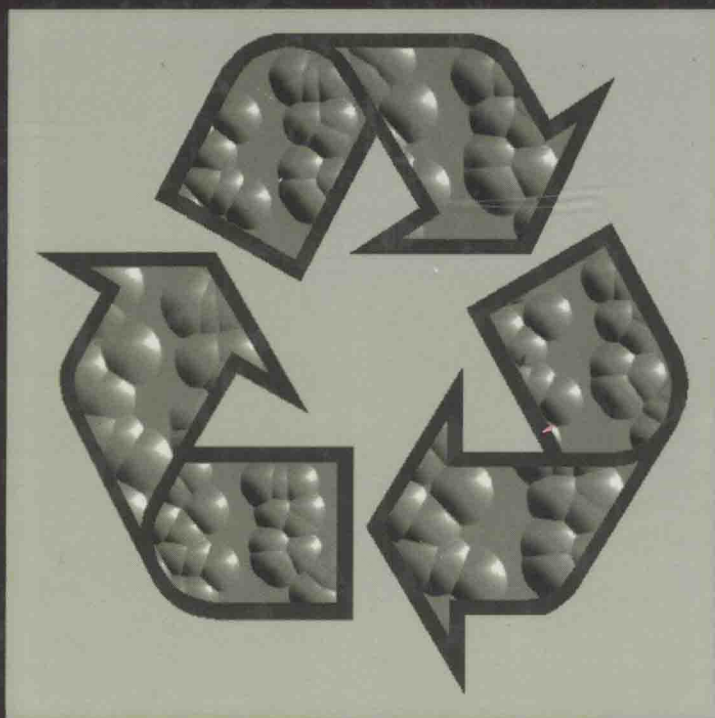


CHEMICAL ASPECTS OF PLASTICS RECYCLING



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Chemical Aspects of Plastics Recycling

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Chemical Aspects of Plastics Recycling

Preface

The management and recovery of material waste has become an increasingly important issue in the closing decades of the twentieth century, as awareness of the environment and the need to conserve raw materials has grown. In areas of waste such as paper and board, waste collection and recycling are an established reality. The varying chemical nature and relative incompatibility of plastics, coupled with problems of segregation, has resulted in slower development of commercially viable recycling processes and products derived from recyclate. In reality, plastics waste management depends on the relative cost-effectiveness of the various options, which include segregation and processing to produce a reusable plastic material, controlled thermal cracking to give mixed hydrocarbons capable of re-polymerisation or using the waste purely for energy purposes.

These proceedings afford a timely review of the current state of plastics recycling, particularly when the economic viability of some jointly sponsored pilot and plant facilities in Europe appears to have been questioned recently. Plastics waste management is set in context within the total waste picture and the current status of plastics recycling and recovery in the EU is quantified.

The importance of identification of plastics in order to separate feeds is emphasised and the application of mid-infrared spectroscopy as a method of identification is used to illustrate of the new techniques being developed for this purpose.

Polyester, PET, PVC, acrylics and polyurethane recycling are all considered in depth, both in terms of processing and end-uses for recyclate. Of particular interest is the use of 'compatibilisers' to enable two or more different plastics to be successfully co-processed. Likewise, the need to re-stabilise some recycled plastics is discussed and shown to lead to recycled material of a higher commercial value.

Finally, other options are considered including the polymer cracking of mixed plastics waste for feedstock recycling and the recycling of mixed plastics by gasification process.

1994 saw the generation of over 26 million tonnes of plastic waste of which 42% came from packaging. With ever growing restrictions on 'landfill' as a ready means of waste disposal, pressure will increase to recycle all forms of waste. In the plastics sector, the challenge is to recover the major part of nearly 20 million tonnes of post-use plastics which would otherwise be lost to landfill.

D. R. Karsa

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Overview

The Effect of Environmental Considerations and Legislative Developments on Packaging

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1 INTRODUCTION

Consumers' concerns about environmental aspects of packaging are often confused or based on misconceptions. In responding to these concerns, legislation in some countries is of debatable environmental value. In other countries legislation is designed to protect the home market but presented in the guise of environmental protection.

