PRODUCTION OF EMULSION PAINT USING POLYSTYRENE WASTE/CASHEW NUTSHELL LIQUID COPOLYMER AS A BINDER

COMPILED

BY

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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 binder polymer composite (CNSL/PS) was carried out and compared with that of the pure PS and others binders. The results obtained are: refractive index (PS = 1.500 and CNSL/PS 35% = 1.620), density (g/cm3) (PS = 0.84 and CNSL/PS 10% = 1.55), viscosity (mPa.S) (PS = 1000 and CNSL/PS 10% = 3000), turbidity (NTU) (PS = 15 and CNSL/PS 35% = 65), melting point (00C) (PS = 120 and CNSL/PS 10% = 182) and moisture uptake (%) (PS = 2.0 CNSL/PS 10% = 0.2). The results revealed improvement in the properties of CNSL/PS compared to that of pure PS. The results obtain were also compared with other binders.

CHAPTER ONE

INTRODUCTION

Binder is a monomeric material that undergoes oxidation- polymerization or some other type of crosslinking reaction. A few binders, such as alkyl silicates and titanates, yield inorganic coatings. Silicone coatings are hybrids of inorganic and organic moieties in which the polymer backbone is inorganic (siloxane) and the constituent or modifying groups are organic. Ceramics and electrolytically deposit metallic coatings are strictly inorganic (Flory, 1995).

The binders of conventional paints are for the most part, raw or processed unsaturated vegetable oils e.g. linseed, dehydrated castor oil, soya oil etc. often modified with natural or low molecular weight synthetic resins. Pigmentation provides opacity and almost endless variety of colours. When the liquid paint is applied to a surface and the solvent evaporates the uncured film is mobilized by the oxidative polymerization via the double bond in the oil (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. 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.

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 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 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 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.

The objectives are:

CHAPTER TWO

MATERIALS AND METHODS

The materials are used as purchased

Collection of Sample

The method reported by Osemeahon et al., (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) was 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.

The cashew nut was obtained and 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 with gasoline as the solvent.

Blend Preparation of CNSL/PS

The method reported by Osemeahon and Dimas (2013) was adopted, in which the blending of polystyrene and cashew nutshell liquid was done by preparing 5% cashew nutshell liquid in polystyrene at room temperature (30^{o}C). The solution was mixed thoroughly using glass rod. The above procedure was repeated with 10, 15, 20, 30 and 35% cashew nutshell liquid concentration (5-35%) and the resulting blends were analyzed. Film of different resins obtained with various CNSL concentrations (5-35) were covered and kept in a water bath in order to allow curing and setting for seven days at 30^{0}C. Hence the physical properties of this resin were investigated.

CHAPTER THREE

Determination of the Physical Properties of the binder

Determination of Viscosity

The viscosity of the resin was evaluated using BM 471 SAYBOLT VISCOMETER SINGLE TUBE and expressed in seconds at 30^{O}C. The viscosity was recorded from flow time in seconds. Three different readings were taken for each sample and the average value was calculated (Vilas *et al.*, 2000).

Determination of Density

The above property was determined according to AOAC (2000). The density of different resins was determined by taking the weight of a known volume of each resin inside a density bottle (20 cm^3) using weighing balance, the density was calculated using the mass volume relationship. Three readings were taken for each sample and the average value calculated.

Melting Point

The melting point of the different film samples was determined by using melting point block and thermometer was attached to the block and three different readings were taken for each sample and the average was calculated. The above property was determined according to standard method AOAC (2000).

Refractive Index

The refractive index of the resin samples was determined by using Abbe refractometer (Oluranti *et al.*, 2011). Three different reading was taken for each sample and the average was calculated and recorded.

Determination of Moisture Uptake

The moisture uptake of the different resin films was 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 was then monitored until maximum weight is obtained. The difference between the wet weight and the dry weight of each sample was then recorded as the moisture intake by resin (Oluranti *et al.*, 2011).

Turbidity

The turbidity of the binder was determined by using DR/89 Colorimeter, the above property was determined according to AOAC (2000).

