WOLKITE UNIVERSITY

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF CHEMICAL ENGINEERING

TITLE:- VARNISH PRODUCTION FROM POLYSTYRENE WASTE

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Declaration

We declare that this project entitled "production of varnish from polystyrene waste" is the result of our own project excepted as in the references. We were fully engaged to write this thesis document. Except we have taken from reference materials all the descriptions, recommendations are our own. Finally, we are intended to tell you this document is a good indicator of how much effort we made to go steps forward in the practical world by integrating it with the theoretical knowledge. We approve this by our name and signature.

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Acknowledgement

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Abstract

Varnish can be produced from both natural and synthetic resins. The main constituents of conventional varnish are resins, drying oil and solvent. Then the varnish is produced by mixing them at specified temperature. Our research work focused on the production of varnish from polystyrene waste and solvent. Three different polystyrene samples were prepared and dissolved using naphthalene as a solvent with (30%, 40% and 50% of w/v). The experimental work was conducted by using three level of temperatures (70^0C, 75^0C and 80^0C),three ratios (1:2, 1:2.5 and 1:3) and solvent namely naphthalene. The characteristics of produced varnish from PS waste were determined for scratch resistance, cracking, non-volatile content, waterproof property and drying time. To assess the quality of the varnish, a comparison with some common varnish was made based on water proofness, NVC, pH, scratch resistance and drying time. Based on the results obtained the varnish with 30% or 1:3 of w/v was chosen as the best one among others. It is found that the dissolution of polystyrene at 70^0C is appropriate in varnish production due to little significance change when operating at higher temperatures relative to energy cost issue for temperature rise. The physical parameters for the best varnish namely drying time and non-volatile content were found to be 30 minutes,30%. The drying time and NVC agreed with the standard of commercial varnish.The scratch resistance test, cracking test and waterproofing property test were also used to check the protective property of the varnishes and showed that this varnish with 30 % w/v resisted the scratch and water was spread on the coated wood samples and it was found that all the wood samples did not change their appearance. Also it is analyzed that solvent taken was employed as a best solvent in varnish production from polystyrene waste.

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List of acronyms and abbreviations

A.O.A.C	Association of official analytical chemists
CD	Compact disc
DSC	Differential Scanning Calorimeter
EC	Electrical conductivity
EPS	Expanded polystyrene
ERCA	Ethiopia Revenue and Custom Authority
ISO	International standard organization
LDPS	low density polystrene
MFI	Melt flow index
NVC	Non Volatile Content
OPS	Oriented polystyrene
PS	polystyrene
UVA	Ultra-Violet Absorber
XPS	Extruded polystyrene

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CHAPTER ONE

1. Introduction

1.1 Background

The term " varnish " is used to designate any solution which, when spread by means of a brush, in a thin layer over the surface of an object, or applied there to in a rational manner by any other suitable means, dries (either by simple evaporation of the solvent, as is the case with spirit varnishes, or by the combined evaporation of the solvent, and the more or less complete oxidation of the residue) to an adherent, smooth, uniform, lustrous, elastic, shining film, unaffected by air or moisture(Livache,1889) .Component of varnish production from polystyrene waste include resin, drying oil, dryer, and solvent. Based upon natural materials such as resins, oleoresins compositions, gums, linseed oils and glue; varnish has been used throughout history for preservation and protection. Today, alkyds dominate the coatings market although varnishes still maintain a critically important role in the preservation and protection of wood especially in the marine environment (Interlux, 2014.Some varnishes harden immediately as the solvent evaporates. So, it produces a film. The other varnishes harden slowly over a period of time. The process of hardening involves oxidation and polymerization. Shellac, Resin and Lacquer dry immediately. Acrylic and some of the water based varnishes evaporate the water or solvent and dry over a period of time. It is also known as curing process of varnishes. Oil based, polyurethane and epoxy varnishes also dry slowly to hard finish. The following factors affect curing process of a varnish: - temperature, humidity of atmosphere and components of varnish. Wood kept outside is normally exposed to big variations of temperatures and weather. It is also exposed to Ultra Violet(UV) rays in the atmosphere. Changes in humidity also affect the wood which results in contraction or expansion of wood. These all factors damage the wood or wooden articles. Hence, varnishes can be used to protect wood and wooden articles.

A good varnish should create uniform appearance on a surface. When a varnish dries, it should create a hard film. The process of drying should be rapid. The coating generated by a varnish should be long-lasting. A good varnish should not crack after drying process.Various factors like moisture content of wooden surface, ambient temperature, radiation exposure, etc. affect the stability of varnishes.Varnishes can be used to protect wooden surfaces like windows, doors, floors and roof trusses from atmosphere. Varnishes may be applied as a topcoat on worn finishes.

In a foamed form, this plastic is known under the trade name Styrofoam. As a foam, the material is primarily used as thermal insulation. Polystyrene is used for CD jewel cases, electric cable insulation, casings for electrical appliances, yoghurt containers, packaging foils, thermal insulation, insulating packaging material. Polystyrene, a thermoplastic substance used in packaging, is among the synthetic resins found as waste in nature after they have been used. It has been found that polystyrene can be a raw material for varnish production. This project aimed at producing and characterizing the varnish made from waste polystyrene.

For years, varnish has been used in wood protection and decoration. Varnish is traditionally a combination of a drying oil, a resin, and a thinner or solvent. During the production of varnish different kinds of resins may be used; natural or synthetic (Khan & Islam,2006). There are many types of formulation of varnish. They fall into two broad categories under todays system of categorization. The simplest type of varnish is classified as spirit varnish. The spirit varnishes were composed of resins and gums dissolved typically in spirits of wine (alcohol) much the same as we prepare todays shellac. In fact, in the 18 and early 19 centuries our modern day shellac would be consider a spirit varnish. The second category is Oleo resinous varnishes. These varnishes are a solution of resins, gums and a curing oil such as linseed oil, walnut oil or poppy seed oil. These varnishes cure by a process of chemical changes as well as solvent evaporation and form complex tough films made up of a mixture of resins and oxidized oil. This project aimed at producing and characterizing the varnish made from polystyrene.

Generally, a varnish contains Linseed Oil or Tung Oil, resins like phenolic, polyurethane or alkyd and solvents like naphtha, mineral spirit or thinner. In preparation of a varnish, the amount of oil with respect to resin used affects the applicability of the varnish. Besides this, a drying agent and additives also serve as components of a varnish. Varnish has little or no color and has no added pigment as opposed to paint or wood stain which contains pigment. However, some varnish products are marketed as a combined stain and varnish. Varnish is primarily used in wood finishing applications where the natural tones and grains in the wood are intended to be visible.

1.2 Statement of the Problem

Polystyrene takes very long time to decompose in the environment, thus it is considered as a pollutant when chucked in the environment. Polystyrene is not easily recycled because of its light weight (especially when colloidal suspension of a gas is in a liquid) and its low scrap value. Polystyrene is slow degrade, and if disposed of improperly, the foam can leach chemical into the environment harming water sources. On the other hand, Ethiopia imports paint and varnish in both aqueous and non-aqueous medium. The data from the Ethiopian Revenue and Custom Authority (ERCA) shows the import cost increases from 14,870,000 Birr (in 2015) to 156,965,717 Birr (in 2020). It is difficult to fulfill the needs of varnish for the country only with the imported varnish. Therefore, searching and utilizing of raw material, which is locally available, for production process is necessary in order to fulfill the need. To compromise the problems we try to produce varnish from polystyrene waste.

1.3 Objectives of the Study

1.3.1 General Objective

The general objective of this study was to produce varnish from polystyrene waste.

1.3.2 Specific Objectives

The specific objectives of this study are:-

- To determine the effect of temperature on polystyrene dissolution.
- To determine the best ratio of polystyrene mass to solvent volume of giving conventional varnish.
- To characterize the varnish produced from polystyrene waste.
- To determine the difference between commercial varnish and produced varnish out of used polystyrene waste in terms of water proofness, non-volatile test, drying time, cracking test, PH and scratch resistance test.

1.4 Significant of the study

This project eventually produces an acceptable varnish from polystyrene waste and help to reduce the problem of environmental pollution from disposal of waste polystyrene materials, the cost of purchasing market varnish, minimize the disposal issue of polystyrene waste and recycling option for waste polystyrene.

1.5 Scope of the project

The scope of this project is the use of waste polystyrene and different type of solvent for the production and characterization of varnish. This project is experimental study to show the effect of solvents, temperature and the ratio of polystyrene mass to volume of solvent on varnish property. The characterization methods such as density, PH,drying time and non-volatile content, and protective properties of varnish such as water proofing, cracking strength and scratching test are included.

