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Development of Polypropylene Plastic Wastes into Emulsion Paint Binder for Water-Resistant Emulsion Paint Formulation

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ABSTRACT

This study addresses the urgent need for sustainable management of plastic waste by presenting a novel approach to convert Polypropylene (PP) waste into a hydrophobic emulsion paint binder. Polypropylene (PP) waste was pyrolised to give pyrolysis oil. Various properties of PP pyrolysis oil, including density, (0.8254g/cm3), viscosity (2.94 cp), refractive index (1.153 bxSc), turbidity (77 NTU), water dispersibility (slightly dispersed), and flashpoint (71 °C) were investigated. This results falls short in crucial aspects like film formation and viscosity. To address these limitations, blending PP pyrolysis oil with Polystyrene (PS) pyrolysis oil was carried out and the result revealed viscosity to be 4.06 cp and film formation was achieved. PS pyrolysis oil possesses complementary properties such as viscosity (4.06 cp), and film formation ability that could enhance the performance of PP pyrolysis oil as a binder. Analysis techniques including FTIR, XRD, SEM, and AFM were employed to characterize the properties of PS, PP and PP/PS blends, demonstrating the potential synergies between the two materials. The resulting PP/PS binder was used to formulate emulsion paint and the quality of the paint investigated. The emulsion paint from PP/PS binder proved to be of high quality with exceptional water resistant behavior (waterproof). This research offers a promising avenue for converting waste into wealth while addressing the poor water resistant associated with conventional emulsion paint and the issue of environmental pollution emanating from plastic waste.

Keywords: *Polypropylene, Polystyrene, Plastic Waste, Pyrolysis, Emulsion Paint, Binder.*

1. INTRODUCTION

Plastics have become indispensable in modern society, serving a multitude of purposes from agriculture to packaging [1]. However, the rampant accumulation of plastic waste globally has triggered significant environmental concerns [2]. Plastic waste not only blights landscapes but also infiltrates water bodies and oceans, with an estimated 1.1 to 8.8 million tonnes entering the ocean annually [3]. By the end of 2013, approximately 86 million tons of plastic marine debris had amassed in the world's oceans [4], a figure that may surpass the weight of fish by 2050 [5].

Despite efforts to curb plastic pollution, such as reducing consumption and promoting recycling, the global production of plastic continues to soar, exceeding the biomass of all land and marine animals combined [6]. Even regulatory measures, such as the Basel Convention amendment in May 2019, have been insufficient to stem the tide, although they aim to curtail the exportation of plastic waste from developed to developing nations [7].

The COVID-19 pandemic has exacerbated the plastic waste crisis, with heightened demand for single-use protective gear and packaging materials leading to a surge in plastic pollution, particularly in oceans [8]. Amidst reports of the plastic industry exploiting health concerns to boost production of disposable items [9], the urgency for effective plastic waste management has never been greater.

While conventional recycling methods have limitations, pyrolysis emerges as a promising solution for managing plastic waste, especially polypropylene (PP) plastics, which are notoriously under-recycled due to contamination and market challenges [10]. Pyrolysis, a thermochemical conversion process, offers an environmentally friendly approach to transforming plastics into valuable fuels and chemicals [11]. This study focuses on the pyrolysis of polypropylene plastics, aiming to valorize waste materials into useful resources.

Transitioning from plastics to another ubiquitous material, paint, the demand for which has surged alongside infrastructure development, underscores the need for sustainable formulations. Emulsion paint, a staple in architectural coatings, relies on binders, solvents, pigments, and additives to deliver both aesthetic appeal and protective qualities [12].

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The binder, often polyvinyl acetate (PVAc), constitutes a significant portion of paint production costs and poses environmental concerns due to its non-biodegradable nature [13]. Solvents, pigments, and additives play crucial roles in paint formulation, offering desired properties and enhancing performance.

In this study, the physicochemical properties of Polypropylene (PP) pyrolysis oil were determined. The density of PP pyrolysis oil is 0.8254. It is relatively lightweight compared to conventional binders used in paints (acrylic binders). The viscosity of PP pyrolysis oil is 2.94 cP. This is lower than typical emulsion paint binders, (acrylic) which can range from 5.00 to 6.00 cP. [14]. The refractive index of PP pyrolysis oil is 1.153. This value is lower than the acceptable level (1.400) in the coating industry. The refractive index of PP Pyrolysis oil is low as a result of its low molecular weight and crosslinked density. The turbidity of PP pyrolysis oil is 77. The value is relatively low. This factor could positively affect its optical properties and transparency in paint formulations. There was a slight dispersion of 2 ml of PP pyrolysis oil in 20 ml of water which indicates limited miscibility between the two substances. This suggests that while some dispersion or mixing may occur, it is not sufficient to create a uniform solution or emulsion. The moisture uptake was not determined; this is due to the failure of PP pyrolysis oil to form a film which suggests that it may not be suitable as a standalone binder for emulsion paint formulations, particularly in applications where moisture resistance is important. Melting point and elongation at break could not be determined in PP pyrolysis oil, due to its inability to form a film which indicates that it lacks the necessary properties to undergo a phase transition from liquid to solid. The inability of PP pyrolysis oil to form a film can be due to its low molecular weight and cross-linking density.

