WASTE REDUCTION AND POTENTIAL FOR RECYCLING OF POLYSTYRENE PACKAGING

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The currently practised waste reduction methods of landfilling and incineration are inadequate to deal with the increasing amount of plastic waste. Landfilling results in a missed opportunity to recover valuable energy resources and provides an atmosphere that retards the degradation of polymers. The emission of toxic gases into the atmosphere is the main concern with the use of incineration as a treatment for waste. Therefore, new methods for waste control need to be adopted in the near future to reduce the environmental threat posed by the use of plastics. This is a global problem, one which producers, consumers and governments can participate in amending, and is the focus of this investigation. For the literature search, after a few iterations, keywords were chosen whose use on databases provided satisfactory citations to research the topic. The production and properties of polystyrene were examined. It was found that the method of manufacture for polystyrene is mature. Polystyrene is a low cost material and has many widespread applications due to its mouldability, transparency and colourability. A survey of the available methods for waste minimisation was conducted. The four main categories for waste minimisation are reduce, re-use, recycle and recover. It was concluded that reduce and re-use should be the main waste minimisation practices until a satisfactory recycling method is discovered. Recommendations were made to further investigate the manufacture of a biodegradable polymer, to examine the possibility of wet oxidation and other tertiary recycling methods for waste minimisation, and to commercialise plastic lumber on a large scale.

1. Introduction

The impact of the industrialised nations on the global environment is an issue of increasing concern. Plastics are used every day in modern life and are often employed in nominally disposable applications, such as packaging. This is the origin of a serious pollution problem, even when these materials are disposed of responsibly. Despite the increasing popularity of recycling and re-use of plastics, the two main methods used by municipal authorities for the disposal of waste are still landfilling and incineration, both of which are undesirable.

The diversion to landfills and the thoughtless discarding into the environment of polystyrene waste has attracted much attention in recent years. Polystyrene has been described in the media as non-degradable, non-recyclable, toxic when burned, landfill-choking, ozone-depleting, wildlife-killing and even carcinogenic. In reality, polystyrene comprises less that 0.5% by weight of the solid waste going to landfills.

One of the main problems associated with the disposal of polystyrene waste is the low density to high volume ratio of the polymer. Expanded or foamed plastics are especially difficult to compact and therefore consume more space in a landfill than would otherwise be necessary. It is interesting to note, though, that application of high temperatures or a solvent will substantially reduce the volume of the polymer by over 90%.

The focus of this investigation is to examine current and potential waste reduction practices for polystyrene on a global scale. A search of databases and the Internet was an effective method for determining existing waste reduction practices and citing potential techniques, such as recycling, which could be adopted on a wide scale in the future to amend the problem of increasing waste.

It would be unrealistic to assume that the problem of disposing of polystyrene waste could be eliminated if these products ceased to be produced. There is high demand for products constructed from polystyrene and, while reducing the number of products produced and inventing solutions for recycling are effective measures for limiting the problem, they do not provide a total solution to the problem. While landfilling is an undesirable location for waste plastics, the thoughtless and uncontrolled discarding of litter into the environment can have more harmful effects. It decreases the aesthetic appeal of the environment and can cause hazards to flora and fauna. Therefore, it must be realised that while polystyrene products are in use, their effect on the environment cannot be eliminated, only minimised.

The two most commonly practised methods for reduction of polystyrene waste are landfilling and incineration. These methods, coupled with some mechanical recycling of expanded polystyrene and re-use of polystyrene products, comprise the waste reduction effort currently in place in Australia. These methods can be considered inadequate as the amount of polystyrene waste requiring disposal is still high and is placing pressure on landfills. If this problem is to be resolved then new methods need to be introduced.

2. Manufacture of Styrene

Almost all of the commercial styrene produced is derived directly from ethylbenzene [2]. Ethylbenzene is manufactured from benzene and ethylene by both vapour and liquid phase processes.

3. Processing of Polystyrene

Processing includes Injection moulding, Structural foam moulding, Blow moulding, Extrusion blow moulding, sheet extrusion and Thermoforming.

