v. 3, n. 30, 2023

Journal of
Engineering
Research

REFORMULATION OF A PAINT BASED ON RECYCLED EXPANDED POLYSTYRENE

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Abstract: Currently in Mexico, one of the problems that affect it is contamination by accumulation of Urban Solid Waste (MSW) in the soil. Within these RSU we find various types of polymers such as cellulose fiber (cardboard), PET, expanded polystyrene (UNICEL or EPS) among others; The latter is one of the residues that can hardly be degraded, which is why various methods have been designed or developed to recycle it and be able to reuse it in various processes in the industry. Therefore, the present work is focused on the search for new alternatives for the recycling and reuse of UNICEL, as is the case of the design of a painting, during which satisfactory results were shown, because the product showed compliance with the compatibility parameters established for the production of paints, as well as adhesion to surfaces, texture, resistance to deformation, viscosity and finish on surfaces. In addition to the fact that it is a product based on the reuse of recycled expanded polystyrene, which has properties related to the manufacture of resins and paints.
Keywords: Recycled, expanded polystyrene, resins, paint.

INTRODUCTION

In recent years, one of the most deeply rooted problems in Mexico is the increase in the consumption of plastics, which are discarded and turned into an environmental threat by consumers of various industry products (construction, auto parts, electrical and electronic. food, pharmaceutical, textile among others), due to the fact that there are still no efficient recycling treatments for said waste, new processes have been sought for its transformation and reuse. One of the most common plastic waste is Expanded Polystyrene (EPS) also known as "Unicel", which is widely used in the packaging, packaging and storage industry by 39.4% worldwide only in 2012, due to be a lightweight and inexpensive material [5,12]; Once this material reaches the end of its useful life, it is discarded in landfills, where it takes about 150 years to degrade, thereby causing water and soil contamination [9]. In 2016, in our country about 148 tons of EPS were consumed per year, of which only 15 thousand tons were reused in the construction sector each year [13]. Due to the above, EPS is considered a material that can be used as a raw material for the development of thermoplastics, since it has advantages such as low density, low energy production, low CO2 emission and renewability, apart from its low cost and light, due to the composition that it presents in its structural matrix of 98% air and 2% polystyrene [10].

On the other hand, styrene is a product that was isolated in 1831 by Bonastre from the amber tree as a natural resin, with which they began to carry out industrial production processes of polystyrene and it was not until the 1930s when its sale began. use in Europe and America [4]. In 1944, the first polystyrene foam was synthesized, which was a porous resin that, when mixed with phenol and formaldehyde, generated a foam, that is, expanded polystyrene was formed [7]. Subsequently, beads, insulating products and continuous EPS extrusion processes would be developed with this material [6].

At present, there are various works focused on the recycling of EPS that allow the development of techniques for the recovery and transformation of UNICEL. One of the methods used was that of Dissolution precipitation in which a better solution was obtained with 30% EPS and a volumetric precipitation 1/3 THF/EG (Tetrahydrofuran/ Ethylene glycol) [12]. Likewise, work has been carried out with the purpose of applying alkyd resins to comply with the quality parameters required for the development of finished products, such as lacquers, sealants and enamels for wood, thus constituting a technologically and economically feasible alternative for the reduction of production costs [2]

Therefore, the present work is focused on the recycling of expanded polystyrene generated in the streets and garbage dumps to try to reduce the contamination caused by the polymer and focus on green or sustainable chemistry, by transforming the EPS into the reformulation of a paint and with this, have a beneficial utility to society by reintroducing the EPS in its life cycle. In addition, this project is based on the substitution of resins used in said paint formulation and thus try to reduce production costs on an industrial scale, as well as the use of solvents that do not harm the environment, are cheap and have the ability to dissolve Styrofoam, resins, pigments and additives for the formulation of paints with adhesion properties, resistance to deformation, corrosion, with good appearance, finish and color.

METHODOLOGY

WASHING AND DRYING PROCESS

This method was carried out by adding a volume of 300mL of standard Thinner and 50g of EPS to a 500mL beaker to form a heterogeneous mixture. Once the mixture was formed, the product was taken to the filtration process until a filter was obtained, which was carried out two more times. Finally, it was recovered in a container and stored to carry out the drying of the product and continue with the determination of solubility.