Industry has to respond to the legislative requirements but it also needs to provide clear information about the real environmental impact of packaging and explain that environmental matters are not discrete issues. In recent years, many environmental assessments of packaging have ignored practical considerations such as maintaining product quality, functioning within economic constraints or responding to social changes.

This paper looks at these issues with particular reference to two studies commissioned by Incpen.

The UK Centre for Economic and Environmental Development, UK CEED, took four very different products - fish, a computer monitor, a liquid detergent and a luxury cosmetic and analysed the relationship between the functional, economic, social and environmental aspects of their packaging.

The study, *Packaging in a Market Economy*, shows that claims about "over-packaging" are often based only on a consideration of environmental or end-use criteria. The many other demands made of packaging are not taken into account, and it concludes that "... it would defy economic logic for a company to package a product *purposely* in excessive materials."

Professor Jan Kooijman has carried out an assessment of the *Environmental Impact of Packaging in the UK Food Supply System*. The results show that demographic changes are likely to have far greater impact on quantities of packaging than anything the packaging industry does even though material use per pack will continue to reduce in response to commercial and environmental pressures.

2 CONSUMERS' CONCERNS

Results of an Incpen survey (Jan 1994) of UK consumers' views on packaging showed that people are ambivalent:-

In general, people believe there is too much packaging and that it generates (a lot of)

waste. On initial consideration, however, their views are neutral. It is only when prompted that they think of the negative aspects. And when encouraged to think about the convenience, hygiene and safety provided by packaging, these positive aspects tend to counter balance the negative attitudes.

The survey also showed that people do not appear to let their negative attitudes to packaging affect their behaviour when it comes to shopping. Those most critical of packaging will still choose to buy packaged goods for convenience and other reasons even when the same product is available in an unpacked form.

2.1 Media Coverage of Environmental Issues Has Perpetuated Myths

As the media started to pay attention to the "waste problem", or "garbage crisis" as it is known in the US, newspapers tended to concentrate on two aspects - toxic waste, and at the other extreme the waste that people know about - household waste and packaging waste in particular. In many articles, the waste problem became a "packaging problem" - perhaps not too surprisingly. People only see packaging at the end of its useful life and not during its journey through the distribution chain. Neither do they have knowledge of industrial wastes.

Packaging is a significant fraction -- between 25% to 30% by weight -- of municipal waste but the consumer does not know that the loads his or her dustmen collect makes up only around 5% of the total solid waste from all sources in a typical European country.

It is not just the average consumer who is misled. The concentration on packaging as waste has led to two separate issues being muddled by even the most informed people in this area. Those two issues are:

- ♦ the need to design good packaging systems that get products from manufacture to consumption with the optimum expenditure of resources, throughout the whole system; and
- ♦ the need to invest in modern solid waste management techniques to reduce the environmental impact of all waste, not just packaging.

This muddle has two unfortunate consequences. First, it gives the false impression that all one has to do to solve the waste problem is remove packaging from waste. Packaging is typically 7% of landfilled waste in Northern European countries. Much less attention is paid to the 93% of other waste put in landfill (Table 1).

Second, it overemphasises one environmental consideration -- waste management --

Table 1 *UK Waste to Landfill*

<i>Type of Waste</i>	<i>Million tonnes</i>
Packaging in household waste	4
Other household waste	16
Packaging in commercial and industrial waste	4
Other commercial and industrial waste	60
Construction and demolition waste	21
Other waste	15
Total	120

Source: Department of the Environment, Incpen

takes no account of raw material and energy use and distracts attention from designing resource-efficient packaging that can make the best use of resources throughout the distribution chain.

However, a few media reports are becoming more critical of some of the commonly held misconceptions. For example, an article in the Wall Street Journal (19 January 1995) explained the actual circumstances about the garbage barge that attracted so much attention in 1987 as it cruised off the east coast of America for two months trying to find somewhere to dump its waste. At the time, newspapers claimed it showed that America was running out of landfill sites.

