# Development of Emulsion Paint from Trimethylol Urea/Polystyrene waste Copolymer Resin.

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**Abstract:** Urea formaldehyde that is trimethylol urea (TMU) was synthesized and copolymerized with polystyrene waste (PS) to form TMU/PS copolymer binder for emulsion paint formulation. Formaldehyde emission and some physical properties of both TMU and TMU/PS were investigated. The resulting copolymer TMU/PS gave a better resin compared to pure TMU in terms of brittleness, low water resistance and formaldehyde emission. The emulsion paint formulated from both TMU and TMU/PS passed pH, viscosity, flexibility, opacity, gloss and storage stability tests. Paint from pure TMU failed adhesion, hardness, tackiness, resistance to blistering and drying time tests while that of TMU/PS paint recorded a pass in all the tests. Both paints were unaffected by the salt medium but surface defect were observed in the case of TMU films in alkali and acid solutions. TMU/PS films were unaffected by both the acid and alkali solutions. This study provides a potential route for both VOC reduction in coating surfaces and environmental pollution from waste polystyrene disposal.

## I. Introduction

Oil-based paints display a lot of advantages such as water resistance, durability and flexibility over water borne paints. However, due to its use of volatile organic solvent (VOC) as solvent and consequent of environmental pollution, the taste for oil-based paint is fast diminishing in many countries all over the world. For the purpose of both environmental and human survival, VOC reduction from coating surfaces is a task that must be done. VOCs are harmful materials to the environment, as they are partly responsible for air pollution, depletion of ozone layer, global warming and health risk to all living organisms [1, 2].

Water borne paint are used in protection and decoration of most building nowadays because of their ease of applications, fast drying, non-odour, good-wash ability and excellent finish. However, water borne paints are limited in application due to the relatively low quality when compared to oil-based coatings. Although researches [3, 4, 5], have been directed towards eco-friendly water-thinnable paints, the dream of obtaining an emulsion paint with satisfactory service properties as compared to solvent based system has not been achieved [6].

Urea formaldehyde resins are extremely tough, scratch resistant polymers which are used for a host of domestic and industrial applications. Some advantages of urea formaldehyde resin includes low price, good technological properties, absence of colors in cured polymer and easiness of application (7, 8]. However, the structure of the thermosetting resin also leads to unwanted properties that restrict their application. Urea formaldehyde resin is too hard and brittle to be used alone as coating material. Urea formaldehyde resin also exhibit poor water resistance and formaldehyde emission hence creating problems of environmental pollution and inconsistency in the quality of product with age. Since Urea formaldehyde resin is soluble in water, it full utilization is needed to meet different requirements of the coating industry in terms of emulsion paint formulation and consequent reduction in VOC in our environment. This is only achievable if the inherent problems of brittleness, poor water resistance and formaldehyde emission associated with urea formaldehyde resin are taken care of [9, 10].

Polystyrene is an important polymer of immence use industrially as it is highly resistance to shock, chemicals and weather conditions. It dissolves in many solvents and has a lot of uses as plastic in industry for domestic purposes [11]. The expanded polystyrene is used extensively due to its cost effectiveness. Although PS has immence usage industrially, most of products end up as municipal solid waste, thereby constituting environmental nuisance. Since the products are not biodegradable, once used and discarded, they become a major waste management challenge resulting into green house emission and ecological damage [12, 13], So disposing polystyrene waste in landfills is not a sustainable practice, and hence, recycling polystyrene becomes a needed alternative [14].

An up-cycling of the post consumer blend wastes for value-added goals remains a challenge for the scientific community [15]. In a recent work, Poly(ethylene) terephthalate (PET) which leads to polymer wastes were recycled and utilized for coating application and the paint showed excellent gloss, flexibility, pencil hardness, adhesion, no cracks and good resistance to acids[16]. Polyester Polyol was Derived from Waste Poly (Ethylene Terephthalate) and used for Coating Application on Mild Steel [17]. Polyethylene waste was used to

modified urea formaldehyde and used as binder for emulsion paint formulation [18]. In this work, TMU was synthesized and copolymerized with PS waste to form a copolymer binder for emulsion paint formulation with the aim of reducing VOCs and the removal of waste polysytrene from our environment.