DETERMINATION OF EPS SOLUBILITY WITH ORGANIC SOLVENTS

To determine the solubility of the EPS with different solvents as shown in Table 1, taking solid percentages of 30, 40 and 50%, while 50, 60 and 70% of each of the organic solvents were added. For this procedure, the finish, viscosity, appearance and volatilization time were evaluated.

Solubility 50% solids – 50% solvent: In a 20mL beaker, 5g of solvent and 5g of expanded polystyrene were added, which were stirred until a completely homogeneous mixture was achieved at room temperature. The process was repeated with each of the solvents in triplicate.

Solubility 40% solids – 60% solvent.: In a 20mL beaker, 6g of solvent and 4g of expanded polystyrene were added with constant stirring until a homogeneous mixture was reached at room temperature. Again, it was performed with each solvent in triplicate.

Solubility 30% solids – 70% solvent.: In a 20mL beaker, 7g of solvent and 3g of EPS were added, stirring constantly until reaching a homogeneous mixture at room temperature and in triplicate.

Solvent	Solvent Type	% Styrofoam Solids	% Organic solvent
MEK	Active	50	50
		40	60
		30	70
Ethyl acetate		50	50
		40	60
		30	70
Acetate of butilo		50	50
		40	60
		30	70
MIBK		50	50
		40	60
		30	70
Xylene	diluent	50	50
		40	60
		30	70
Toluene		50	50
		40	60
		30	70
naphtha gas		50	50
		40	60
		30	70
Ethanol	Latent	50	50
		40	60
		30	70

Table 1.- EPS percentages and organic solvents for solubility tests

EPS COMPATIBILITY WITH ORGANIC SOLVENTS

To determine the compatibility, various mixtures of EPS and the organic solvents with the highest solubility were carried out at different concentrations as shown in Table 2..

Mix XTEPS. In a 20mL beaker, 3.5g of xylene, 3.5g of toluene and 3.5g of EPS were added, which were shaken until a homogeneous mixture at room temperature in triplicate..

Mix 20AeXEPS. In a 20mL beaker, 2g of ethyl acetate, 5g of xylene and 3g of EPS were added, stirring vigorously until reaching a homogeneous mixture at room temperature, the procedure was carried out in triplicate..

Mix BXEPS: In a 20mL beaker, 2g of MIBK, 5g of xylene and 3g of EPS were added, which was stirred until the mixture was homogeneous at room temperature and in triplicate..

Mix AbXEPS: In a 20mL beaker, 2g of butyl acetate, 5g of xylene and 3g of EPS were added, and the mixture was stirred until homogeneous at room temperature and in triplicate.

At the end of each mixture, the rooting test was carried out to validate the efficiency of the method and thus the formation of a film to verify compatibility.

Mix	Components (%)					
	EPS	Xyle-ne	To-luene	Ethyl acetate	Acetate of butilo	MIBK
XTEPS	30	35	35	***	***	***
AeXEPS	30	50	***	20	***	***
BXEPS	30	50	***	***	***	20
AbXEPS	30	50	***	***	20	***

Table 2.- EPS and organic solvent percentages for compatibility tests

CHARACTERISTICS EVALUATED IN SOLUBILITY AND COMPATIBILITY TESTS

Finished: In the solubility evaluation, different parameters were evaluated, such as the finish, which was determined according to three types: glossy, semi-matt and matte, taking the root of the paint.

Viscosity: This parameter was evaluated with Gardner tubes (bubble viscosity), obtaining viscosities from Z1 to Z3, these viscosities being very high in centipoise and very low compared to other liquid resins (nitrocellulose, alkyd, formaldehyde, etc.), their viscosities range from Z3 – Z5 or higher, but in conclusion if the viscosity is in Z1 to Z3 it is ideal for making a paint.

Appearance: This method of analysis was evaluated through sight, obtaining three types, which are: transparent, opaque and yellowish, after having carried out the rooting of the mixture made with the components.

Due to the above, it can be said that a yellowish or opaque appearance appears, this indicates an incompatibility between the solvent and the EPS, polymers, resins or organic solvents for the formulation of paints. On the other hand, if it presents a transparent appearance, it indicates excellent compatibility between the components of the mixture and the formulation with organic solvents and alkyd resins.

Volatilization time: This method is carried out by performing the rooting and taking the time it takes for the sample to dry with each of the solvents used for the test.

