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REPORT

Problems Associated with the use of Recycled Plastics within the UK

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ABSTRACT

Only 7% of the 2.3 million tonnes of plastic waste generated in the UK each year is reprocessed to form 'new' products with the remainder being landfilled or incinerated. This situation will change due to the introduction of European legislation that forms part of the EC's strategy for dealing with the increasing waste disposal problem that exists within the community. EU legislation concerned with packaging and packaging waste became law in 1994. Additional Directives targeted at the automotive industry and manufacturers' and suppliers of electrical and electronic goods are currently being discussed.

This report describes the status of recycling within the UK as seen by companies representing recycle brokers, materials suppliers, moulders and extruders. The important issues highlighted by the respondents are discussed and areas where technical innovation or understanding is required are identified.

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Approved on behalf of Managing Director, NPL, by Dr C Lea,
Head of Centre for Materials Measurement & Technology

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APPENDIX 1

1. INTRODUCTION

The issue of recycling plastics is becoming increasingly important as a result of new legislation that is being introduced within the UK, in response to new EC Directives that are focused on the management of waste within Europe. The Directives contain targets for recovery and recycling of plastics that are set to increase with time. Compliance with the targets will require a change in the design of plastic parts, the establishment of new markets for plastics that contain recycled materials and new technology for converting certain waste plastics into useable materials. Not surprisingly there are a number of issues that will need to be addressed including the development of efficient sorting methodologies and an understanding of the properties of recycled plastics, and in particular how they are likely to behave in the long term. This has resulted in a number of studies that have addressed issues such as the economics of recycling plastics⁽¹⁾, the cost of extracting plastic from scrap cars⁽²⁾ and the potential metrological requirements for characterising the performance of recycled plastic^(3,4). These studies have been funded by the DTI and consortia of companies specifically established to consider recycling issues. Recycling has also been a topic for discussion in a number of conferences and exhibitions^(5,6) and most professional bodies, such as the British Plastics Federation now have an “Environmental” section which covers this topic.

2. THE SCALE OF THE PROBLEM

During 1995-6 some 1.6 million tonnes of post consumer plastics waste was recycled in western Europe⁽¹⁾. However, in the same period 25.9 million tonnes of plastics were produced and about 17.5 million tonnes of plastic waste generated. This latter figure is expected to increase to around 23 million tonnes by the year 2000⁽⁷⁾.

In the UK about one eighth of all refuse is recycled, with plastics being the least recycled fraction of this material in comparison with metals, glass and paper. Only 7% of the 2.3 million tonnes of plastic waste⁽⁸⁾ generated in the UK each year is recycled to form ‘new’ products with the remainder going to landfill or being burnt in municipal incinerators. However this is set to increase to 38% by the year 2000 in response to both the recently introduced and proposed EU Directives that are discussed in Section 3. By this time it is projected that the plastics waste stream will be composed of the following fractions (Table 1):

Polymer	Percentage of the plastics waste stream
Polyethylene	50
Polypropylene	25
PET	10
PVC and PS	6
Other	9

Table 1: The composition of the plastics waste stream by the year 2000

3. CHANGES IN LEGISLATION THAT IMPINGE UPON RECYCLING

The legislation that is driving recycling within Europe at present is being introduced as part of the Fifth Environmental Action Programme which forms part of the EU strategy for waste management that was endorsed in 1993. Promotion of material recovery and minimisation of final disposal form two objectives of the waste management strategy. These objectives have been given targets within the Fifth Environmental Action Programme i.e. at least 50% of paper, glass and plastic must be reused or recycled by the year 2000 and waste production should be reduced and stabilised to the level it was in 1985 by the same date. Whilst it is recognised that it may not be possible to achieve these targets within this timescale the EU has introduced a series of Directives which will force member states to reassess their waste management schemes. These Directives contain targets and timescales for plastics recycling that will have to be met. The suite of Directives are summarised in Table 2 which shows that most of them are still under discussion by the member states.

