and film properties. Most binder are often high molecular weight, non-reactive organic polymers or low to medium molecular weight, reactive polymer capable of being further polymerized via chain extension or crosslinking reactions to high molecular weight films (Candau, 1990).

Although oil paint is superior to emulsion paint in many respects such as water resistance, durability, gloss and flexibility. The use of oil paint is becoming a problem worldwide due to VOC, and hence the need for an alternative binder which will use water as good solvent but produce the good properties of an oil paint.

To reduce the effect of ozone layer depletion, global warming caused by the emission of VOCs from surface coating. Also it will reduce cost, increase quality and develop local technology in the coating industry while improving environmental health of the society.

The World Health Organization (WHO) has reported a 20%-40% increased risk of certain types of cancer (in particular lung cancer) for those who come into regular contact with, or work with oil paint while Danish researchers point to the added possibility of neurological damage. As oil paint is applied, the World Health Organization report that the levels of volatile organic compounds (VOC's) given off are as much as 1000 times higher than found outdoors. During the life-time of the oil paint on your walls, it will also continue to release chemicals into the environment as invisible paint pollution.

The scope of this study includes the development of emulsion paint using waste polystyrene and cashew nutshell liquid as a binder and to convert waste to wealth. Effects of some physical properties such as drying time, viscosity, elongation at break, density, melting point, moisture uptake, refractive index, will be determined.

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

The aim of this research is to develop an emulsion paint using waste polystyrene and cashew nutshell as a binder with the aim of reducing VOCs and waste from our environmental.

Collection of Sample

The method reported by Osemeahon (2013) was used. Waste polystyrene was collected from refuse dump sites in Bauchi metropolis and the cashew nutshell was obtained from yelwa Tudu market Bauchi.

Method

The collected samples (PS) were washed and dried to remove impurity present. PS sample (20) g was introduced into an empty water bottle container containing 5 ml volume of gasoline. This was covered and kept for 24 hours to allow the polystyrene to dissolve. At the end of this time, the content was blended with cashew nutshell liquid at different concentration (5, 10, 15, 20, 30 and 35%) and stirred using glass rod and a high viscous solution of PS/CNSL was made which is the paint binder. This was covered for future use in paint formulation.

The cashew nut obtained was washed with clean water and dried, the seed inside were separated carefully and the shell (waste) was powdered using pestle and mortar. The CNSL was extracted from the powdered sample using soxhlet extractor using gasoline as the solvent.

TABLE I: Emulsion Paint Formulation Recipe with CNSL/PS as a Binder

S.No	Materials	Quantity
1.	Water	250ml
2.	Kaolin (off white)	20g
3.	Calcium Carbonate	30g
4.	Deformer	20ml
5.	Sodium hexametaphosphate	5ml
6.	PS/CNSL	30ml
7.	Yellow paste	0.1ml
8.	Yellow oxide	1g
9.	Formalene	20ml
10.	Cellulose ether	4g(mixed with 20 ml of water)
11.	Ammonia solution	10ml

Evaluation of paint samples

pH Determination

The pH of paints sample produced was determined by using digital pH meter. 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 recorded (SON, 1990).

Adhesion Test

The method described by SON (1990) 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 was made at 27^0C for each sample and average value was recorded

Resistance to blistering

Resistance to blistering was determined thus; undiluted paint sample was applied to a glass panel with an applicator to give a wet film thickness, 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 of triplicate determinations of each sample.

Viscosity Measurement

Viscosity of paint sample was determined according to Standard Organization of Nigeria method (SON, 1990). saybolt viscometer was used. Paint sample (65 ml) was introduced into cup of the instrument at 27^0C and stop watch was used to take the time taken for 60ml of the paint sample poured into the saybolt viscometer cup to drain out and recorded, three replicate of the procedure was carried out for each sample produced and the average was recorded.

Opacity Test

The opacity of the paint samples produced was evaluated according to SON (1990) 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.

Drying Time

The drying time of the paint samples produced was evaluated according to SON (1990) 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.

Dry to Touch and Dry to Hard Test

The dry test of the paint samples was evaluated according to SON (1990) 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.

Flexibility Test

Flexibility test was performed according to SON (1990) method. Paint sample was applied on aluminium panel with the aid of paint applicator. The film was allowed to air dry under room temperature (27^0C) for 7days. The panel with the film was then bent through 180^0 with a smooth action (taking 1 – 2 seconds). The panel was then returned to its normal state and examine for cracking or loss of adhesion. Any crack or loss of adhesion indicates inflexibility or brittleness. This was repeated for triplicate for each of the paints sample produced and average evaluation taken.