PAINT FORMULATION

This procedure was carried out from the determination of the solubility and compatibility tests, to determine the addition of an alkyd resin. Once the mixture was selected according to the solubility and compatibility tests, the addition of 10% of synthetic resin was carried out and the corresponding determinations were made.

RESULTS

WASHING AND DRYING PROCESS

During this process it was observed that when washing the EPS with standard Thinner, impurities were eliminated as shown in Figure 1 item b, leaving the polymer free of these; then it was filtered and allowed to dry (see Figure 1, item c) for later storage and use in solubility and compatibility tests.

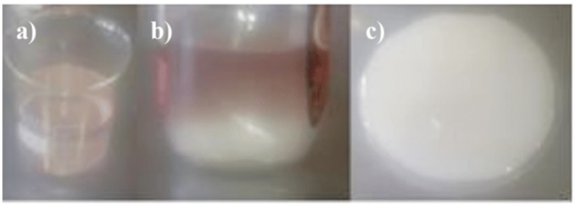

Figure 1.- EPS pretreatment: a) Thinner; b) EPS washing with Thinner; c) EPS drying

The impurities of the EPS are eliminated with Thinner, because the solvent has a mixture of undefined organic compounds (alcohols or latent solvents), therefore, it has the ability to retain them and leave the EPS free of impurities, without generating a homogeneous mixture; This solvent has different formulations having various components such as toluene, methyl alcohol, ethyl acetate, methyl ethyl ketone, heptane, hexane, acetone, benzene and other smaller substances that help separate impurities, since they are organic solvents of different polarities., which provide affinity to both polar, mildly polar, and polar substances [8].

DETERMINATION OF EPS SOLUBILITY WITH ORGANIC SOLVENTS

In the case of the solubility of EPS in organic solvents, the parameters of finish, appearance and viscosity in the different mixtures were taken into account, because the classification of these can be considered for proportions of 50% (solids) - 50 % (solvent) are heterogeneous mixtures; likewise for proportions of 40% (solid) - 60% (solvent) they are considered colloids and finally for proportions 30% (solid) - 70% (solvent) they are homogeneous mixtures [1].

As shown in Table 3, the mixtures with a

30% (solids) - 70% (solvent) ratio in almost all solvents except ethanol, presented similar characteristics in the appearance of the product, in addition to the fact that EPS was incorporated into the mixture homogeneously.

Solvent Type	Active Solvent	Notes
Active	MEK (50-50)	Heterogeneous mixture
	MEK (40-60)	Colloid
	MEK (30-70)	Homogeneous mixture Mate Viscosity Z1 (Gardner) yellowish layer
	Ethyl acetate (50-50)	Mezcla heterogénea
	Ethyl acetate (40-60)	Colloid
	Ethyl acetate (30-70)	Homogeneous mixture
		shiny
		clear coat
		Viscosity Z3 (Gardner)
	Acetate of butilo (50-50)	Heterogeneous mixture
	Acetate of butilo (40-60)	Colloid
	Acetate of butilo (30-70)	Homogeneous mixture
		shiny
		clear coat
		Viscosity Z2 (Gardner)
	MIBK (50-50)	Heterogeneous mixture
	MIBK (40-60)	Colloid
	MIBK (30-70)	Homogeneous mixture
		shiny
		clear coat
		Viscosity Z2 (Gardner)
Latent	Ethanol (50-50)	Incompatible
	Ethanol(40-60)	Incompatible
	Ethanol(30-70)	Incompatible
Diluent	xylol (50-50)	Heterogeneous mixture
	xylol(40-60)	Colloid
	xylol(30-70)	Homogeneous mixture
		shiny
		clear coat
		Viscosity Z3 (Gardner)
	Toluene (50-50)	Homogeneous
		mixture
	Toluene (40-60)	Colloid
	Toluene (30-70)	Homogeneous mixture
		shiny
		clear coat
		Viscosity Z3 (Gardner)
	naphtha gas(50-50)	Incompatible
	naphtha gas(40-60)	Incompatible
	naphtha gas(30-70)	Incompatible

Table 3. EPS soluble with organic solvents

On the other hand, the mixtures with the proportion 50% solids - 50% solvent presented saturation and did not mix properly; while the mixtures with a proportion of 40% solids – 60% solvent presented a partial saturation, this type of mixtures are known as colloids. In the solubility tests, the solvents that showed incompatibility with the EPS were ethanol and naphtha gas.