In reality, it was the result of a badly negotiated deal organised by a local haulier to profit from regional price disparities. The waste was ordinary Municipal Solid Waste and there was (and still is) plenty of landfill capacity. But this incident was used by the environmental movement to excite local groups into campaigning *against* dumps and incinerators in their neighbourhood and campaigning *for* household waste recycling.

According to the article, the large waste management companies did nothing to contradict the misinformation. The public's belief in a waste crisis helped them increase prices. The Environmental Protection Agency, EPA, did nothing and even called on each state to cut disposal nationally by 25%. EPA now agrees that there is no landfill shortage and never was. Yet literature that it continues to distribute warns of a shortage and cites it as one of the reasons for recycling.

This is not to say that countries should continue to dispose of all their waste in landfills. There are better options in some circumstances and efforts to reduce and recover waste before landfilling, preferably treated, residues should be encouraged. However, there is not, and never has been, a waste "crisis" in any country and therefore panic responses are not necessary. Careful planning will produce far better results.

One other point in the Wall Street Journal article is worth noting. The item stated:

"Consumers want to recycle everything these days, and that is a big headache for packaging and consumer-products companies. They blame environmental groups, the media and government for raising consumers' recycling hopes beyond reason. But, increasingly, the companies have themselves to blame. Their own advertisements and advertising claims, often misleading, have only reinforced consumers' belief in the ease of recycling."

This has undoubtedly done a lot of harm, not least by making people confused and cynical about the environment. There are signs, though, that companies are thinking twice before using environmental claims as a marketing ploy and some of the more ridiculous claims of a few years ago are a little less in evidence today.

2.2 Consumers Believe Packaging Waste Has Increased

Another common perception is that packaging waste has increased over the years. This also does not appear to be true. There are certainly more packaged goods available - 2,000 product lines in the 1960s and over 15,000 now but the amount of packaging used for each pack is much less than it used to be. So much less that the total weight of material used for all packaging is probably no more than it was 20 years ago (Table 2).

Information on the contents of household waste - though limited - tends to support this view. It is not packaging that contributes to the growth in waste. According to US figures the largest contributor is durable goods.

Even if we could recycle all the used packaging in household waste, there would still

Table 2 *UK Household Dustbin Waste*

<i>Type of Waste</i>	<i>1970 DOE est. kg/week</i>	<i>1980 Merseyside/ Incpen kg/week</i>	<i>1990 Sheffield/Warren Spring kg/week</i>
Used packaging	3	2.6	2.4
Total waste	13.5	11.2	10.5

be more than enough waste that would need to be handled by other methods, and certainly more than enough to justify building more incineration capacity in the UK (Table 3).

2.3 Responsibility for Used Packaging

The main influence on waste quantities is population growth. Industry takes its share of responsibility for used packaging and this is resulting in programmes to increase source reduction and increase recovery of used packaging.

Industry also takes responsibility for ensuring that products are protected from damage or spoilage, are safe to use, meet consumers' expectations and comply with a number of legal and regulatory requirements.

But industry cannot be responsible for demographic factors, such as size of household or change in lifestyle such as separate family eating times and some of these developments are likely to increase quantities of used packaging. For example, the trend to buying more prepared meals which need sophisticated packaging to provide adequate protection may

Table 3 *Potentially Recyclable Household Waste*

<i>Category</i>	<i>Max. Available for Recycling Percent by Weight</i>		<i>Remainder Percent by Weight</i>
	<i>Packaging</i>	<i>Non-packaging</i>	<i>Other treatment /incineration/landfill</i>
Paper/board	6	20	7
Plastics packaging	3		5
Plastics non-packaging			3
Textiles			2
Glass	7		1
Metals	4		1
Garden/kitchen			24
Misc. combustible			9
Other			9
Total	19	20	61

Source: National Household Waste Analysis Programme

increase packaging waste, though this often has a positive trade-off in reducing overall waste.

Professor Jan M Kooijman of the Netherlands has carried out a series of environmental assessments of food distribution systems that demonstrate this point. He found that typically 15% of bread goes to waste usually because it is kept too long and becomes hard or mouldy. In the Netherlands, this equates to 70 thousand tonnes of bread per annum that ends up in the household waste stream (with a - wasted - energy content of 1300TJ).