CHAPTER TWO

2. Literature Review

2.1 Overview of Varnish

Varnishes are solvent solutions of resins and gums that dry or cure to form a thin, tough, glossy film on the surface of wood.Varnish is a formulation of resinous matter,as copal or lac,dissolved in oil or alcohol or any other liquid.when a varnish is applied to the surface of wood or metal,it dries and leaves a hard and generally transparent coating.it is a shiny coating which is applied on a floor or furniture.it dries clear and luminous.it gives a hard,lustrous and transparent finish to the surface. In the 17,18 and 19 centuries alcohol and a variety of vegetable oils such as linseed oil,walnut oil and poppy seed oil were the common solvents. Natural resins harvested from a wide range of plants, insect secretions or minded from fossilized vegetable materials such as amber were the primary component of most varnishes. Natural gums were used in small quantities as plasticizers in order to make the resins flexible enough not to crack or craze from the natural seasonal expansion and contraction of the wood (Ralph & Viking, 1982; Rutherford & George, 1966).

2.2 Varnish manufacturing

A varnish is an unpigmented colloidal dispersion or solution of natural or synthetic or both resins in oils in absence or presence of thinners (Senapati, 2002).The manufacture of varnish involves the mixing and blending of various ingredients such as resins, thinners and drying oils to produce a wide range of products. Usually, chemical reactions are initiated by heating. On industrial scale varnish is cooked in either open or enclosed gas-fired kettles for periods of 4 to 16 hours at temperatures of 93 to 340°C (Stenburg, 1959).Once coated, varnishes dry on the surface by evaporation, oxidation and polymerization of its constituents leaving behind a hard, transparent, glossy, lustrous and durable film.

2. 2.1 Characteristics and properties of varnish

A good varnish should be soft, tender, dry quickly, produce glossy and shining film on drying. It should not shrink or crack after drying. It must adapt itself to the contraction/expansion of coated material like wood due to temperature. Varnishes are generally applied by brush and the brushing properties are determined largely by the viscosity.

If this is too high, brush drag will be experienced and the varnish will be difficult to spread; if too low, the varnish will form runs on vertical surfaces and the film will be excessively thin (Morgans, 2000)

The drying time of a varnish is dependent on the composition but, in addition, it is influenced by film thickness, temperature and humidity of the air, nature of the substance acted upon in a biochemical reaction and the amount of light reaching the surface (Morgans, 2000). The property which is important from a practical viewpoint is the resistance of the film to mechanical injury and this depends on a combination of hardness and toughness.

Table 2.1 The properties of types varnish (https://www.researchgate.net/figure/properties-ofvarnishes-Used-in-Test_tbI1_263216123/downloaded sited on Jan 18 at 10:30 pm)

Types of varishes	PH	Solid content (%)
Water based (filler)	6.95	26
Water based (finishing)	8.93	39
Synthetic	8.87	54
Celluloses lacquer(filler)	4.08	29
Cellulose lacquer(finishing)	4.2	26
Polyurethane (filler)	6.55	55
Polyurethane (finishing)	6.25	42

2.2.2 Advantage and disadvantage of varnish

Advantages of varnish

The varnish is introduced on unpainted furnishings as well as other wood carvings to beautify the layer by covering the exquisite grain of the wood and also to preserve the surface from the harmful effect of the environmental,The painted surface is decorated to improve the quality of the paint also maximize the longevity of the paint film,for more molecular stability,a high concentration of resin ,Thicker finishing,simple application,cheap to buy ,Enabled at one degree of brightness(glossy),Bright finishing and Simple to identify.

Disadvantages of varnish

It's not robust so it shouldn't be flood-resistant,More resistant than urethane varnish,clear and bad scent,Turns yellow in time,Dry painfully,Needs to wear a mask ,Masks the grain of the trees,Toxic and detrimental to your wellbeing needs the move of citizens

2.2.3 Types of Varnish

There are two types of varnish based on basic components it composed of:

- Spirit varnishes
- Oleo resinous (oil) varnishes

Spirit varnishes

These are solutions of natural resins like shellac, rosin, copal, dammar, kaurigum in methylated spirit or some other completely volatile non film forming solvent. These varnishes dry rapidly but undergo cracking and peeling in absence of plasticizers.

Oleo resinous varnishes (oil varnishes)

These are homogeneous solutions of one or more natural or synthetic resins in drying oil and a volatile solvent. Some plasticizers can also be added to the oil. This type of varnish dries up by evaporation of volatile solvent, followed by oxidation and polymerization. Consequently, such varnishes take comparatively longer periods (nearly 24 hours) for drying, but the film producing is hard, quite lustrous and durable.

2.2.4 Types of Oil Based Varnishes

Phenolic Resin: - This varnish is made with phenol (a plastic) and formaldehyde. The phenol is a solid and is made into liquid by heating it with oil and then adding in the other ingredients. When the finish is applied in a thin film and exposed to the air, the solvent will evaporate and it will turn back to its solid form.

Alkyd Resin: - Less expensive, this is a type of polyester resin that is combined with alcohol and acid. It is also cooked with oil to create a varnish. This is the most commonly used resin in commercial varnishes today.

Polyurethane: - Polyurethane is classified as an oil based varnish, although some purists will disagree. Initially developed to be used as a substitute for other plastics, polyurethane has become one of the most commonly used resins in the manufacturing of many wood finishes. Polyurethane is a very tough, abrasion resistant resin. There are many types and forms of polyurethane, but the kind of polyurethane finish you are used to seeing in paint and wood finishing supply stores is not pure polyurethane, but rather an alkyd varnish that has been modified by adding some polyurethane into it.That is why polyurethane should be classified as a varnish. Perhaps a better description would be modified varnish, but nevertheless, still varnish. It is applied and it cures in the same manner as other oil based varnishes. Contrary to what many people say about polyurethane, most modern high quality polyurethanes do not dry leaving a plastic appearance. They are available in various sheens from satin to semi-gloss to gloss and can also be rubbed to a beautiful smooth luster.Polyurethane's abrasion resistance makes it one of the most commonly used finishes today.

2.2.5 Factors affecting the Life of a Varnish

In dealing with the lifetime of a varnish, the environment has the most influence over how long a system will last.The amount of quality time and effort expended in varnish application is directly proportional to the degree of finish beauty and durability achieved. Certain climatic areas are much more severe on the life of a varnish. Varnish will not last as long in the Caribbean as it will in the Great Lakes for example (Interlux, 2114).The following is a list of factors that affect the longevity of varnish:

- **Oxidation** is caused by the presence of oxygen reacting with the varnish over a long period of time the film becomes more and more brittle and, therefore, becomes much more prone to cracking and crazing.
- **Water penetration** through the varnish to the wood will cause cracking and delimitation. Although no varnish is completely impermeable to water penetration it is generally negated with the use of hard resin. If the varnish is constantly immersed the water will penetrate and cause the varnish will blister and delaminate.
- **Contamination** of a surface from salt is another important factor that affects longevity.
- Therefore, it is very important to keep the varnish film clean of contaminants.
- **Chemical resistance** to common chemicals such as gasoline or jet fuel is also important.
- **Natural Oil** from within certain types of wood, like teak, will rise to the surface of the wood‟s fibers and begin to lift the varnish. This can result in detachment of the varnish. Care must be taken to remove as much oil as possible prior to varnishing(Interlux, 2014).

2.2.6 Uses of varnishes

The main use of oil varnishes has been the finishing of wood for improving the appearance,used to brighten the look of natural grains in wood and intensifying the ornamental grains of wood surfaces (Morgan, 2000).Varnishes can also be used to fight against corrosion. The inventive method for protecting from corrosion and scale deposit and restoring tubes of heat-exchanging equipment consists in applying a polymeric coating on the internal surface of tubes by gradually and rotationally moving an excessive volume of polymeric material there along and in hardening said material (Golovin, et al,. 2010).

2.3 components of varnish

These days the following varnishes are generally prepared whose gradients are given below.

1. Resins

Resins, form hard and lustrous film on drying. Generally it is said that more the quantity of resin in varnish, more hard and lustrous but weak it will be.

2. Drying Oils

Drying oils like linseed oil inhibits the property of elasticity and insolubility in the film of varnish, upon which the durability and adhesiveness depends. Generally it can be said that more the quantity of oil in varnish, more strong and durable it will be.

3. Dryer

Driers are very important in coatings. They accelerate the drying process and increase the hardness of the coating. The blend of driers that is used in a varnish has a great impact on the clarity, color, the actual rate of dryness and the stability of the product.

4. Solvent

The use of Solvent and their importance is well known in making a product brush able and usable. The blend of solvents is very important to the levelling characteristics and varnishes are no exception. Solvents are used to increase the standard flow-out without destroying the full bodied resin content. Levelling refers to the reduction of brush marks on a coating resulting in a level, smooth finish. Solvents are also critical to maintaining the wet edge capacity of varnish. Wet edge is very important as it all allows the varnish to be applied without any trace of brush marks from overlapping new areas (Interlux, 2014).

