A Review of Biodegradation of Synthetic Plastic and Foams

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Abstract

Synthetic polymeric foams have pervaded every aspect of modern life. Although foams provide numerous benefits, they also cause a significant environmental litter problem because of their recalcitrant and xenobiotic nature. Biodegradation may provide solution to the problem, but not enough is known about the biodegradation process of synthetic plastic and plastic-based foams. This review has been written to provide an overview of the current state of plastic foam biodegradation. Several biodegradation pathways of a few select synthetic polymers are also presented along with a discussion on some of the physico-chemical factors that can influence the biodegradation of plastic foams.

Index Entries: Plastic foam; synthetic polymer; biodegradation.

Introduction

Plastic foams are synthetic polymers that are used widely throughout the world for various applications. The first successful synthesis of plastic foams took place nearly a century ago (1), and since then their use has been increasing incessantly. At present, thousands of tons of plastic foams are used throughout the world for diverse applications. They are used in industry, automobiles, agriculture, space exploration, and irrigation, as well as in environmental, health, and numerous other sectors. Prior to the discovery of the method to synthesize plastic foams, natural sponges harvested from deep-sea beds were in use worldwide for centuries (2). It is not
known when sponges were put to use by humans, but some ancient writings of Plato, Homerus, and Aristotle mention that sponge was an object commonly used for bathing (3, 4).

It is estimated that global synthetic plastic production is approx 140 million tons per annum (5). Data between 1939 and 1998 (6) indicate that global production of plastic is increasing at a rate of 2.2% per year. Table 1 shows the 1990 data for global market share of different types of synthetic plastics (7).

The synthetic foam market accounts for about 10% of the total plastic resins produced in the United States, which is growing at an average rate of 2.8% annually. The 2003 demand for specialty plastic foams (such as those used in gaskets, heat shields, and seals) in the United States alone was estimated to be approximately at US$1 billion (8). Table 2 provides an example on the current US market trend on cellular foam demand (8).

Similarly, the European polymer foam market was valued at EUR 4.7 billion in 2004, and it has been forecast that it will grow at an annual rate of 5.2% in the coming years (9). This shows that plastic foam production occupies a potentially huge market worldwide.

Although synthetic plastic foams have provided numerous benefits, they have also caused some serious environmental concerns in the form of a solid waste management problem almost in every part of the world. One estimate reports that almost 11.3% of the total municipal solid wastes com-

### Table 1

Global Plastic Market (7)

<table>
<thead>
<tr>
<th>Plastic type</th>
<th>Market share by volume produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene (PE)</td>
<td>29%</td>
</tr>
<tr>
<td>Polyvinyl chloride (PVC)</td>
<td>17%</td>
</tr>
<tr>
<td>Polypropylene (PP)</td>
<td>12%</td>
</tr>
<tr>
<td>Polystyrene (PS)</td>
<td>9%</td>
</tr>
<tr>
<td>Polyurethane (PUR)</td>
<td>5%</td>
</tr>
<tr>
<td>Others</td>
<td>28%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
</tr>
</tbody>
</table>

### Table 2

US Markets for Polymeric Foam (8)

<table>
<thead>
<tr>
<th>Foam type</th>
<th>2001 (million kg)</th>
<th>2006 (million kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyolefin</td>
<td>136</td>
<td>164</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>870</td>
<td>923</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>1800</td>
<td>2145</td>
</tr>
<tr>
<td>Polyvinyl chloride</td>
<td>525</td>
<td>598</td>
</tr>
<tr>
<td>Other foam</td>
<td>41</td>
<td>46</td>
</tr>
<tr>
<td>Total</td>
<td>3373</td>
<td>3877</td>
</tr>
</tbody>
</table>