

Thermo-Catalytic Conversion of Waste Thermocol and Acrylic to Paint

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Waste thermocols and waste acrylic contribute towards environmental pollution due to their non-biodegradability, and improper disposal leads to respiratory and digestive problems in the human beings. This study proposes a thermo-chemical reutilization technique for these materials for the synthesis of paint-solvent. Paint solvents were experimentally synthesized using waste thermocol and spent acrylic via thermo-chemical processing. These solvents were further utilized to form paint with iron oxide and other pigments as pigment and raw thermocol as a binder. FTIR spectroscopy was performed to identify the organic functional groups in the liquid fraction obtained after thermo-chemical treatment. The liquid fraction obtained after the thermo-chemical treatment was uniformly mixed with a binder and pigment, and the resulting synthesized paint, whose characteristics were compared with those of conventional polystyrene paint. The use of waste thermocol and spent acrylic in the synthesis of paint not only reduces the amount of waste but also has the potential to replace resins and solvents in conventional paints derived from refined crude oil by products. This study provides a promising solution to this waste management problem and highlights the potential use of waste materials in paint synthesis.

Keywords: Waste Thermocol, Waste Acrylic, Paint Preparation, FTIR

1 Introduction

Owing to the high demand for plastic in various sectors, such as agriculture, households, and packing, a large production of plastic has become inevitable. Extensive studies have disclosed that global plastic production has been increasing by an average of 5% annually since 1950¹. In countries such as India, the USA, China, the UK, Japan, and Indonesia, plastics typically account for 7-10% of the MSW composition^{1&2}. Recent studies have revealed that urban areas in India produced approximately 62 metric tons of municipal waste (450 gm per capita per day) years 2015 in India. Polystyrene (PS) waste accounts for approximately 10% of the total annual plastic waste generated over the past decade^{3&6}.

Polystyrene and Acrylic are widely used plastics. On a commercial note, expanded polystyrene (EPS) is often regarded as Thermocol and is generated from a mixture of various compounds comprising 90 to 95% of polystyrene and 5 to 10% of gaseous blowing agents like pentane (C₅H₁₂) or carbon dioxide (CO₂). With their extensive application in packing materials, these polymers are being synthesized in large volumes⁴.

Acrylic is the common name for *Poly(methyl methacrylate)*, described as (C₅O₂H₈)_n, and it is utilized in lens-making, glass fabrication, fashion accessories, and display products (LEDs, laptops, etc.,)⁵. Similar to thermocol, acrylic manufacturing is huge for use in various products/gadgets, but ultimately lands in the MSW stream. Acrylic and thermocol materials have been used in interior design and as insulating agents in the field of construction. Polystyrene and acrylic eventually form an 8-10% part of waste plastic⁶.

Conventional paints contain of binders, solvents, pigments, and additives. The binder is the actual film-forming component responsible for both the protection and imbibing mechanical properties of the paint. Resins of alkyd, epoxy, polyurethane, etc., form a dry film on the substrate in a different manner. Pigments impart color to the paint and are either finely ground inorganic or organic powders with a higher Refractive Index (> 1.5), dispersed in numerous of media to formulate paints or inks. Solvents (or thinners) are employed in paints and lacquers to reduce the viscosity or consistency of the material, thus facilitating the application of a uniform coating. Improper handling of solvents can induce burns/irritation on the skin. Additives are minimal amounts of various chemical ingredients that modify paint characteristics⁷.

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Urbanization has led to rapid growth in both economic and individual vested interests, resulting in the extensive application of products such as paints, plasters, and coating materials for furnished houses⁸.

Recently, various experimental studies have been conducted to decrease the paint/adhesive load. Literature reports that studies such as (*D Bellon et. al*) have devised a substitutional method for expanded polystyrene (EPS) by converting it to an enamel paint base applicable to construction firms to reduce construction costs. This study focused on the assimilation of expanded polystyrene (EPS) waste into waterproof paint. (*S. Myint, et. al*) has prepared paint based on expanded polystyrene, in which the formulation of paint was done by using expanded polystyrene as a binder. They used 27 % waste polystyrene in their experiment. (*Appala Naidu Uttaravalli et. al*), reviewed various feasible options for the application of waste thermocol with a distinct approach to their process chemistry, parameters, and yielded products. This study considered the potential utilization of waste thermocol for various applications, including value-added chemicals, adhesive materials, and aggregate materials in the construction field, as additives for the preparation of composite and porous carbon material. (*Achyut K. Panda, et, al*) used Kaoline clay and amorphous silica-alumina as catalysts in waste thermocol (Expanded polystyrene) degradation in a stainless steel autoclave surrounded by a furnace at varying temperatures of 350-550°C under partial oxidation. The major fraction of the pyrolysis reaction is a highly volatile liquid that has been analyzed using FTIR and hydrocarbon analyzer (detailed) for detection of elemental composition. In addition to styrene, other crucial products available in the liquid fraction are benzene (C₆H₆), ethyl benzene (C₆H₅OH), toluene (C₆H₅CH₃), and methyl styrene (C₉H₁₀)⁹⁻⁸⁻⁶⁻⁴.