The physicochemical properties of Polypropylene (PP) pyrolysis oil, shows the inability of PP pyrolysis oil to meet the required characteristics of an emulsion paint binder, such as forming a film, undergoing moisture uptake, and potentially lacking flexibility and film-forming ability, which suggests that it may not be suitable for standalone use in paint formulations. However, blending PP pyrolysis oil with PS (polystyrene) pyrolysis oil could offer a potential solution to enhance its compatibility and performance as a binder in emulsion paint formulations. Polystyrene pyrolysis oil, derived from the thermal decomposition of polystyrene, possesses complementary properties that could address some of the limitations of PP pyrolysis oil.

For instance, PS pyrolysis oil exhibits varying properties such as density (0.9192 g/cm3), refractive index (1.433 bxSc), turbidity (57 NTU), moisture absorption (0.001 %), melting point (125 oC), elongation at break (1200%) and film-forming attributes in contrast to PP pyrolysis oil. These distinctions may contribute to enhancing the blend's overall efficacy and adaptability.

By blending PP and PS pyrolysis oils, it may be possible to achieve a balance of properties that meets the requirements for emulsion paint binders. Blending PP pyrolysis oil with PS pyrolysis oil holds promise as a potential strategy to overcome the limitations of PP pyrolysis oil and enhance its suitability as a binder in emulsion paint formulations. As the quest for sustainable solutions intensifies, exploring alternative binders and eco-friendly additives becomes imperative to mitigate the environmental impact of paint production and applications.

2.0 MATERIALS AND METHODS

Polypropylene (PP) plastic waste from various sources such as drinking straws, disposable cups, spoons, margarine containers, custard containers, and yogurt containers were collected from households and dumping sites in Sabon Gari, Girei LGA of Adamawa State. The collected plastics were primarily free of non-plastic contaminants and additives, ensuring the purity of the raw materials for the pyrolysis process.

2.1 Raw Materials for the Pyrolysis Process

Plastic dump *Sorted and clean PP.* *Shredded PP waste*

Plate 1: Waste plastics sorted from refuse into PP wastes and shredded for pyrolysis

2.2 Blending of PP with PS

The PP/PS pyrolysis oils were measured in a 40:60 % ratio and then transferred into a container. Using a stirring rod, the oils were thoroughly blended at a moderate speed to ensure even dispersion. Instrumental analysis of infrared (IR) analysis of PS, PP, and PP/PS blends was conducted using an infrared spectrophotometer, X-ray Diffraction (XRD*)* Analysis, Scanning Electron Microscopy (SEM) analysis and Atomic Force Microscopy (AFM) was utilized for dynamic analysis of PS, PP, and PP/PS and characterization of the blend was carried out.

2.3 Paint formulation

The formulation technique described by Akinteriwa *et al*. [15] to create water-resistant emulsion paint involved a three-stage production process:

1. Initial Preparation: Additives such as dispersants, deformer, thickener, anti-skin, drier, wetting agents, stabilizer, pH adjuster, and preservatives were added to create a conducive environment for particle dispersion. After introducing 185 mL of distilled water into the mixing tank, 12.7g of additives were added, and the mixture was stirred for 15 minutes using a high-speed stirrer.

2. Millbase Dispersion: Pigments and extenders were dispersed in the mill, termed the "millbase" stage. The stirrer speed was significantly increased, and the mixture was stirred for another 15 minutes to ensure thorough dispersion. Binder was intentionally omitted to prevent structural deformation under high mechanical forces.

3. Letdown Stage: The remaining additives from the initial stage were combined with 15 mL of water in the "letdown" stage. The mixture was stirred at a moderate speed for an additional 15 minutes. To minimize energy losses during millbase dispersion, thickeners were added before this stage.

The details of the formulations are in the table 1 below.