## Materials/reagents

## II. Materials And Method

Urea, formaldehyde, sodium dihydrogen phosphate, sulphuric acid, sodium hydroxide, pellets, butanol, Ammonia and sucrose were reagent grade products from the British Drug House (BDH). Titanium dioxide, calcium carbonate, sodium carbonate, kaolin, aluminium silicate, calgon, anti-skining agent, nicofoam, genepour, drier, bermocoll, troystan, dispersant, water, gasoline were obtained from yola market Nigeria. All materials were used as received. Polystyrene waste was collected from refuse dumps around Yola, Nigeria.

## Methods

The methods used for the resin synthesis and determination of the film properties were according To: [18].

#### **Resin synthesis**

Trimethylol urea (TMU) was prepared by using one mole (6.0 g) of urea to react with three moles (24.3 ml) of 37% (w/v) formaldehyde using 0.2g of sodium dihydrogen phosphate as catalyst. The pH of the solution was adjusted to 6 by using 0.5M  $H_2SO4$  and 1.0M NaOH solutions. The solution was heated in a thermostatically controlled water bath at 70°C. The reaction was allowed to proceed for 2 h after which the sample was removed and kept at room temperature (30°C).

### Formation of liquid PS

Solid PS was constituted into liquid form by dissolving 5g of PS waste in 25ml of gasoline. The mixture was stirred continuously and allowed to stay for 24h to achieve a homogenous solution.

## Preparation of TMU/PS blends and films

Blend of TMU and PS was prepared by adding varying amount of PS (0-70%) in TMU resin. The mixture was stirred and left for 24 h at room temperature ( $30^{\circ}$ C) and then poured into a glass Petri dish for casting. The resin was allowed to cure and set for seven days at ( $30^{\circ}$ C). The physical properties of the resin films were investigated.

#### Determination of viscosity and gel time

A 100 ml Phywe made graduated glass macro-syringe was utilized for the measurement. The apparatus was standardized with 20% (W/V) sucrose solution whose viscosity is 2.0 mPa.s at 30°C. The viscosity of the resin was evaluated in relation to that of the standard sucrose solution at 30°C. Five different readings were taken for each sample and the average value calculated. The gel point of the resin was determined by monitoring the viscosity of the resin with time until a constant viscosity profile was obtained.

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

The density of the resin was determined by taking the weight of a known volume of resin inside a density bottle using metler (Model, AT400) weighing balance. Five readings were taken for each sample and average value calculated. The turbidity of the resin samples was determined by using Hanna microprocessor turbidity meter (Model, H193703). The melting points of the film samples were determined by using Galenkamp melting point apparatus (Model, MFB600-010F). The refractive indices of the resin samples were determined with Abbe refractometer. The above properties were determined according to standard method [19].

### Determination of moisture uptake

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

## Determination of formaldehyde emission

Formaldehyde emission test was performed by using the standard 2 h desiccator test. The mold used was made from aluminium foil with a dimension of 69.6 x 126.5 mm and thickness of 12.0 mm. The emitted formaldehyde was absorbed in 25.0 ml of water and analyzed by a refractometri technique using Abbe refractometer. Triplicate determinations were made for the samples and the average value taken.

## Elongation at break

The elongation at break was measured using Inston Tensile Testing Machine (Model 1026). Resin films of dimension 50 mm long, 10 mm wide and 0.15 mm thick was brought to rapture at a clamp rate of 20 mm/min and a full load of 20kg. A number of five runs were carried out for each sample and the average elongation evaluated and expressed as the percentage increase in length.

### Water solubility

The solubility of the TMU/PS blend in water was obtained by mixing 1ml of the resin with 5ml of distilled water at room temperature ( $30^{\circ}$ C).

### Paint formulation

The method described by [6]; was adopted for the paint formulation. Paint production process involves three main stages:

#### **First Stage**

At the first stage, additives such as, dispersants, defoamer, thickener, anti-skin, drier, wetting agents, stabilizer, pH adjuster and preservatives were added. The basic purpose of this stage is to provide a favourable environment for wetting and dispersion of particles. A volume of 185 ml of distilled water was introduced into a litter mixing tank and the overhead stirrer switched on after the addition of 12.7g of the additives as shown in Table 1. This mixture was stirred using a high speed stirrer for 15minutes.