Several literature articles have suggested the use of organic solvents, such as benzene/xylene, in paint synthesis for effective utilization. However, such formulations are not cost-effective because of the high cost of BTX solvents. In the current work, the liquid fraction obtained from the thermo-chemical processing of acrylic and thermocol wastes was used as the solvent. Such synthesis not only makes the formulation economical (compared with the use of commercial solvents) but can also utilize thermocol

and acrylic waste. On a small institutional campus, more than 50 kg of waste thermocol and approximately 25 kg of acrylic waste are generated per year. The current study focuses on a proper paint preparation technique using waste thermocol and acrylic as the chief ingredients.

1.1 Environmental Effect

The conventional estimate recommends that large metric tons of waste polystyrene are generated and transported to landfills annually, a large volume of landfill compared to its weight. Thermocol and Acrylic can instigate an environmental hazard owing to their lower density and dispersed nature making their proper disposal a crucial issue. Incineration and land filling are not the ultimate treatment solutions for plastic waste the management. These methods lead to air and land pollution, because incineration causes greenhouse gas emissions, which lead to carcinogenic gas emissions that affect climate change phenomenon¹⁰⁻⁸.

Impact on Human health

- With the polystyrene combustion of polymers, foam cups, egg containers, meat trays, and yogurt-deli containers, styrene evolved. Adsorption of styrene gas on human skin and lungs instantaneously induces severe ill-health effects including asthma and emphysema. This can cause rashes, and headache impacting the nervous system, and result in multi-organ failure involving the kidneys, and heart¹¹.
- At exceeding limits, styrene vapor can plausibly damage the human eyes and mucous membrane.

In addition, waste thermocol and acrylic are non-biodegradable, which raises major environmental concerns. The major chunk of waste thermocol & acrylic results was untreated and turned out to be voluminous piles on the land. Polystyrene becomes unusable after use as a packing material.

2 Material & Methods

The Overall process of the paint synthesis block diagram is shown in Figure 1, and the detailed process descriptions are explained below.

2.1 Waste feed material collection

Waste polystyrene (WP) was collected from the MSW dump site, and Waste Acrylic powder was collected from the Workshop. Iron Oxide (Fe₂O₃) was purchased from Sigma-Aldrich (India).

2.2 Waste thermocol volume reduction by vapor-phase reaction

First, large sheets of the thermocol were manually cut into small pieces using a cutter. Subsequently, small pieces of waste thermocol were fed to the top section of the cylindrical drum, which was divided into sections comprising a thermocol shrinker at the top section, vapor generation at the bottom, and a two-section porous sheet was fixed as a separator, as shown in Fig. 2.

Air is introduced into the commercial thinner-organic solvent, which evolved vapors that shrink the thermocol in the top section. The Vapor Phase Reaction data & Specification of shrinking reactors Shown in Table 1. The experimental study revealed over 90-95% volume reduction of the waste thermocol occurred. The reduction volumes of waste thermocol before and after the reaction are shown in Figure 3.

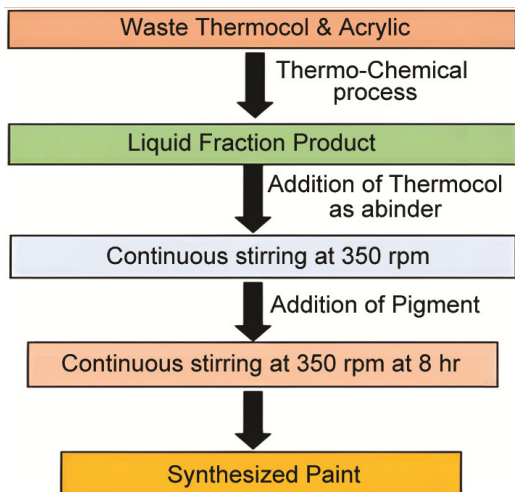


Fig. 1 — Block Diagram overall process.