Table 1: Emulsion Paint Formulation Recipe of PP/PS as a Binder

Stage	Materials	Quantity (g)
Initial	Water	185
	Anti-foam	0.2
	Drier	0.2
	Calgon	1.16
	Genepour	1.16
	Bermocoll	2.5
	Troystan	1.14
	Dispersant	0.2
	Butanol	5
	Ammonia	10
Millbase	TiO_2	50
	$Al_2(SiO)_3$	11.2
	Na_2CO_3	0.58
	Kaolin	2.52
	$CaCO_3$	123
Letdown	Binder	200
	Water	15
	Dispersant	0.2
	Nicofoam	0.2
	Anti-skinning agent	0.2
	Total	**609.46**

2.4 Test Procedures for Paint Samples

Paint samples were analyzed following the guidelines outlined in the Niger Cedar laboratory handbook of paint formulation recipes and the methods set by the Standard Organization of Nigeria [16].

2.4.1 Viscosity

Viscosity was determined using a Brookfield DV-E viscometer, where 50 ml of paint was mixed with 200 ml of distilled water in a beaker. A spindle with number 63 was employed at a speed of 100%, spinning for approximately five minutes. Triplicate measurements were taken for each sample, and the viscosity was recorded in centipoise.

2.4.2 Stickiness (tackiness)

Stickiness was evaluated qualitatively by hand-feeling the dried film to determine its tackiness. Triplicate samples were assessed, and the average quality was recorded.

2.4.3 Water resistance

The water resistance test involved applying paint samples to smooth bricks, which were then immersed in water for seven days. Afterward, the bricks were removed, and poor water resistance was indicated by the presence of paint particles in the water.

2.4.4 pH and Opacity

Refinement of paint properties involved several procedures. pH levels were assessed using a Phywe pH meter (model 18 195.04), while opacity was gauged with a Mohest chart after allowing paint samples to dry for 24 hours.

2.4.5 Adhesion property

Adhesion was tested on metal panels by applying paint coats and conducting crosshatch tests. The adhesive tape was held at it 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 27-30oC for each sample for quality assessment.

2.4.6 Chemical resistance

Chemical resistance was evaluated on flexible aluminum panels immersed in various solutions (NaOH, HCl, NaCl) for 48 hours, and any surface defects post-treatment.

2.4.7 Dry time and flexibility

The evaluation of dry time involved applying the paint sample onto a glass panel using a bar applicator and allowing it to dry. The point at which the paint film was no longer sticky to the touch marked "dry to touch," while resistance to fingerprinting indicated "dry to hard." This process was repeated three times for each sample, and the mean values were recorded.

For flexibility testing, the paint sample was applied to freshly degreased and chromate treated aluminum using a paint applicator. After air-drying for seven days at room temperature (27-30°C), the panel with the film was bent 180 degrees smoothly over 1-2 seconds. Inspection for cracking or loss of adhesion indicated the presence of inflexibility or brittleness. Triplicate determinations were made for each sample at the specified temperature range for quality assessment.

2.4.8 Resistance to blistering

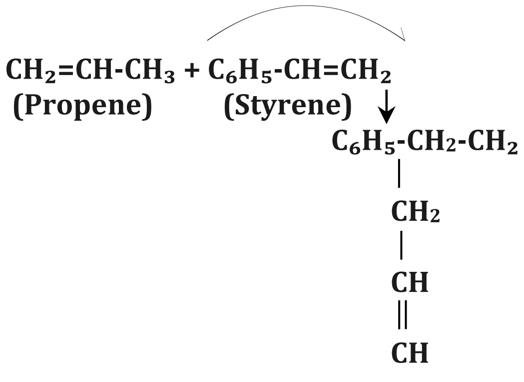
The assessment for resistance to blistering involved applying an undiluted paint sample onto a glass panel using an applicator, creating a wet film thickness of approximately 120um. After allowing it to dry for 24 hours, 4 ml of distilled water was placed as a circular drop on the film. Any blistering, wrinkling, swelling, or cracking observed within 30 minutes indicates inadequate water resistance. Quality assessment was based on the mean of triplicate determinations for each sample.

3.0 RESULTS AND DISCUSSION

PP Pyrolysis Oil PS Pyrolysis Oil PP/PS Pyrolysis Oil

Plate 1: Pyrolysis oil of PP, PS and PP/PS

Scheme 1: The structural reaction between propene and styrene:



$$CH_2{=}CH{-}CH_3 + C_6H_5{-}CH{=}CH_2 \rightarrow C_6H_5{-}CH_2{-}CH_2{-}CH_2{-}CH{=}CH$$

Polymer (PP/PS)

From the reaction above in scheme 1, the double bond in propene ($CH_2{=}CH$-) adds to the double bond in styrene (C_6H_5-$CH{=}CH_2$), forming a longer polymer chain.