Water Solubility

Water solubility of PS/CNSL was 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 Damis, 2014).

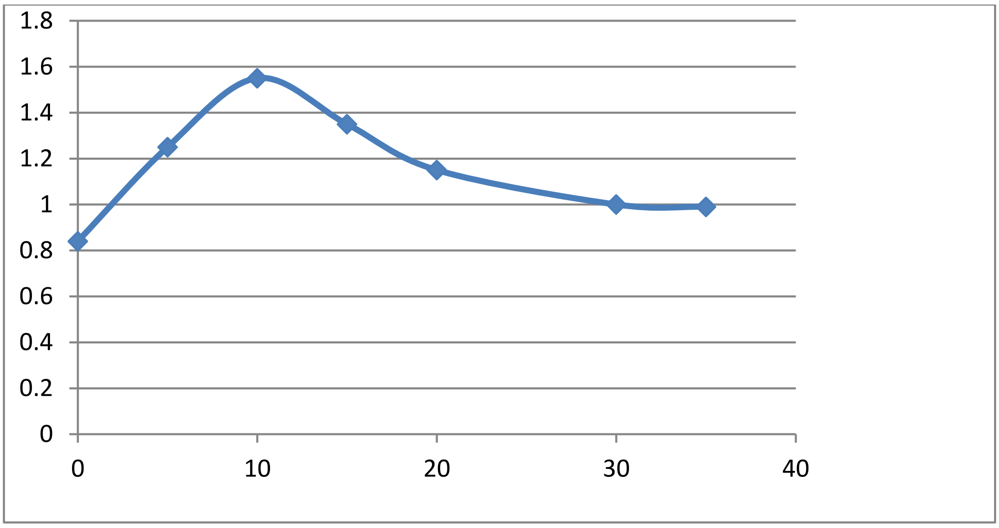
CHAPTER FOUR

RESULTS AND DISCUSSION

RESULTS: All the results of the binder analysis (such as refractive index, density, viscosity, turbidity, solubility, melting point, and moisture uptake) of CNSL/PS composite in this work is reported below:

Effect of CNSL Concentration on the Density of CNSL/PS Resin *Composite:* the graph below shows the result of the effect of CNSL on Density of CNSL/PS composite

Density g/cm^3



Concentration of CNSL in CNSL/PS composite

Figure 1 Effect of CNSL Concentration on the Density of CNSL/PS

Effect of CNSL Concentration on the Refractive Index of CNSL/PS Resin Composite:

The graph below show the result of the effect of CNSL on Refractive index of CNSL/PS composite