4. Fabrication of Polystyrene

Polystyrene can undergo further processing called fabrication. *Bonding* involves joining components using adhesives based on organic solvents, normal heat sealing, or impulse heat sealers. This latter technique is most widely used on thin sheets for packaging.

5. Uses for Polystyrene

Polystyrene can be used to produce items such as cutlery, yoghurt containers, clear salad bar containers and household items such as toys, containers, furniture, video and audiocassette housings. Foamed polystyrene is mainly used in a protective capacity. Grocery stores use foamed polystyrene in virtually all meat and poultry trays as well as egg cartons and other produce packages such as fruit trays. Moulded packaging is extruded and designed to protect specific items such as televisions and computers.

6. Degradation

Styrene plastics are susceptible to degradation by heat, oxidation, UV radiation, high energy radiation and shear.

7. Disposal

Landfilling is probably the most unacceptable method of disposing of polystyrene waste because it represents a missed opportunity to recover valuable resources. The concern over the amount of plastic waste being diverted to landfills is global. Landfill sites in Europe are reaching capacity so a solution needs to be found. Since plastics are a growing proportion of municipal solid waste (MSW), they are under increasing scrutiny. Many countries in Europe and the USA are opposed to using incineration as the solution because of the toxic combustion gases. The preferred method currently practised worldwide is incineration with energy recovery. The concern over increasing amounts of polystyrene waste has resulted in many studies researching the possibilities for reducing and recycling the amount of waste.

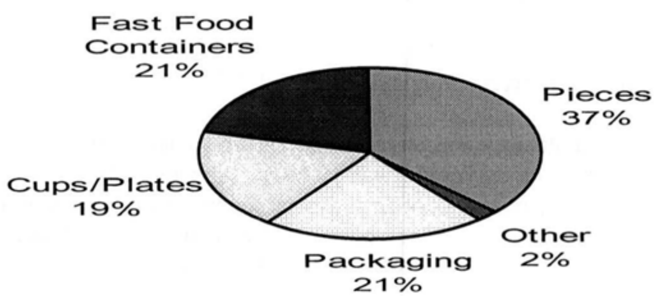

Figure 1: Types of polystyrene waste. (Data from Clean-up Australia Day 1997.)

8. Organisations Promoting Recycling of Polystyrene

Groups involved in the recycling of polystyrene waste include:

- *Plastics and Chemicals Industries Association* (PACIA)
- *Polystyrene Australia* (PSA)
- *Polystyrene Packaging Council* (PSPC)
- *Alliance of Foam Packaging Recyclers*
- *Canadian Polystyrene Recycling Association* (CPRA)
- *The National Polystyrene Recycling Company* (NPRC)
- *EPA* – promotes recycling for every product.

9. Thermal Depolymerisation of Polystyrene

Thermal depolymerisation of polystyrene resembles polymerisation, since the three major steps of initiation, propagation and termination are mirrored in the process. Once initiation occurs, depolymerising, propagation and termination by either hydrogen abstraction, disproportionation or radical coupling follows. The products at various temperature ranges of thermal depolymerisation are shown in the table below.

Temperature (°C)	Products Formed
200-300	Reduction of chain molecular weight, no volatiles
300-350	Volatile products and oligomers (dimers, trimers formed)
350+	Larger amounts of volatile products, including toluene, ethylbenzene, cumene, styrene, ∝-methylstyrene and alkylbenzenes

Yamamoto and Takamiya [7] employed a distillation type reactor with a silica-alumina catalyst to depolymerise polystyrene at temperatures of 250-330°C in an atmosphere of nitrogen. It was discovered that the distillate contained (wt.%): benzene, 53; ethylbenzene, 10; and cumene, 15. Under non-catalytic conditions, the main component was styrene.

Zmierczak et al. [8] reported that, at high temperatures, the catalyst chosen could influence the main component of the product stream.

Maksimova et al. [4] also employed catalysts to extract desired products from thermal decomposition.

10. Waste Reduction Options for Polystyrene

Today, the poor biodegradability and large volume to low density ratio of polystyrene has been recognised as a serious environmental problem. Although the environmental threat posed by the use of CFCs as blowing agents for the production of polystyrene foam has been eliminated, there is still concern over the volume of polystyrene waste. Currently, there are several methods for reducing this waste and new methods are continually being discovered and put into practice.

