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Effect of Polystyrene Concentration on the Development of Polystyrene Oil as a Solvent and Binder for Non-Volatile Oil Paint Formulation

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ABSTRACT

In this study, waste polystyrene (PS) plastic was converted into a binder and solvent via pyrolysis. The physicochemical properties of the polystyrene oil (PSO) and the binder at different concentrations (10%-30%) were investigated. The density ranged from 0.8567 to 0.8797 g/cm^3, viscosity, 6.3 to 8.2 cP; refractive index, 1.3601 to 1.4214; melting point, 155.3 to 179.8 ^{o}C; dry time, 240 to 385 minutes; and turbidity, from 97.3 to 192.8 NTU. The performance test for the oil was also carried out and the result showed that, at the velocity of 1.6 cP which was obtained for PS oil, there was no film formation when applied on a testing substrate. Various weights of PS solid (10 g, 15 g, 20 g, 25 g and 30 g) were dissolved in separate volumes of 100 g/cm^3 of PS oil, and were tested for their performance on substrates: some failed and some passed the film formation test. Blending of the PS/PSO binder was carried out. It revealed that binder with 20 g of PS (P20) is with values within the acceptable standard as a binder in the coating industry. Polystyrene which would have been a polymer waste is recycled and utilized for coating application.

Key Words: Polystyrene; binder; paint; plastics; coating

INTRODUCTION

As the world's population grows, so does the amount of plastic that is consumed, which leads to an increase in plastic trash. Although there are alternative methods for dealing with plastic waste, the most popular one is still disposing of it in landfills, which is an unsustainable approach [1]. The disposal of plastic waste in landfills has several negative effects on the environment and public health because it is not biodegradable. Many studies have been conducted to develop safe and environmentally beneficial solutions to plastic waste [2].

Out of the six plastic waste management strategies (landfills, recycling, pyrolysis, liquefaction, road construction and tar), the most effective ones are road construction, tar

and concrete manufacturing. This is due to the numerous benefits, which include lower greenhouse gas emissions, simpler localization, and better sustainability and longevity of buildings, roads, and manufacturing products [3]. On the other hand, landfills are the least preferred option because to the related health and environmental risks. Recycling offers both advantages and disadvantages. In contrast, pyrolysis and liquefaction are advantageous because they produce fuel and char [4].

Polystyrene plastic waste can be recycled and used for the production of different valuable products. Though recycling programmes for polystyrene are not currently in place on a large scale [5]. An interesting application of the recycled material is in the preparation of a paint binder from waste polystyrene pyrolysis oil. Over the years, there have been gaps in the preparation of a binder that that does not contain volatile organic compounds (VOCs) in the cause of formulation of paints [6]. These VOCs when released from paints during usage go into the atmosphere and deplete the ozone layer thereby leading to global warming. This research to prepare a novel binder that does not contain any VOCs in the vehicle to be used in the formulation of non-volatile oil paint. Therefore, it is important to minimize the waste by applying various practical approaches such as prevention, minimization, reuse or recovery [7].

Therefore, the aim of this study is to find out the effect of polystyrene when dissolved in PSO so as to build up the viscosity of the PSO/PS as a binder and solvent in the formulation of non-volatile oil paint.

MATERIALS AND METHODS

The waste polystyrene was collected from electrical appliances shops and stores and construction packaging all in the Jimeta Metropolis of Yola, Adamawa State, Nigeria. The PS was cleaned, dried and shredded into smaller particles.

Pyrolysis batch reactor (fabricated) was used. Vibroviscometer, model (SV-10), Stopwatch, Density Bottles, LaMotte smart2digital Turbidimeter, Heidolph stirrer No 50111, digital pH meter HI 2211 by Hanna Instruments, LA 164 weighing machine, Measuring Cylinder, Optimelt Automated melting system, Thermometer, Desiccators, and Refractometer 700 model.

Pyrolysis Experimental Set-Up for Pyrolysis of PS

A pyrolyser (batch-reactor) was fabricated that operated at a maximum temperature of 700 ^{o}C with water condenser and reactants tank. A galvanized iron cover loading waste PS was

put in the furnace and a lead for the feedstock was located in the centre of the furnace heating zone. A thermocouple was attached to the furnace to read the pyrolysis temperature with a heating rate of 10 $^{o}Cmin^{-1}$.

Determination of the physicochemical properties of the PS oil

Determination of pH

The pH of the PS oil was evaluated using a digital pH meter HI 2211 by Hanna Instruments. Triplicate readings were taken and the average value was recorded [8].

Determination of density

The density was determined according to AOAC [9]. A weighing balance was used to weigh a known volume of the resin in a density bottle in order to estimate the density of the resin. The mass-volume connection was used to determine the density (Equation 1). For the sample, three readings were made and the average value was determined.

$$\text{Density} = \frac{(\text{wt of empty bottle} + \text{sample}) - (\text{wt of empty bottle})}{\text{volume of sample}} \quad (g/cm^3) \qquad (1)$$

Determination of melting point

The melting point of the sample was determined by using an Optimelt Automated melting system. Three different readings were taken for the sample and the average was calculated. The above property was determined according to standard method (10).

