# Final Report of the IUPAC Working Party on Recycling of Polymers

Norbert M. Bikales

National Science Foundation, 4201 Wilson Boulevard, Arlington, VA 22230, U.S.A.

The Macromolecular Division of the International Union of Pure and Applied Chemistry (IUPAC) has a long-standing interest in the recycling of polymers, as evidenced by the international symposium it sponsored already in 1991 (Ref. 1). Because of the great societal concern about this issue, the Macromolecular Division followed up this action by formally establishing a Working Party on Recycling of Polymers. The Working Party was charged with reporting on the state of recycling (Ref. 2) as applied to industrial polymers, and to make suitable recommendations. The Working Party met on three occasions: in 1993 in Lisbon, Portugal; in 1994 in Arlington, Virginia, USA; and in 1995 in Guildford, UK. In addition, it carried out extensive correspondence and was a principal sponsor of the Microsymposium on Recycling of Polymers that was held in Prague, Czech Republic, on 14-17 July 1997. The Working Party authored a number of papers, which are placed in this volume after those presented at the Microsymposium. It also formulated certain recommendations, given below, which were adopted by the Working Party, the attendees of the Prague Microsymposium, and the Macromolecular Division at the IUPAC General Assembly in Geneva on 26 August 1997.

The members of the Working Party who participated in at least some of its activities are the following:

 CCC 1022-1360/98/$ 17.50

Prof. Takashi Akehata, Science University of Tokyo, Tokyo, Japan

Prof. Ann-Christine Albertsson, Royal Institute of Technology, Stockholm, Sweden

Dr. Norbert M. Bikales, *Chairman,* National Science Foundation, Paris, France

Dr. Johannes Brandrup, Verband Kunststofferzeugende Industrie, Frankfurt, Germany

Dr. Michael M. Fisher, American Plastics Council, Washington, DC, USA

Prof. Walter Heitz, Phillips-Universität Marburg, Marburg/Lahn, Germany

Prof. James D. Idol, Rutgers University, Piscataway, NJ, USA

Dr. Fred W. Mader, Association of the Plastics Manufacturers in Europe, Brussels, Belgium

Prof. Robert H. Marchessault, McGill University, Montreal, PQ, Canada

Prof. James H. O'Donnell (deceased), University of Queensland, Queensland, Australia

Prof. Hans W. Schnecko, Hanau, Germany

Dr. Rowan W. Truss, University of Queensland, Queensland, Australia

A number of other persons also contributed to the activities of the Working Party; their names are given as authors or co-authors of the papers published in this volume. Support from the International Union of Pure and Applied Chemistry and the International Council of Scientific Unions is gratefully acknowledged.

(1) W. Heitz, symp. ed., "Recycling of Polymers," *Macromol. Chem., Macromol. Symp.* **57**, 1992, 395 pp.

(2) For the purposes of this Report, *recycling* is considered to include materials recycling as well as energy recovery. Materials recycling, in turn, can be divided into mechanical recycling and feedstock recycling (reuse of the chemical content). In all of these cases, use is made of polymeric materials that would otherwise be disposed of in wasteful ways, e.g., in landfills.

## Recommendations of the IUPAC Working Party on Recycling of Polymers

The Working Party considers recycling of polymers to be part of sustainable product use and development.

Sustainability as applied to recycling means consideration of appropriate ecological, economic, and societal aspects.

Ecological aspects to be considered should encompass:

- the conservation of resources
- the reduction of emissions
- the avoidance of hazardous substances
- the reduction of waste

Ecological, economic, and societal aspects should be balanced.

The Working Party considers mechanical and feedstock recycling to be *materials recycling*. Combustion for heat production with controlled emissions is regarded as *energy recovery*, as shown in Figure 1.

Mechanical recycling of polymers should be applied when:

- the processing energy put into the virgin product can be saved to a large extent through reasonable technical efforts;

- the legal, medical, and safety rules established for the use of plastics and rubber are also observed for recyclates;

- the applicable (current and future) standards of plastics and rubber are not deteriorated.

