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Development of Waste Polystyrene as a binder for emulsion paint formulation I: Effect of polystyrene Concentration.

[1]Osemeahon, S.A; [1]Barminas, J.T; [2]Jang, A.L
[1]*Department of Chemistry, Moddibo Adama University of Technology, Yola, Nigeria*
[2]*Department of Chemistry, Taraba State University, Jalingo, Nigeria*

ABSTRACT
In our continuous desire to find suitable methods of recycling waste, expanded polystyrene waste was converted into a paint binder using gasoline as a solvent. Some properties of the binder at different concentrations (5% - 30%) were investigated. The melting point, refractive index, density, viscosity, turbidity and elongation at break were found to increase with increase in binder concentration. The solubility of the binder was however, found to decrease with increase in binder concentration. At a concentration of 20% w/v, the binder was found to be insoluble in water. Thus, the processing of waste polystyrene binder for emulsion paint formulation should therefore be carried out below this concentration level. This study provides polystyrene waste as a potential binder for emulsion paint formulation.

KEYWORDS: *waste expanded polystyrene, gasoline, physical properties, emulsion paint.*

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I. INTRODUCTION

In recent years, reprocessing of polymers has been widely used in plastics converting industries (Ronkay, 2013). It is connected to the increasing awareness of environmental issues, and the desire to save resources. Polymeric materials are a unique product that exhibit different durability based on its backbone of a chain. As the use of polymers has increased in numerous applications, the issue of polymer waste disposal has also gained significant importance.

Expanded polystyrene is produced massively in order to fulfill the needs and requirement of packing industry (Aminudin et al, 2011). As this product continuously increase, the total amount of plastics that ends up in waste stream is in a similar trend. The environmental problems associated with the traditional methods of polymer waste disposal such as incineration and landfill are of concern due to the increment cost of landfill disposal (Hamad et al., 2010) and the environmental regulations are becoming increasingly stringent worldwide (Mamoor et al, 2012). There is also a high demand for the recycling of scraps considering the relatively high cost of polymer production (Ronkay, 2013).

To address this problem, the polymer waste can be recycled and used for the manufacturing of different valuable products. Though, recycling programs for polystyrene are not currently in place on a large scale (Gu et al, 2010). An interesting application of the recycled material is in the preparation of a paint binder from waste polystyrene. Therefore it is important to optimize the waste by applying various practical approaches such as prevention, minimization, reuse or recovery (Vilapana and Karlsson, 2008).
Methods of Polystyrene recycling include: Mechanical recycling, which usually requires the combination of high temperatures & shear stresses (energy consumption), Chemical recycling, that usually requires depolymerisation of the recycle material through solvolysis and thermal catalytic recycling (Melo et al., 2009).
The present research is aimed at recycling polystyrene into a binder for emulsion paint formulation.

II. MATERIALS AND METHODS

Materials

Waste expanded polystyrene (EPS) were collected around homes and refuse dump within jalingo metropolis, and gasoline was obtained from Maihanchi fuel station in jalingo; EPS was used as collected and gasoline was used as purchased

Preparation of EPS Binder solutions

The method of Abdul-karim & Al (2012) was adopted with a slight modification, the solvent in this case being gasoline.Waste expanded polystyrene (EPS) binder solution was prepared by dissolving a known weight of waste EPS (5%, 10%, 15%, 20% and 25%) in a fix volume (100ml) of gasoline and stirred for 45minutes at 30^{o}C.

Film preparation

Films of different binders obtained at various EPS concentrations were cast on glass petri dish (which was lined with aluminium foil) using solution casting method(Osemeahon and Barminas, 2007). The binders were then allowed to cure and set for seven days at 30^{O}C. The melting points of the films and tensile properties were investigated.

Determination of viscosity

The method reported by Barminas and Osemeahon (2007) was adopted for the determination of viscosity of EPS solution. A 100ml Phywe made graduated glass microsyringe (Phywe, Gottengen, Germany) was utilized for the measurement. The apparatus was standardized with a 20% (w/v) sucrose solution whose viscosity is 2.0mPa.s at 30^{o}C. The viscosity of the EPS solution was evaluated with respect to that of the standard sucrose solution at 30^{o}C. Three different readings were taken for each sample and the average value calculated.