2.3.1 Characteristics of a Good varnish

A good varnish should create uniform appearance on a surface. When a varnish dries, it should create a hard film. The process of drying should be rapid. The coating generated by a varnish should be long-lasting. A good varnish should not crack after drying process. Various factors like moisture content of wooden surface ambient temperature and radiation exposure affect the stability of varnish.

2.4 Overview of polystyrene

Polystyrene (Poly (1-phenylethane-1, 2-diyl)), is an aromatic polymer made from the aromatic monomer styrene, a liquid hydrocarbon that is commercially manufactured from petroleum by the chemical industry (Polystyrene).

For many years, polystyrene has been used for different purposes such as packaging material, disposable cups making, CD cases making and many more. However, it has been found that when no longer used polystyrene-based products are discarded in nature where they become pollutants. Furthermore, it is known that resins are ones of the most vital components of varnish. Polystyrene being a resin was thought to be a raw material for varnish production. Hence, these polystyrene-based products can be used in varnish production (Goodier, 1961).

2.4.1 Structural features and properties of polystyrene

2.4.1.1 Structural features

Polystyrene is represented by the chemical formula, C8H8 and is made up of two chemical elements, carbon and hydrogen (Denis H, *et al,* 2005).

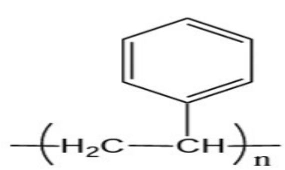


Figure 2.1 Chemical structure of a building block unit of polystyrene complex

2.4.1.2 Properties of polystyrene

The unique physical and chemical properties of polystyrene makes it good material for a wide range of applications. In solid form, polystyrene is a colorless and rigid plastic. However, this material may also be returned to a liquid state by heating and used again for molding or extrusion.Polystyrene is transparent, light, and has excellent moisture resistance. It has good electrical insulation characteristics. Polystyrene is hard but brittle and has a density of 1.050 g/cm3. Most of the polystyrene properties are due to properties of carbon. It is highly flammable and burns with an orange yellow flame, giving off soot, as a characteristic of all aromatic hydrocarbons. Polystyrene, on oxidation, produces only carbon dioxide and water vapour (Goodier, 1961).

2.4.1.3 Preparation of polystyrene

Polystyrene is manufactured by the addition polymerization of styrene monomer unit. The main manufacturing route to styrene is the direct catalytic dehydrogenation of ethyl benzene.

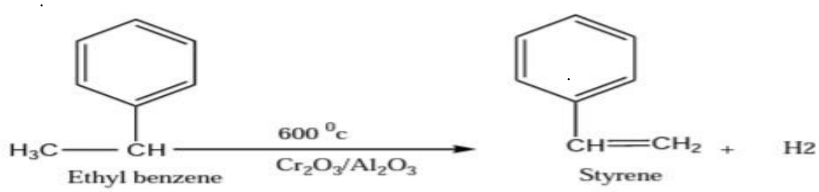


Figure 2.2 synthesis of styrene from ethyl benzene

The reaction shown above has a heat of reaction of 121 KJ/mol (endothermic). Nearly 65% of all styrene is used to produce polystyrene.

The overall reaction describing the styrene polymerization is:

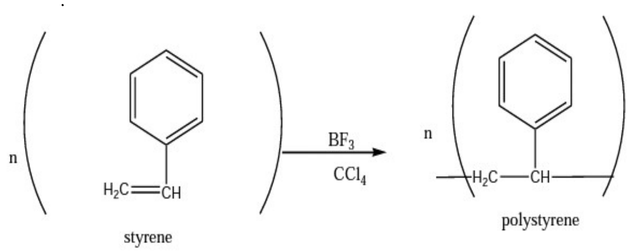


Figure 2.3 Synthesis of polystyrene from styrene

2.4.1.4 Types and importance of polystyrene

In general, there are four main types of polystyrene: sheet, foams, copolymers and oriented polystyrene (Goodier, 1961).

A. Sheet or molded polystyrene

Polystyrene is economical, and is used for producing plastic model assembly kits, plastic cutlery, s moke detector housings, license plate frames, and many other objects where a fairly rigid, economical plastic is desired. Production methods include thermoforming and injection molding.Polystyrene petri dishes and other laboratory containers such as test tubes and microplates play an important role in biomedical research and science (Mihai, *et al*, 2007).

B. Foams

Polystyrene foams are good thermal insulators and are therefore often used as building insulation materials, such as in structural insulated panel building systems. They are also used for nonweight-bearing architectural structures (such as ornamental pillars). PS foams exhibit also good damping properties, therefore it is used widely in packaging (Mihai, *et al*, 2007).

- **Expanded polystyrene**

Expanded polystyrene (EPS) is a rigid and tough, closed-cell foam. It is usually white and made of pre-expanded polystyrene beads. Familiar uses include molded sheets for building insulation and packing material ("peanuts") for cushioning fragile items inside boxes. Sheets are commonly packaged as rigid panels, which are also known as "bead-board". A growing use of EPS in construction is insulating concrete forms (Heneault,.*et at,* 2007).

- **Extruded polystyrene foam**

Extruded polystyrene foam (XPS) consists of closed cells, offers improved surface roughness and higher stiffness and reduced thermal conductivity. Extruded polystyrene material is also used in crafts and model building, particularly architectural models. Because of the extrusion manufacturing process, XPS does not require facers to maintain its thermal or physical property performance. Styrofoam is a trademarked name for XPS; however, it is often also used in the United States as a generic name for all polystyrene foams (Goodier, 1961).

C. Copolymers

Pure polystyrene is brittle, but hard enough that a fairly high-performance product can be made by giving it some of the properties of a stretch material, such as polybutadiene rubber.

D. Oriented polystyrene

Oriented polystyrene (OPS) is produced by stretching extruded PS film, improving stiffness (Heneault,.*et at,* 2007).

2.4.1.5 The factors that affecting the varnish production

Juvenal Mukurarinda and Jean François Régis Nisengwe showed the effect of polystyrene mass to solvent (naphtalene) volume ratio on the production of varnish. Their research work focused on the production of varnish from one of the synthetic resins, polystyrene. Five different polystyrene solutions prepared in toluene (6%, 10%, 14%, 18%, 22% of w/v) were determined for density, viscosity, non-volatile content, thickness, waterproof property and drying time using Densitometer, Haake viscometer, watch glass and calculation method.

Generally, the factors that affecting process of a varnish include:-

- Temperature
- Component of varnish
- Moisture content of wooden surface
- Drying time
- Hardness
- Scratch resistance
- cracking
- water proofness

Wood kept outside is normally exposed to big variation of temperature and weather. It is also exposed to Ultra Violet (UV) rays in the atmosphere. Changes in humidity also affect the wood which results in contraction or expansion of wood. These all factors damage the wood or wooden articles. Hence, varnishes can be used to protect wood and articles.Generally, a varnish contains linseed oil or tung oil, resins like phenolic, polyurethane or alkyd and solvents like naphthalene, mineral spirit or thinner. In preparation of varnish, the amount of oil with respect to resin used affects the applicability of the varnish. Less amount oil but a large amount of resin in a varnish may result in a hard and brittle finish. Besides this, a drying agent and additives also serve as component of a varnish.

2.4.1.6 Effect of temperature on solubility

Polydispersity, number average molecular weight, and decomposition polystrene wastes are affected bytemperature variations. As consequence of the soft heating an incipient polymer thermal degradation could be produced. This fact lead to that the polymer decomposition can occur at temperatures much lower than those at which initially occurs. It can be observed that, although the decomposition temperature practically does not vary, the polydispersity slightly increase with increasing temperatures and number average molecular weight decrease, probably due to the beginning of degradation chains. Considering these results it may be stated that temperatures higher than 80 ^{0}C are not interesting because, although solubility are higher at higher temperature, it is produced a degradation of polymer chains .

CHAPTER THREE

3. Materials and Methods

3.1 Chemicals and materials

The experimental work was done in laboratory of chemical engineering department.

3.1.1 Chemicals used

- ✓ Naphtalene and oil: -used for dissolving expanded or foam polystyrene.
- ✓ Distilled water: - used for washing flasks, beakers and to normalize the probe during pH measurement.
- ✓ Tap water: -for washing dusts on external surface of polystyrene waste
- ✓ Buffer solution: - for standardization of pH Meter

3.1.2 Materials used

- ➢ PH meter: - to measure the acidity and alkality of sample.
- ➢ Stove: - For heating purpouse.
- ➢ Conical Flasks: - for preparation, mixing container and storing of sample.
- ➢ Stirrer: - for mixing uniformly during dissolution.
- ➢ Aluminum foil: - for packing the flasks that contains a sample.
- ➢ Electronic Balance (PW 124): - for measuring the weight of raw material (polystyrene pieces).
- ➢ Wood sample: - In which the test varnish is applied.
- ➢ Brush: - to polish the wood sample

3.2 Methods

The materials that is used for varnish production is polystyrene waste based-materials. The procedure for the production is divided into two parts: varnish production and characterization ofthe produced varnish. Steps involved in the production is:-

1. Collecting raw material and preparation

A. Collecting raw material

The raw materials will consist of foam polystyrene, and solvent(naphthalene).The Polystyrene waste was obtained from waste sources. solvent was taken from Total of Gubre town.