#### Second Stage

In the second stage, also known as "Millbase", pigments and extenders were dispersed in the mills. Immediately after dispersion, the stirrer speed in the millbase stage was increased to a very high speed and the mixture was stirred for another 15minutes. In millbase, binder was not added to avoid its structural deformation under the high mechanical forces.

#### **Third Stage**

Finally, binder plus the rest of the additives used in the first stage were mixed with 15ml of water . This stage is called "Letdown". In this stage, the mixture was stirred at moderate speed for another 15 minutes. Energy losses in the mill base are minimized by adding thickeners before the dispersion stage of the production process. The above processes was repeated using pure TMU as binder. The details of the formulations are in Table 1.

Stage	Materials	Quantity in g
First	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	0.54
Millbase	TiO <sub>2</sub>	50
	$Al_2(SiO)_3$	11.2
	Na <sub>2</sub> CO <sub>3</sub>	0.58
	Kaolin	2.52
	CaCO <sub>3</sub>	123.0
Letdown	Binder	100
	Water	15
	Dispersant	0.2
	Nicofoam	0.2
	Anti-skining agent	0.2
Total		500g

**Table 1:** Recipe for the formulation of emulsion paints from TMU/PS binders.

## Test procedures for paint samples

Paint samples were analysed as described in Niger Cedar laboratory hand book of paint formulation recipe and standard organization of Nigeria methods [20].

## Viscosity

Viscosity of paint sample was determined by using an I.C.I. Rotothinner viscometer. The 500 ml tin sample container of the instrument was filled with paint sample under test to 0.3 mm of the top rim of the dept gauge. The sample was stirred with a thermometer and the temperature maintained at  $27^{\circ}$ C. The container with the paint sample was placed in the processing ring on the turntable and the lever pulled down to switch on the motor automatically. The disc was allowed to run until a steady state is reached (5 minutes). At the end of the required time, the viscosity was recorded in poises. Triplicate determinations were made for each sample and mean value recorded.

## pH and Opacity

The pH of paint sample was determined by using phywe pH meter model 18 195.04. Opacity was determined by using the standard Mohest Chart. The paint sample was applied on the Mohest Chart (i.e hiding power chart) and allowed to dry for 24 hr. The opacity was evaluated by comparing the dried sample film with the hiding power chart. Three determinations were made for each sample and mean value assessment recorded

## Drying time and flexibility

To evaluate the dry time, paint sample was applied on a glass panel with the aid of bar applicator and allowed to dry. Dry to touch was taken when the paint film is no longer sticking to the finger and dry to hard taken when the film resisted finger print. Triplicate evaluations were made for each sample and mean value assessment recorded. For flexibility test, paint sample was applied on a freshly degreased and chromate aluminium with the aid of paint applicator. The film was allowed to air dry under room temperature  $(27^{\circ}C)$  for 7 days. The panel with the film was inserted into the conical Mandrel Bend Tester and the panel bent through  $180^{\circ}$  with a smooth action (taking 1-2 seconds). The panel was removed from the tester and examined for cracking or loss of adhesion. Any crack or loss of adhesion indicates inflexibility or brittleness. Triplicate samples were made and average evaluation taken.

#### Adhesion property

To evaluate the adhesion property of paints, a coat of paint film was applied with film applicator on a degreased metal panel and allowed to dry for 48 hours. Two sets of lines, one crossing perpendicularly over the other were drawn with a crosshatch tester on the paint film. An adhesive tape was pressed firmly with the thumb covering all the interactions of the perpendicular line. The adhesive tape was held at its 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  $27^{\circ}$ C for each sample and average assessment recorded.

#### Specular gloss

Specular gloss at  $85^{\circ}$  of paint sample was determined by using gloss meter (Digital instruments, model RSPT-20). Paint film was prepared by using 4mesh (100 microns) applicator over a pre clean glass panel and the film allowed to dry for 24 hours. The ASTM gloss-meter was allowed to warn up for 10 min and using the black glass standard held against the pot-hole, the meter was adjusted to read 92.5%. The sample cast on the glass panel was held against the pot-hole in three separate positions along its length and the mean gloss calculated in percentage with a difference of not more than 5% between the highest and the lowest. Triplicate measurements were made for each sample and mean value recorded.