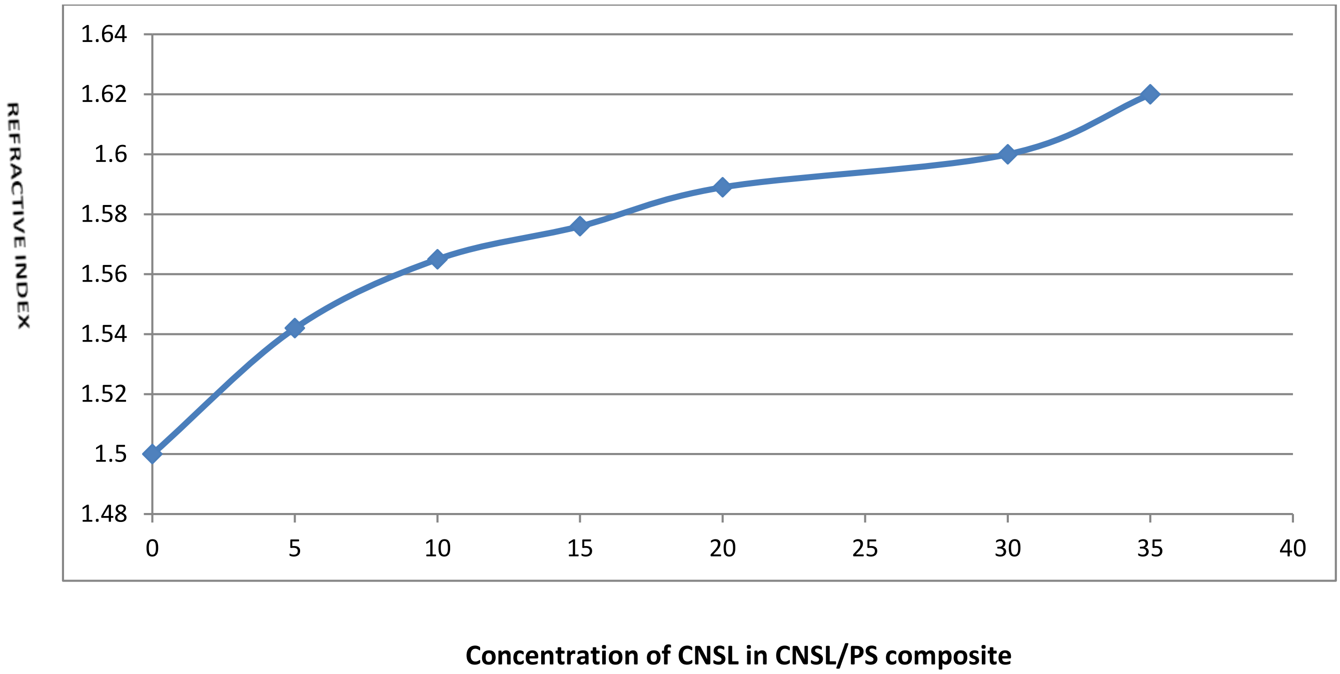


Figure 2 Effect of CNSL Concentration on the Refractive Index of CNSL/PS

Effect of CNSL Concentration on the Moisture Uptake of CNSL/PS Resin Composite

The graph below show the result of the effect of CNSL on moisture of CNSL/PS composite