Determination of density, turbidity, melting point, and refractive index.

The properties above were determined according to standard methods (AOAC, 2000). The density of the different solutions was determined by taking the weight of a known volume of binder inside a density bottle using metler Model AT400 (GmbH,Greifensee, Switzerland) weighing balance. Three readings were taken for each sample and the average value calculated. The turbidity of the binders was determined by using Hanna microprocessor meter Model, H193703 (Villafranca Padovana, Italy). The melting point of the different films of samples was determined using Galenkamp melting point apparatus Model, MFB600-010F (Loughborough, UK). The refractive index of each sample was determined with Abbe refractometer (Bellinglam and Stanley, Tunbridge well kent, UK). Three readings were taken for each sample and the average value calculated for each of the parameters above.

Tensile test

Tensile property (elongation at break), was measured using instron testing machine (model 1026). The resin films of dimension 50mm long, 10mm wide and 0.15mm thick was brought to rapture at a clamp rate of 20mm/min and a full load of 20kg. Five runs were made for the sample and the average evaluated and expressed as percentage elongation and tensile strength.

Determination of moisture uptake

The moisture uptake of the resin film was determined gravimetrically. Known weights of the sample were introduced into a desiccators containing a saturated solution of sodium chloride .the increase in weight (wet weight) of the sample was monitored until a constant weight was obtained. The difference between the wet weight and dry weight was then recorded as the moisture uptake by the resin. Triplicate determinations were made for the sample and the average value recorded.

Solubility

The solubility of EPS binder in water was obtained by mixing 1ml of the binder with 5ml of distilled water at room temperature (30^{o}C). The solubility was ascertained by physical observation (Osemeahon and Archibong, 2011)

III. RESULTS AND DISCUSSION

Effect of Waste EPS Concentration on Viscosity of EPS Solution.

Viscosity is traditionally regarded as one of the most important material properties; the viscosity of the binder is also an important factor to the coating industry. This is because the viscosity of the binder controls many of the processing and application properties such as flow rate, leveling and sagging, thermal and mechanical properties, dry time of paint film and adhesion of the coating to the substrate (Osemeahon and Archibong, 2011). The effect of concentration on viscosity of the binder is shown on figure 1. As the concentration increases, the viscosity also increases. This implies that the viscosity increases with increasing solid content (Yin et al, 2013). The effect observed here may be due to a density increase and a free volume decrease (Tuteja and Mackay, 2005). Also unlike dilute solutions, concentrated polymer solutions show a great deal of interaction between the macromolecules. The higher the concentration, the higher the viscosity can be observed (Taghizadeh and Foroutan, 2005).

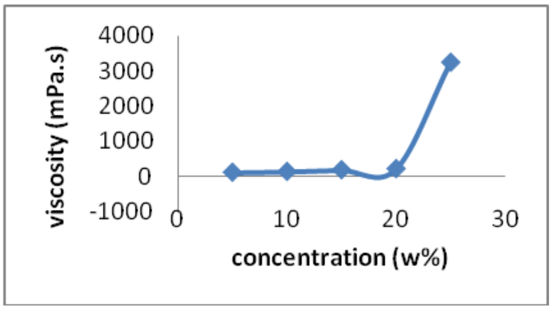

Figure 1: effect of waste EPS concentration on viscosity of solution.

Effect of Waste EPS Concentration on Refractive index of EPS Solution.

High values of refractive index of polymer solutions may have some connection with their viscosity (Panda et al, 2012). The effect of EPS concentration on the refractive index of EPS solution is shown in figure 2. It is observed that the refractive index of EPS increases with increase in concentration of EPS which is in agreement with the work of Lee et al, (2013).

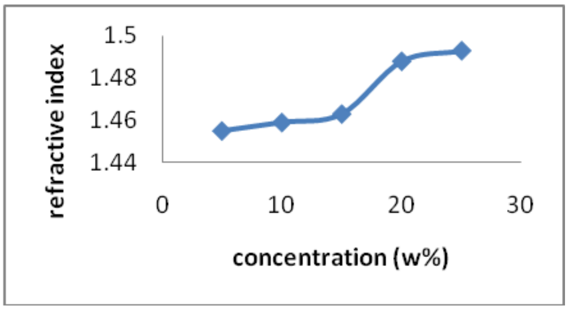

Figure 2: Effect of waste EPS concentration on the refractive index of solutions.