#### Stickiness and pencil hardness

This was done qualitatively on the dried film by hand feeling to find out if the paint film is sticky or not. Stickiness of a dried paint film is an indication that the film is tacky. Triplicate samples were used for each determination and the average quality assessment recorded. Pencil hardness of the paint films was also determined according to ASTM standard methods (ASTM D 3363-74 3363-74).

#### **Resistance to blistering**

To test for resistance to blistering, undiluted paint sample was applied to a glass panel with an applicator to give a wet film thickness of about 120  $\mu$ m and was allowed to dry for 24 hours. At the end of this period 4 ml of distilled water in the form of circular drop was placed on the film. The presence of blistering, wrinkling, swelling or cracking within a period of 30 minutes indicates poor water resistance. Triplicate samples were used for each determination and the average quality assessment recorded.

## Stability test

The paint sample was fully sealed in a container and allowed to stay at room temperature  $(27^{0}C)$  for 4 months. At the end of this incubation period, the sample was re-examined for any change in viscosity or coagulation of the emulsion paint. Absence of coagulation or any change in viscosity is regarded as a pass. Triplicate samples were used for each determination and the average value recorded.

## Chemical resistance

To evaluate the chemical resistant of the paint films, three flexible aluminium panels (150mm x0.3) were used as the test panels. A coat of paint with paint applicator was applied on the way to the panel. One litter glass beaker was filled with 0.1 M NaOH solution to a depth of 150mm and the test pieces immersed for 48 hours to the depth of approximately 120mm. The test piece was removed, washed with running water and stood to dry for 2 hours. The above procedure was repeated by using 0.1M HCl and 0.1M NaCl respectively. The presence of any surface defects such as cracking, blistering, peeling or change in colour will indicate poor chemical resistance.

Tuble 2: some physicoenemical properties of the synthesized Time and Time/Te						
Property	UF	UF/PS				
Viscosity (mpa.s)	2.39	19.70				
Melting point ( <sup>0</sup> C)	280.00	262				
Density (g/cm <sup>3</sup> )	1.125	1.099				
Turbidity(NTU)	91	878				
Refractive index	1.1400	1.4250				
Moisture Uptake (%)	4.72	1.0100				
Formaldehyde emmision (ppm)	0.0905	0.0233				
Elongation at break (%)	116	450				

III. Result And Discussion

Table 2: some physicochemical properties of the synthesized TMU and TMU/PS

Table 2 compares some physical properties of pure trimethylol urea (TMU) resin and trimethylol urea/polystyrene (TMU/PS) copolymer resin. It was observed that the viscosity, turbidity, refractive index and elongation at break of TMU/PS blend are very high compared to those of TMU. The increase in viscosity is as a result of increase in molecular weight due to inclusion of polystyrene in the polymer matrix which give rise to increase in crosslinking density and hence the increased in viscosity [21]. Turbidity increases because pure TMU is clear and transparent. However on addition of PS, the system became colloidal and light scattering increases leading to corresponding increased in turbidity [22]. The increase in refractive index can be attributed to high refactive index of polystyrene. Elongation increase because of the addition of soft segment PS in the TMU/PS blends which impacts flexibity [23].

The density, moisture uptake and formaldehyde are lower compared to those of TMU. The decrease in density with PS inclusion in the TMU/PS blend can be due to increase in soft segment. It is expected that the density of the blend will fall between the density of TMU resin and PS, since PS has lower density relative to pure TMU [23, 24]. The low moisture uptake in the TMU/PS blend is lower than TMU as a result of the excellent hydrophobicity of PS in the blend. PS inclusion result in an increase in crosslinking density which narrows the voil spaces and reduces moisture uptake [25, 26]. Formaldehyde emission of TMU/PS is lower than TMU resin. This may be as a result of reduction in stress during cure which reduces emission resulting from improved flexibility. PS also disrupted the continuity in the TMU matrix, therefore making it more difficult for the reactive groups of urea and formaldehyde to come close and interact [27, 28].