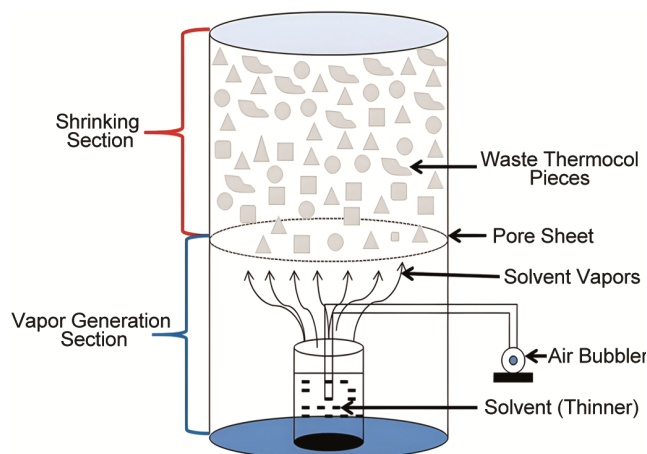


Fig. 2 — Waste Thermocol Shrinking Set-up.

Reaction Temperature & pressure Conditions:

Temperature = 29°C (Atmospheric)

Pressure = 1 atm

$$\begin{aligned} \text{Volume Reduction \%} &= (\text{IV Thermocol} - \text{FV Thermocol}) / \text{IV Thermocol} * 100 \\ &= (6250 - 310) / 6250 * 100 \\ &= 95\% \end{aligned}$$

Where, **IV** = Initial Volume

FV = Final Volume

2.3 Solvent preparation

Shrunk thermocol and different catalysts (Silica-alumina/ BaCO₃ / CaCO₃) were mixed in a ratio of 10:1 and fed into a fixed bed reactor, as shown in Figure 4. A N₂ atmosphere was maintained throughout the processing time using a continuous gas flow (0.2 l pm) from one opening, and a thermocouple was introduced for temperature control. The heater was switched on and maintained at a constant heating rate, above 200°C. The generated vapors were passed through a condenser and a liquid product was obtained after condensation. The same process parameters were used for synthesizing the solvent from waste acrylic powder (1 mm). These liquid products were used as solvent for paint preparation.

2.4 Paint preparation procedure

2.4.1 Experimental Procedure

The process of paint preparation is shown in Figure 5. Initially, waste polystyrene (thermocol) was crushed into small pieces and dissolved in a solvent (liquid products formed through the thermal and catalytic processes of waste thermocol and acrylic). The mixture was thoroughly stirred at 350 RPM until all the waste PS was completely dissolved, resulting in a homogeneous blend. A Pigment (Fe₂O₃) was carefully added at a 2:10 ratio, and the mixture was stirred for 8 hours until a uniform paste was achieved. This process was repeated with other standard commercial pigments, such as titanium dioxide.

Table 1 — Vapor Phase Reaction data & Specification of shrinking reactor

Specification	Results
Volume of Reactor	6250 ml
Initial Volume of Waste Thermocol	6250 ml
Initial Volume of Solvent	500 ml
Final Volume of Waste Thermocol	310 ml
Final Volume of Solvent	440 ml
The Volume of Solvent Used	60 ml



Waste Thermocol Volume before Reaction

Waste Thermocol Reduced Volume after Reaction

Fig. 3 — Reduction of Thermocol Volume.

