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Research review paper

New insights into polyurethane biodegradation and realistic prospects for the development of a sustainable waste recycling process

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ABSTRACT

Polyurethanes are polymeric plastics that were first used as substitutes for traditional polymers suspected to release volatile organic hazardous substances. The limitless conformations and formulations of polyurethanes enabled their use in a wide variety of applications. Because approximately 10 Mt of polyurethanes is produced each year, environmental concern over their considerable contribution to landfill waste accumulation appeared in the 1990s. To date, no recycling processes allow for the efficient reuse of polyurethane waste due to their high resistance to (a)biotic disturbances. To find alternatives to systematic accumulation or incineration of polyurethanes, a bibliographic analysis was performed on major scientific advances in the polyurethane (bio) degradation field to identify opportunities for the development of new technologies to recondition this material. Until polymers exhibiting oxo- or hydro-biodegradative traits are generated, conventional polyurethanes that are known to be only slightly biodegradable are of great concern. The research focused on polyurethane biodegradation highlights recent attempts to reprocess conventional industrial polyurethanes via microbial or enzymatic degradation. This review describes several wonderful opportunities for the establishment of new processes for polyurethane recycling. Meeting these new challenges could lead to the development of sustainable management processes involving polymer recycling or reuse as environmentally safe options for industries. The ability to upgrade polyurethane wastes to chemical compounds with a higher added value would be especially attractive.

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1. Introduction – the entrance into the plastic era

Synthetic plastics first appeared in 1835 after the discovery of the polymerisation reaction performed with vinyl chloride by Henri Victor Regnault. By definition, synthesised plastics are manufactured products composed of numerous long chains of polymers containing oil, carbon and natural gas. The consumption of plastics increased from 1.5 million tons per year (Mt/year) in 1950 to an incredible 265 Mt/year in 2011 (Fig. 1a). Due to their relatively low prices, plastic production plants are located all over the world to limit importation costs, but only several countries contribute significantly to its worldwide production, as illustrated in Fig. 1b.

Among the synthesised plastics, polyurethanes, mostly in the form of foams, ranked as the 6th most common type of plastic used worldwide,

and they accounted for 6 to 7% (10 Mt/year) of the total plastics produced (Fig. 2) (Cangemi et al., 2008; Caudron, 2003; PlasticsEurope, 2011). However, the history of polyurethanes begins more recently than that of traditional PVC polymers (polyvinyl chloride). Polyurethanes were first synthesised by Dr. Otto Bayer in 1937. The synthesis of polyurethane foam at the industrial scale began in the 1950s, and their use grew slowly until the 1990s. Technological advances led to new formulations, and the production of polyurethanes increased by 4.3% per year due to use in the automotive, footwear and furniture industries (Caudron, 2003). Cangemi et al. (2008) estimated that the worldwide production of polyurethane foams grew from 8.5 Mt/year in 2000 to 10.8 Mt/year in 2004 (Caudron, 2003; Silvan, 2011). In Western Europe, the production and consumption of polyurethane foams were estimated at over 3.7 Mt/year (PlasticsEurope, 2011).

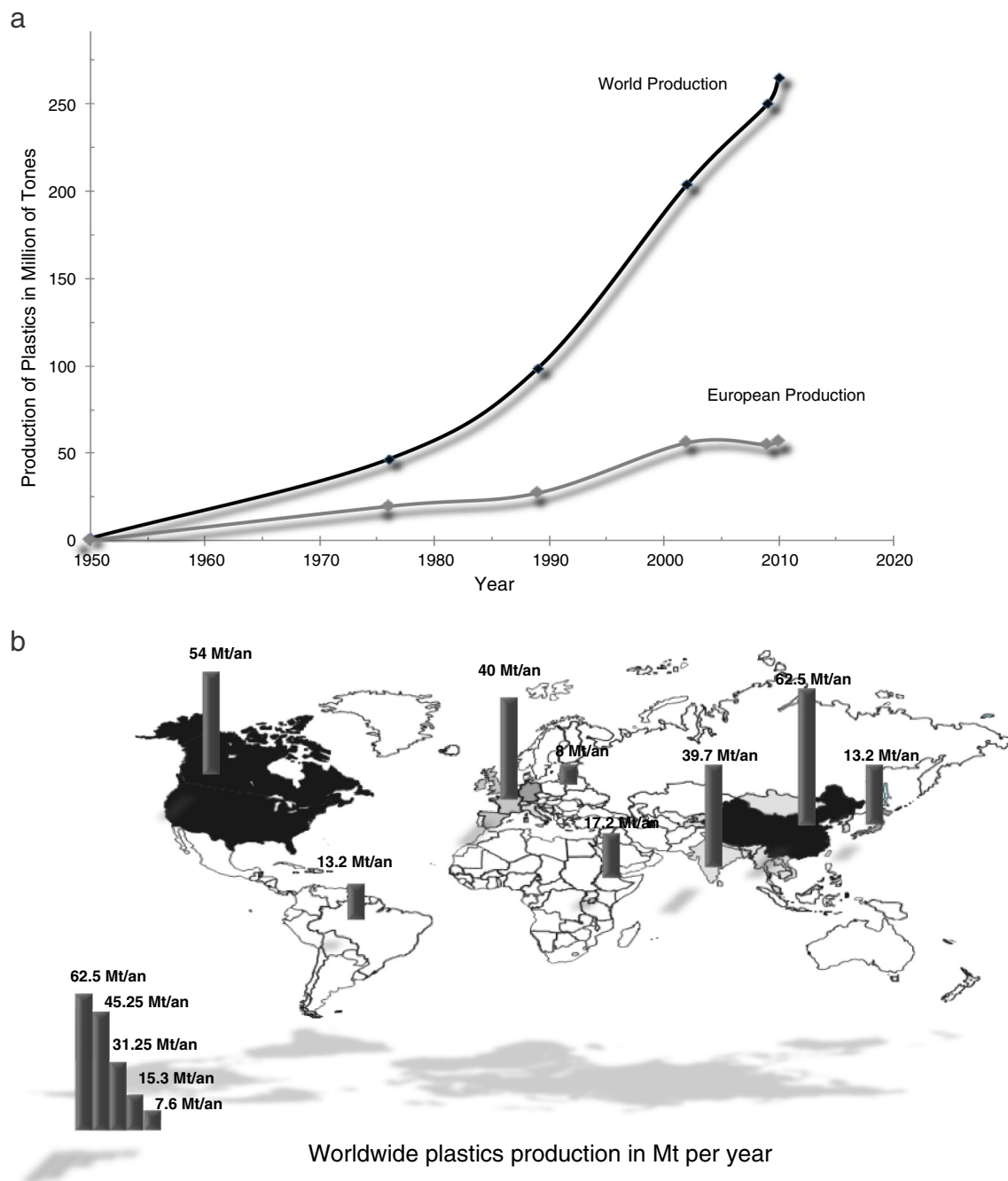


Fig. 1. Worldwide and European plastic production over the last 60 years (a) and the locations of the main plastic synthesisers (b) (Caudron, 2003; PlasticsEurope, 2011).

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