Figure 3.1 A.Collection of raw material B.Collected resin

B) **Cleaning**

The raw materials were separated from the chaffs and other impurities. This preparation is very important since any impurity in the polystyrene will eventually reflect on the varnish produced.

Figure 3.2 washing the raw material

C) Drying

After cleaning the dirty and dust of the polystyrene was dried by sun.

Figure 3.3 drying of the raw material

D) Size reduction

From the back groun3 of heat and mass transfer unit operation: when surface area increase there is also increasing of heat transfer rate, q=UA (ΔT). Therefore, when size of the polystyrene is reduced we can maximize the surface area of heat transfer and easily produce varnish.

Figure 3.4 size reduction of polystyrene

Mixing

The manufacture of varnish involves the mixing and blending of various ingredients such as resins and naphthalene, which is found between gasoline and benzene to produce a wide range of products.

Figure 3.5 mixing of polystyrene with naphthalene.

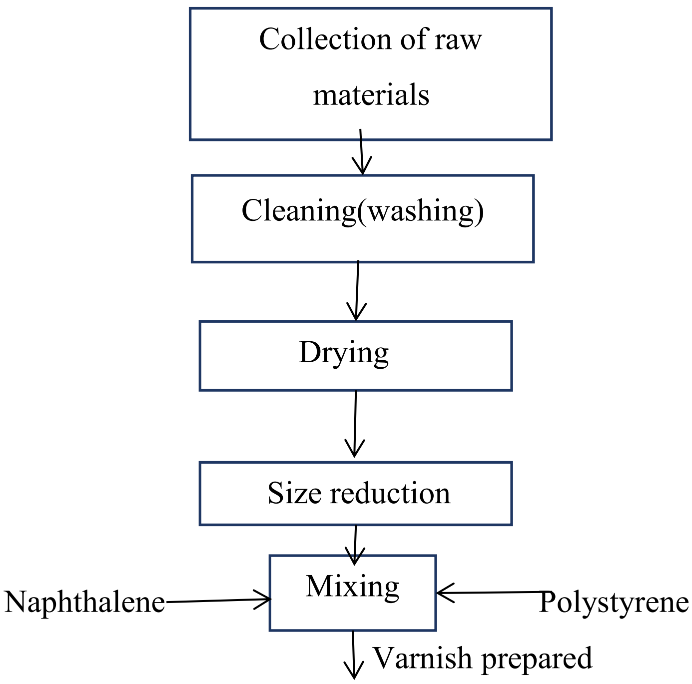


Figure 3.6 Process flow diagram of varnish production

3.3 Experimental design

In the production of varnish from polystyrene waste, three factors were selected to conduct the experiment. Those are: types of solvent , mass of polystyrene to volume of solvent ratio and temperature. For the experiment, two types of solvent, three levels of polystyrene to solvent ratios and three levels of temperature were considered, hence there was three levels of ratios, two levels for type of solvent, and three levels for temperature. Therefore, the numbers of experimental runs in the study were 9.

Number of run =3*3=9

No of run	Polystyrene(g)	Solvent(ml)	PS/Solvent(w/v)	Resin(g)	Temperature (0C)
1	15	50	1:3	11.4	70
					75
					80
2	20	50	1:2.5	11.4	70
					75
					80
3	25	50	1:2	11.4	70
					75
					80

Table 3.1 Experimental design

3.4 Experimental procedure

The experiment of production was carried out in chemical engineering Lab.Different type of varnishes products was generated by mixing different weight of foam (in grams) to volume of solvent (in ml) (w/v). Stove, beakers, stirrer, solvents, polystyrene waste,and volumetric cylinder were prepared.

The procedure was: -

50 ml of naphthalene was measured and poured in to beaker. The desired temperature (70^0C) was set initially, nothing the temperature of the solvent in the beaker. Once the temperature of the solvent was stabilized at the preset temperature, desired amount of finely chopped polystyrene (15 gram) was poured into the solvent. A simple stirrer was placed in the beaker on the heating plate to facilitate the dissolution. After all polystyrene had been dissolved, the beakers were closed with an aluminum foil to avoid oxidation and evaporation. The experiment was repeated by preparing desired mass of polystyrene to the volume of solvent ratios. The following ratio was prepared 30%(1:3), 40%(1:2.5) and 50%(1:2) and the procedures was followed as first steps above. The required mass of waste polystyrene foam and the volume of naphthalene was measured and each prepared ratio were mixed at each desired temperature. The temperature was varied for each category of sample to ensure adequate analysis based on the objectives. The effect of temperature on the solubility was investigated in the temperature of 70^0C, 75^0C and 80^0C for each solvent. Higher temperature were not used to avoid polymer degradation. The mixture was stirred to facilitate the dissolution. The time required to dissolve the polystyrene samples until clear solution is observed were recorded at different temperature. The final product was stored and conditioned for characterization.

3.4.1 Solvent selection for varnish production

The solvents used for preparing the polymer solution were generally selected based on the solubility parameter between polystyrene and solvent. However, the solvent with the highest solubility is not always the best solvent for the varnish production process. Initially xylene was intended to use as a solvent in varnish production, but due to the availability substitution by other solvent was carried out. For the experiment of varnish production naphthalene were selected.

Figure 3.7 Dissolution of polystyrene in solvent

Product conditioning

The produced varnish was inspected by visual observation and the varnish was cooled 70^0C and kept at safe place for some days before characterization.

Figure 3.8 Produced varnish

3.4.2 Characterization of the product

All those different varnishes that had produced were studied with regard to different characterization parameters.The following parameters were examined: time taken to dry, non-volatile matter and PH.

3.4.3 Non-volatile content

Non-volatile matter of vanishes is a residue by mass obtained after evaporation from the stove at high temperature. The non-volatile matter was determined according to A.O.A.C Official Method of Analysis 960.19, 2000). The non-volatile content of varnish was measured using glass watch,drying,stove and analytical balances.The produced Varnishes was weighted, recorded and put to watch glass,then after it was taken to stove at the temperature higher than that of the 70^0C in the pursuit of the evaporation. The mass of the residue left in the glass was measured and recorded. To calculate non-volatile matter (NVC) in % of mass the following equation was used:

$\boldsymbol{NV}C = M2/ M1 *100\%$

Where,M1- mass of test sample of vanish(g)

M2 – mass of a residue(g).

3.4.4 Drying time

Drying time is the time taken to dry the paint of varnished wood products.The drying time taken for the samples was measured by preparing different pieces of smooth wood and varnished.Then, the samples were exposed to sunlight and the time taken to touch dry was measured using stop watch. The measurement was repeated for each sample of varnish.Triplicate evaluations were made for each sample and mean value assessment record.

3.4.5 Determination of pH

The pH of the varnish was determined using A.O.A.C Official Method of Analysis 960.19, 2000).A sample of varnish was taken and placed in a clean and dry 25 ml beaker. Then the pH electrode was immersed in to the sample. The pH electrode was standardized with a buffer solution first andthen the electrode was washed with distilled water and immersed in to the sample and the pH was read and recorded .The measurement was repeated for each sample.

Figure 3.9 PH meter and prepared varnish

3.5 Test of the protective properties of prepared varnishes

A good varnish should create uniform appearance on a surface. When a varnish dries, it should create a hard film. The process of drying should be rapid. The coating generated by a varnish should be long-lasting. A good varnish should not crack after drying process. Various factors likemoisture content of wooden surface, ambient temperature and radiation exposure affect the stability of varnishes. The following tests was carried out on the produced varnishes applied on wood samples. The resulted effect of all tests was analyzed by visual observation whether it have accepted water proofing, scratch resistance and cracking resistance test or not.

3.5.1 Water proofing

This test was performed using observation with naked eyes throughout the week by looking and spraying water three times a day (morning, noon and evening) on each varnishes coated wood samples labeled differently. The water proofing ability of varnish sample was observed and the best varnish was noted.

3.5.2 Scratch test

The produced varnishes coated on wood surface was tested using a sharp edge by taking each wood samples coated with different portion of varnish then scratch with sharp edge. The scratch tester created a scratch on the wood sample that could be seen with naked eye and the coated wood that resist to the test was selected.

3.5.3 Cracking test

Different wood samples were coated with sample of varnish and was kept at the safe place in the laboratory. The coated wood sample was left for a week and later through observation with naked eyes, the sample that resisted to cracking from them was noted.