3.1 Instrumental Analysis of PS, PP Pyrolysis Oil and PP/PS

3.1.1 FTIR Analysis

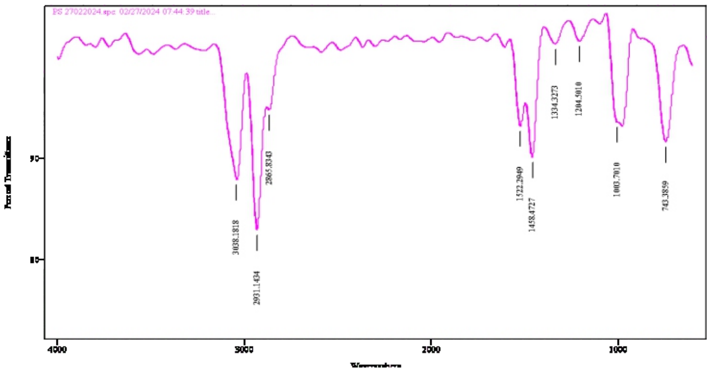


Figure 3.1: FTIR Spectrum of PS

In polystyrene, specific functional groups exhibit characteristic wavenumbers, as outlined below:

- 3038.1818 cm-1: Aromatic C-H stretch
- 2865.8343 cm-1 and **2931.1434 cm^-1**: Aliphatic C-H stretch
- 1458.4727 cm^{-1}: Benzene ring deformation
- 1522.2949 cm-1: Aromatic C-C stretch
- 1204.5010 cm-1: C-C stretching
- 1003.7010 cm-1: Aromatic in-plane C-H deformation
- 743.3859 cm-1: Out-of-plane aromatic C-H deformation

Polystyrene, a synthetic polymer composed of styrene monomers (C_8H_8), can be analyzed using FTIR to identify these functional groups. The resulting spectrum illustrates the absorption of infrared radiation by various functional groups within the molecule. For instance, the peak at 3038.1818 cm-1 signifies the presence of aromatic rings, while peaks at 2865.8343 cm-1 and 2931.1434 cm-1 indicate aliphatic C-H stretching [17]. This analysis provides compelling evidence of polystyrene's composition and structure.

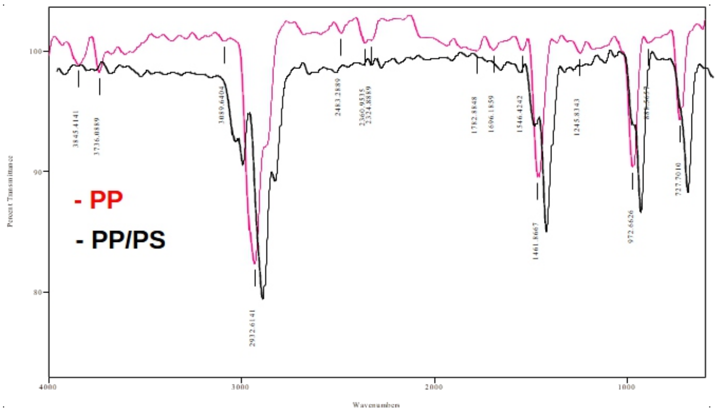


Figure 3.2: FTIR Spectra of Polypropylene (PP) and Polypropylene/Polystyrene (PP/PS)

Figure 3.2 showed the FTIR spectra of Polypropylene (PP) and (PP/PS). The peak between 3000-2800 cm^{-1} is assigned to the stretching vibrations of C-H bonds in alkanes. In the PP spectrum, there are two peaks observed at 3089.64 cm^{-1} and 2932.61 cm^{-1}, which can be assigned to the stretching of aliphatic CH groups in the polypyrole backbone [17]. In the PP/PS blend, these peaks are slightly shifted to 3074.41 cm^{-1} and 3033.13 cm^{-1}, possibly due to the influence of polystyrene aromatic rings [18]. The peaks between 1782 cm^{-1} (PP only) is assigned to the C=O stretching vibration of carbonyl groups. This peak is absent in the PP/PS blend spectrum, indicating that there are no carbonyl groups in polystyrene [19]. The peaks between 1500-1400 cm^{-1} is assigned to the bending vibrations of C-H bonds in alkanes. Both PP and PP/PS show peaks in this region at 1461.87 cm^{-1} (PP) and 1461.56 cm^{-1} (PP/PS), which can be assigned to the bending of CH_2 group. The peak 1200-1000 cm^{-1} is assigned to the stretching vibrations of C-C and C-O bonds. Both PP and PP/PS show a peak at 972 cm^{-1}, which can be assigned to the in-plane bending mode of aromatic CH groups in polystyrene [18].

The peak at 1782 cm^{-1}, assigned to the C=O stretching of carbonyl groups, is present in PP but absent in PP/PS. This indicates that there are carbonyl groups in Polypropylene that are not present in polystyrene. There are some minor shifts in the peaks between PP and PP/PS. These shifts could be due to interactions between the Polypropylene and polystyrene in the blend. The FTIR spectra confirms the presence of both Polypropylene and polystyrene in the PP/PS blend. The presence of characteristic peaks from both materials indicates that the blend is not miscible on a molecular level, but rather a physical mixture of the two components. The presence of both PP and PS characteristic peaks suggests a physical mixture rather than complete miscibility on a molecular level.

