International Journal of Scientific Research in Chemistry (IJSRCH)
© 2019 IJSRCH | Volume 4 | Issue 3 | ISSN : 2456-8457

Sustainable Waste Management of Polyurethane Polymers

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ABSTRACT

The general class of polymers are polyurethanes (PU), which are prepared by the polyaddition of isocyanates and hydroxyl groups of different compounds. Polyurethane linkages are formed by the reaction of poly-isocyanate and multi-functional hydroxyl compounds and results polyurethane foam. The foams have wide range of densities and may be flexible, semi-flexible or rigid in nature. The blowing agents are responsible for the structure of foam and are introduced during foam formation through volatilization of low-boiling liquids or through the formation of gas due to chemical reaction. Besides these agents, surfactants, catalysts, etc. are also used during the manufacturing of foams. This polymeric material is the most important for making different types of daily need items. Therefore, it is essential to recycle the wastes of it. There are so many methods to recycle the wastes of polyurethane, but no methods have yet been of commercial purpose and regular practice. The objective of our study is to develop a new sustainable technology of recycling the wastes of polyurethanes.

Keywords: Polymers, Polyurethanes, Foam, Recycling, Sustainable , Waste Management

I. INTRODUCTION

The plastic industries produce million tons of polyurethane (PU) polymeric material every year in the world. PU is the most widely used material due to cost benefits, energy savings and durability. PU foams are flexible, semiflexible, semirigid, and rigid foam. Being versatile, PU is widely used for furniture, insulation walls, roofs, coatings, adhesives, and automotive parts. [1], [2], [3] . PU amounts to about 7.7% of the global plastic demand. PU also generates significant amounts of wastes in the various forms after use. Due to natural slow decay of PU materials and poor disposal management PU wastes create a severe hazard to environmental pollution. The recycled and reusable material is, therefore, of great interest in the production of new materials because the combustion process could be wrong leading to generate poisonous gas that contribute to the greenhouse effect and pollute the environment [4].

II. METHODS AND MATERIAL

PU Wastes

The waste management of PU can be carried out by three metods that is physical recycling, chemical recycling , and combined chemolysis. Physical recycling of PU foam waste is simple, cost-effective, convenient, and environmentally friendly. The two most important ways to recycle PU foam wastes are: mechanical/physical recycling and chemical recycling [5] . The most effective method [6] to triturate polymer foams and to integrate them into a new material (Figure 1). Mechanical recycling covers recycling routes to reuse PU without chemical decomposition.

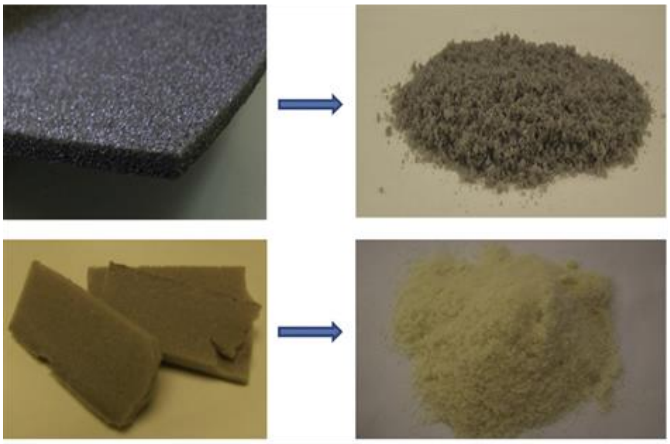

Figure 1. Different PU foam samples after foams and waste mechanical grinding.

Mechanical recycling reduces the waste into small particles to employs as inert filler or as a diluent for polyols to produce new PU compound. On the other hand, chemical recycling includes glycolysis, hydrolysis, aminolysis, and thermo chemical and biodegradation processes. The objective is to produce high-quality recycled monomers of polyol to include in a new polymer of the same nature. Biodegradation is the action of microorganisms that causes decomposition of polymeric chains into smaller molecules [7] and can be enhanced either by hydrolysis or oxidation reactions from chemical or biochemical origins and involving natural or from other sources [8] [9] [10] [11] . Recycled Lightweight PU Plaster Materials is a grinding PU foams into powders letting them to be reprocessed as fillers in a novel plaster material with thermal isolating properties [12]. and contributes to the workability time of the plaster, not only increasing it but also improving the time that elapses before the onset of setting. The PU filler loading decreases the density while, the thermal resistance improves proportionally. Recycled Lightweight PU Mortar Materials normally use (cement, additives, and water) with recycled PU with a grain size of 0 - 6 mm are used as an aggregate replacing traditional sand, perlite, and vermiculite. Recycled Lightweight PU Asphalt Materials is the application of various types of waste materials for modification of asphalts has been successfully used in road pavements [13] [14] [15] [16] . PU as reactive polymer with functional groups capable to chemically interact with bitumen compounds for obtaining PU modified bitumen [17] . Despite bitumen composition, dimensionally stable bituminous foams can be successfully obtained, even from the softest base [18] . More stable and less deformable bituminous mixtures were obtained with a lower quantity of cavities, which contributes to greater hardness. Eco-Friendly PU Coatings and Adhesives have good properties as flexibility and durability. Recycling option is really interesting for PU foam wastes from scrapped buildings as well but is a complex process due to the use of flame retardants, catalysts and other additives in these kinds of materials [19] [20] [21] .