CHAPTER FOUR

4. Results and Discussions

4.1 Effect of temperature on Polystyrene dissolution time

The following table shows the effect of temperature on the time required to dissolve the polystyrene samples at different ratio of mass of polystyrene(g) to volume of solvents(ml) that dissolve it.

PS(g)	Amount of solvent(ml)	PS(g)/Solvent(ml)	Temperature(^{0}C)	Time(min)
15	50	1:3	70	6.18
			75	4.80
			80	4.14
20	50	1:2.5	70	9.67
			75	5.33
			80	4.69
25	50	1:2	70	13.27
			75	7.53
			80	6.34

Table 4.1 Effect of temperature on PS dissolution time

The group of experiments was carried out in order to determine the temperature at which the dissolution should be performed. The levels of temperatures studied were 70^{0}C,75^0 C and 80^{0}C. Higher temperatures were not tested to prevent polymer chain degradation.Results obtained are shown in table 4.1.As it is observed, an increase on temperature produces an increase the solubility of polystrene in solvent studied. Nevertheless,the costs of the process would increase considerably as a consequence of the temperature increase, despite the fact that dissolution time did not decrease significantly. Therefore, the most adequate temperature to carry out this process is 70^{0}C while not so cold to reduce drastically the solubility.Naphtalene took less dissolution time than oil at corresponding temperatures. This might be the result of having higher similarity in solubility parameter with PS than oil does.The variation of dissolution time with temperature can be illustrated by the following graph.

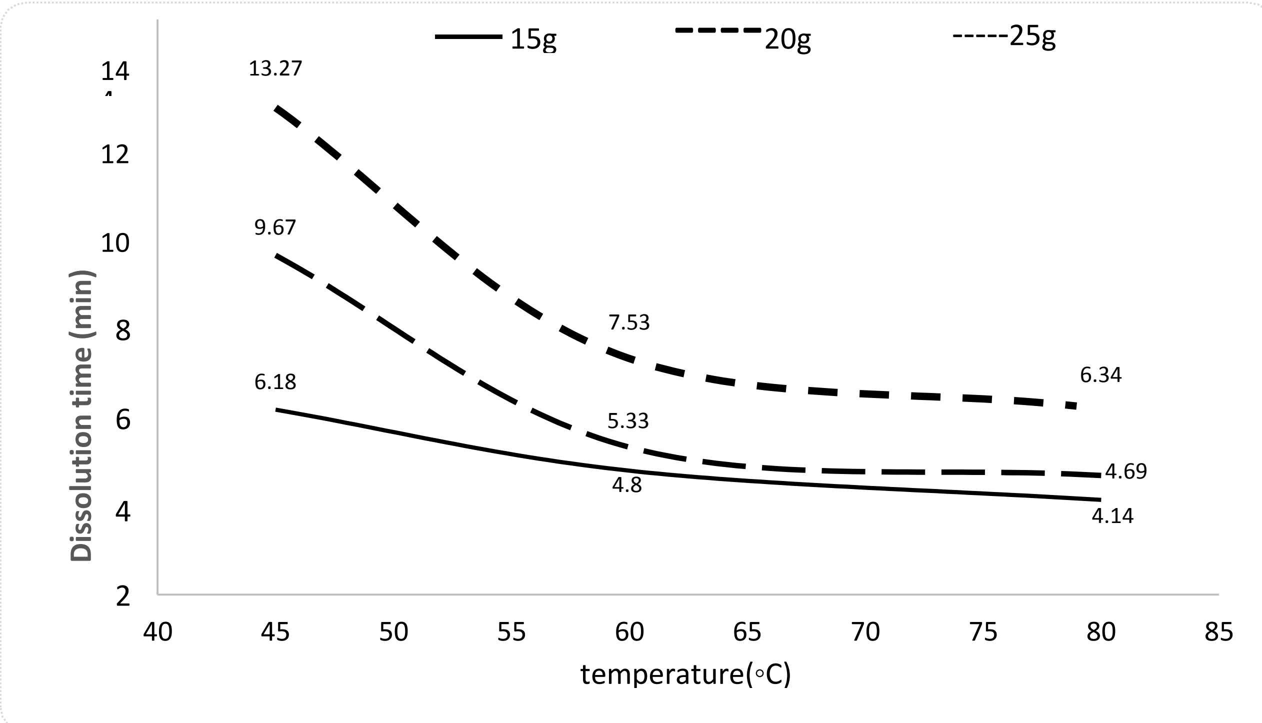


Figure 4.1 Effect of temperature and ratio on dissolution time

Let,X=Temperature

Y=Dissolution time

As shown in the above graph, as the X increases for each ratio the Y decreases. The least Y is observed at 70^0C and 1:3 ratio. This is due to the smallest mass of polystyrene used in the dissolution process. And as X increases the solubility of polystyrene increases and hence Y decrease.

4.2 Characterization of the product

All those different varnishes that had produced from discarded polystyrene were studied with regard to different characterization parameters. The following parameters were examined: time taken to dry, non-volatile matter, PH and density and protective properties. The result of all characterization is recorded and analyzed in the following section.

4.2.1 PH and drying time of produced varnish

Some Physical Properties of varnish are tabulated in table below from the table, pH of varnish is found between a range of 6.01-7.46 .The drying time of varnish is obtained between a range of 13-29 minutes at various ratio.

Table 4.2 PH and drying time of varnish

PS (g)	Solvent (ml)	PS(g)/Solvent (ml)	Temp. (0C)	PH	Time(min)
15	50	1:3	70	6.75	6.18
			75	6.42	4.80
			80	7.46	4.14
20	50	1:2.5	70	6.01	9.67
			75	6.34	5.33
			80	6.97	4.69
25	50	1:2	70	6.69	13.27
			75	6.56	7.53
			80	6.72	6.34

As seen from the above table the pH of varnish for each samples are not far apart each other. The pH of our varnish agree with the pH most types of varnishes that are produced commercially.

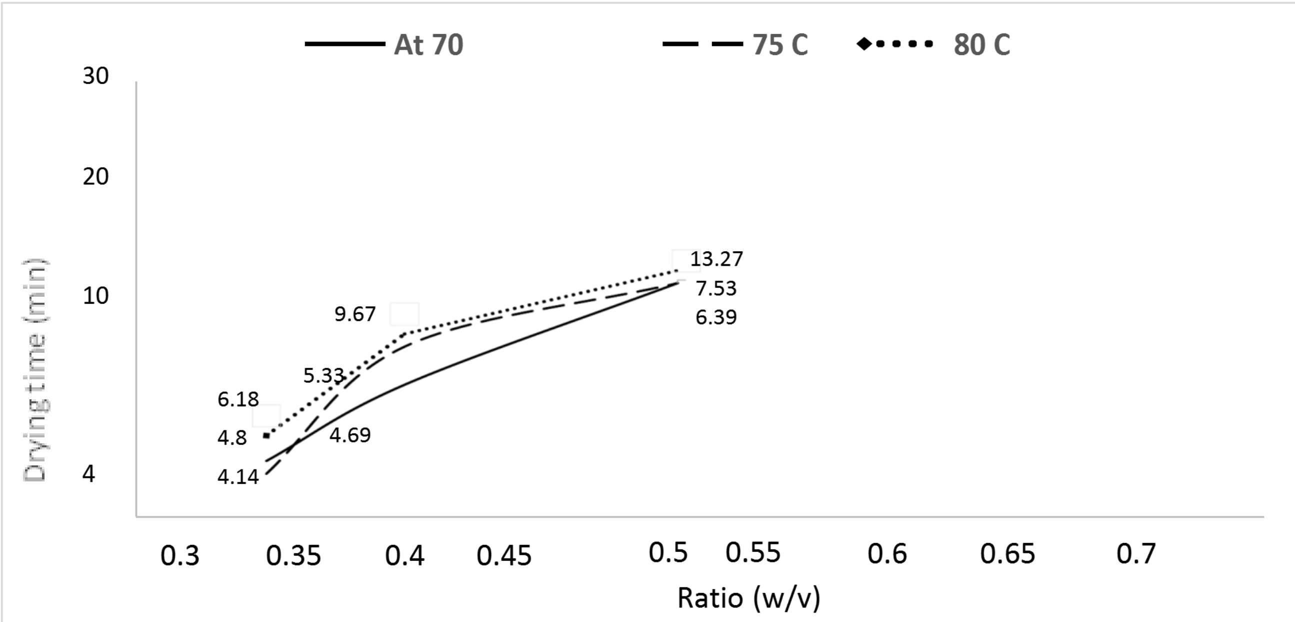


Figure 4.2 Effect of ratio on drying time of varnish

Let,X=Mass of polystyrene per solvent(w/v)

Y=Drying time

The above graph shows the drying time of varnish produced from polystyrene and naphthalene at different temperature and ratios. As shown in the figure 4.2 as X increased from 1:3 to 1:2,Y also increased for each temperature. The maximum Y is recorded for the varnish produced from PS at X of 1:3 and temperature of 70^0C by applying on wood sample. from our finding, all varnish samples have smaller drying time when compared to some conventional commercial varnishes.The smallest drying time is due to the solvent used in the production. Naphtalene have lower boiling point than most oils that are used to produce commercial varnishes. So, when the varnish produced from polystyrene is applied on wood, its drying time is reduced due to the boiling point of naphtalene. This can be considered as an advantage because the contamination may be reduced as drying time is low during real time applications.