Directive	Status	Sectors affected
Packaging and packaging waste	Adopted in 1994, contains recycling and recovery targets for the period 1996-2001, which may be revised during this period.	Non-specific. Any company with a turnover in excess of £5m that uses or sells packaging in excess of 50t per annum.
Automotive	Still in draft form	Automotive, including car assemblers and component suppliers
Electrical	Still in draft form	Manufacturers and suppliers of all electrical/electronic goods.
Future priority waste streams?	Still under discussion	

Table 2: The status of EC recycling Directives

In December 1995 the UK Government published a White Paper entitled 'Making Waste Work' in response to the EC Environmental Action Programme. This paper describes the Governments strategy for managing the disposal of waste in the UK and has three key objectives;

- to reduce the amount of waste produced,
- to make the best use of the waste that is produced,
- to choose waste management practices that minimise the risks of environmental pollution and hazards to human health both now and in the future.

The cost of landfilling waste has increased due to the recently introduced landfill tax (October 1996) in an effort to limit the amount of refuse that is buried regardless of its potential value for being reused or recycled. This tax is now £10 per tonne for all non-hazardous materials⁽⁹⁾. The projected increases in this tax may also contribute to the need 'to reduce waste'.

Under the UK Producer Responsibility Obligations (Packaging Waste) Regulations that came into force in 1997, any business that manufactures, fills or sells packaging in excess of 50 tonnes per annum will be obliged to recover and/or recycle specified percentages of packaging waste, including plastics. This will ensure that the Governments national packaging recovery and recycling targets of

38% and 7% respectively by material during 1998-9 are met. These targets are set to increase over the next three years to 43% recovery with at least 11% recycling by material by 2000 and to 52% recovery with at least 16% recycled by 2001. Thus during the next three years there will be a steadily increasing volume of plastic waste of varying cleanliness generated for which suitable markets and end uses will have to be found.

The End of Life Vehicles (ELVs) draft Directive proposes that reuse and recovery rates for all end of life vehicles should increase to 85% by the year 2005 and 95% by the year 2015. Producers must ensure vehicles are designed and manufactured to achieve these rates of reuse, recycling and recovery⁽¹⁰⁾. The remaining plastics located in small items such as fasteners, carpet or cable sleeves are more costly to extract and are currently not removed prior to vehicle shredding. Once the metals have been removed, the shredder residue, or "fluff", containing fragmented plastics, foams, rubbers and glass constitutes about 25% of a cars weight. At present shredder fluff is landfilled. This reservoir of plastic that could be recycled equates to 350,000 tonnes per annum within the UK.

The draft Directive on Waste from Electrical and Electronic Equipment (WEEE) aims to limit the amount of redundant equipment and fittings that are currently landfilled. At present the Directive specifically excludes incineration as a recycling option for these products. Separate targets are proposed for collection and recycling, ranging from 40 to 90 percent of waste material depending on the type of product⁽¹¹⁾. There are eleven categories of equipment that cover IT equipment, large and small household appliances, medical appliances, toys, automatic dispensers etc. The Directive also aims to effect a cultural change in people who tend to hoard outdated or defunct electrical equipment in the belief that it has some value, and encourage them to recycle these items.

4. CURRENT ACTIVITIES IN THE UK

The questionnaire presented in Appendix 1 was distributed to 350 companies involved in the plastics industry to obtain a 'snapshot' of the current state of plastics recycling within the UK. The survey yielded a return of 16% from companies representing recyclate brokers, materials suppliers, moulders and extruders. The information gleaned from the responses to the questionnaires has been supplemented by findings from the literature as well as discussions with company representatives and members of trade organizations. The aim of this study is to seek answers to the following generic questions;

- What is the current level of activity in the UK regarding plastics recycling?
- What are the perceived driving forces encouraging use of recycled plastics?
- How is the quality and consistency of recycled feedstock assured and assessed?
- What are the problems associated with using recyclates?
- What are the perceived limitations to developing existing or new markets for products containing recycled materials?

Figure 1 shows that most of the companies who responded to the questionnaire were either injection moulders or extruders, serving a range of different sectors as shown in Figure 2. Principally the markets served by companies that recycle plastics are the automotive, electrical and packaging sectors. This is perhaps not surprising since these markets consume a significant amount of plastic and are currently the subject of the new European legislation. A small number (5) of companies who responded to the survey said that they did not use recycled plastic because they had problems with contamination, colour matching and had concerns regarding the performance of recyclates particularly during processing.