Stability Test

The paint sample was fully sealed in a container and was allowed to stay at room temperature (27^0C) for 4 months. At the end of this incubation period, the sample was re-examined for any change in viscosity or coagulation of the emulsion paint. Absence of coagulation or any change in viscosity is regarded as a pass. Triplicate sample was used for each determination and the average value was recorded.

Table 2 Physical Properties of the Formulated Emulsion Paint

Property	**PS**	**5%**	**10%**	**15%**	**20%**	**30%**	**35%**	**SON Standard**
pH	7.80	8.00	8.02	8.04	8.06	9.00	9.02	7-9.50
Viscosity (poise)	8.0	14.1	15.0	12.5	10.5	8.6	8.6	6-15
Dry time (mins)	10-15	10-15	10-15	15-20	20-25	25-30	25-30	20-30
Dry to touch (mins)	30-40	30-40	30-40	40-50	50-60	70-80	70-80	60-120
Dry to hard (hours)	14-16	14-16	14-16	16-18	17-19	18-20	18-20	24
Adhesion	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Blistering	Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Opacity	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Flexibility	Fail	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Discussion of Results

Effect of CNSL on Emulsion Paint Production

The results of some physicochemical parameters tested for the paint samples formulated using CNSL/PS as binders are discuses below:

The emulsion paints were formulated using CNSL/PS as a binder. During the formulation, PS was blended with CNSL at different concentrations and was used as the binder, which gave good compatibility with the pigment in each case. The paints showed more levelness and gave a deeper colour in all the cases. However, the higher the concentration of the CNSL used the more the colour depth. The paints showed good flow property which made them easy to apply and was also found to possess high opacity.

PS which is an accepted binder in the coating industry is used in this production to check the possible effect of CNSL on the formulation procedure on the paint properties and also to compare the results for the different binders, and with the Standard Organization of Nigeria's (SON) specifications.

All paint samples produced passed the adhesion, gloss, blistering and flexibility test indicating a good potential for emulsion paint (Butt *et al.*, 2007). The six paint samples produced are alkaline with the pH favourably falling within the SON specification range. The pH of the CNSL/PS paint is however higher than that of the PS, and this can be due to the OH group from the CNSL. Depending on the nature of the inhabitant microbes in a particular environment, paint pH can be used to inhibit microbial activities in the film (Obidi *et al.*, 2009). Paint pH has also been reported to be used in corrosion control (Montemor, 2014). From these results obtained, PS paint produced had a pH of 7.80 while CNSL/PS paints samples 5%, 10%, 15%, 20%, 30% and 35% had PH values of 8.00, 8.02, 8.04 8.06, 9.00 and 7.02 respectively. The PH increased as the concentration of the CNSL increased in the formulation. PH can be adjusted using ammonia solution or pH adjuster in its formulation so as to mitigate against its tendency to corrode metal surfaces when put into used (Akpabio, 2010).

(i) Adhesion:

All the paint samples produced passed the adhesion test. This can be attributed to the present of CNSL which is used as a laminating resin, incorporated its laminating characteristic into the copolymer and also due to the high molecular weight and crosslinking density of the resin (CNSL/PS). The quality and durability of a coating is directly related to the nature of adhesion (Butt, 2007).

(ii) Blistering

All the paint samples produced passed the blistering test this can be attributed to the present of CNSL which is hydrophobic in nature, which incorporated its hydrophobicity into the paints sample produce thereby reducing affinity for water which causes blistering. This result is in consistent with that obtained for the adhesion, as blistering signifies adhesion failure (Mower, 2001). The ability of these formulations to withstand blistering is very commendable since this goes to address one of the short coming of emulsion paint (Osemeahon *et al.*, 2009).

(iii) Viscosity

All the paints sample produced showed moderate viscosity which indicated good flow property from the results of the viscosity measurement (table 2). It was observed that CNSL had some influence on the viscosity. The low viscosity paint produced (above 15%) may be due to incomplete dissolution or solubility of the binder in the paints produced and showed good leveling, with high opacity. The gloss of the paints was also higher. 10% paint exhibits the highest viscosity compared to the rest concentration, this is due to the level of interaction and crosslinking of the CNSL with PS. The different levels of interactions gave rise to polymers with different morphology and crosslink density (Qi *et al.*, 2002).