Determination of refractive index

The refractive index of the resin sample was determined using Refractometer 700 model [11]. Three different readings were taken for each sample and the average were calculated and recorded.

Determination of turbidity

The turbidity of the binder was determined by using LaMotte smart2digital Turbidimeter. Triplicate readings were obtained and the average value taken. The above property was determined according to Osemeahon and Archibong [12].

Determination of viscosity

About 50 ml of the sample was used to determine the viscosity using a vibroviscometer, model (SV-10). Triplicate readings were taken and the average value was recorded [13].

Determination of specific gravity

This test was carried out to evaluate the ratio of the density of a substance to the density of the referenced substance (9).

$$\text{Specific gravity} = \frac{w_2 - w_o}{w_1 - w_o} \quad (2)$$

W_1 = Wt of paint + density bottle

W_2 = Wt of H_2O + density bottle

W_o = Wt of empty density

Effect of polystyrene solid concentration on the physicochemical properties of polystyrene oil/polystyrene solid

A known mass (10 g, 15 g, 20 g, 25 g and 30 g) of PS solid was separately weighed and added into each beaker containing 100 cm^3 of PS oil. The solutions were left to dissolve effectively at room temperature for 24 hours. Then the content of each beaker was put in a container with a tight cover and kept for various analyses to determine some of the physicochemical properties. The optimized binders were characterized so as to ascertain some of their physicochemical properties such as viscosity, turbidity, refractive index, melting point, pH, drying time, adhesion and blistering properties.

RESULTS AND DISCUSSION

Table 1 shows the effect of PS solid on PS oil.

Table 1: Effects of PS on PS oil viscosity and performance

PS Oil (g/dm^3)	PS added (g)	Viscosity (cP)	Film formation
100	0	1.6	Fail
100	10	6.8	Fail
100	15	7.1	Pass
100	20	7.5	Pass
100	25	7.9	Pass
100	30	8.2	Pass

The physiochemical test has shown that PS oil when extracted from PS has low viscosity between 1.2 cP to 1.7 cP. The test carried out using this PS oil gave a viscosity of 1.6 cP which was tested for the formulation of binder. The performance test of the PS oil did not form any film because of the low viscosity of the oil. The test showed that the oil was wet and created runs. Hence, it was instead used as a solvent because of its low viscosity of 1.6 cP in the formulation of a non-volatile oil paint [14].

Consequently, the viscosity of the PS oil was built-up by adding known mass of PS (10 g, 15 g, 20 g, 25 g, 30 g) in separate test volumes of 100 g/dm^3 of PS oil. Various viscosities were obtained for the different samples. Performance test was carried out for each of the samples and the best sample with physical/chemical parameters and particularly the viscosity that meets the standard was selected to be used as the binder. The binder with the viscosity of 7.5 cP was selected.

Utilization of the PS Oil/PS Solid as Binder

Effect of Solid PS Concentration on refractive index

The effect of solid PS concentration on refractive index is shown in Figure 1.

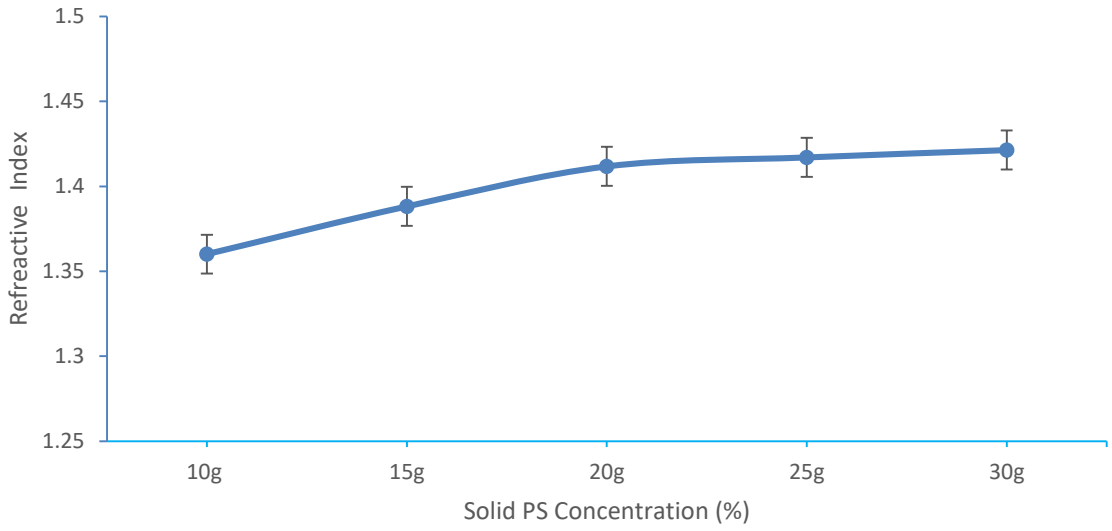

Figure 1: Effect of concentration on refractive index

It is observed that the refractive index increases with increase in the binder concentration which is in agreement with previous research works [15]. The change in the refractive index of binder concentration from (1.43–1.47) % in the blended binder samples could be as result of intermolecular orientation in the polymer material.