Effect of Waste EPS concentration on Density of EPS solution.

In the coating industry the density of the paint binder has a profound influence on factor such as pigment dispersion, brushability of paints, leveling and sagging (Osemeahon and Archibong, 2011). Figure 3 shows the effect of concentration on the density of EPS binder. It can be seen that the density of the solution increases gradually at first, followed by a slightly sharp increase with increase in EPS concentration. The density which is mass per unit volume, as we increase the weight of the polymer (waste EPS) in a fix volume of solvent, there was a steady increase in density. This is in agreement with previous research work (Abdul-karim & al, 2012)

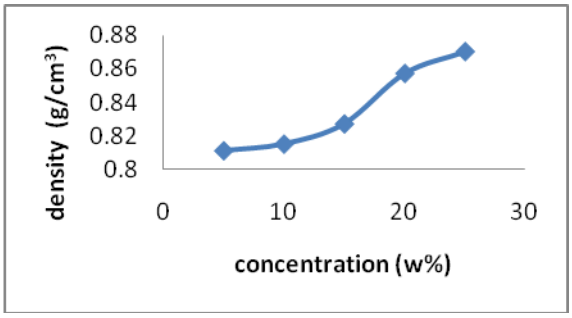

Figure 3: Effect of waste EPS concentration on the density of solution

Effect of Waste EPS Concentration on Turbidity of EPS solution.

The turbidity of binder is an important property to the chemist in the coating industry, this property is very important because it is related to the gloss property of the binder (Trezza and Krochta, 2001). Figure 4, shows the effect of waste EPS concentration on the turbidity of the solution. It can be seen that the turbidity increases with an increase in EPS concentration. The particles in the solution absorb and refract light. As the concentration increases, the solution becomes denser; this can have an observable optical effect. Less light passes through the solution at higher EPS concentration.

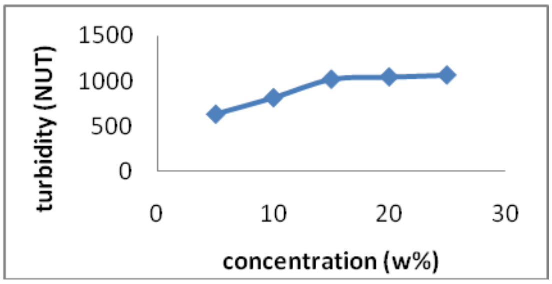

Figure 4: Effect of waste EPS concentration on the turbidity of solution.

Effect of Waste EPS concentration on Melting point of EPS Films.

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 effect of concentration on the melting point of EPS binder is shown on figure 5. An increase in the melting is observed with increase in viscosity of the binder. This can be explained on the bases of a decrease in the packing nature of the molecules, because of the closeness of the molecules, weak forces of attraction can exist between the molecules which in turn led to increase in melting point as the concentration increases.

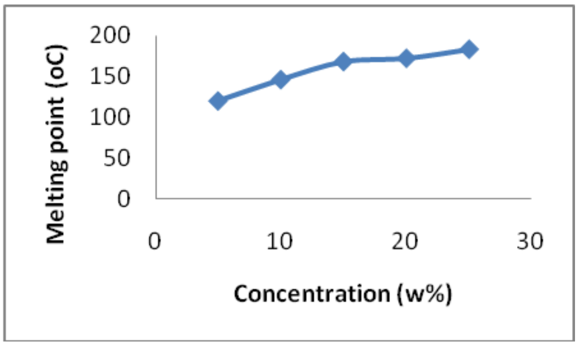

Figure 5: Effect of waste EPS concentration on the melting point of EPS Films.

Effect of Waste EPS Concentration on Elongation at Break of EPS Films.