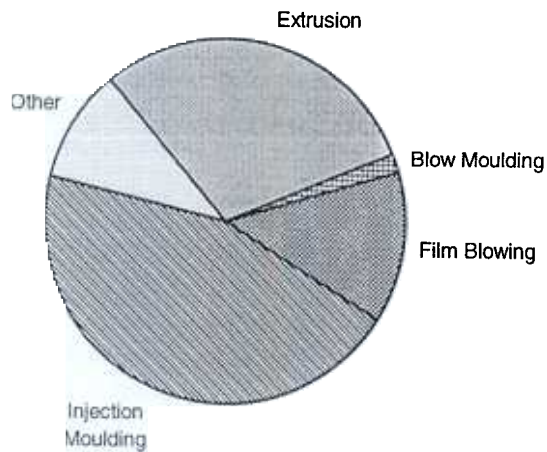


Figure 1: Manufacturing processes used by respondents to the questionnaire

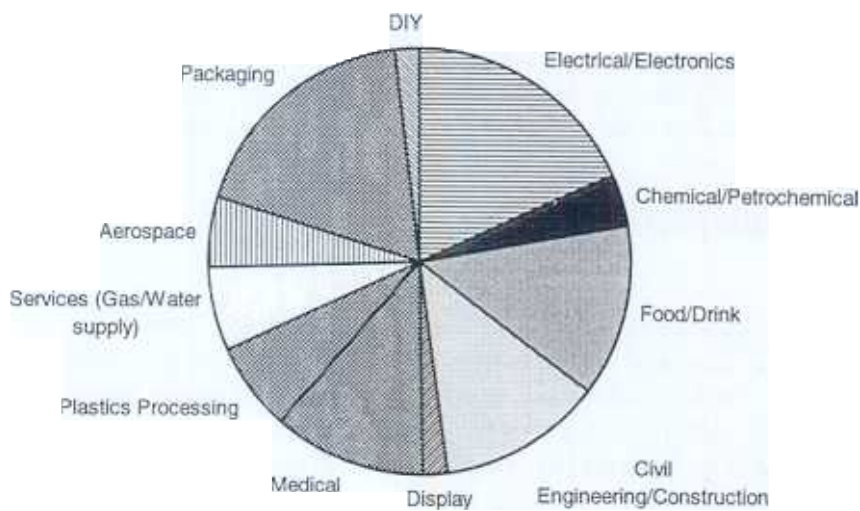


Figure 2: Sectors served by questionnaire respondents

4. INDUSTRY’S RESPONSE TO LEGISLATIVE CHANGES

Since the proposal of EC legislation setting targets for the recycling of ELVs, a number of companies have united to form bodies that represent their interests, investigate how the targets can be implemented and act as industry wide interface between the EC, the DTI and individual companies. The automotive sector within the UK is represented by CARE (the Consortium for Automotive Recycling) and ACORD (the Automotive Consortium on Recycling and Disposal)⁽¹²⁾. Both these organisations bring together vehicle manufacturers, component suppliers, trade associations, dismantlers, government bodies and members of the disposal and recycling industries. CARE has been particularly active in looking for new markets that can utilise waste plastic and rubber from vehicles and at ways of establishing economically viable routes for plastics from disassemblers to moulders. This entails conducting pilot tests to investigate which plastics and plastic parts can be economically recycled and whether or not the resultant products can be used in more critical

applications in vehicles other than wheel arches. This work has led the consortium into discussions with organisations such as SATRA (Shoe and Allied Trades Association) regarding the incorporation of recycled materials into footwear. CARE also plays an active role in removing some of the prejudice vehicle designers, plastic processors and component suppliers have with respect to using recycled materials.

With the introduction of the UK packaging waste regulations in 1997, all eligible companies (see table 2) have to be able to prove to the Environment Agency that they have recovered/recycled a designated amount of waste. This is facilitated by the use of Packaging Recovery Notes (PRNs) which are issued by accredited waste processors on receipt of the waste. To fully comply with the regulations, companies are held responsible for the storage, transport and delivery of the waste to the processors. They must use accredited waste hauliers and have fully traceable records of all waste movements. Instead of 'going it alone', companies can instead join a 'compliance scheme' registered with the Environment Agency. These schemes were set up to handle, at a price, their member's obligations under the regulations. Essentially acting as waste brokers, the schemes deliver their member's waste to accredited waste processors (e.g. recyclers, paper mills, glass manufacturers etc.) in return for PRNs which are sold back to the members. There are many compliance schemes in place, some concerned with specific waste streams and others with mixed waste⁽¹³⁾.