3.1.2. XRD Analysis

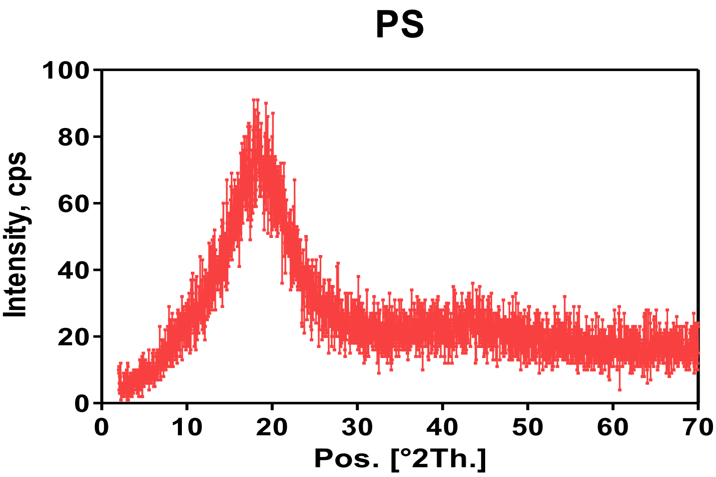


Figure 3.3: XRD spectrum of PS

The XRD spectrum of polystyrene confirms its primarily amorphous nature, as evidenced by a broad peak around 20° (2θ). This peak reflects X-ray scattering by short-range order within the polymer chains. While crystalline polystyrene exhibits distinct peaks, the absence of such defined peaks in this sample suggests minimal crystallinity [20].

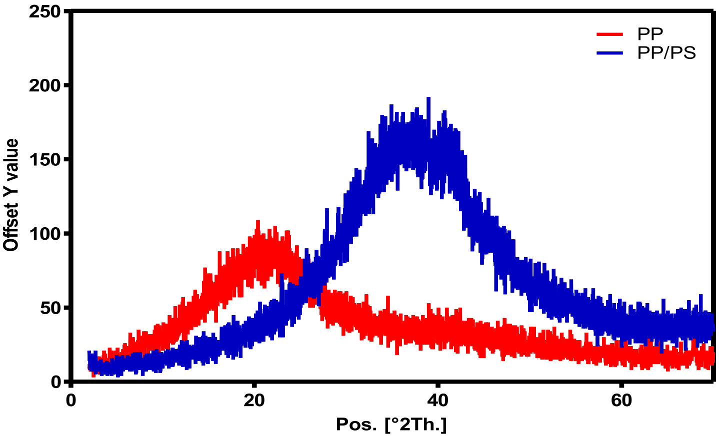


Figure 3.4: XRD spectra of Polypropylene (PP) and Polypropylene/Polystyrene (PP/PS)

The X-ray diffraction (XRD) analysis is a technique used to identify the crystalline structure of a material. In figure 8, the red line represents the intensity of the X-ray beam diffracted by the PP sample, and the blue line represents the intensity of the beam diffracted by the PP/PS sample. The X-axis of the graph shows the position (2 Theta) in degrees. The y-axis shows the offset Y value. The higher the intensity (y-axis), the sharper and more intense the peak, which indicates a more ordered crystalline structure.

The XRD pattern of PP showed a sharp peak at 21° (2θ). This peak correspond to the crystal structure and interatomic distances within the material. The intensity of the peaks reflects the degree of crystallinity in the sample. Both the PP and PP/PS samples show several sharp peaks, which suggests that both materials are semi-crystalline. Polypropylene (PP) is a semi-crystalline polymer, meaning it has both crystalline and amorphous regions. The amorphous regions are less ordered than the crystalline regions. Polystyrene (PS) is an amorphous polymer, meaning it does not have a well-defined crystalline structure [21].

The presence of PS, an amorphous polymer, affected the PP crystallinity. When PP and PS are blended, the crystalline structure of the PP is disrupted by the amorphous PS. This can be seen in the XRD pattern of the PP/PS sample, where the peaks are broader and less intense than the peaks in the PP sample. The disruption of the crystalline structure can affect the properties of the blend, such as its strength and stiffness [19]. New peak appeared in the PP/PS pattern due to PS crystallizing under certain blend conditions [17].