Chemical Recycling

The treatment is carried out through degradation in the presence of various reagents. Hydrolysis of PU Foam is based on the chemolysis of waste PU foam with water vapor and alkali metal hydroxide as a catalyst at high temperature (250˚C - 340˚C) under high pressures as shown in Figure 2. This chemolysis process formed amines, alcohol, and CO2. Hydrolysis of PU foam [22] has many side reactions which are responsible for undesired by-products such as 4,4'-diaminodiphenylmethane (MDA), 2,4-toluylene diamines, and 2,6-toluylene diamines. Most of these are highly toxic chemicals and affect largely by increasing viscosity of the reaction system.

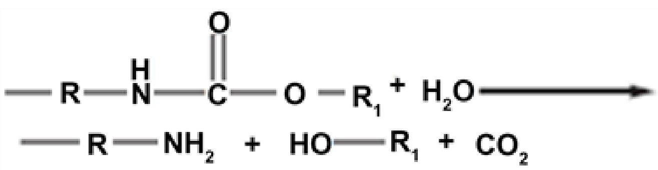

Figure 2. Hydrolysis of PU foam

Acidolysis of PU Foam [23] was carried out in the recycling of waste of PU foam. Acidolysis reactions were carried out by various types of inorganic and organic acids. The urethane group present in PU foam was decomposed using inorganic acids and formed substituted amine salts and substituted polyol according to the following reactions scheme as shown in Figure 3.

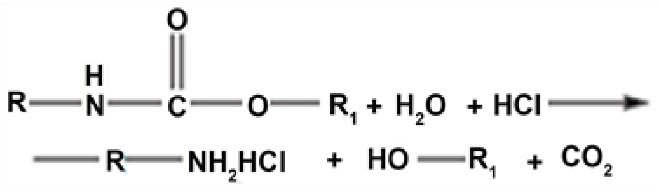

Figure 3. Acidolysis of PU foam

4. Hydroglycolysis

PU foam is degraded by a combination of various chemicals such as water, diethylene glycol, and alkali metal hydroxides such as lithium hydroxides (LiOH), sodium hydroxides, and potassium hydroxides at elevated temperature, i.e., 200˚C. This process is referred to as hydroglycolysis [24] [25] [26] [27][28] the process is comparatively a complex chemical treatment process which is carried out by adding water to a glycolysis steps. Ford Motor Company established this process; they claimed that this process produces higher quality product mixture against simple glycolysis process Figure 4.

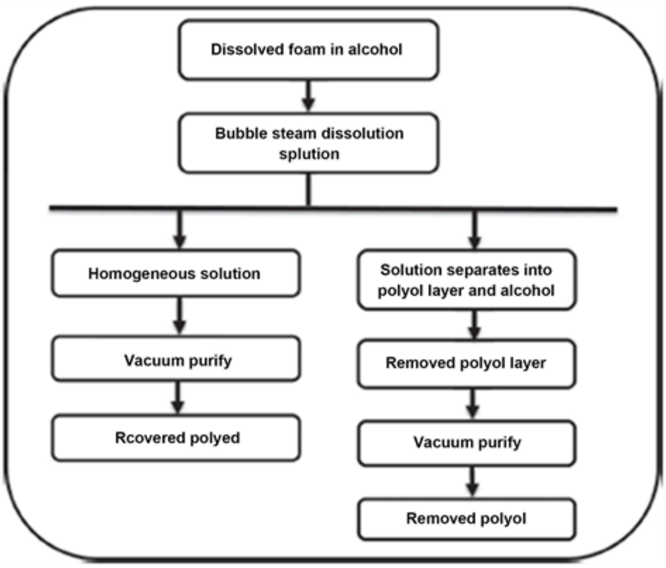

Figure 4. Hydroglycolysis recycling method

III. RESULTS AND DISCUSSION

Polyurethanes are an integral part of the human lifestyle today. Landfill is currently the leading route preferred to dispose of the waste. However, PU isn't readily biodegradable and the presence of various additives, surfactants, blowing agents, catalysts, etc. make it even more. difficult to re-process. Even though many routes are available in the industry, PU waste recycling hasn't become a commercial success due to many process limitations and the variety of the material itself. In the current state, none of the recycling options available for PU are able to provide a consistent, high quality, re-usable product. In-spite of the various routes available today for PU foam recycling, like landfill, chemical degradation, physical breakdown, etc., none of these routes have been economically successful as a business model. Also, from the environmental point of view, none of the methods are able to produce high quality, re-usable, virgin-like raw materials that can allow foam manufacturers to use the products formed after PU degradation to make new products without compromising on the properties of the final product/foam. A high conversion yield and high product quality process is required for recycling of PU foams to be seen as a viable and profitable solution to manage foam waste. The process needs to economical for large businesses to develop interest while also being environmentally important giving high quality raw materials for re-processing. With increasing environmental awareness and depleting natural sources, recycling is proving to be more than the need of the hour. High conversion, high quality recycling will not only reduced the rate of environmental damage but support in building a sustainable future.

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Cite this article as :

Digvijay Singh Yadav, "Sustainable Waste Management of Polyurethane Polymers", International Journal of Scientific Research in Chemistry (IJSRCH), ISSN : 2456-8457, Volume 4 Issue 2, pp. 01-05, May-June 2019. URL : http://ijsrch.com/IJSRCH19431