Companies operating in the electrical and electronic sectors can join the Industry Council for Electronic Equipment Recycling (ICER) which behaves as an interface between the DTI, the EC and its members. ICER has very recently fed the responses of its members to the first draft of the EC Directive on Waste Electrical and Electronic Equipment (WEEE) back to the EC via the DTI. ICER has produced a list of thirty major concerns⁽¹⁴⁾ over issues of the handling and disposal of defunct equipment disposal and changes in design. As might be expected the issue at the forefront of these discussions is one of cost. At present there is no well defined route for companies to 'take back' used products i.e. collect defunct equipment from households, retailers or wholesalers. For example one of the more established routes for the disposal of used white or brown goods involves a significant contribution from 'totters' who make a living recovering items of value from municipal waste sites. To establish a reliable infrastructure for collecting waste, dismantling and segregating plastics will require a substantial investment.

A new industry has emerged within recent years that forms an interface between collectors of post-consumer plastics waste, for example local authority reclamation schemes or vehicle dismantlers, and moulders. These companies act as brokerages segregating incoming waste into different types of plastic and provide granulated or pellatised material for moulders as shown in Figure 3.

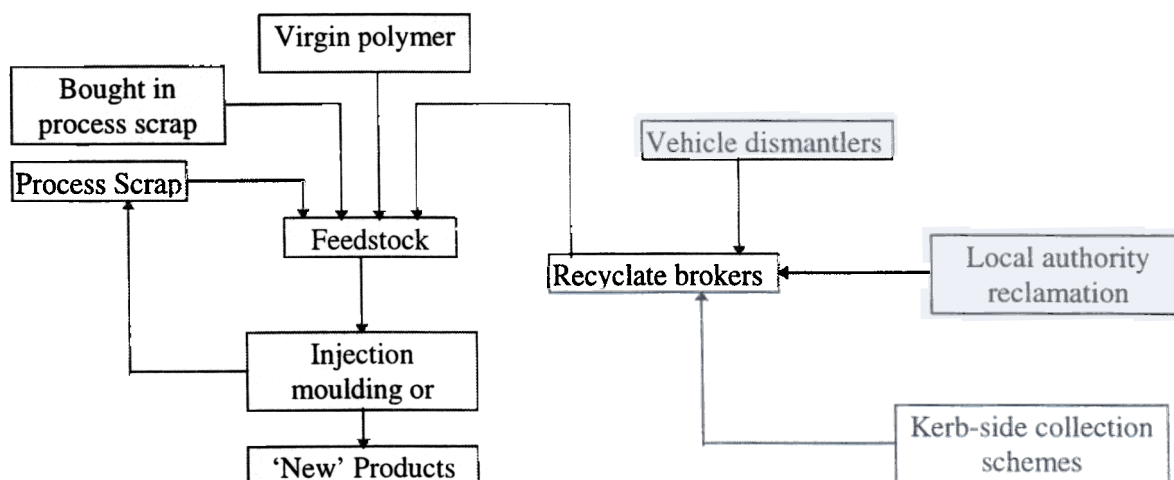


Figure 3: Potential routes for recycle

4.2 USE OF RECYCLED MATERIALS

Moulding companies have traditionally recycled a significant percentage of their process scrap: sprues and runners removed from mouldings are granulated on-line and fed back into the in-line feedstock. This is borne out by Figure 4 which shows that most of the questionnaire respondents who use recycled material only recycle process scrap, including a significant proportion who purchase process waste from other companies. Only 15% of respondents use either single or mixed grade post-consumer scrap. It should be noted that process scrap is not normally used in items that are perceived as being safety critical. The amount of process scrap generated during moulding is likely to decrease in the future due to improvements in mould design that utilise smaller, more efficient sprue-runner systems and the increased use of hot runners.

Manufacturers of containers such as bottles and paint cans have used co-injection technology for a number of years to produce packaging with properties that are specific to the products that they contain. This is most obvious in packaging manufactured for the food industry where the incorporation of oxygen-impermeable barrier films limits the oxidation of the contents. Mixed plastic recyclate is often incorporated in to these multi-laminate structures. These often dissimilar plastics are bound together by thin layers of adhesive such as EVA (ethylene vinyl acetate). Using recyclate as a core filler can reduce the cost of the product without compromising the surface finish.