The mechanical properties of a resin system are used to compare formulations and determine the suitability for an application. Generally, paint resins need to be hard and rubbery. Figure 6; shows the effect of concentration on the elongation at break of EPS resin. It is observed that, elongation at break increases with increases in concentration of EPS in the film. This implies an increase in concentration improves the ductility of the film which allows for large deformation or large extension.

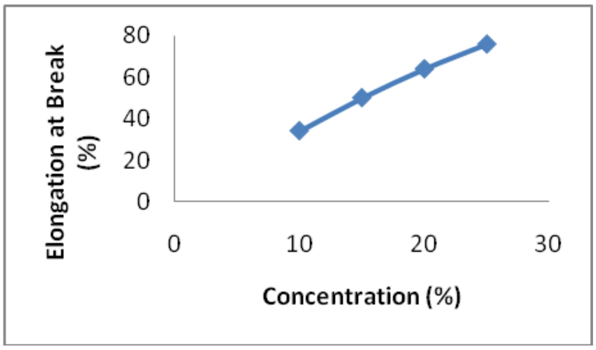

Figure 6: Effect of waste EPS concentration on elongation at break of films.

Effect of solvent on moisture uptake of EPS resin

The permeability and water uptake of films affects its performance, because they can promote the film degradation and / or damage the substrate (Yuri et al, 2007). Water also deteriorates thermochemical properties and adhesion, it induces chemical degradation of the network and also generates stress because of swelling. For all the films , it was observed that, the water uptake is minimal (less than 2% - almost negligible). This implies there will be little or no fear of film degradation due to water uptake**.**

Solubility

In other to develop an emulsion paint binder from EPS, the solubility of the binder in water is crucial; it is important both from the technical and processing point of view. This is so because the solubility of EPS binder in water decreases with increase in viscosity (Park et al 2001). The effect of EPS concentration on the solubility of EPS binder is shown on table 1. Below the concentration of 20% w/v, the binder is soluble in water, and at 20% w/v and above, the binder is insoluble. Thus processing of EPS as a binder for emulsion paint formulation is suggested to be below this level

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Waste EPS concentration (% w/v)	Solubility in water
5	soluble
10	**soluble**
15	**soluble**
20	**insoluble**
25	**insoluble**

Table 1: Effect of waste EPS concentration on the solubility of binder.

Table 2: comparison of some physical properties of EPS resin with other paint resins

Type of Resin	Refractive index	Density (g/cm3)	Melting point (oC)	Viscosity	Moisture uptake(%)	Elongation at break(%)	Literature
This study	1.464	0.84	168	500	2	50	Current study
Alkyd Resin and Palm oil Blend	ND	0.95					Itoua et
Low			ND	5000	ND	ND	al,2012
Refractive Index Polymer Cladding Resin	1.363	ND					
							Yoon et al,
			ND	ND	ND	ND	2010
Alkyd Resin from Castor oil							
Polyvinyl acetate from Vinyl	1.474	ND					Hlaing & Oo, 2012
acetate			ND	4	ND	ND	
Polymethyl Siloxane	1.40	1.25					Uthman, 2012
Toughened Epoxy Resins			ND	0.43	ND	ND	
Elastomeric Acrylic Resin	ND	ND					Whidad & Emad, 2009
Epoxy Resin			ND	ND	ND	21.83	
Filled with Ferrite Powder							Procopio et al, 2012
	ND	ND					
Methyl methacrylate resin			ND	ND	ND	68	
							Stabic et al,
Polyvinyl Chloride Resin	ND	1.17					2009
			ND	10000-15000	ND	ND	Im et al, 2009
	1.49	1.16					
							Unar et al,
			160	ND	ND	ND	2010
	ND	ND					
			ND	ND	ND	56	

ND= Not Determined

IV. CONCLUSION

This study examined the effect of using different concentrations of waste EPS on some physical properties of EPS binder solution. It shows that the concentration of waste EPS has an effect on the physical properties of EPS. At a concentration below 20% w/v, the binder is soluble in water. This suggests that the processing of waste EPS binder for emulsion paint formulation should be done below this concentration. The implication is that, for emulsion paint formulation using polystyrene as binder, low viscosity is a processing necessity. The research also indicates that converting waste polystyrene to paint binder is an efficient way of recycling waste EPS and creating wealth out of waste.

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