## Some Physical Properties of Paints formulated from TMU and TMU/PS Binders

Some Physical Properties of TMU and TMU/PS paints are tabulated in Table 5. As seen from the Table, some properties such as pH, viscosity, flexibility and opacity of both TMU and TMU/PS falls within the the acceptable ranges for paints [20]. TMU/PS paint exhibited good adhesion, tackiness and hardness properties resulting from the increased in crosslinked degree, but the paint from pure TMU showed poor adhesion, hardness and tack properties. This behaviour of TMU paint can be due to low molecular weight and hence low crosslink density of the pure TMU binder [29, 30].

Resistance to blistering of the different paints formulated are also provided in Table 5. The paint from the TMU/PS binder passed resistance to blistering test while those formulated with the pure TMU binder failed the test. These results indicate that PS segment has been cross linked into the TMU/PS copolymer thereby impacting hydrophobic character. The higher degrees of cross-linking gave rise to less free volume and solvent molecules hardly pass through the crosslinked network [31, 3, 5]. This implies that the paint can perform well when exposed to environmental conditions such as rain and sun. The pure TMU paint failed water resistance test as a result of the inherent property of urea formaldehyde resin in addition to low molecular weight of the TMU binder used in the paint formulation [8, 32].

The drying time of TMU/PS paint met specification, while that of TMU paint is outside the specified range [20]. The long drying time displayed by TMU paint is attributed to the low molecular weight and hence low crosslink density of the TMU binder while the TMU/PS has high crosslinked density due to increased in molecular weight which enhanced drying [33]. The gloss results shows that both TMU and TMU/PS have gloss value within the range specified, but TMU/PS has a higher gloss due to the higher refractive index of PS incorporated into the blend [34]. Stability in storage is an important factor for coating system. Amino resin when use as a paint binder can undergo self-condensation making the system too viscous and gel like for coating application. From Table 5, all the paint formulation passed the standard stability test because of the addition of butanol (stabilizer) during formulation. The TMU/PS paint has better resistance to scratching than TMU paint. Resistance of coated material againt scratching is a function of surface hardness. TMU/PS paint has better pencil hardness because the more the network formed in the polymer matrix, the higher the cross-linking density and the harder the resulting coating film [35, 17].

Parameter	TMU	TMU/PS paint	SON Standard
pH	7.1	7.3	7-8.5
Viscosity (poise)	6.5	13	6-15
Flexibility	Р	Р	Р
Opacity	Р	Р	Р
Adhesion	F	Р	Р
Hardness test	F	Р	Р
Tackiness	F	Р	Р
Resistance to blistering	F	Р	Р
Drying time(min)			
Touch	168	10	20
Hard	700	35	120
Storage Stability (4 month)	Р	Р	Р
85 <sup>°</sup> Gloss	29.0	32.0	16-50
Pencil Hardness	2B	2H	_

Table 5: some physical properties of paint formulated from TMU/PS Binders

P and F means Pass and fail SON test respectively.

#### Chemical resistance

The ability of a paint film to resist chemical attack is one of the desirable qualities of a good coating film. Table 6 shows the resistance of the TMU/PS coating system on exposure to a number of chemicals. From the results, both TMU and TMU/PS are unaffected by the salt medium. TMU/PS films are also unaffected by both the acid and alkali solutions, while surface defect were observed in the case of TMU films in alkali and acid solutions. TMU/PS has better chemical resistance due to high crosslinked density of network which decreases their exposure to environment [5].

		Media	
Samples	0.1M NaCl	0.1 MHCl	0.1 NaOH
TMU	a	b	с
TMU/PS	a	a	a
	a= No effect	b= Cracking c= Blistering	

**Table 6:** Chemical resistance of TMU and TMU/PS paint films

## IV. Conclusion

Some physical properties of both TMU and TMU/PS were studied. The inherent problems of brittleness, poor water resistance and formaldehyde emission traditional associated with urea formaldehyde resin were addressed using TMU/PS copolymer resin. The emulsion paint formulated using TMU/PS binder exhibit good consistency, it was smooth and uniform. The paint showed excellent gloss, adhesion and flexibility. The pH, viscosity, Opacity and Drying time of the TMU/PS paint conform to SON standard. It showed good pencil hardness, no cracks and good resistance to acidic, alkaline and salt medium compared to the pure TMU paint. The use of polystyrene waste for coating will open new market of recycled polymer and a potential solution to the problem of solid waste management.