The ecological gain is the bigger, the smaller the technical effort for recycling. Collection and sorting costs – although ecologically rather unimportant – are economically very costly and have to be considered as part of the overall recycling scheme.

Mechanical recycling leading to the substitution of virgin plastic resins is the preferred route for waste that is rather homogeneous in composition and largely uncontaminated. Because of this limitation, it is very often restricted to production or processing scrap.

Mechanical recycling of mixed plastics, leading to substitutes for wood or concrete products, cannot by itself solve the large problem of post-consumer waste.

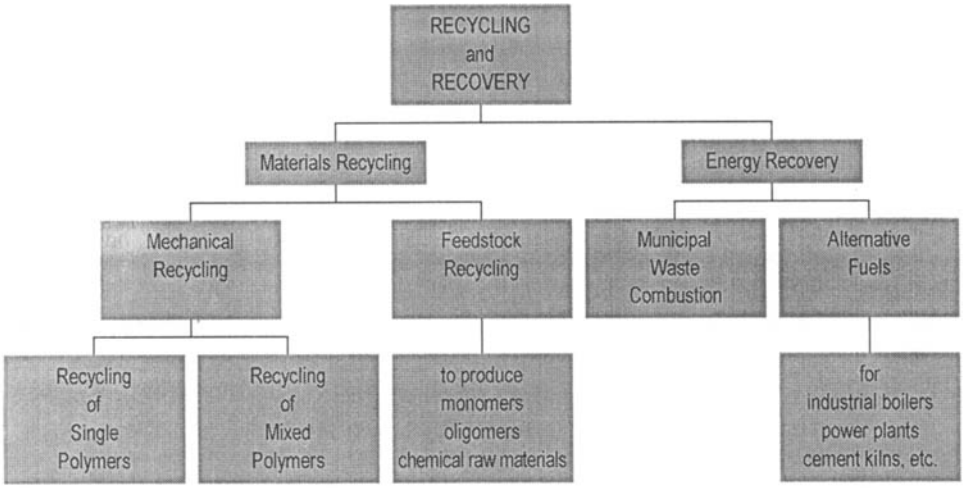


Fig. 1 Recycling and Recovery Options for Polymers

Table 1. Recommended Recycling and Recovery Options for Different Types of Polymer Waste

| Type of Polymer Waste | Mechanical Recycling | Feedstock Recycling | Energy Recovery |
|---|---|---|---|
| Sorted, Single Polymers | ++ | + | + |
| Mixed Polymers | + | ++ | ++ |
| Mixed Polymers with Paper, etc. | - | - | ++ |
| Polymers in Municipal Solid Waste | - | - | ++ |

Costs increase as more collection and separation are required

- = not recommended; + = suitable; ++ = preferred

The Working Party recommends that heterogeneous, mixed, and contaminated waste should, instead, be treated by the methods of feedstock recycling or energy recovery as outlined in Table 1.

The Working Party points out that plastics and rubber in effect store the energy content of the crude oil, and that the recycling loop will be closed when that energy is regained by energy recovery methods.

So-called cradle-to-grave-approaches for products should be used for finding the most sustainable route for fulfilling human needs. Detailed life-cycle analysis seems to be a proper tool for evaluation.

The Working Party considers that all recycling of plastics and rubber should have an ecological or economic goal. Without such justification, it should not be done simply for its own sake.

The Working Party recalls that scientific and technological advances have produced a large variety of tailor-made plastics and rubber products that have been manufactured in order to satisfy a broad range of human needs, often in a sustainable way. This important and sometimes critical societal contribution of polymers must be considered in a balanced way.

The Working Party recommends that IUPAC promote:

- research that leads towards the development of polymers and composite materials within a framework of sustainability;

- technologies and standards for polymer recycling and recovery; and

- the establishment of a polymer recycling network that would permit easy exchange of information and act as an information database.

These recommendations were presented by the Working Party at the IUPAC Microsymposium on Recycling of Polymers in Prague in July 1997 and at the meeting of the IUPAC Macromolecular Division in Geneva in August 1997 and were unanimously approved in both cases.