4.2.2 Non Volatile content of varnish

Non-volatile matter of vanishes is a residue by mass obtained after evaporation from the stove at high temperature (105(^{0}C)for 1 hr). As shown in the table below, non-volatile content increases as the ratio of polystyrene to solvent increases. This is due to the increasing of solid content used in the preparation.

The highest non-volatile content of varnish was obtained at 80(^{0}C) and ratio of 1:2.

Table 4.3 Non -volatile content of varnish.

PS(g)	Solvent (ml)	Ratio(w/v)	Temp.(0C)	Mass of sample M1(g)	Mass of residue M2(g)	M2/M1*100%
15	50	1:3	70	12.32	1.78	14.44
			75	13.33	1.67	12.56
			80	12.16	1.86	15.32
20	50	1:2.5	70	16.32	3.67	22.49
			75	16.83	3.17	18.83
			80	14.11	3.99	26.58
25	50	1:2	70	19.11	5.88	30.76
			75	19.21	5.99	31.18
			80	19.28	5.93	30.76

The above data can be plotted into a graph of non-volatile content of produced varnish against temperature and ratios. The ratio is on the horizontal axis and the NVC(%) on vertical axis.

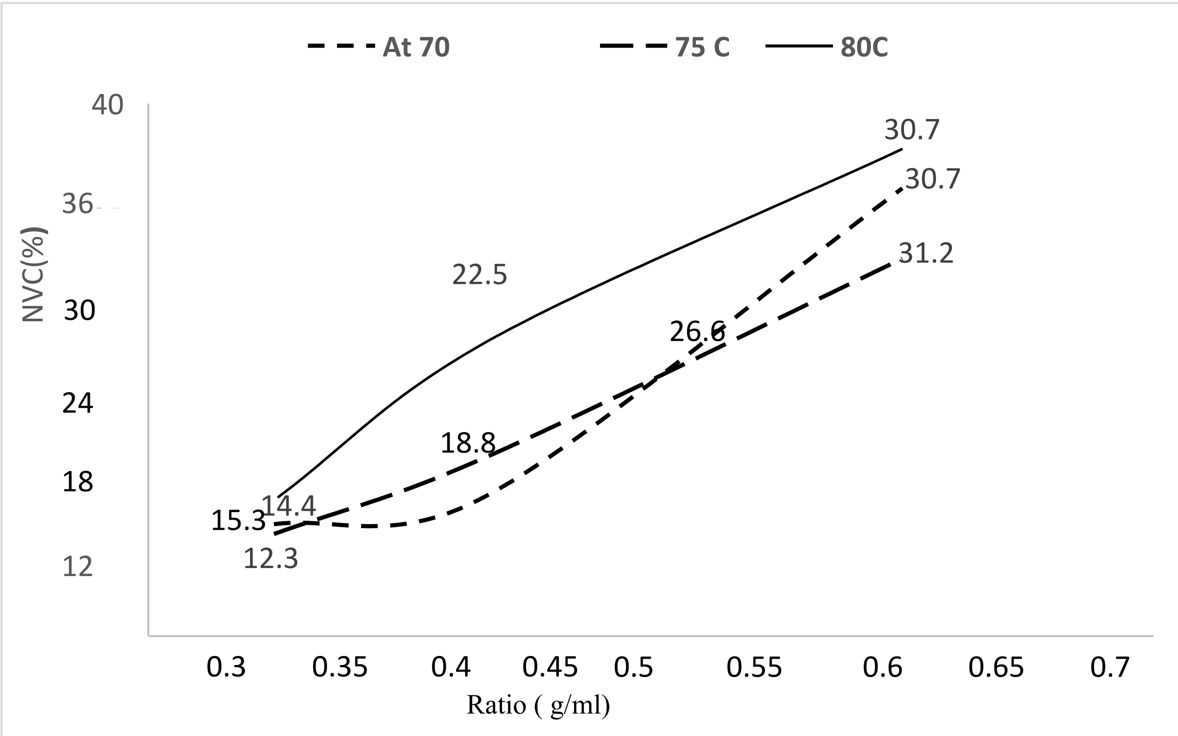


Figure 4.3 Effect of temperature and ratio on NVC of produced varnish for solvent.

Let X=Ratio

Y=NVC

As shown in the figure 4.3 As th X of PS mass to solvent volume increased the Y of the varnish increases for each temperature. The increasing in Y is due to the increasing of solid content of the varnish as the X increased from 1:3 to 1:2. The varnish produced at X of 1:3 and 70 (^{0}C) is 14.44% for solvent. This result agrees with the commercial varnishes that have Y between range of 26-54%.

4.2.3 Testing of produced varnish on wood

The following tests were carried out on the produced varnishes by applying on wood samples. The following tests are conducted on wood sample using a varnish for ratios of 1:3,1:2.5 and 1:2. The observed result is recorded on table below.

Table 4.4 Protective property tests result

Ratio(PS/Solvent)	Tests result		
	Water proofing	Scratch resistance	Cracking
1:3	Very good	Very good	Very good
1:2.5	Good	Good	Very good
1:2	Very good	Very good	Good

The results of the tests showed that all the samples resisted water and that some samples with 30%of weight to volume (w/v) resisted the scratch. As for the cracking, it was found that again most samples did not show signs of cracking while a few samples with lower ratio did not give the shyness behavior and hard film when applied to wood.

4.2.4 Scratch resistance test

The produced varnishes coated on wood surface was tested using a sharp edge by taking each wood samples coated with different portion of varnish then scratch with sharp edge. Based on the test, the sample with ratio of 1:3 have the best resistance to scratch.A sample with ratio of 1:2.5 have lower scratch resistance than 1:2. The highest scratch resistance might be resulted due to the high solid content of polystyrene in the dissolution with solvents. The highest solid content results higher NVC and hard film on woods when applied and high resistance to scratch.

Figure 4. 4 Scratch Resistance Test

4.2.5 Water proofing test

This test was performed using observation with naked eyes throughout the week by looking and spraying water three times a day (morning, noon and evening) on each varnishes coated wood samples labeled differently. Based on this test all samples are water proofed this might be due to excellent hydrophobicity or low moisture uptake of PS. Polystyrene does not dissolve with water.

4.2.6 Cracking resistance test

Different wood samples were coated with sample of varnish and was kept at the safe place in the laboratory. The coated wood sample was left for a week and later through observation with naked eyes, based on the test, all samples did not show the sign of crack but the lower ratios (1:2.5 and 1:3)did not form hard film on wood. This might be due to the strongest cross linking of polystyrene inthe dissolution with solvents.

CHAPTER FIVE

5. MATERIAL AND ENERGY BALANCE

5.1 Material balance

Polymer solutions with concentration higher than 50% w/v are quite viscous and, thus, difficult to handle. In the procedure described below, the concentration of the resulting solutions is chosen to be equal to 30% w/v. Lower concentrations would result in higher volumes of solvents to treat,Since most of plastic types that exist and cause a great effect are low density polystyrene. So that we select these as input raw materials. Our design for material balance is the volume of dissolution vessel. Our design is to process 60g feed at one batch. A 15g of polystrene and 30ml naphthalene feed to the first vessel was mixed. The mixture was stirred for 30 min at 70° C to ensure that all the quantity of LDPS has been dissolved. It was then moved to the second vessel at 75° C filter to remove the non-dissolved PS pellets. In the second vessel, LDPS was precipitated. The mixture was filtered back to the first vessel and 70 g wet LDPS was received on the filter. The wet LDPS was dried .

5.1.2 Mass Balance

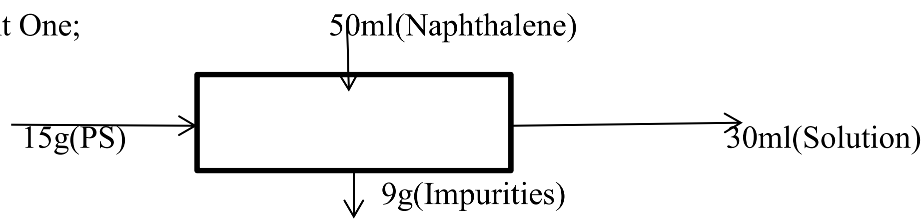
We use the law of conservation of mass which states that Mass input to process is equal to mass output(use densities of each solvent to calculate mass of each. Assumption for the mass balance:- Assume the sample of plastic waste weight is increasing and dissolving stage or wet plastic and it decreases its weight after drying.