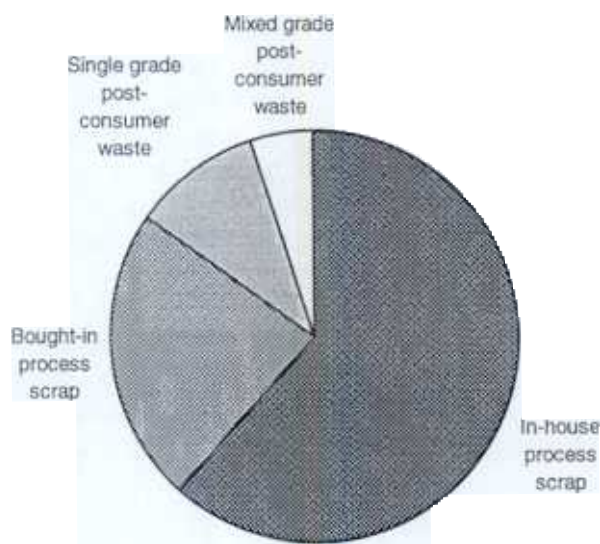


Figure 4: Sources of recyclate

Figure 5 shows that the majority of companies who do use recyclate add up to 10% of this material to their feedstocks. Companies that use higher concentrations of recyclate are typically those supplying the lower specification markets that cover products such as fencing, waste collection bins and garden furniture.

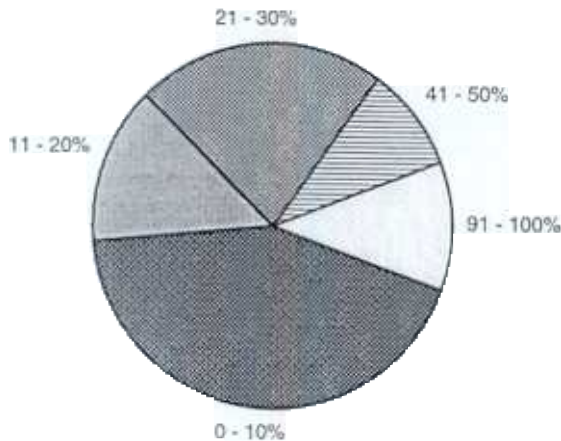


Figure 5: Concentrations of recyclate used in feedstocks

5. ECONOMIC CONSIDERATIONS ENCOURAGING THE USE OF RECYCLATE

A Delphi Study conducted by Boks and Tempelman⁽¹⁵⁾ in 1997 was aimed at charting the technical feasibility and economic attractiveness of various recycling techniques. The study consisted of a number of questionnaires sent out to a panel of sixty eight specialists in the field of recycling within academia and the automotive, electronic and disassembly industries. Their study concluded that legislative forces will be the principal driver for companies to use recycled plastics until around the year 2010 by which time it will be superseded by market forces. Currently the markets for recycled polymers are in their infancy and will require large amounts of investment, and as such are not profitable.

Results from the NPL survey (Figures 6 and 7) show that the principal driving force for individual companies to utilize recycled material is the desire to reduce manufacturing costs either by sourcing a cheaper feedstock or by limiting the amount of waste material produced. Current and perceived legislation together with changes in public opinion although significant are not seen as major driving forces in comparison with costs, although this balance may shift with time. This survey showed that customer demands and environmental issues are relatively minor considerations. Much of the cost of recyclate is attributable to the time taken to extract and identify plastics from the waste stream.