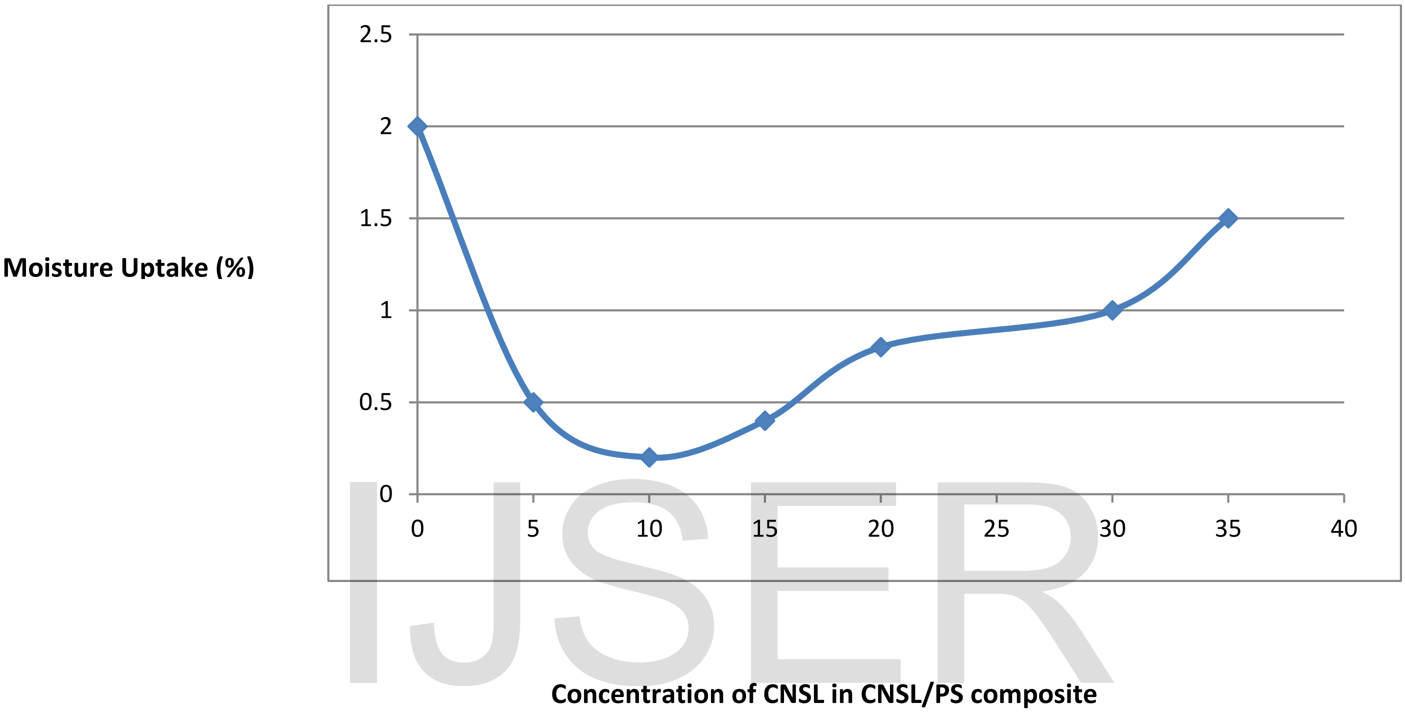


Figure 3 Effect of CNSL Concentration on the Moisture Uptake of CNSL/PS

Effect of CNSL Concentration on the Viscosity of CNSL/PS Resin Composite

The graph below show the result of the effect of CNSL on viscosity of CNSL/PS composite