3.1.3. SEM Analysis

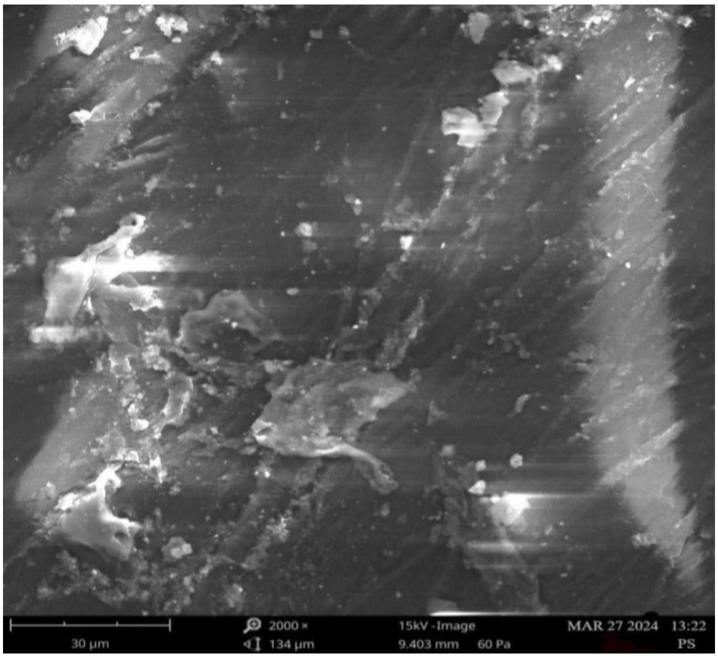


Figure 3.5: SEM of Polystyrene (PS) at x2000 magnifications

SEM images of polystyrene reveal significant changes in surface morphology, likely due to decomposition processes or environmental factors. The presence of irregular features such as pits and protrusions indicates structural alterations induced by decomposition. Additionally, variations in electron emission suggest differences in composition or surface characteristics within the sample [22].

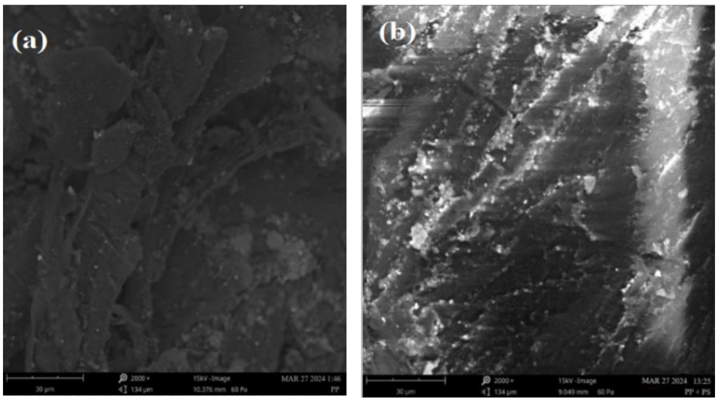


Figure 3.6: SEM of (a) Polypropylene (PP) and (b) Polypropylene/Polystyrene (PP/PS) at x2000 magnifications

Figure 3.6 shows SEM images for Polypropylene (PP) and Polypropylene/Polystyrene (PP/PS), showcasing the microstructure of materials at a high magnification level. (a) Polypropylene (PP), the surface displays a rough and irregular texture with fragmented shapes and particles, indicating a complex structure. On the other hand, (b) Polypropylene/Polystyrene (PP/PS) reveals a more structured surface with distinct striations and patterns, suggesting a layered material composition. Both images provide valuable insights into the microstructure of the materials, offering details on the surface texture, patterns, and features at a microscopic scale.

The smoother surface in the PP/PS image (b) suggests the presence of PS, which is typically a non-crystalline and amorphous polymer. The rougher, wrinkled features in the PP/PS image (b) are likely due to the presence of PP, which can adopt various morphologies depending on the synthesis conditions [23]. The observation of two distinct morphologies in the PP/PS blend suggests that PP and PS might be partially miscible on the microscale, forming separate domains within the blend [24].

3.1.4. AFM Analysis

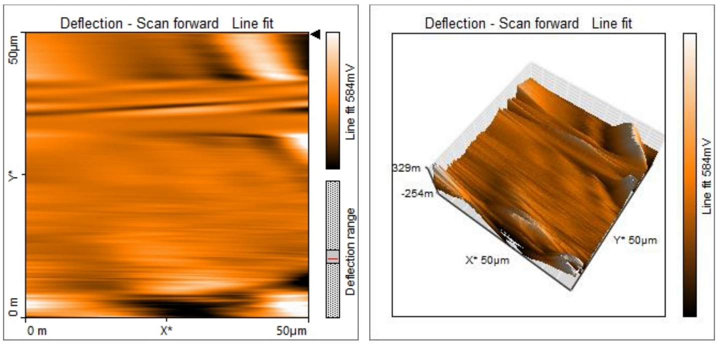


Figure 3.7: AFM analysis of polystyrene (PS)

AFM analysis provides high-resolution surface images of polystyrene, depicting its smooth surface with some roughness characteristics [25]. While the current representation appears simplified, AFM data can be presented in 2D or 3D formats, detailing height variations and spatial arrangements within the sample. Each image's width is indicated as 50 micrometers by the scale bar at the bottom, offering insight into polystyrene's surface morphology and topography.