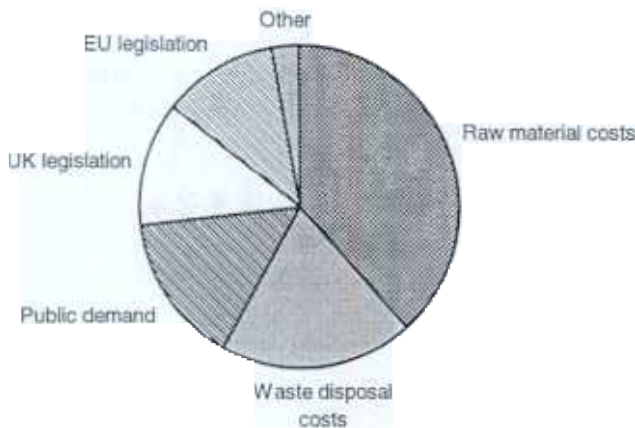


Figure 6: Driving forces encouraging the use of recyclate

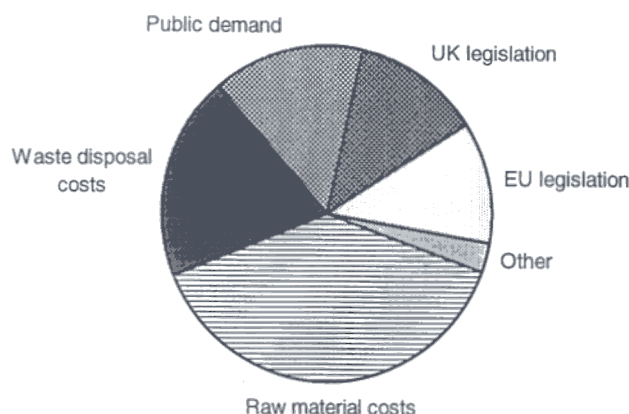


Figure 7: Reasons for recycling as prioritised from the NPL survey

Although it is recognised that most reclaimed post-consumer plastic could be used as a comparatively low cost feedstock to manufacture 'new' plastic products, its value to industry depends on a number of factors. Irrespective of other considerations recycled plastics have very little value unless there is a market for products that contain them. This is currently the situation for coloured PET, that has a value of £0-25 per tonne when delivered to a recyclate broker as clean, shredded material. At this price material is supplied to brokers at a loss after accounting for delivery, collection and sorting costs. At the present time the prices of commodity plastic recyclates are comparable to those of the virgin material for many and hence there is no economic advantage to using them. Where small economic advantages do exist they are often offset by concerns over batch-to-batch variation, reliability of supplies and uncertainty over their long-term performance. These difficulties can to some extent be constrained by recycling material from known sources e.g. car battery cases, (polypropylene) or soft-drinks bottles, (PET). This single source post-consumer waste is being used to manufacture 'new' items e.g. car battery cases or other high value products e.g. PET fleece for clothing manufacture. However a number of unresolved technical issues remain such as;

- How to assess the influence of contaminants on material properties and performance,
- How do different additives interact,
- How can plastics that contain (now) banned additives e.g. cadmium be reprocessed.

Industry believes both the market for recycled material and its value will increase over the next five years, although some companies feel that both will reach a plateau during this time⁽¹⁵⁾. In practice the market for recycling is strongly dependent on the identification of suitable end use applications which in the absence of either legislative pressures or strong economic advantages may be slow to emerge. The value of recyclates will also reflect how much particular materials are in demand. It is quite possible that the price of recyclate will fall, either for all or certain types of plastic which will happen if the legislation results in a proliferation of recycling schemes and a glut of material to appear before markets suitable for its disposal have been established.

6. SPECIFIC PROBLEMS ASSOCIATED WITH RECYCLATES

Products manufactured from plastic are generally regarded as being inferior and of lower value compared to similar products manufactured from metals or glasses. In part this perception is based on the assumption that plastics are cheap materials. These preconceived ideas do not bode well for selling customers products manufactured from recycled materials particularly if there is no price differential between parts made from virgin or recycled feedstocks.

In recent years there has been a considerable investment in improving the quality of data for designing products and in developing computer packages that simulate manufacturing processes. The availability of these products is enabling designers to design products using the minimum amount of material. Whilst this approach is laudable it is likely to encounter manufacturing problems if recycled feedstocks are substituted for virgin ones as the materials properties of the recycled materials are likely to differ from those of the virgin plastic.

The survey identified the threat of contamination as being the principal problem associated with using recycled thermoplastics as shown in Figure 8. Recyclate can become contaminated in many ways ranging from metal particles, paint flakes and chemical contamination to dirt picked up during the service life of the item. Some contaminants such as plastics can effect profound structural changes in items manufactured from 'dirty' recyclate by forming immiscible blends as occurs when PVC when mixed with ABS. This particular problem has been encountered during the recycling of telephones. Very little information has been published in the literature concerning the potentially adverse effects that metal flakes or previously degraded plastics could have on the properties of recycled material both in the short and long term.