There are four main methods for waste reduction:

- *Reduce*: Reduce the amount of natural resources used by design optimisation.
- *Re-use*: Re-use the product in its original application.
- *Recycle*: Reprocess the material to make new products such as coathangers, CD cases etc., as well as thermal and chemical recycling.
- *Recover*: Plastics have a high calorific value and can be incinerated to produce a valuable energy source.

11. Pyrolysis

Kaminsky [3] recognised pyrolysis is an alternative to incineration. Pyrolysis is defined as thermal cleavage in the absence or at least a lack of air, with simultaneous generation of pyrolysis oils and gases, suited for chemical utilisation or generation of energy. During pyrolysis, the monomers of the parent polymer can be recovered, pelletised and reformed into the parent product for production of recycled materials. Pyrolysis can be undertaken in blast furnaces, autoclaves, rotary kilns and fluidised bed reactors [3].

Audisio and Bertini [1] noticed that unfavourable secondary reactions occurred when the reactor temperature was high during pyrolysis of polystyrene. Hydrous pyrolysis, which employs liquid water under subcritical conditions, was suggested to reduce the occurrence of these reactions and to increase the monomer yield.

Another modification to pyrolysis has been made by Simionescu et al. [6]. The catalytic pyrolysis of a variety of hydrocarbon polymers was examined, a topic that has rarely been studied. Zhu et al. [9] examined the thermal and thermo-oxidative degradation of polystyrene in the presence of ammonium sulfate. Therefore, while pyrolysis appears to be a worthwhile contender in the treatment of polystyrene waste, there are several problems associated with its use.

12. Combustion

Combustion involves flaming thermal decomposition products. Nicholson [5] noted the char to be a brittle solid of variable composition, though generally with an extremely high carbon content. These gaseous emissions are an environmental concern and this form of waste reduction is therefore rendered undesirable unless the emissions can be captured and treated. However, combustion is an effective method for reducing the overall volume of waste.

13. Gasification

Another solution is gasification of plastics as done by Energiewerke Schwarze Pumpe (ESPAG), where plastics are converted into synthesis gas by adding oxygen and steam. The process could be used for the production of methanol and ammonia. Energy Developments Limited Australia has patented a process for gasifying biomass into energy. The biomass is subject to high temperatures and is converted into syngas that can be utilised as fuel for power generation or other industrial use. The company also extracts methane gas from landfills to produce energy. Both technologies provide effective and environmentally friendly methods for utilising MSW.

Conclusions

Polystyrene Properties and Production

The current methods for polystyrene production are mature and efficient, with the main method of manufacture being bulk polymerisation. Polystyrene is rigid but can be expanded to form a foam material. It is employed globally on account of its desirable properties, which include excellent colour range, transparency, low water absorption and relative cheapness. There are many uses for polystyrene, ranging from packaging to insulation.

Current Waste Reduction Methods

The two most commonly practised methods for reduction of polystyrene waste are landfilling and incineration. These methods, coupled with some mechanical recycling of EPS and re-use of polystyrene products, comprise the waste reduction effort currently in place. These methods can be considered inadequate as the amount of polystyrene waste requiring disposal is still high and placing pressure on landfills. If this problem is to be resolved then new methods need to be introduced.

Viable Options for Waste Minimisation

- SOURCE REDUCTION
- RE-USE OF CONTAINERS AND EPS PACKAGING
- SECONDARY RECYCLING
- PLASTIC LUMBER
- CONVERSION INTO FUEL OILS
- CONVERSION INTO COMMODITY CHEMICALS
- WET OXIDATION
- PYROLYSIS
- COMBUSTION
- GASIFICATION
- BIODEGRADABLE PLASTIC
- LEGISLATION: Force suppliers and users to manage disposal of polystyrene waste and put high taxes on products causing most problems.
- TREATMENT WITH ACETONE OR OTHER SOLVENTS: A viable process for reducing the overall volume of waste.

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