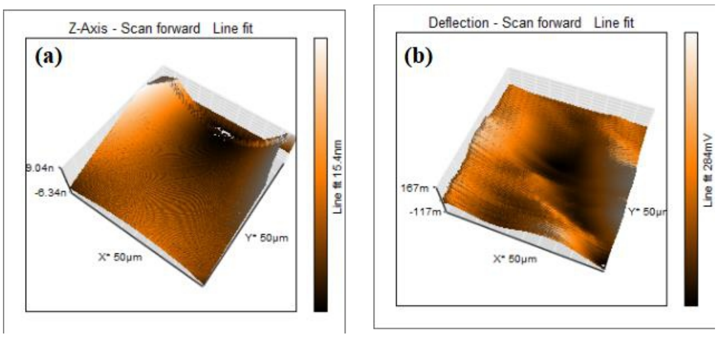


Figure 3.8: AFM analysis of (a) PP and (b) PP/PS)

Figure 3.8 is the result of an AFM (Atomic Force Microscope) analysis, showcasing surface characteristics of two samples: Polypropylene (PP) and a blend of Polypropylene and Polystyrene (PP/PS).

In panel (a), labeled "Z-Axis - Scan forward Line fit," the surface plot indicates variations in the Z-axis ranging from approximately -6.34nm to 9.04nm. This suggests relatively big topographical differences or surface roughness in the Polypropylene sample [26].

On the other hand, panel (b), labeled "Deflection - Scan forward Line fit," displays a more pronounced range of deflection values, spanning from around -117m to 167m. This wider range of deflection values in the Polypropylene/Polystyrene blend (PP/PS) sample may indicate more significant surface variations or roughness compared to the pure Polypropylene sample. This could be due to the presence of polystyrene particles in the PP/PS blend. Polystyrene particles are typically much larger than polypropylene molecules, so their presence would likely increase the roughness of the surface [17].

3.2 Characterization of the PP/PS Blend

Table 2: Summary of the Results for PP/PS Blend at Ratio 40:60

Resin	Density (g/cm3)	Viscosity (cp)	Refractive index (bxsc)	Turbidity (NTU)	Moisture uptake (%)	Melting Point (^{0}C)	Elongation at break (%)
PP/PS 40: 60	0.882	4.06	1.356	63	0.007	80	900

From Table 2, the blended PP pyrolysis oil and PS pyrolysis oil binder in emulsion paint yielded improved results compared to PP pyrolysis oil alone. The characterization results of the blended binder have indicated improvements in certain properties such as film formation, moisture resistance, or flexibility compared to PP pyrolysis oil alone. However, there may still be room for improvement in other key characteristics such as durability and gloss retention.

3.3 Some Physical Properties of the Paint Formulated using PP/PS Binder

Emulsion paints formulated with PP/PS binders exhibit unique physical properties due to the characteristics of these polymers. PP (polypropylene) and PS (polystyrene) are thermoplastic polymers known for their durability, flexibility, and resistance to water and chemicals. When used as binders in emulsion paints, they contribute to various physical properties. The performance of coatings is greatly impacted by their physical properties. Over time, the coating applied to a substrate experiences various mechanical and environmental stresses, such as impacts, weathering, and changes in substrate dimensions. These stresses can lead to damage to the coating film [27]. Therefore, it must fulfill essential criteria such as flexibility, hardness, toughness, water resistance, and chemical resistance.

The stickiness test results, detailed in Table 3, demonstrate that the paint sample passed successfully. The duration required for paint to achieve a specific level of dryness upon contact, commonly referred to as set-to-touch time, is known as drying time. In applications involving water-based paint, drying time assumes significance as it correlates directly with film formation. A shorter drying time results in reduced susceptibility of the paint layer to contamination from external components that could potentially cause damage [13]. When paint fails to dry completely, it can become sticky and tacky. Factors such as high humidity, extreme temperatures, or applying thick coats can hinder the drying process [28]. As seen from Table 3, the paint sample passed the opacity test. Opacity is the ability of a paint to remove or disguise the color of the substrate, and opacity is a function of the refractive index of the pigment, which is a numerical measurement of the ability of the pigment to bend light rays hitting its surface.