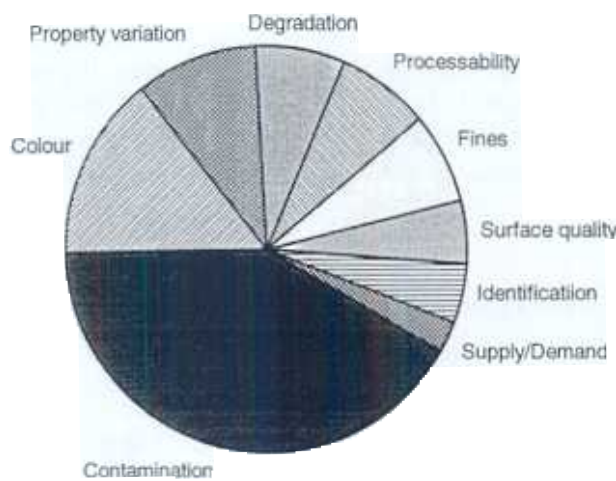


Figure 8: Problems associated with the use of recyclates

A major car manufacturer has experienced a problem of odour retention in recycled plastic. In particular odours from oil or petrol remain in plastics after reprocessing. To avoid the problem of these odours tainting the air in the passenger cabin, the company has decided for the present time not to incorporate recycled plastic in components destined for use in this area or the associated air intake ducting. Problems of odour retention are most common in recyclate derived from items that have been used to store strong smelling produce in products such as fish crates or perfume bottles. One company has exploited this property to manufacture perfumed plastic discs from post-use perfume bottles for use as drawer fresheners. Undesirable odour emissions can occur during the processing of bottles or drums that formerly contained chemicals that are an obvious health risk. A project to recycle used oil containers was terminated for this reason.

The effects of chemical contamination on the properties of recyclates or the performance of the additives contained within them has received scant attention. The chemical contaminants present can

reflect the substances that the product has been in contact with during its lifetime e.g. fertiliser in recycled fertiliser bags. Less well defined chemical contamination of mouldings occurs on cars and lorries that are exposed to, for example, fuel residues. Contamination with other plastics is comparatively common in items manufactured from mixed plastics that are incompatible with each other. Even small quantities of contaminant can spoil a large batch of recyclate i.e. PVC (bottle caps) in batches of PET (bottles). Attention is now being paid to the design of complex mixed plastic assemblies with a view to their potential for recycling. Unfortunately it will take a long time for these 'new' designs to enter the recycling stream that still leaves the problem of how to recycle current mixed plastic assemblies.

Certain plastics when exposed to ultra violet light degrade with time. This effect can be seen as an off-grey surface finish on items such as black car bumpers. It is not clear whether or not this material is compatible with un-degraded material or what influence exhausted UV stabilisers may have on the long term performance of reprocessed plastic. Recyclate may also contain fragments of metal from threaded inserts, fasteners, hinges, foil (used extensively to seal dairy product packaging) or copper braid (used in some plastic welding operations). Many new designs avoid the use of metal hinges and fasteners that are replaced by plastic snap fittings and 'living' hinges. This type of design not only facilitates recycling but also results in reduced manufacturing cost as these mouldings can be produced in a single step obviating the need for metal fasteners and hinges and secondary assembly operations.

Contamination is a major concern of ICER members, in particular, white and brown goods often contain rotting food and other chemical residues which pose potential health and safety problems both at the collection and dismantling stages as well as contaminating the recycled polymers. Many discarded electrical appliances contain unknown or substances that have now been banned, these include CFCs. Similar chemical contamination can be found in automotive waste from brake fluids, oils, fuel and anti-freeze although there are mechanisms for recycling these fluids.

7. ASSESSMENT OF RECYCLED PLASTICS

While contamination of recycled plastics is perceived as being a major problem in using these materials, Figure 9 shows that few companies clean the material destined for recycling. This may be because any operation to clean or segregate materials contributes to its cost. Plastics destined for recycling are generally sorted by grade and colour. This result is not surprising given that most of the companies who completed the questionnaire are recycling process scrap i.e. sprue-runner systems from injection moulding machines.