The packaging for the loaves also ends up in household waste and is equivalent to 6 thousand tonnes of plastics and paper (energy content of 150TJ).

In another example, he studied the distribution of milk in a range of container types - reusable glass bottles, paperboard cartons and polycarbonate bottles - and again recorded the waste in the home.

Milk wastage is typically between 5% and 30% (mainly due to prolonged storage in the fridge). Table 4 shows the energy content of the milk and its packaging. Even at 5% wastage, this represents a waste of 250kJ/litre. All the containers use between 400kJ and 600kJ to deliver a litre of milk and this then also eventually becomes waste.

There have been many lifecycle analyses of milk packaging and many claims that one is better than another. Professor Kooijman shows that the maximum saving per litre of changing from the most energy intensive container system to the least is 168kJ - only two-thirds the energy saving achievable by reducing the 5% milk waste.

He concludes that product wastage could be reduced by producing a wider range of pack sizes to better match supply to consumer demand. Smaller pack sizes produce more waste packaging per litre but if this reduces overall waste the environmental gain is greater.

3 ENVIRONMENTAL IMPACT OF PACKAGING IN THE UK FOOD SUPPLY CHAIN

In 1995 Incpen commissioned Professor Kooijman to carry out a study of the environmental impact of packaging in the UK food supply system. Many of the principles

Table 4 *Energy Content of Milk and its Packaging*

	<i>Energy content kJ/litre</i>
Milk	5,000
Packaging system (paperboard carton, glass bottle or polycarbonate bottle)	400 - 600
Milk wasted in the home (5% - 30% mainly due to too long storage in the fridge)	250 - 1,500
Energy saved in changing from one packaging system to another	40 - 168

Source: 'Environmental Assessment of Packaging: Sense and Sensibility', *Environmental Management*, 1993, 17 (5), 575.

apply also to non-food packaging.

The basic data for the study was the government's annual National Food Survey which provides detailed information on food purchases from over 8,000 households, split by size of household (number of inhabitants). Information on how much of the purchased food is actually eaten was obtained from a survey of a small number of different sized households, each keeping a record of food used during a two week period. These data were supplemented by information from a similar survey in the Netherlands. Over 200 different combinations of food and packaging were analysed.

The study was overseen by a Steering Committee, which included representatives of consumer and environmental organisations. The initial results were reviewed by a group of 50 experts at a meeting towards the end of 1995 and the full report was published in September 1996.

Results show that much more attention needs to be paid to matching packaging to consumers' needs. In particular, because the average household size is forecast to continue to drop, there will be an increased demand for smaller product quantities and consequently more packaging will have to be used to satisfy that demand. These demographic changes will increase the environmental impact of the food supply system and future policy on packaging needs to take these factors into account.

Quantity of food bought per head decreases as household size increases both in adult only households and those with children. One reason for this is that larger household sizes bring the opportunity for economies of scale with the purchase of larger sizes and reduced food spoilage and waste (Table 5).

The table also shows that food packaging protects on average 10 times its weight in food (with variations between 1 and 200 for different products).

However, material flows are only part of the picture. Energy has also been used to produce the food (and packaging) and a considerable environmental impact is hidden in the energy use along the food chain. The further down the chain the food travels the greater the environmental disbenefit if it becomes waste.

3.1 Energy Use in the Food Supply Chain

It is common for people to claim that they do not waste food because they either put it on a compost heap or feed it to animals. This argument is used, for example, to justify buying an unwrapped whole lettuce instead of a pre-packed bag of lettuce leaves. If the

Table 5 *Impact of Household Size on Quantity of Food Purchased and Packaging*

Household size	1 Person	2 Person	3 or more persons
	Kg per consumer per annum		
Food Purchased	590	560	470
Packaging			
primary	51	42	31
secondary	20	19	14
Total	71	61	45
Food Waste	120	90	50

Table 6 *Energy Performance in the Food Chain*

	GJ/ year*
Food supply	9.0
Primary packaging	1.3
Secondary packaging	0.6
Distribution	0.6
Retailing	0.5
Consumer purchasing	0.3
Consumer cooling	3.0
Consumer heating	2.5
Total	17.8

* Averaged over all size of households

lettuce is not eaten before it starts rotting then it can be composted but this ignores the fact that it wastes the significant resources invested in growing, transporting and selling it. On the other hand, the pre-packed leaves keep fresh longer, provide a quantity that is sufficient for one or two meals but the bag needs to be disposed of. However the "wastage" of the energy of the lettuce head represents a far greater waste of resources than the energy in the 2 or 3 grams of the plastic bag.