Mass of in put =Mass of out put

Mass of naphtha in put =Mass of naphtha out put

Mass of PS in put =Mass of PS out put

Experiment One;



- Mass Balance on :- Polystyrene in = Polystyrene out impurities using PS out = 15g-9g =6g

15g/50ml = PS out/30ml

Ps out = 30ml*15g/50ml

=9g

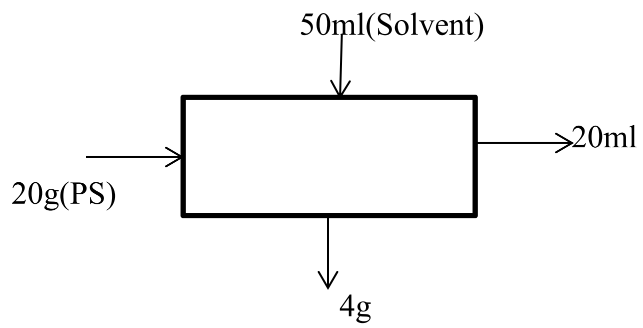
- Mass balance on:- Naphthalene in = Naphtalene out

15g/50ml = 9g/naphta out

Naphta out = 50ml*9g/15g

=30ml

Experiment Two;



Mass balance on:- polystyrene in= polystyrene out impurities using PS out = 20g-8g =12g

20g/50ml =PS out/20ml

PS out =20g/50ml*20ml

= 8g

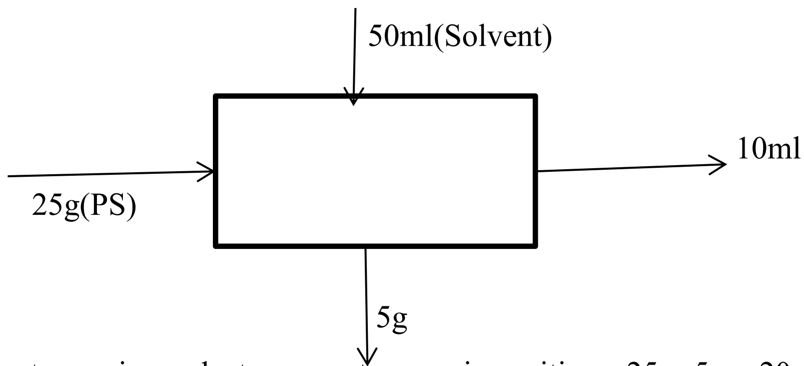
Mass balance on :- naphthalene in =naphthalene out

20g/50ml=8g/naphtha out

Naphta out = 8g*50ml/20g

=20ml

Experiment Three;



Mass balance on :- polystyrene in= polystyrene out impurities = 25g- 5g = 20g

25g/50ml=PS out/10ml

Ps out = 25g*10ml/50ml

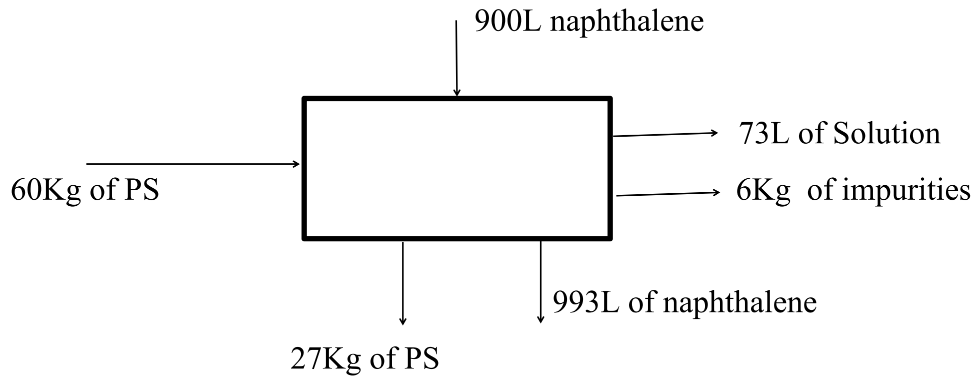
=5g

Mass balance on :- naphthalene in = naphthalene out

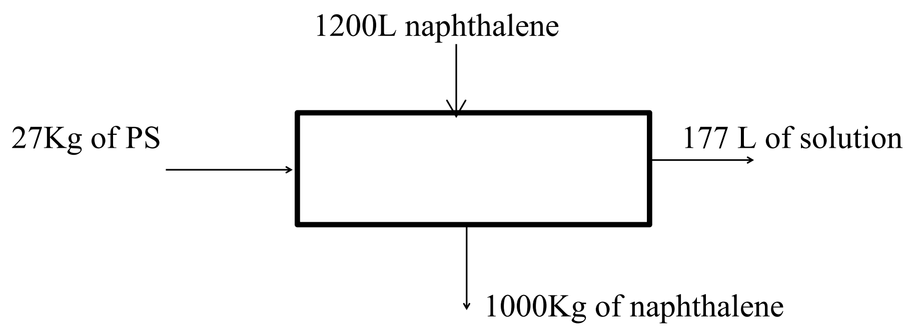
25g/50ml =5g/naphta out

=10ml

By scale up the laboratory to the industry level:-



The non-dissolved PS recovered from the first filtration will be dissolved in 300L naphthalene at 100° C and then precipitated and dried as described above. For both polymers the recovery will be:



5.2 Energy balance

The stove power is 400w in which an experiment lasted an average of 30 minute.

E=P*t, where, E=Energy

P=Power

t=time

Energy utilized for one experiment=0.4KW*0.5hr

=0.2KWhr to 177L of varnish solution

5.3 Equipment lay out

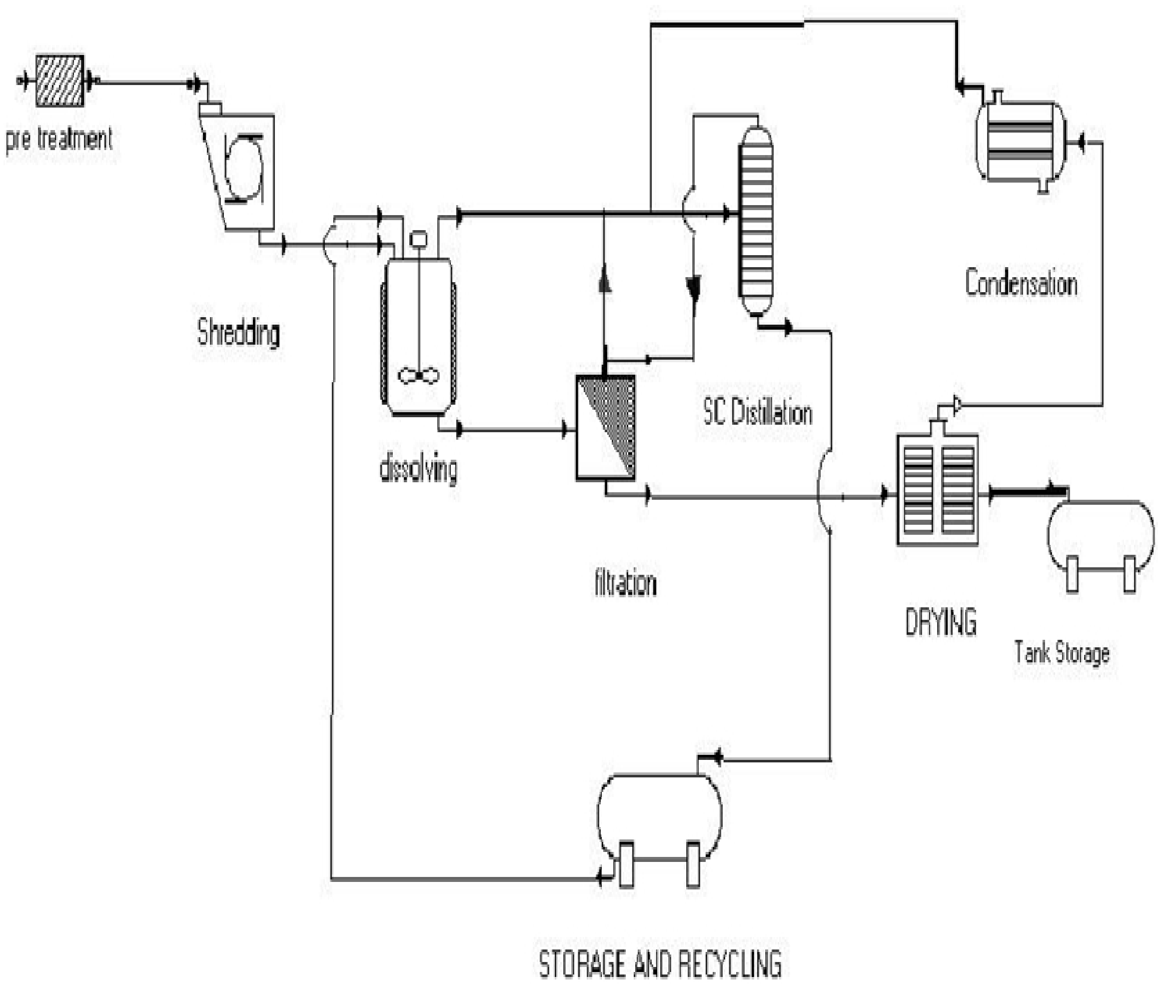


Fig 5.1Equipment layout

CHAPTER SIX

6.TECHNO-ECONOMIC AND FEASIBILITY STUDY

6.1 Economic evaluation of plant

6.1.1 Equipment Cost

The Purchased equipment cost can be calculated as follows

Table 6.1: Purchased equipment cost

Equipment type	Equipment price (birr)
single shaft plastic shredder	1200
Dissolving tank	2500
Dryer	1000
Mechanical sieve	1520
Bucket elevator	1700
Plastic extruder and heater	6000
Screw conveyor	1500
Purchased economic cost= 16420	