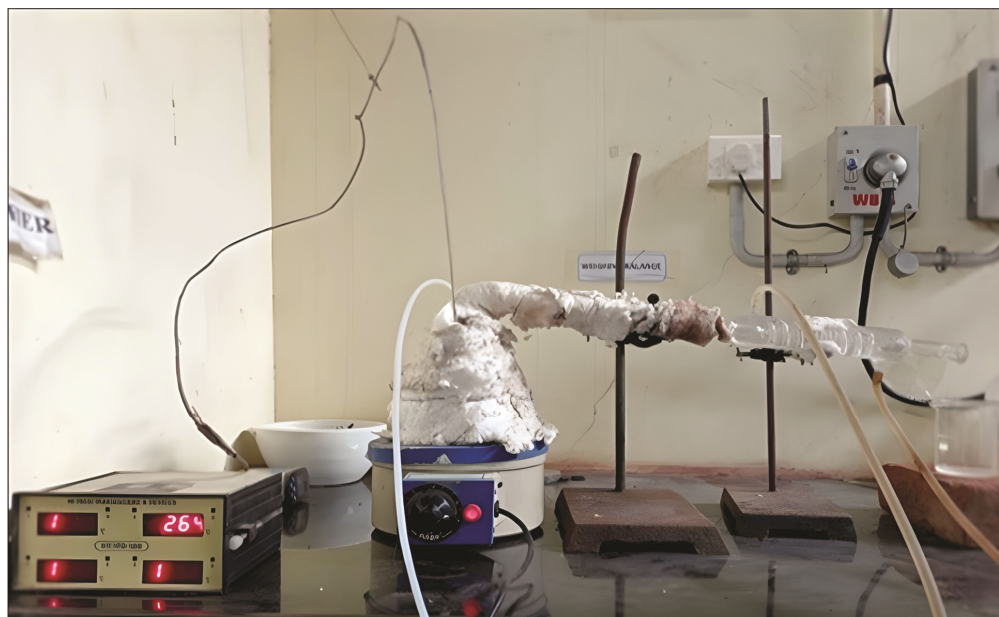


Fig. 4 — Solvent Preparation Set-up.

3 Result and Discussion

The result of thermo-chemical process shown in Table 2 indicates that Silica-Alumina, Barium Carbonate (BaCO_3) is a better catalyst than Calcium Carbonate (CaCO_3), although the latter is more cost-effective. The Physical tests were carried out on paint product. Table 3 shows the results physical properties of paint produced.

3.1 Water Resistance Test

i) Firstly, the paint was applied to the metal plate, dried properly, and then cross-cuts were made on it.

ii) 3 standard solutions were prepared which 1st solution consisted of calcium sulphate (1.3 gm), magnesium sulphate (1.7 gm), magnesium chloride (2.6 gm), and sodium chloride (21.4 gm) in 1 liter of distilled water¹¹ & the 2nd solution was prepared using 5% of NaCl & 3rd was pure distilled water.

iii) The solutions (200 ml) of the two prepared solutions were placed in two conical flasks, and the painted metal piece was immersed in the solution and checked daily.



Fig. 5 — Paint Preparation Procedure.

Table 2 — Experimental Data of thermo-chemical Process

RawMaterialName	Weight of Raw material (gm)	Catalyst Name	Weight of catalyst (gm)	Liquid Product (ml)	Residue (gm)
Waste Thermocol	50	Silica-Alumina	5	50	4
Waste Thermocol	50	Silica-Alumina	5	51	3
Waste Thermocol	50	BaCO ₃	5	48	6
Waste Thermocol	50	BaCO ₃	5	50	3
Waste Thermocol	50	CaCO ₃	5	47	6
Waste Thermocol	50	CaCO ₃	5	48	6
Waste Acrylic	50	Silica-Alumina	5	43	11
Waste Acrylic	50	Silica-Alumina	5	43	12
Waste Acrylic	50	BaCO ₃	5	40	14
Waste Acrylic	50	BaCO ₃	5	41	12
Waste Acrylic	50	CaCO ₃	5	39	15
Waste Acrylic	50	CaCO ₃	5	39	13

Table 3 — Paint Test Result

Test Name	Results
Viscosity (sec)	60
Specific Gravity	1.088
Non-Volatility Content	56%
Adhesive Test	ASTM Class-3B

iv) The result of blistering was found in both solutions 1 and 2 after 4 days in paint metal sheets shown in Figure 6, but rust was not observed in either solution. However, no blistering or rust was observed on the metal paint sheet dipped in solution 3.

3.2 Weather resistance test

Test pieces coated with waste polystyrene paint were kept open to natural weathering on campus for

6 months in an outdoor environment where the mean temperature was atmospheric, during the rainy season (June to September). After every month, the effect of weather on the paint was checked; however, it was observed that weather did not have any effect on the color of the paint. Monthly observations of the paints are shown in Figure 7 below.