Table 6 shows the need for all parts of the supply chain to share responsibility for reducing its environmental impact, and that includes the consumer. Reducing packaging's impact alone will not help the environment. On the contrary, it could increase the waste of resources.

Legislators, however, have taken a narrow view of the environmental impact of packaging and have focused only on waste, and, even then have ignored product wastage. The Packaging and Packaging Waste Directive, 94/62/EC, is a typical example.

4 LEGISLATION

The Packaging and Packaging Waste Directive came into effect on 1 July 1996. It covers all packaging marketed in the EU and all packaging waste. It aims to harmonise national measures, to reduce environmental impact and to remove obstacles to trade within the Union. Member States have to:

- ♦ establish systems to recover 50%-65% of packaging waste within 5 years, within which recycle 25%-45% with no material recycled at less than 15%; (Member States that wish to set higher targets may do so with permission from the European Commission provided the higher rates do not create distortions or hinder another country's compliance with the Directive);
- ♦ comply with certain "Essential Requirements" including manufacturing packaging to use the minimum adequate weight and volume to maintain the necessary level of safety, hygiene and acceptance for the packed product and for the consumer; suitability for reuse, material recycling, energy recovery or composting.

No one knows if achieving these targets will produce environmental gains but, since

the viability of recycling depends on a number of variables, such as weight of material, existing waste handling system and proximity to a reprocessing plant, there is no scientific basis for setting national arbitrary targets. However, they will be reviewed in 5 years time, by which time industry should have better information to support a case for more flexible targets.

Some countries' regulations are also based on unscientific assumptions.

4.1 Denmark

The European Court of Justice case in 1988 against Denmark's restrictions on the sale of beer and soft drinks in non-refillable containers is believed to have been the trigger for the EU Commission to produce the "Packaging" Directive.

The Commission lost the case on the grounds that environmental considerations must take priority over trade. No one would dispute that protection of the environment is more important than trade but what it often overlooked is that Denmark was not asked to justify how its ruling benefited the environment. There was an automatic - and wrong - assumption that refillable containers are always environmentally superior to one trip containers. In addition, the specific ban on the sale of cans for beer and soft drinks was not considered in the case. If it had been, it is quite likely that the case would have gone the other way and the consequent flood of national measures on packaging in the name of the environment might not have followed.

4.2 Germany

In Germany the concept of making industry responsible for used packaging has been taken furthest. Recycling rates have increased but at a huge financial cost to industry and to consumers. In Germany the public is paying both as consumers, in increased cost of goods in the shops, and as taxpayers, because the promised decrease in waste disposal costs as a result of packaging waste being removed separately has never been realised.

Germany undoubtedly has a problem in finding disposal sites to replace the old ones it used to use in the East of the country and in other nearby countries - but splitting up the waste stream and giving each fraction back to its producer is proving to be an expensive way of tackling it.

4.3 United States

In 1988 the US Environmental Protection Agency, EPA, set a voluntary national goal that the country should recycle 25% of its "trash" by the end of 1992. Now its recycling rate is over 25%, there are vast numbers of drop-off sites and more than 4000 communities have curbside collection. And the EPA Administrator who set the target says that "recycling is a good idea that has gone too far" and it is costing far more than anyone ever imagined.

His advice now is to step back and look at the goals again. He believes that a good recycling rate for most locations is about 20% to 30% because high recycling rates have already been reached for the more valuable, easy to collect items.

His suggested recycling agenda for the Clinton/Gore administration includes:

- ♦ better analysis of the costs of recycling so local decision makers and taxpayers can compare waste management alternatives (current costs are \$100-\$200 per tonne