#### Reference

- [1]. A.A. Yousefi, M. Pishvae and A. Yousefi, Preparation of water-based alkyd/acrylic hybrid resins. *Progress in Color, Colourant and Coatings*, 4, 2011, 15-25.
- [2]. J. Faucheu, L. Chazeau, C. Gauthier, J. Cavaillé, M. Goikoetxea, R. Minari and J.M.Asua, Latex imaging by Environmental STEM: Application to the study of the surfactant outcome in hybrid alkyd/acrylate systems. *Langmuir* 25, 17, 2009, 10251-1025.
- [3]. S.P.Hasmukh and J.P. Sumeet, Novel surface coating system based on maleated shellac. *E –Journal of chemistry*, 7(S1), 2010, S55-S60

- [4]. V. Kumthekar and S. Kolekar, Attributes of the latex emulsion processing and its role in morphology and performance in paint. *Progress in Organic Coatings*, 72 (2011), 2011, 380-386.
- [5]. A.M. Motawie, M.H. Sherif, M.M. Badr, A.A. Amer and A.S. Shehat, Synthesis and characterization of waterborne epoxy resins for coating application. *Austr.J of Basic and Appl. Sci.*, 4(6), 2010, 1376-1382.
- [6]. F. Karakas, G. Pyrgiotakis, M.S. Celik and M.M. Brij, Na-Bentonite and Mgo mixture as a thickening agent for waterbased paints. Kona Powder & Particle J., 29, 2011, 96-106.
- [7]. U.D Akpabio, Retention of urea formaldehyde resin finish on cellulosic fabric and its effect on water absorbent capacity of the treated fabric. *Int. J. of Advanced Sci.* & tech. Research, 2 (5), 2010, 31-39
- [8]. S. Ayoub, T. Taghi, K. Abolghasem and S. Ahmadreza, Improving some of applied properties of oriented strand board (OSB) made from underutilized low quality paulownia (Paulownia fortunie) wood employing nano-SiO<sub>2</sub>. Industrial Crops and Products, 42 (2013), 2013, 1-9.
- [9]. M.Cakir, I. Kartal, H.Demirer and R.Samur, Effect of water absorption on the wear behaviour of sol-gel processed epoxy/silica hybrids. *Scientific research and essays*, 7 (7), 2012, 805-812.
- [10]. S.A. Osemeahon, I.I. Nkafamiya, C. Milam and U.U. Modibbo, Utilization of amino resin for emulsion paint formulation: Effect of urea formaldehyde viscosity on urea formaldehyde and Soybean oil copolymer composite. *Afri. J.Pure and Applied Chem.* 4 (1), 2010, 001-006.
- [11]. J.E.D. Al-bermany, Study some physical properties of post-irradiation for polystyrene dissolved in Toluene. American J. Sci Research, 29, 2011, 130-141
- [12]. N. Atiq, S. Ahmed, M.I. Ali, S. Andleeb, B. Ahmed and G.Roson, Isolation and Identification of PS biodegrading bacteria from soil. African J. microbiology Research, 4 (14), 2010, 1537-1541.
- [13]. O. I. Nkwachukwu, C. H. Chima, A.O. Ikenna and L. Albert, Focus on potential environmental issues on plastic world towards a sustainable plastic recycling in developing countries. *Int. J. Industrial chemistry*, 4 (34), 2013.
- [14]. G. Ricky, L. Oscar and S. Yusef, An Investigation into Polystyrene Recycling at UBC. Dawn Mills APSC 262. The University of British Columbia. 2010, pp. 1-18
- [15]. J. Jesmy, P. Jyotishkumar, M.G. Sajeev and T. Sabu (editors Leib A, Grigoryeva O). Recycling of polymer blends, *Recent dev. in polymer recycling*, 2011:187-214.
- [16]. 16. A.S. Sabnis, V.G. Bhave, M.S. Kathalewar, S. Mare and P.P. Raut, New polyester polyol derived from recycled poly (ethylene terephthalate) for coating application. *Archives of Applied Science Research*, 2 4 (1), 2012, 85-93