The liquid fraction, which was obtained by the thermo-chemical reaction of waste thermocol at 400-450°C, was used for the FTIR analysis shown in Figure 8. The results showed that most of the aromatic compounds detected were similar to those used in the paint industry. The presence of different functional groups in the liquid fraction is shown in Table 4. Based on these observations, the suitability

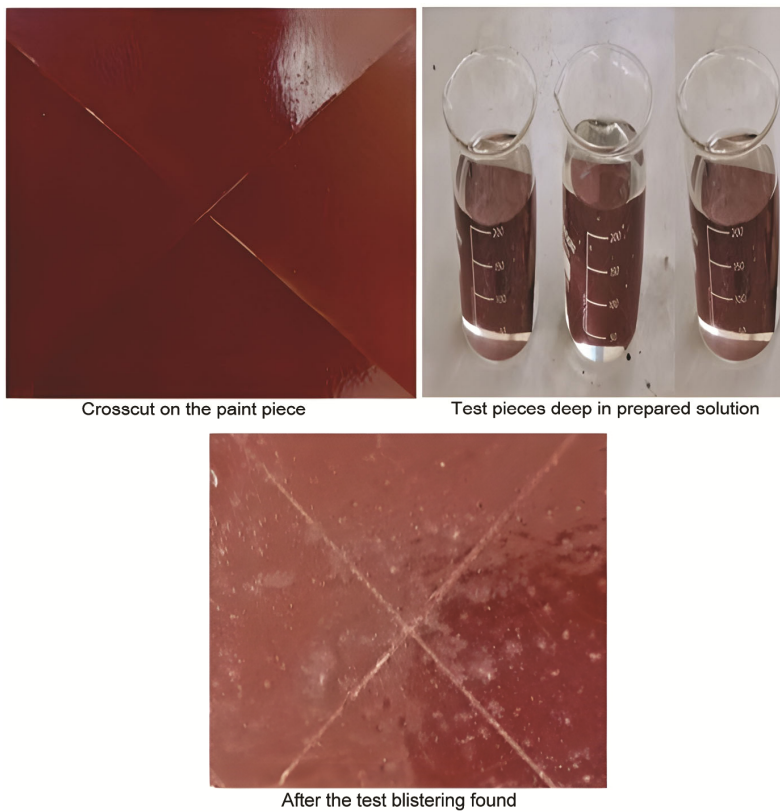


Fig. 6 — Water Resistance Test Observation.

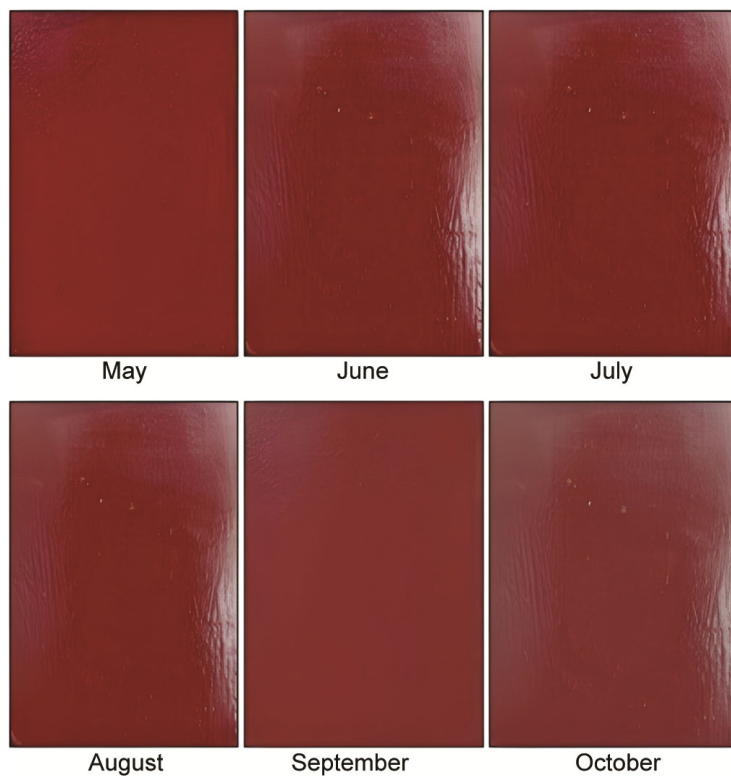


Fig. 7 — Monthly weather resistance test thus characteristics of the paint synthesized in this study were similar to those of the commercial paint.