Drying Time

Drying time of the emulsion paint samples produced at different CNSL concentration was taken into consideration. Drying time of paint depends on the environment, mainly on temperature and humidity. The laboratory result revealed that the emulsion paint produced displayed shorter surface drying times of 10 to 15 minutes for PS, 5%, 10% and 15% than commercial paints, which ranged between 20 to 30 mins. (Abbas *et al*., 2014). This can be attributed to the present of CNSL which is hydrophobic in nature; which invariably reduced the volume of water (used as diluents in the formulation) (Igwebike & Clementina, 2015; Qi *et al.*, 2002).

(v) Dry to Touch and Dry to Hard

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, further coat can be satisfactorily applied (Egbewatt *et al.*, 2014) 35% and 30% of the test 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 CNSL concentration. This change tends towards the disruption of the existing macrostructure and hence the change in density of the composite resins (Fernandes *et al*., 2013). However, 35% paint exhibits the longest hard dry time, followed by 30%, 20%, 10%, 5% and PS respectively.

(Vi) Opacity

Table 2 represent the opacity of the formulated emulsion sample paints at different CNSL concentration, as obtained in the laboratory using ceiling board and brush. The opacity result on sample PS paint produced was less than that of 5% and the opacity of 5% was also less than that of 10% and the opacity of 10% was also less than that of 15% continuously up to 35%. The opacity was found to be increasing with increased in CNSL concentration; this is due to the dark nature of the CNSL, it quantity present and these values are considerably high, and can be explained due to the high values of refractive index due to the binder, which has the ability to scatter light more significantly and contribute more to opacity. 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 (Idris & Rashan, 2017).

(vii) Storage Stability

All the paint samples produced passes the stability test, which indicates good storage characteristics for the paint samples. All the emulsion paint samples produceddisplayed good stability after 4 months of storage at 0±2^{o}C and 27±2^{o}C. Therewas no evidence of biochemical deterioration in all the six CNSL/PS paints sample produced which often manifests as changes in colour, coagulation, viscosity loss, pH drift, development of offensive odour (Igwebike & Clementina, 2015).This clearly shows the efficacy of the fungicides and bactericides present in the CNSL used in the formulation. 20%, 30% and 35% they was a change in their colour but since there is no change in coagulation, viscosity loss, pH drift, development of offensive odour, it say to be that all the paint samples produced pass the stability test, which indicates good storage characteristics for the paint samples.

(Viii) Temperature Stability

All the paint samples pass the stability test, which indicates good characteristics for emulsion paint. Stability is a good property for judging the shelf life of emulsion paint product as it relates to microbial attack and pigment dispersion(Igwebike & Clementina, 2015).All the paint sample produced showed good stability when stored at room temperature of 27^{o}C as they substantially retained their physical and chemical integrity.The stability of the samples was evident in the absence of offensive odour and deterioration in paint quality which can be attributed to the efficacy of the CNSL used which serve as preservative as well as the relative stability of the PS

(X) Brushing Properties

The entire paint samples produced displayed good application properties, similar to those of SON, in terms of ease of application, flow and spread of the paint on the substrate when applied with brush. This is not unexpected since the formulations are the same except for the type of binder used, which evidently did not affect the brushing properties (Igwebike & Clementina, 2015).

(Xi) Re-coating Properties

The entire paint samples produced were similar to that of SON 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 (NIS, 2008)

Conclusion

One of the best and advisable waste management system (Recycling and Reused) have been successfully used in this research to recycle waste polystyrene and blend at different concentration with CNSL and 10% showed the best results of all the different concentration of the properties of the paint samples produced (CNSL/PS copolymer) investigated.

This study has established that CNSL/PS is suitable for use as binder in emulsion paints. The results also revealed that the CNSL/PS-filled emulsion paints displayed good performance and application characteristics in conformity with the requirements for premium quality paint. In addition, emulsion paints formulated with CNSL/PS surpassed those of PS (the reference standard) in some attributes, namely, viscosity, opacity, blistering, adhesion, flexibility and settling resistance but were similar to those of PS in drying properties, storage stability, temperature stability and application properties. CNSL/PS therefore serves as a good, cheap, abundant, readily available, renewable binder for the production of emulsion paints.

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.

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