Gloss is as a result of the reflection and absorption of light and it is a necessary coating property when the aesthetic or decoration of the surface becomes the desired. Specifically, the binder sample with 30 g concentration exhibit the highest refractive index of 1.4214, while the binder of 10 g results in the lowest refractive index. Similar result was obtained by Sonntag et al [16] which shows the effect of concentration on the refractive index of expanded polystyrene (EPS) binder. This phenomenon can be explained by the

intrinsic properties of the materials involved. As the concentration of concentration increases, the refractive index rises, possibly due to an increase in the discontinuities within the molecular structure of the resin or as a rise in crosslinking density [17].

The values of refractive index of this binder is important as it has effect on the gloss. The values obtained for this binder fall within the acceptable standard of other binders in the coating industry [18, 19].

Effect of solid PS concentration on turbidity

Figure 2 shows the effect of concentration of binder on turbidity

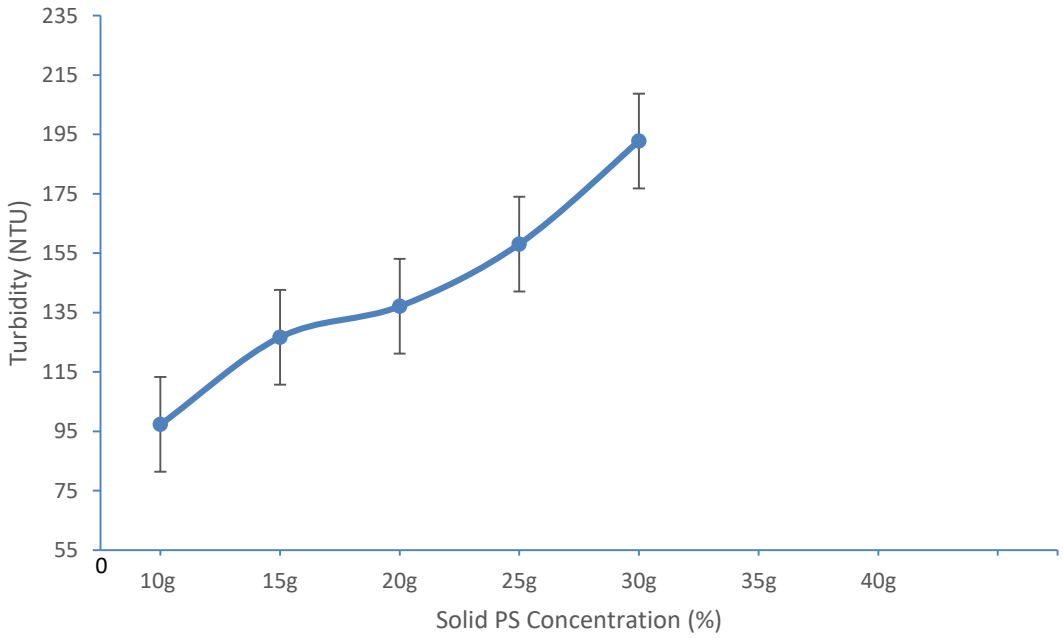

Figure 2: Effect of solid PS concentration on turbidity

The turbidity values provide an understanding of how the composition affects the optical clarity of the material. The data indicates that a higher concentration of the binder leads to decrease in turbidity, with the binder 30g showing the highest turbidity value of 192.8 NTU and the binder 10 g showing the value of 97.3 NTU.

The phenomenon observed can be attributed to the particle size and distribution in the solution. The blended binders likely form smaller particles that scatter light more effectively, thereby increasing turbidity. As the concentration of the binders increased, the particles are less prevalent, resulting in decreased light scattering and consequently, lower turbidity. This is consistent with the principle of light absorption and refraction, where an increase in the concentration of less turbid component dilutes the overall turbidity of the solution [19].

These findings align with the previous research by Gidibi et al [20], who observed a decrease in turbidity with increase in the concentration within a copolymer matrix. This similarity in behaviour reinforces the understanding that turbidity is influenced by the concentration and nature of the components within a composite.

Turbidity, defined as the degree of cloudiness or haziness in a fluid is a key parameter in assessing the quality and suitability of materials for various industrial applications, especially those requiring optical clarity [20]. The insights gained from this study are valuable for industries that rely on the precise control of material properties such as in the production of coatings; where the visual appearance of the product is critical. It may be associated with the mismatch in terms of refractive indices of the randomly oriented amorphous polymeric strands as well as connected with the change in the molecular morphology as the concentration increase. This intermolecular aggregate and cross-linking increases to the light scattering critical point [21].