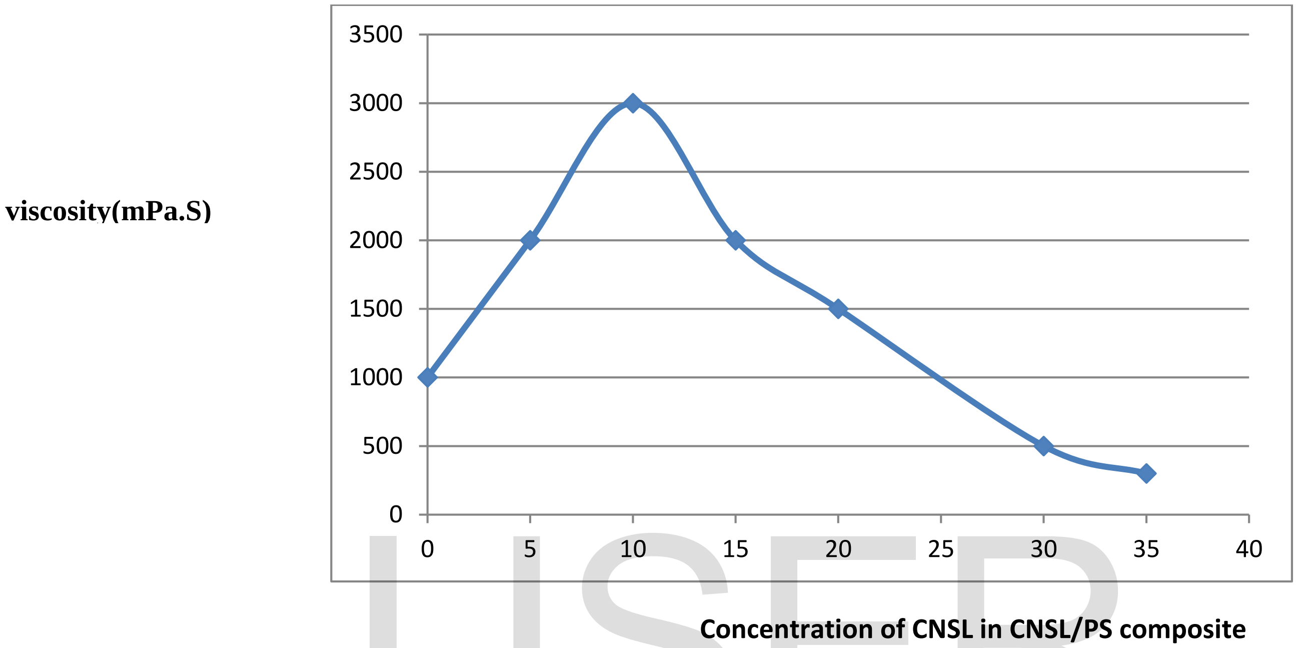


Figure 4 Effect of CNSL Concentration on the Viscosity of CNSL/PS

Effect of CNSL concentration on the melting point of CNSL/PS resin

The graph below shows the result of the effect of CNSL on melting point of CNSL/PS Resin composite

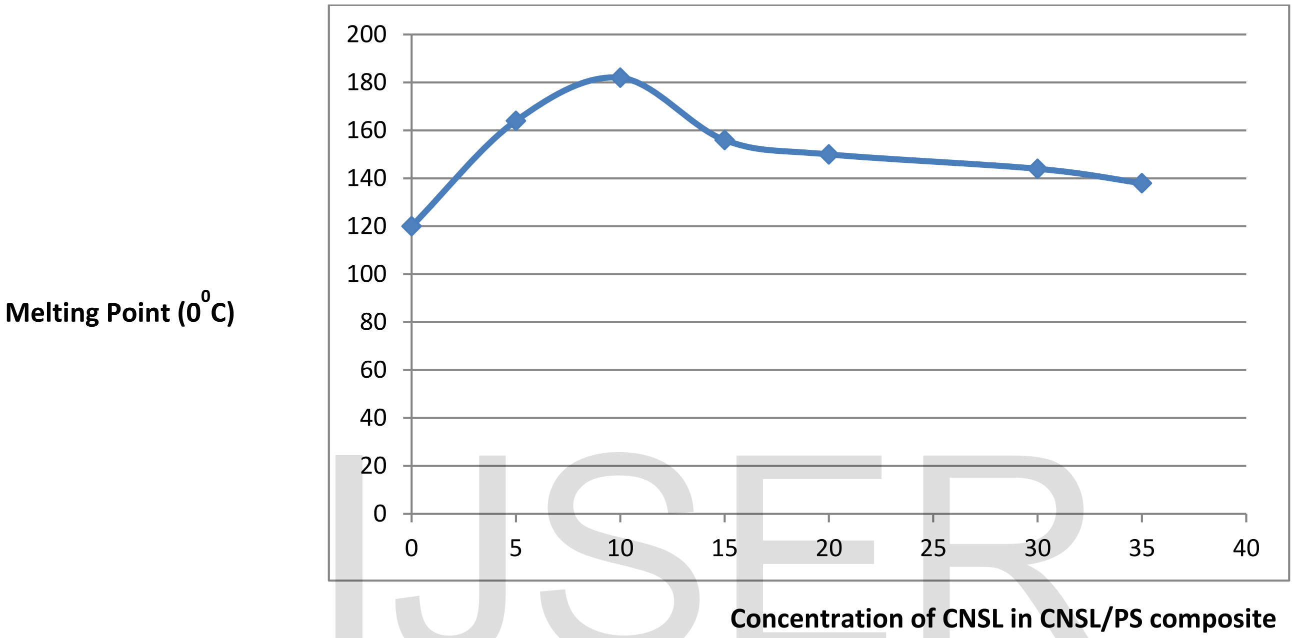


Figure 5 Effect of CNSL concentration on the melting point of CNSL/PS

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Effect of CNSL Concentration on the Turbidity of CNSL/PS Resin Composite The graph below show the result of the effect of CNSL on turbidity of CNSL/PS composite