In the paint composition used in this study, TiO_2 has the main role as an opacity former, while $CaCO_3$ act as a hiding power agents and extenders [29]. As indicated in Table 3, the paint samples align with the alkalinity requirements outlined in the SON specifications. Water-based paints typically have a slightly alkaline nature, with a pH above 7, which is crucial for preserving their performance. A decrease in pH can lead to inferior flow characteristics, alterations in color, and viscosity, as noted by Montemor [30].

Table 3 outlines the impact of water on blistering in paint samples. Notably, the PP/PS paint sample exhibits remarkable resistance to blistering, likely due to the hydrophobic characteristics of the PP/PS molecules employed in its production. Blistering refers to the emergence of bubbles in the outer layer of decorative paint, caused by a localized breakdown in adhesion and subsequent detachment of the paint film from the surface beneath. This detachment can rapidly result in flaking and peeling [31] as indicated in Table 3, the paint sample demonstrated excellent adhesion. The adhesion of a coating denotes its robust connection with the underlying substrate. It's a crucial attribute in the paints and coatings sector, guaranteeing the coating's longevity, particularly in harsh environments. The level of adhesion directly impacts the coating's durability and overall quality [32]. The paint sample's viscosity falls within the SON standard range. Viscosity, an essential attribute, gauges a paint's resistance to spreading. It dictates its performance with various application tools such as brushes, rollers, and sprayers. A thick, viscous paint retains brush texture longer due to its slower self-smoothing nature compared to less viscous ones [33]. The flexibility of a paint sample refers to its ability to bend or stretch without cracking, peeling, or otherwise losing adhesion to the surface it's applied to. Table 3 demonstrates that the paint sample successfully passed the flexibility test. This outcome could be attributed to the adaptable properties of the polymeric materials employed in the binder formulation. The test results showcased in Table 3 also demonstrate that emulsion paint derived from waste PP/PS pyrolysis oil binder successfully passed the assessment, further highlighting its resilience. Oil-based coatings exhibit excellent water resistance, enabling them to thrive in challenging environmental conditions like high temperatures and humidity.

This product therefore challenges oil paint, since it will reduce the present overdependence on oil paint which is very costly and environmentally unfriendly due to its volatile organic compounds VOCs component. A novel emulsion paint is here introduced into the paint industry.

Determining the stages and rate of dry film formation of a paint sample is crucial for making appropriate application recommendations. Touch-dry and hard-dry represent key stages in this process. Touch-dry refers to the period when particles coalesce and the solvent evaporates, while hard-dry signifies optimal adhesion and cohesion, allowing for further coat application if desired [34] According to Table 3, the tested paint sample has a touch-dry time longer than the SON standard, but a shorter hard-dry time. Adjusting the pH of the paint will take care of this dry to touch.

Table 3: Comparison of the physical properties of the paint Formulated using PP/PS binder with SON standard

Property	PP/PS	SON Standard
Opacity	Pass	Pass
Water resistance	Pass	Pass
pH	7.10	7-8.5
Adhesion	Pass	Pass
Blistering	Pass	Pass
Stickiness	Pass	Pass
Viscosity (cp)	12.5	6-15
Flexibility	Pass	Pass
Dry to touch (min)	45	20
Dry to hard (min)	90	120

4.0 Conclusion

Pyrolysis emerges as a commendable waste management solution. In this study, it successfully converted waste polypropylene, blending it with polystyrene at various concentrations. Notably, 80% concentration yielded optimal results among the tested PP/PS copolymer concentrations, indicating its potential to compete in the coating industry as an efficient emulsion paint binder. The combined analysis using FTIR, XRD, SEM, and AFM techniques provided a comprehensive understanding of the structural, morphological, and surface characteristics of the PP, PS and PP/PS materials. The FTIR spectra confirmed the presence of both PP and PS components in the blend, with some minor peak shifts indicating interactions between the two polymers. The XRD analysis revealed that the incorporation of amorphous PS disrupted the crystalline structure of PP, leading to broader and less intense diffraction peaks in the PP/PS sample. The SEM images showed distinct differences in the surface morphology, with the PP/PS blend exhibiting a more structured and layered appearance compared to the rougher surface of pure PP. The AFM analysis further corroborated these findings, indicating increased surface roughness and variations in the PP/PS blend due to the presence of PS particles. The combined characterization techniques provide valuable insights into the structure-property relationships of the PP and PP/PS materials, which can inform their selection and optimization for various applications

The successful production of an emulsion paint utilizing a PP/PS binder in which values of viscosity, drying time, flexibility, adhesion, pH, and tackiness, resistance to blistering and chemical resistance obtained from this experiment are within the requirements outlined by the SON standard underscores the efficacy and suitability of this formulation for meeting industry benchmarks and ensuring quality assurance in paint manufacturing processes.

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