Due to the above, using organic solvents is considered the best option for the solubility of EPS, because the safety data sheets for physical and chemical properties show that expanded polystyrene is compatible with aromatic, halogenated, ketone, and such form is insoluble in water and alcohols [11].

Subsequently, it was decided to select the mixture with 30% solids (film former) -70% solvent (liquid phase) for showing satisfactory results with respect to the solubility of the EPS, because it does not present a saturation or supersaturation in the mixture. and the components are adequately incorporated to obtain a homogeneous mixture, in addition to the fact that heterogeneous mixtures and colloids could generate irregular roots in finishing and appearance tests and with it, erroneous analysis.

On the other hand, the values about the drying of the solvent were obtained, which are shown in the following Table:

Solvent	Dust dry (min)	Touch dry (min)	Hardness (min)
MEK	3	5	10
Ethyl acetate	3	5	7
Acetate of butilo	4	6	10
MIBK	4	6	10
Xilol	10	20	25
toluene	15	20	30

Table 4: EPS drying time with organic solvents during the solubility test

According to Table 4, the solvents have different drying times, where the ideal active solvents to solubilize expanded polystyrene are MIBK and butyl acetate, while in diluent solvents there are xylene and toluene, since they have the retard drying feature. Taking into account the above, it can be mentioned that the MEK solvent is not convenient to use due to the characteristics of paint manufacturing because it showed an opaque appearance and not very good quality, likewise the ethyl acetate has fast drying, that is to say it volatilizes very quickly and is a disadvantage in the preparation of paints. Therefore, the solvents that could be used for the manufacture of paint are MIBK, butyl acetate, xylol and toluene for their volatilization time qualities.

EPS COMPATIBILITY WITH ORGANIC SOLVENTS

For the compatibility test, the parameters of appearance, finish, viscosity and volatilization time were again taken into account, where the results represented in Table 5 were observed:

Mix	Notes
XTEPS	Immiscible
AeXEPS	miscible shiny Viscosity Clear Coat Z_3 (Gardner)
BXEPS	dissolved Mate very plastic coating Viscosity Z2 (Gardner)
AbXEPS	miscible semimatt clear coat Viscosity Z2 (Gardner)

Table 5. EPS compatibility with organic solvents

Taking into account the previous Table, it was shown that the AbXEPS test would be the ideal one to carry out the mixture, since both solvents present adequate properties for the preparation of the paint, in addition to having the function of being able to form a single phase between the two. and take advantage of this to delay the volatility due to the action of xylene and consequently the drying time. In the paint manufacturing process, it is recommended to use a higher proportion of the component with a shorter volatilization time (xylene) and a lower proportion of the active solvent with a longer volatilization time (butyl acetate), in order to obtain a longer of ideal volatilization. On the other hand, a rapid volatilization is not recommended, because it can reduce the dissolving power in the mixture, and with it, the poor incorporation of the raw materials and the decrease in the volume of the paint.

Mix	Dust dry (min)	Touch dry (min)	Hardness (min)
XTEPS	***	***	***
AeXEPS	6	10	18
BXEPS	7	11	16
AbXEPS	8	12	19

Table 6. EPS drying time with organic solvents during the compatibility test

Table 6 shows the evaluation of the drying time in the compatibility test in which xylene and butyl acetate were added, the latter accelerates the drying speed and with it, the time is reduced, due to the fact that xylene retards drying while acetate increases it, thus generating an average volatilization index and with some miscibility between components, for which the AbXEPS mixture was selected.

In addition to performing the drying time test, the rooting test was obtained with the selected mixture. The test consisted of priming the AbXEPS mixture to check the adhesion and resistance of the film former, as a result of the test the formation of the film was shown, but with a detachment of it, due to the fact that the mixture lacked adhesion.

Although the 20Ab-50X-30EPS mixture (Table 8) has presented the necessary properties for a paint, it was subjected to a test of adhesion and resistance to the primer, as a result it was observed that the film former (see Figure 2) was detached from the surface, this is because expanded polystyrene (being a polymer) lacks adhesion.