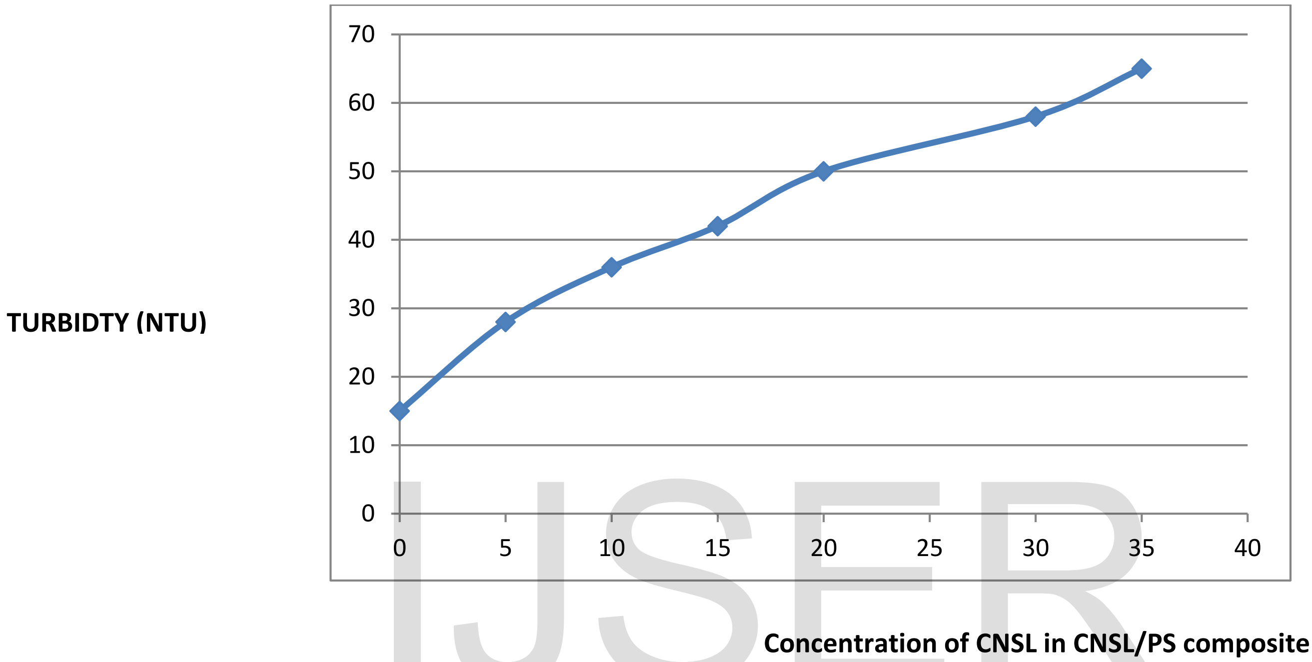

Figure 6 Effect of CNSL Concentration on the Turbidity of CNSL/PS

Table 1 Effect of CNSL Concentration on the Solubility of CNSL/PS Resin

CNSL/PS %(v/v)	SOLUBILITY IN WATER
0	Soluble
5	Soluble
10	Soluble
15	Slightly Soluble
20	Insoluble
30	Insoluble
35	Insoluble

Figure 7 Effect of CNSL Concentration on the Solubility of CNSL/PS

Comparison of Resins

The table below shows some physical properties of CNSL/PS films in comparison with other paint binders

Table 2

Types of Resin	Density (g/cm^3)	Refractive Index	Melting point (^0C)	Moisture uptake (%)	Viscosity (mPa.s)	Turbidity (NTU)	Literature
This study	1.55	1.620	182	0.20	3000	36	Current study
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
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
TMU/PS	1.0990	1.425	262	1.02	19.70	1100	Osemeahon& Dimas, 2014
DMU/PS	1.1953	1.4295	181.42	0.26	35.60	611	Osemeahon et al., 2015
TMU/PS	1.0990	1.4250	262	1.01	19.70	878	Osemeahon& Dimas, 2014
Commercial UF	ND	ND	ND	2.00	451	ND	Suurpere et. al., 2006
TMU/NR	0.5708	1.3501	260	ND	220	ND	Osemeahon&Barminas, 2007
UF/CS	1.166	1.417	130.00	0.6	11.1	ND	Dimas et. al., 2013
XASO	0.912	1.467	ND	ND	900	ND	Oladipo et al., 2013
Innovative UF	ND	ND	ND	0.25	ND	ND	Zorba et al., 2008
MAGPP/ER	ND	ND	ND	200	ND	ND	Shieh et al., 2001
EBDE	1.04	ND	179	ND	38.0	ND	Gawdzik&Matynia, 2001