Effect of solid PS concentration on density

Figure 3 shows the effect of solid PS concentration on density

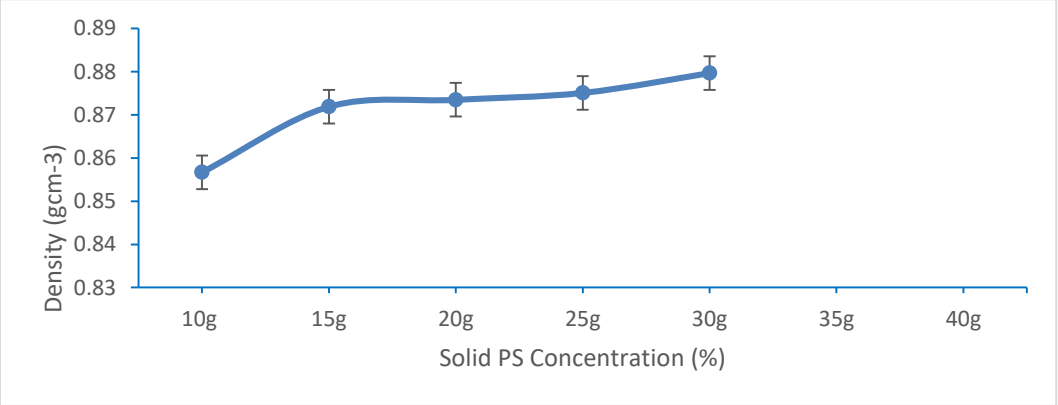

Figure 3: Effect of solid PS concentration on density

The density of the solid PS concentrations decreases with increasing addition of PS solid. The density of the binder concentration decreased from 0.8567 g/cm^3 in binder 10 g to 0.8797 g/cm^3 in binder 30 g as its concentration rises· The density increase observed with a lower binder concentration can be linked to the greater molecular weight of the PS solid which inherently possesses a higher density than PS fuel oil. Increase in the concentration of PS solid led to the gradual decrease in the density of the binder concentration.

Density is a physical property of matter that expresses a ratio of mass to volume and is an important physical parameter in polymer engineering processes. Density depends on

the atomic mass of an element or compound. Since different substances have different densities, density measurements are very useful for the identification and characterization of different substances and a significant factor that affects the production cost and profitability of the manufacturing process. The density of a binder in the adhesive and coating industry has an important influence on factors such as dispersion, flow and spreading of binder [22].