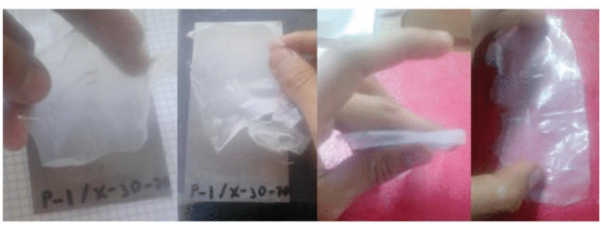

Figure 2. Film former of the AbXEPS mixture

Taking into consideration that polymers lack adherence (see Figure 3, section a), this can be compensated by an acid or resins with adherent properties, these give great flexibility and the generated film former is very resistant to deformation (resistance to the primer).

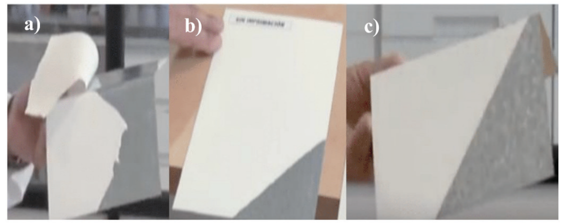

Figure 3. Adhesion and primer of the forming film: a) lacking adhesion; b) and c) with adherence

Therefore, the AbXEPS mixture was compensated with a medium chain alkyd resin, which is used to formulate solvent-based paints for domestic and automotive use and thus improve adhesion and resistance in the priming process.

PAINT FORMULATION

For the formulation of the paint, the addition of a 10% alkyd resin was made, as well as titanium oxide, xylene, dispersant, antifoam as additives to improve the characteristics of the paint. In the first place, the alkyd resin improved the compatibility of the AbXEPS mixture, since it presented the characteristics of being miscible, semi-matte, transparent layer, in addition to a Z3 (Gardner) viscosity. In addition, in dust drying it showed a time of 13 minutes, dry to the touch of 9 minutes and it reached hardness at 23 minutes.

The results observed in the formulation showed a modification in the minimum viscosity of the paint when adding the medium chain alkyd resin, observing an increase in viscosity without presenting saturation or a long mixing time, this is important, since in the industry For paints, it is necessary to look for resins with high viscosity, so that the paint does not show a high degree of dilution, in order to add extra solvent until reaching the viscosity desired by the buyer[3].

On the other hand, by incorporating the alkyd resin, it modified the drying times, which was 23 minutes; this was less than that used

Journal of Engineering Research ISSN 2764-1317 DOI 10.22533/at.ed.3173302314099

for a paint that corresponds to approximately 30 minutes, since it is the time it takes to dry a resin with standard characteristics, it may also vary depending on the solvent used and the paint formulation. The AbXEPS-RAlq mix (AbXEPS mix added with alkyd resin) showed excellent adhesion and resistance to priming as shown in the following Figure:

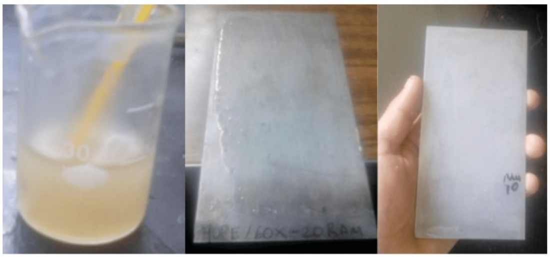

Figure 4. Film former of the AbXEPS-RAlq mixture

Finally, the AbXEPS-RAlq mixture was added with the additives, this improved the miscibility, the semi-matt appearance, it showed excellent adhesion, resistance and primer with a drying time to dust of 15 min., and dry to the touch with a time of 20 min, reaching hardness at 25 min.

CONCLUSION

The expanded polystyrene painting that was made met all the quality standards necessary for a painting, such as good adhesion, resistance to deformation, viscosity and a semi-matt finish. Firstly, it was shown that adding thinner to EPS removes impurities without exception. It was also possible to obtain the capacity of each of the organic solvents to solubilize the EPS, as well as the compatibility with mixtures of solvents to improve the drying times of the paint and reduce them in some cases. In addition to the addition of alkyd resin to obtain excellent adhesion and resistance during primer tests in film formation.

Finally, it can be mentioned that by recycling EPS for the reformulation of paints, production costs can be reduced for the use of waste materials and their reuse to produce products with different proportions of resins, solvents, additives and pigments to achieve a great variety. of paints with different properties and means of application (shades, finishes, viscosities, drying modes, etc.).

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