AESO	ND	ND	ND	ND	13,000	ND	Habib &Bajpai, 2011
RSOMAR	0.95	ND	ND	ND	3.11	ND	Aigbodion&Pilla, 2001

CHAPTER FOUR

DISCUSSION OF RESULTS

Density

Figure 1 reveals the gradual increase in density with increase in CNSL loading from 5-10% and above 10% it was found that the density start deceasing. This may be attributed to the change in the morphology of the composite resin with change in CNSL concentration. This change tends toward the disruption of the existing macrostructure and hence the change in density of the composite resins (Fernandes *et al*., 2013). Above 10% further inclusion of CNSL into the copolymer, results in polymer dissociation, signaling overloading above the optimal level. Polymer dissociation results in fragmentation of long chain polymer into shorter chain oligomers (Osemeahon and Dimas, 2014).

Refractive Index

Figure 2 presents the gradual rise in refractive index of CNSL/PS with increase in CNSL loading. This can be attributed to the changes in proportion of the amorphous and crystalline phases in the copolymer composites as this primarily arouse light scattering (Fratini, 2006). It may also be due to the orientation and a state of aggregation established by CNSL, thereby creating light scattering boundaries and discontinuities in the molecular structure of the copolymer composite (Jain, 2008 and. Wiley, 2012). CNSL is a dark yellowish coloured liquid and hence its ability to impact haze and increase the refractive index of the pure PS which is less yellowish in colour (liquid). It is observed that the refractive index of CNSL increases with increase in concentration of CNSL which is in agreement with the work of Lee *et al.*, (2013).

Moisture Uptake

Figure 3 presents reduction in moisture uptake with CNSL loading 5 - 10%. This can be associated with the hydrophobic nature of CNSL (Sohel *et al.*, 2014). As its concentration increases 5 - 10% this property is more significantly established by increasing the water repellency of the CNSL/PS. A possible interaction between CNSL and PS can also lower the OH groups in the copolymer resin, hence reducing its affinity for water molecules; the different levels of interactions gave rise to polymers with different morphology and crosslink density (Qi *et al.,* 2002). The molecular size hole was small at 5 – 10%. Moisture uptake obtained for CNSL/PS in this study is lower compared to PS resin reportedly used in formulations for coating applications (Zorba *et al.,* 2008). This may be due to laminating property of CNSL and shared its hydrophobicity properties with PS hence lowering affinity for water molecule. Hydrophobic components in the binder give the best combination of improving water resistance of water-borne coating. Water deteriorates thermo-mechanical properties and adhesion; it induces chemical degradation of the network and also generates stresses, because of swelling and hence blistering of the coating film (Gonzalez *et al*., 2012; Toloei *et al.,* 2013). This implies that there will be little or no fear of film degradation, especially if blended at 10%.

Viscosity

Figure 4, Shows the effect of CNSL concentration on the viscosity of CNSL/PS. Viscosity is a fundamental rheological parameter of macromolecular compounds (polymer) that defines resistance to flow and is related to the characteristics of composite materials widely used in many field of industry. This is because the viscosity of the binder controls many of the processing and application properties such as flow rate, levelling and sagging, thermal and mechanical properties, dry time of paint film and adhesion of the coating to the substrate (Osemeahon and Archibong, 2011). In Figure 4, the rise in viscosity from 5 – 10% in the copolymer composites can be associated with the change in molecular features (i.e. polydispersity) and the molecular weight with rise in CNSL concentration (Oladipo *et al*., 2013). CNSL/PS exhibits viscosities higher than those of CNSL and PS and this rise may be due to crosslinking interaction between CNSL and PS, resulting in a new macrostructure with higher viscosity. After 10% further inclusion of CNSL into the copolymer results in polymer dissociation, signaling overloading above the optimal level; Polymer dissociation results in fragmentation of long chain polymer into shorter chain oligomers (Osemeahon and Dimas 2014). This shows weak intermolecular forces and fewer bonds, which reduced the viscosity of the blended copolymer.