Effect of solid PS concentration on viscosity

Figure 4 shows the effect of solid PS concentration on viscosity

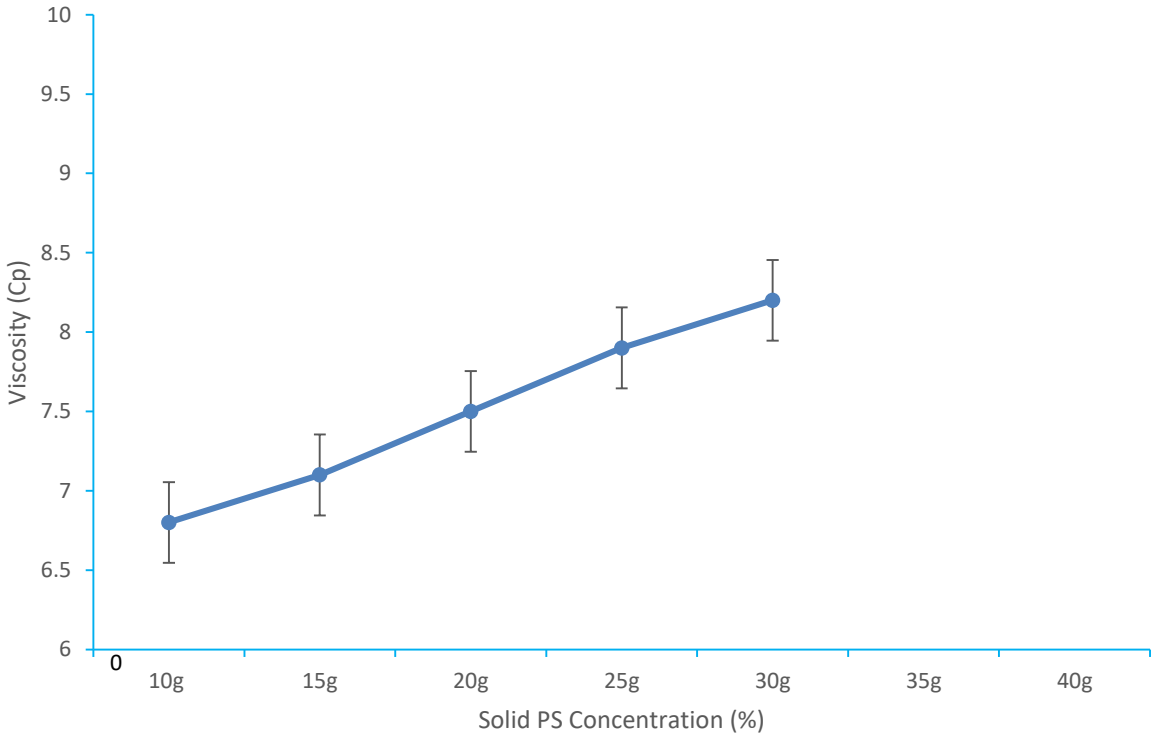

Figure 4: Effect of solid PS concentration on viscosity

The viscosity is observed to rise gradually until it reaches 30% concentration. Increase in viscosity, arises as a result of the increase in the polymer strands of the binder concentration. This in turn alters the cumulative mobility of the macromolecules in the solution as number of chains per unit volume with the concentration rises [23]. The increase signaled increment in the intermolecular attraction between the polymer strands. The polymer cross-linking may also contribute to the increase in the viscosity. This explains the reason why there is a steady rise from 6.8 in binder 10 g to 8.2 g in binder 30 g, hence, as the binder concentration load increases, the molecular flux of the resin density rises [24].

Effect of solid PS concentration on pH

Figure 5 shows the effect of solid PS concentration on pH

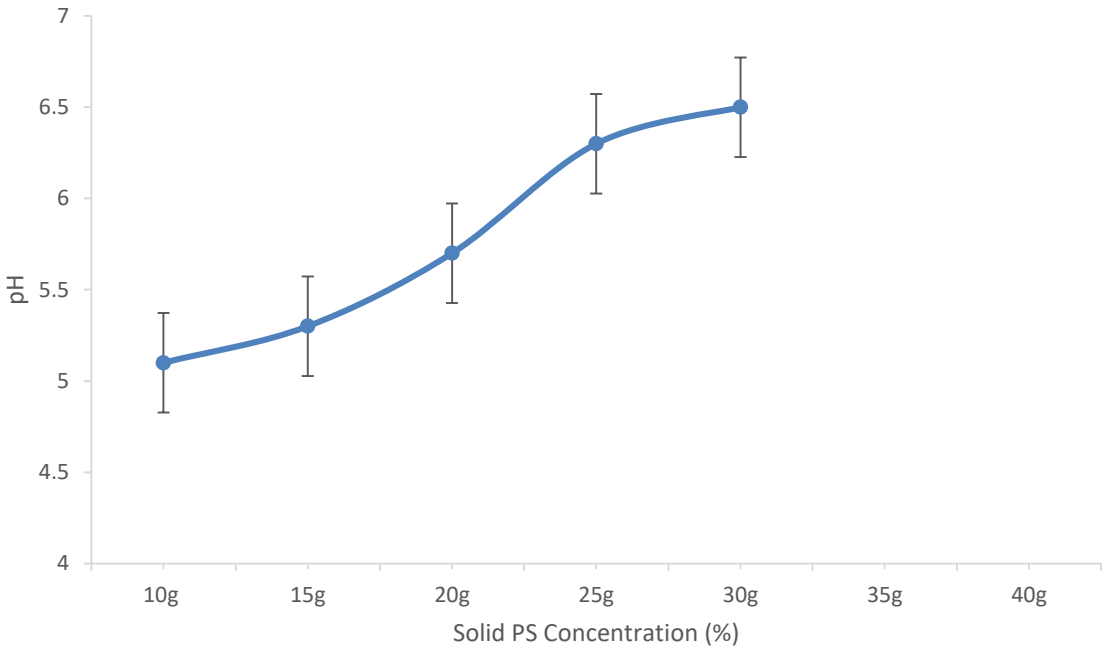

Figure 5: Effect of solid PS concentration on pH

The pH is observed to rise optimally from medium towards neutral; and these results were obtained at 28 ^{0}C. The result is indicative that these binder concentrations are of close range in terms of acidity. Within this pH range, the resins qualities are not susceptible to serious threats of corrosion and deterioration of iron surfaces and wood and walls as a result of their exposure of the surface they are applied on to air, water and soil [25]. The major influence on pH might have been the degree of acidity of the binder sample 10 g; which has a pH value of 5.1. pH speeds up the rate of hydrolysis of resin. One of the factors affecting the functionality of binder is the pH, thus requires adjustment of the type of pH adjusters that is used in the formulation of the paint [26].

Effect of solid PS concentration on melting point

Figure 6 shows the effect of solid PS concentration on melting point.

The result shows a gradual increase in the melting point with increase in the concentration. The highest value of the melting point is obtained in binder concentration 30 g with the value of 179.8 ℃whereas the lowest value of the melting point obtained is in binder concentration 10 g with a value of 155.3 ℃. The increase in melting point with increase in concentration could be as a of polymer detachment.