- [17]. J. Purohit, G. Chawada, B. Choubisa, M. Patel and B. Dholakiya, (2012). Polyester polyol derived from waste poly (ethylene terephthalate) for coating application on mild steel. *Chemical Sci. J.*, 2012, 1-7.
- [18]. S.A. Osemeahon and C.A. Archibong, Development of urea formaldehyde and polyethylene waste as a copolymer binder for emulsion paint formulation. J. of Toxi. & Environment Health Sciences, 3 (4), 2011, 101-108.
- [19]. AOAC, Official Method of Analysis international (Horwitz, W, Editor) Gaithersburg Mongland, USA, 1 (41), 2000, 1-68.
- [20]. SON, Standard for Paints and Varnishes part 6: Test Methods for paints for Decorative purpose, 1990, pp1-24.
- [21]. S.K. Reddy, N.M. Prabhakar, K.P. Babu, G. Venkatesulu, K.U. Rao, C.K. Rao and S.M. Subha, Miscibility Studies of Hydroxypropyl Cellulose/Poly(Ethylene Glycol) in Dilute Solutions and Solid State. International Journal of Carbohydrate Chemistry, 2012, 2012, 1-9.
- [22]. A. Nodar, Preparation and characterization of crosslinked polymeric nano particles for enhanced oil recovery applications, University of Oslo. 2009.
- [23]. M.N. Mavani, Mehta and H.P. Parsania, Synthesis and physico-chemical study of polyester resin of 1,1- bis (3- methyl-4-hydroxy phenyl). Cyclohexane and rininoleic acid and its polyurethaneswith polyethylene glycol. J. Sci. & Ind. Res., 66, 2007, 377-384
- [24]. V.I. Blaise, D.S. Ogunniya, P.R. Ongoka, J.E. Moussounga and J.M. Ouamba, Physio-Chemical properties of alkyd resin and palm oil. *Malaysian Polymer Journal*, 7 (2), 2012, 42-45.
- [25]. H. Nouailhas, C. Aouf, C. Guerneve, S. Caillol, B. Boutevin and H. Fulcrand, Synthesis and propertie of biobased resin.Part 1. Glycidation of flavonoids by epichlorohydrin. J. Polym .Sci. Part A: Polym. Chem., 49 (2011), 2011, 2261-2270.
- [26]. Z.A. Abdullah and B.D. Park, Influence of acrylamide copolymerization of urea-formaldehyde resin adhesives to their chemical structure and performance. J. Appl. Polym.Sci., 117 (6), 2010, 3181-3186.
- [27]. J. Lee, J. Jeon and S. Kim, Green adhesives using tannin and Cashew nut shell liquid for environment-friendly Furniture Materials. *Journal of the Korea Furniture Society*, 22 (3), 2011, 219-229.
- [28]. H.S. Purwantiningsih and Z.A. Mas'ud, Synthesis and Application of Jatropha Oil based Polyurethane as Paint Coating Material. *Makara Journal of Science*, 16 (2), 2012, 134-140.
- [29]. K. Xu, S. Zhou and L. Wu, Preparation and properties of thermosetting acrylic coatings using titanium-oxo-cluster as a curing agent. Chinese J.Polym. Sci., 27 (3), 2009, 351-358.
- [30]. J.H. Naghash, A. Karimzadeh, R.A. Momeni, R.A. Massah and H. Alian, Preparation and properties of triethoxyvinylsilanemodified styrene-butyl acrylate emulsion coploymers. *Turk. J. Chem.*, 31(2007), 2007, 257-269.
- [31]. T. Zorba, E. Papadopoulou, A. Hatjiissaak, K.M. Paraskevopoulos and K. Chrissafis, Urea-formaldehyde resins characterized by thermal analysis and FTIR method. *J. Thermal Analysis and Calorimetry*, 92, 2008, 29-33.
- [32]. D.O Onukwli and K.P.Igbokwe, Production and characterization of castor oil-modified alkyd resins, J. Eng. Appl. Sci., 3 (2), 2008, 161-165.
- [33]. V.V. Jain, Evaluation of second generation indirect composite resins. (Master's thesis, Indiana University, 2008).
- [34]. B. Kaygin and E. Akgun, A nano-technological product: An innovative varnish type for wooden surfaces. Scientific Research and Essay, 4 (1), 2009, 001-007.