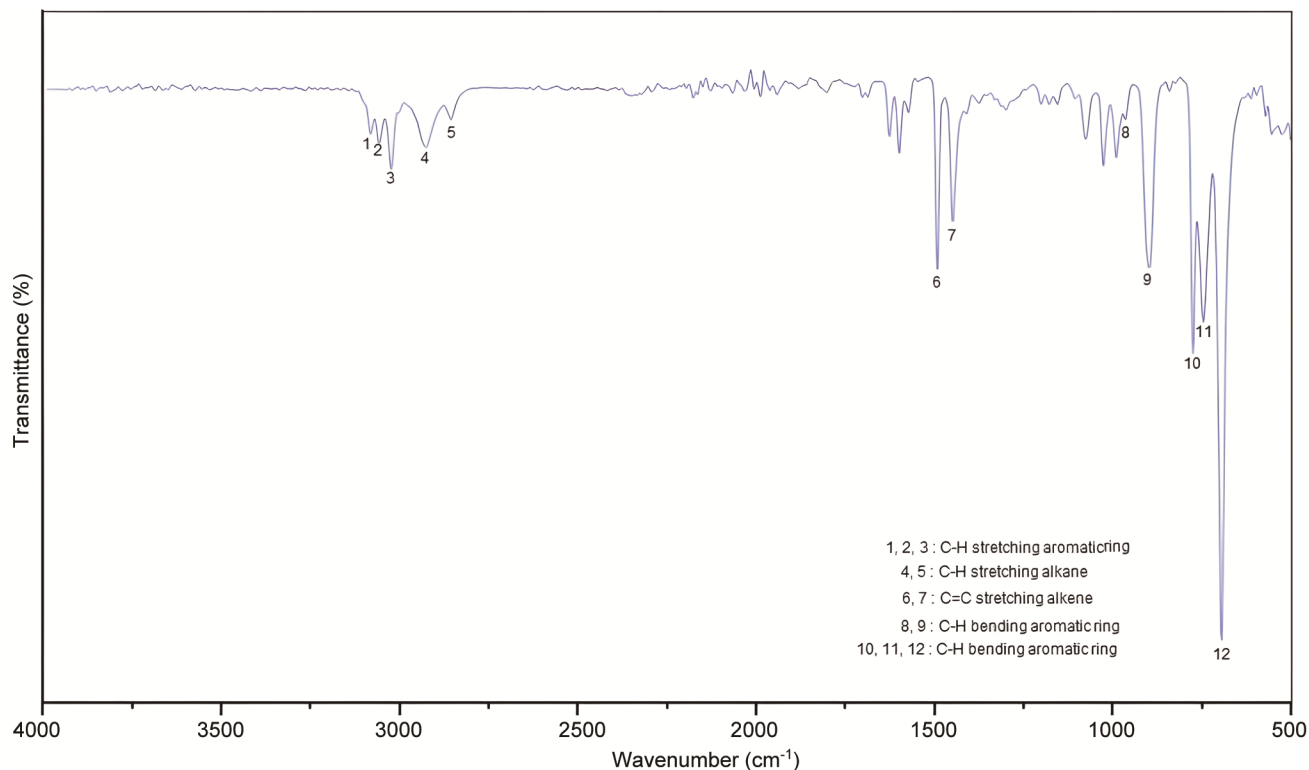


Fig. 8 — FTIR graph.

Table No. 4 — FTIR result of Liquid Product obtained from waste Thermocol

Wave number cm^{-1}	Functional Group
3026.29	
3060.11	C-H stretching Aromatic Ring
3083.74	
2857.90	C-H stretching Alkane
2927.77	
1452.11	C=C stretching Alkene
1494.06	
897.07	C-H Bending Aromatic ring
991.12	
694.84	
754.30	C-H Bending Aromatic ring
775.66	

of the liquid fraction as a paint solvent was concluded.

The results obtained from FTIR of this study in line with previously reported studies (Ref. No. 4).

4 Conclusion

The aforementioned protocol concluded that the liquid produced from the thermo-catalytic processing of waste thermocol and spent acrylic works well as a commercial paint solvent and can be used as a paint solvent. Moreover, it was found that

paint made from acrylic dried faster than paint made from waste thermocol. These findings suggest that waste thermocol and spent acrylic, and their combination with other such materials, could be used in paint production as a cost-effective alternative to traditional solvents and resins. This new waste disposal technique for waste thermocol and waste acrylic can be adopted widely to eliminate waste from untreated waste, going untreated resulting in increased environmental pollution. This research work is in progress to improve the paint results obtained in earlier tests.

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