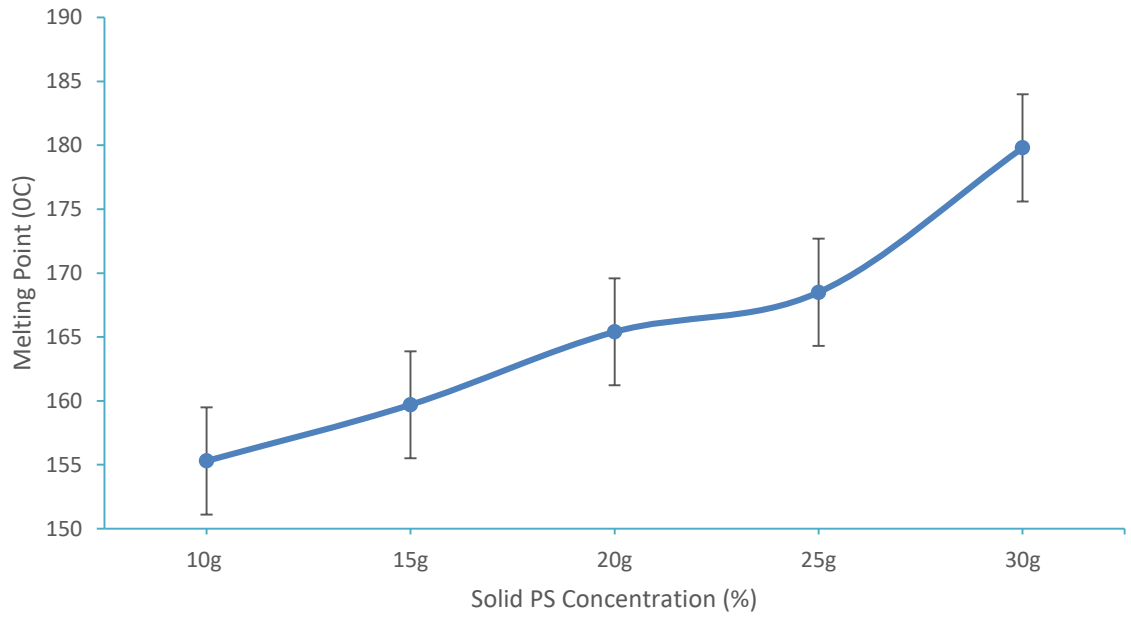

Figure 6: Effect of solid PS concentration on melting point

The melting point of a polymer is connected to its viscosity, molecular weight and the grade of crosslink density. Specifically, in coating industry, the melting point of a binder is related to its thermal resistance as well as its brittleness. Melting point of polymers varies depending on the molar mass, intermolecular Van der Waals interactions and intrinsic structures that affect the rigidity [27].

Effect of solid PS concentration on drying time

Figure 7 shows the effect of solid PS concentration on drying time.

The highest drying time is obtained in binder 30 g with the value of 385 minutes while the lowest value of dry time was obtained in binder 10 g with a value of 240 minutes. All other values of the dry time for the binders fall within the highest and lowest values obtained. The dry time of any paint is a function of its binder gel time among other factors. On the technical front, the dry time enable paint formulators to ascertain the optimum storage period of a binder before its utilization for paint formulation and it is important in the determination of adhesion [26, 29, 30].