6.1.2 Total capital investment

Total capital investment calculated based on the purchased equipment cost.

Table 6.2: Total capital investment

Direct cost	Cost
Purchased equipment cost	16420
Equipment erection	6240
Purchased equipment installation	164
Instrumentation and controls	2464
Piping	2120
Electrical	1642
Building	2670
Yard improvement	1670
Service	1010
Land	2136
Total direct plant cost= $36534	

Table 6.3: Indirect cost

Indirect cost	
Engineering and supervision & Construction Expenses	4060
Contingency	1200
Contractors fee	821
Total Indirect Plant Cost	$6081
Fixed capital investment(FCI)	42615
Working Capital	4262
Total Capital Investment	$46877=1312556 birr

PCE=Physical cost of equipment

Fixed

capital=36534+6081=42615 dollar=1193220 birr

6.1.3 Raw Material Cost

Waste Plastic

Labor cost for plastic collection is about 15 birr/kg which encourage entrepreneur to start a business (information from salesman compound P.L.C)

Assuming this factory process eight batches with each batch 60 kg of plastic.

Then the amount of plastic waste processed per day

For 420 kg/day the money invested will be

Assume it works for 300 days per year:

Annual raw material cost =189000 birr /year=$6750 approximately

Solvents

Amount of money invested on solvents have been calculated per a week since they are recyclable.

400liter/week*20 birr/liter+1000liter*30birr/liter respectively

= 8000birr/week solvent+30000 birr/week oil

=38000 birr/week

Total annual cost=43 working weeks*38000 birr/week=1634000 birr/year

=58357.14286 dollar

Raw material cost annual=1634000+1823000 birr/year=$65107.14

Process	Process requirement	Per shift	Unit	Wage
			Personnel wage birr /month	Birr/Month
Washing	6	2	800	4800
Shredder	3	1	1000	3000
Sieving	3	1	600	2400
Dissolving	3	1	1200	3600
Extrusion	3	1	1000	3000
Material handling	6	2	700	4200
			Total wage/month= 21000	

Table 6.4 : Operating labor cost

Birr / month=$750

Total wage per month=21000 birr /month*12 month per year

Total operation labor cost annually=21000

Total labor cost=252000birr/year=$9000

Total production cost with out depreciation

TPC=1.24(CRM)=2.74(C-OL)+0.233*FCI+1.24C-UT

Taking CUT=0.15*PC=0

Rearranging and calculating for TPC

TPC=1.24(CRM) +2.74COL+0.233FCI+1.24*0.15TPC

TPC=(1.24/0.814)*CRM+(2.74/0.814)COL+(0.233/0.814)FCI

TPC=$52762.14=1477339.92birr/annum

6.1.4 Unit cost

We want to produce water conduit with a unit size of 1 kg weight, 3-inch diameter and 3 meter in length.
Conduit production per annum = 57 pieces/day * 300days = 17100

Unit cost = Total Production cost/ annual production capacity

Unit cost = 14773339.92 /17100= 86 birr Taking a profit margin of 20% the selling price = 99 birr/ unit conduit.

6.1.5 Profit analysis

Gross profit Annual sales =Total rate of production*unit selling cost

=17100*99 birr/unit conduit =1692900 birr

Gross profit = sales -TPC=1692900-1477339.92

Gross profit =215560.08

Depreciation=FCI/10 years =42615/10=4261.5$=119322 birr

Depreciation =119322 birr/income tax = tax rate*(Gross profit - Depreciation)

Assuming income tax = 30% Income tax =0.3*(215560.08-119322)=28871.424 birr

Net profit =gross profit - income tax - depreciation

= 215560.08-28871.424-119322=67366.656 birr=67366.656 birr/year

6.2 Plant location and environmental pollution

6.2.1 Plant location

The geographical location of the production site has an influence on the profitability of a project, the visibility of the project and the final product of the production. The main factors considered during site selection are as follows.

The site should far away from the residential area. That is because the factory may produce massive smoke during the operation process. The site had better have plenty of water to use in case that the factory may catch fire when the machine is working. The site should be close to the place we get our raw material. This can reduce the cost that paid to transport the material. By using the above three main factors our production site is sebeta city. In addition to the above criteria‟s those are the reasons that helps to select the city are:- Availability of raw material ,Availability of infrastructure Since the city is near to Addis Ababa it is easy to distribute the products ,Supply of utility. Eg (electricity, water…) ,Easy to gate maintenance for equipment's , Labor and land supply with relatively minimum cost and High transport facilities.

Environmental pollution

The industry have waste on the process of pretreatment of waste plastics which is used as fertilizers. In distillation of solvent there are additives of plastics which remain in a column.it should be cleaned properly on time. But other operations have no significant environmental pollution.

CHAPTER SEVEN

7. Conclusion and Recommendation

7.1 Conclusion

Our work focused on the production of varnish from the polystyrene waste which is mostly disposed to the environment. Three different polystyrene samples were prepared and dissolved using solvent with (30%, 40% and 50% of w/v), hence it is used as varnish. The produced varnish from PS were determined for non-volatile content, waterproof property and drying time using compared with some commercial varnishes. Based on the results obtained the varnish with 30% or 1:3 of w/v was chosen as the best one among others. And it is found that the dissolution of polystyrene at 70°C is appropriate in varnish production due to little significance change when operating at higher temperatures relative to energy cost issue for temperature rise. The physical parameters for the best varnish namely drying time,non-volatile content were found to be 30% ,29 minutes.The drying time and NVC agreed with the standard of commercial varnish.The varnish with 25% w/v resisted the scratch test and water was spread on the coated wood samples and it was found that all the wood samples did not change their appearance. Generally, it can be concluded that the use of polystyrene waste in varnish production is appropriate and the production process at 70°C and 1:3 or 30% is convenient in terms of heating energy cost and characteristics of varnish and both solvents can be used in varnish production from polystyrene waste.

7.2 Recommendation

In this work the solvent used in the production of varnish which are slightly toxic chemical solvent. Further work is required in the use of polystyrene waste for varnish production using most environmentally friendly solvent(naphthalene).The produced varnish is a clear and may be less decorative on coating, so further work can be done on improving the appearance of varnish by using additives.Surfaces stabilizer which works at the surface to repair damage from UV light and Anti-skinning agents which allow the varnish to maintain a wet surface upon exposure to the oxygen were not added to the final produced varnishes because of the lack of these chemicals. Further work is required to fully demonstrate suitability of this varnish for the proposed application and testing to establish the effects of such additions on properties and Ultra-Violet Absorber (UVA) to protect the coating from singular attack on the film occurred so that they dispersed evenly through

Out the coating. Anti-oxidants that impacts long-term performance and are used to combat photo-Degradation and the effects of oxidation on the varnish film. Without the use of an effective anti- oxidant, the varnish will gradually fade and become cloudy. With a clear coating, it is particularly important to maintain its color, as any change will be readily detectable.

Reference

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Appendix

1.List of formula

A. Non- volatile content (NVC)

$\boldsymbol{NV}\text{C} = M2/\text{M1} \times \mathbf{100}\%$

Where: M1 –net mass of test sample of vanish, g; M2– net mass of a residue, g.

M1 = mass of test sample with petri dish – mass of petri dish alone M2 = mass of residue within petri dish – mass of petri dish alone

B. Ratio

Ratio = mass of polystyrene in g /volume of solvent in ml

or mass of sample (g) : volume of solvent (ml)

2. List of photos in varnish preparation steps



Raw material collection　Size reduction of PS　Varnish preparation

Scratch Resistance Test

Collected resin