Melting Point

Figure 5 the melting point of a polymer is related to its molecular weight, degree of cross-linking and the level of rigidity of the polymer (Bindu *et al*, 2001). The melting points of the PS and CNSL are very different which probably result from different contributing factors. The result shows a gradual increase in melting point from 5 - 10% concentration of CNSL in the blend, this may be due to increase molecular weight, degree of cross-linking and the level of rigidity of the polymer (Bindu *et al.*, 2001), or at the initial stage there are strong specific interaction resulting in the formation of a compacted structure thereby introducing some form of hardness to the system (Qi *et al.*, 2002). Result shows a gradual decrease in melting point from 15% concentration of CNSL in the blend gradually. From 15% CNSL loading, further inclusion of CNSL into the copolymer results in polymer dissociation, signaling overloading above the optimal level. Polymer dissociation results in fragmentation of long chain polymer into shorter chain oligomers with (Osemeahon and Dimas 2014).

Turbidity

Figure 6, shows the turbidity of the CNSL/PS Resin. Increase in turbidity and light scattering may be due to the mismatch in the refractive indices of the randomly oriented components in the copolymer composite (Park *et al.*, 2013). Figure 6 shows an increasing in turbidity as the concentration of CNSL is increased in the CNSL/PS Resin. It may be associated with increase in the molecular weight of the Resin composite and change in the morphology with increase in CNSL concentration (Park *et al.*, 2013). Light scattering properties have been directly related to turbidity (De Kruif, 1993). When we have homogeneity and few particles, there will be less scattering; hence, higher scattering is observed when we have a non homogenous system with a lot of particles (CNSL/PS). From the Figure 6 above, it shows that turbidity is relatively low at 100% PS (0% CNSL), this is because PS has a transparent nature and is homogeneous in nature with fewer particles. However, from 5% above on addition of CNSL it becomes colloidal with more particles and light scattering increases. As the concentration of CNSL increases, the growth of large interpolymer aggregate increase and the turbidity increased, hence turbidity of the system can be used as an indicator of the level of interchain cross-linking (AlManasir, 2009). The more the CNSL loading, the more the light scattering and this consequently leads to corresponding increase in the turbidity of the system

Water Solubility

Figure 7, indicates the water solubility and is an important parameter in the consideration of any resin as a binder for emulsion paint formulation. Figure 7 reveal that the CNSL/PS concentration (%) Solubility 0 Soluble, 5 Soluble, 10 Soluble, 15 slightly soluble, 20 Insoluble, 30 Insoluble, and 35 Insoluble loading, this is due to increasing concentration of CNSL which is hydrophobic in nature. The copolymer is in a hydrophobic state above 15%, with hydrophobicity of CNSL dominating. Above 15% inclusion of CNSL, the copolymer seems to adopt hydrophobic stand with the hydrophobic now dominating.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMENDATION

The summary, conclusion and recommendation of the binder investigated are discussed below:

Summary

In working towards an environmentally friendly society we have successfully convert waste polystyrene and cashew nutshell to emulsion paint binder encouraging the use of local resources in our environment to wealth.

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 binder of the CNSL/PS copolymer investigated.

This study has established that CNSL/PS is suitable for use as binder in emulsion paints.

Recommendations

From the result obtained from the properties of CNSL/PS binder investigated; its shows that CNSL/PS copolymer have display a very good quality of a binder in coating application but limited in pure PS are favourable modified. Variation in the concentration of CNSL presents gradual change in the qualities of the CNSL/PS Resin, hence its optimization. At 10% is recommended for formulation in production of emulsion paint on the other hand, its production will be economical and contributory in waste management emission level in our society.

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