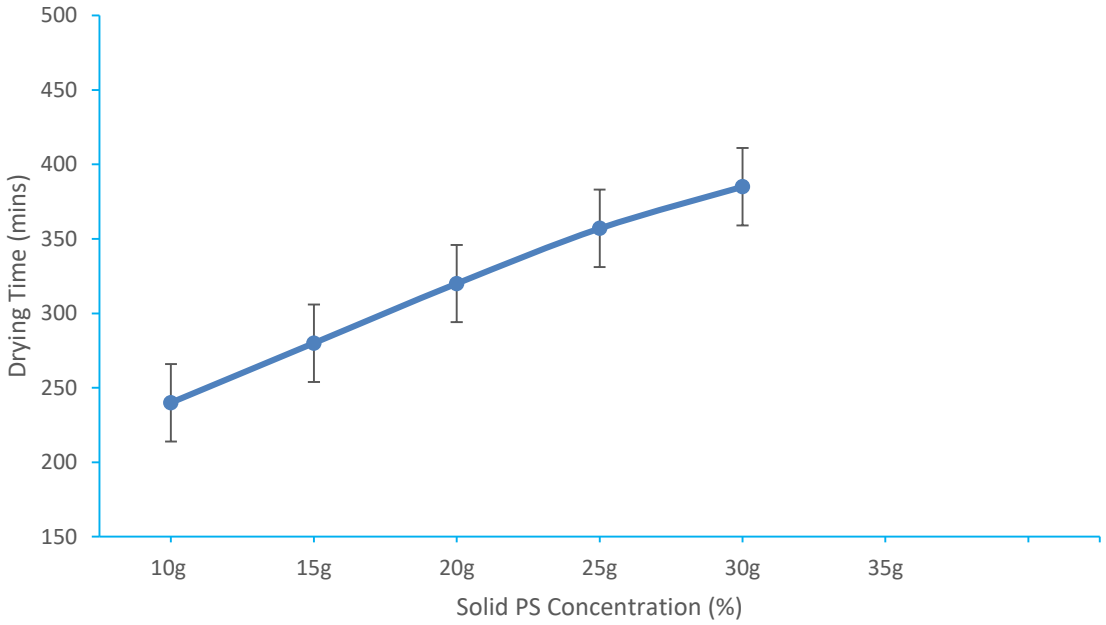

Figure 7: Effect of solid PS concentration on drying time

From the graph, it can be seen that the dry time increases gradually as the concentration increases. This behavior is attributed to the increase in the molecular weight and crosslinking density which leads to increase in the viscosity and reached a stage where nucleation process begins to produce micro gel particles which enhanced increase in the viscosity built up. The longer time it takes a polymer to gel, the same time it takes for the paint to cure or dry. Short dry time is harmful to the paint film just like if the dry time is too long. This factor must be monitored in order to ascertain the rate it will take a paint formulated from a particular binder to dry [29].

Table 2 shows some physical properties of PSO/PS Solid Binder in comparison with other paint binders

Table 2: Comparison of resin with other binders

Types of Resin	Density (g/cm^3)	Refractive index	Melting Point (^0C)	Moisture uptake (%)	Viscosity (mPa.s)	Turbidity (NTU)	Literature
PSO/PS Solid	0.8735	1.4118	165.4	0.0	7.5	137.1	Present study
DMU	1.1840	1.4210	261.4	3.00	10.30	112	[17]
DMU/PS	1.0583	1.4245	205.70	0.61	149.45	597	[17]
PS(diff. solvent)	0,82	1.454	164	2.00	200	1000	[33]
PS(gasoline solvent)	0.84	1.464	168	2.00	500	1000	[33]
TMU/PS	1.0990	1.425	262	1.02	19.70	1100	[34]
DMU/PS	1.1953	1.4295	181.42	0.26	35.60	611	[33]
TMU/PS	1.0990	1.4250	262	1.01	19.70	878	[34]
Commercial UF	ND	ND	ND	2.00	451	ND	[32]
TMU/NR	0.5708	1.3501	260	ND	220	ND	[33]
UF/CS	1.166	1.417	130.00	0.6	11.1	ND	[34]
XASO	0.912	1.467	ND	ND	900	ND	[24]
Innovative UF	ND	ND	ND	0.25	ND	ND	[35]
MAGPP/ER	ND	ND	ND	200	ND	ND	[36]
EBDE	1.04	ND	179	ND	38.0	ND	[37]
AESO	ND	ND	ND	ND	13,000	ND	[38]
RSOMAR	0.95	ND	ND	ND	3.11	ND	[39]

CONCLUSION

The pyrolysis of waste polystyrene plastic to obtain polystyrene oil was successfully carried out. This study examined the effect of polystyrene solid on polystyrene oil and its effect on the physicochemical properties of the PS/PSO binder solutions. It showed that the concentration of the polystyrene has an effect on the physical properties of the binder. At a concentration below 20%w/v, the binder had high viscosity. This shows that the formulation of a non-volatile oil paint should be done below this concentration. The implication is that, for oil formulation using PS/PSO as a binder, high viscosity is a processing necessity. The research also indicates that converting waste polystyrene to oil paint binder is an efficient way of recycling waste PS, thereby providing a simple economic route for the recycling of waste polystyrene and hence an important practice for sustaining recycling.

REFERENCES

[1] Hunt, A.J., Sin, E.H.K., Marriott, R. & Clark, J.H. (2015). The sustainable use of plastics. In: *Waste: A Handbook for Management*, 2nd ed., pp. 321-340.

[2] Aisbl, P. (2018). Plastics - the Facts 2018: An analysis of European plastics production, demand and waste data. *Plastics Europe*, pp. 1-60.

[3] Mwanza, B.G., Mbohwa, C. & Telukdarie, A. (2018). Strategies for the management of plastic waste. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, pp. 1-12.

[4] Andrady, A.L. (2003). *Plastics and the Environment*. John Wiley & Sons.

[5] Gu, L., Ozbakkaloglu, T. & Han, Y. (2010). Recycling of waste polystyrene. *Journal of Cleaner Production.* 18(4), 331-339.

[6] Carter, A. (2017). *Paint Formulation and Application*. Springer.

[7] Vilapana, F. & Karlsson, S. (2008). Recycling of plastics. In: *Handbook of Environmental Degradation of Materials*, pp. 583-606.

[8] Vilas, V., Gupta, S.K. & Sharma, D. (2000). Determination of pH in polymer solutions. *Journal of Polymer Science*. 45(3), 234-241.

[9] AOAC (2000). *Official Methods of Analysis*, 17th Edition. Association of Official Analytical Chemists, Washington, DC.

[10] Yelwa, J.M., Barminas, J.T. & Osemeahon, S.A. (2017). Characterization of polymer binders. *Journal of Applied Polymer Science*. 134(8), 1-8.

[11] Oluranti, A., Adebayo, A. & Akinlade, O. (2011). Refractive index measurements in polymer science. *Polymer Testing*, 30(5), 543-549.

[12] Osemeahon, S.A. & Archibong, A.E. (2011). Turbidity measurement in polymer blends. *Journal of Polymer Materials*. 28(4), 567-574.

[13] Osemeahon, S.A. & Dimas, B.J. (2014). Viscosity and physicochemical properties of TMU/PS binders. *International Journal of Polymer Science*. 1-9.

[14] Caesar, E.J., Osemeahon, S.A. & Barminas, J.T. (2024). Preparation of non-volatile oil paint binder from waste polystyrene. *Journal of Coatings Technology and Research*. 21(2), 345-358.

[15] Osemeahon, S.A., Barminas, J.T. & Musa, H. (2013). Physicochemical properties of polystyrene binders. *Journal of Chemical and Pharmaceutical Research*. 5(6), 78-85.

[16] Sonntag, R., Beyer, P. & Oster, A. (2019). Refractive index of expanded polystyrene binders. *Polymer Engineering and Science*. 59(5), 1023-1030.

[17] Akinterinwa, A., Osemeahon, S.A. & Barminas, J.T. (2015). Preparation and characterization of DMU/PS blend binders. *Journal of Applied Polymer Science*. 132(15), pp. 1-10.

[18] Archibong, A.E., Osemeahon, S.A. & Dimas, B.J. (2021). Coating industry standards for refractive index. *Progress in Organic Coatings*, 152, 106132.

[19] Osemeahon, S.A. & Barminas, J.T. (2007). Light scattering properties of polymer solutions. *Journal of Polymer Research*. 14(4), pp. 287-294.

[20] Gidibi, S., Barminas, J.T. & Osemeahon, S.A. (2019). Turbidity behavior in copolymer matrices. *Journal of Polymer Engineering*. 39(7), 611-618.

[21] Khwaldia, K., Linder, M. & Salmieri, S. (2005). Light scattering in polymer systems. *Journal of Food Engineering*. 68(3), 345-353.

[22] Kazys, R. & Rekuviene, R. (2011). Density measurements in polymer processing. *Polymer Testing*, 30(8), pp. 891-897.

[23] Godinho, M.H., Ribeiro, A.C. & Martins, A.F. (2012). Polymer viscosity and molecular mobility. *Journal of Polymer Science Part B: Polymer Physics*. 50(8), 561-568.

[24] Oladipo, O.O., Osemeahon, S.A. & Barminas, J.T. (2013). Xylenol-formaldehyde resin as binder. *Journal of Coatings Technology and Research*. 10(4), 543-551.

[25] Abdulsalam, M. & Maiwada, U. (2015). pH effects on resin properties. *Journal of Polymer Materials*. 32(3), 301-310.

[26] Carter, J. (2016). pH adjusters in paint formulation. *Paint and Coatings Industry*, 32(5), 44-52.

[27] Afsoon, M., Sadeghi, M. & Hamidi, A. (2011). Melting point behavior of polymers. *Journal of Thermal Analysis and Calorimetry*. 104(3), 1027-1035.

[28] Desai, S.R., Shah, P.P. & Patel, H.S. (2003). Drying time of paint binders. *Pigment & Resin Technology*, 32(4), 215-222.

[29] Menkiti, M.C. & Onwuli, D.O. (2011). Binder gel time and paint drying. *Progress in Organic Coatings*, 72(3), 421-428.

[30] Ayoub, M., Zia, K.M. & Bhatti, I.A. (2013). Adhesion properties of polymer binders. *International Journal of Adhesion and Adhesives*. 44, 1-7.

[31] Osemeahon, S.A., Barminas, J.T. & Musa, H. (2015). DMU/PS blend binder properties. *Journal of Polymer Engineering*. 35(4), 341-349.

[32] Suurpere, J., Klas, E. & Tamm, T. (2006). Commercial UF binders. *European Polymer Journal*. 42(8), 1889-1896.

[33] Osemeahon, S.A. & Barminas, J.T. (2013). TMU/NR binder properties. *Journal of Adhesion Science and Technology*. 27(15), 1673-1684.

[34] Dimas, B.J., Osemeahon, S.A. & Barminas, J.T. (2013). UF/CS binder characterization. *Journal of Applied Polymer Science*. 128(6), 3985-3993.

[35] Zorba, T., Papadopoulos, A. & Salmieri, S. (2008). Innovative UF binder properties. *Journal of Polymer Research*. 15(5), 381-389.

[36] Shieh, J.Y., Chiou, K.C. & Hung, K.Y. (2001). MAGPP/ER binder properties. *Journal of Applied Polymer Science*. 82(7), 1743-1750.

[37] Gawdzik, B. & Matynia, T. (2001). EBDE binder characterization. *Journal of Polymer Science Part A: Polymer Chemistry*. 39(15), 2669-2677.

[38] Habib, F. & Bajpai, M. (2011). AESO binder viscosity. *Journal of Coatings Technology and Research*. 8(3), 341-348.

[39] Aigbodion, A.I. & Pillai, C.K.S. (2001). RSOMAR binder properties. *Journal of Applied Polymer Science*. 80(7), 1079-1086.