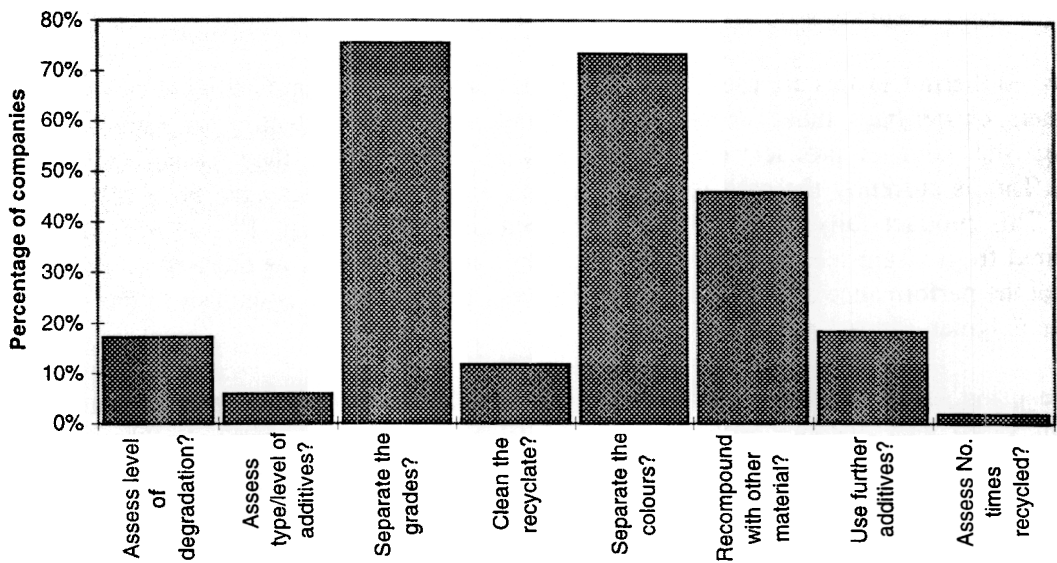


Figure 9: Company responses to questions concerned with the analysis and treatment of recycled plastics.

The questionnaire revealed that a few companies comprehensively test batches of recyclate whilst the majority rely on one or two tests. Table 3 shows that 21% of the companies do not measure any properties of their recyclates. This figure may be unduly high if the companies sampled are purchasers of recycled material that may have been characterized by the vendor or if the company is mainly recycling its own process scrap.

Material characterization methods	Percentage of respondents
None	21
Melt Flow Index (MFI)	17
Mechanical testing	62

Table 3: Recyclate properties measured

A commonly used measurement within the industry is melt flow index (MFI). This relatively simple test is easy to perform and gives some indication of the flow properties of the plastic. This can be used to assess the polymer’s processability and goes some way to indicating how it will mix with other materials. The MFI of the recyclate can be altered by adding higher or lower MFI virgin grades of the same material until the blended material has an MFI comparable to those of virgin grades. Thus in principle the recyclate blend can be substituted for a particular virgin grade and be processed in the same way without changing the processing parameters. Unfortunately since the MFI index is only a loose measure of the rheological properties of a material it is a poor indicator of any other property changes that may exist with respect to a virgin feedstock.

Survey replies showed that where impact properties are used to characterise recyclates, they are determined mainly by the Izod and Charpy methods. These tests reflect the properties of very localized regions of the test-pieces and are unlikely to identify the presence of discrete impurities within the bulk material.

8. LIMITATIONS TO DEVELOPMENT OF NEW MARKETS

Most recycled thermoplastics are used in “lower grade” or secondary applications such as; paint or oil containers, carrier bags, tubes for packaging and underground cable ducting. In more demanding applications the value of products can be adversely affected because they do not comply with standards. This is currently the case for PVC mineral water bottles that have been recycled into guttering. This product fails to meet with British Standard BS 4576 pt 1⁽¹⁶⁾ as it is not solely manufactured from virgin feedstock. This is frustrating for the company as there is no evidence to suggest that the performance of the product manufactured from recyclate is inferior to that produced from virgin polymer.

Barriers to using recycled materials are also being experienced by companies who have quality systems in place that comply with ISO 9000⁽¹⁷⁾. This standard requires health and safety documentation to be provided for the materials used in manufacturing. This documentation is often difficult to provide for recyclates because of their uncertain history. Companies wishing to use post-consumer scrap are apparently trying to seek a compromise solution to this problem.

9. CONCLUSIONS

The results from the NPL survey show that many plastics processing companies are at the present time only recycling their own process scrap. Problems may be encountered if bought-in recyclate is substituted for virgin feedstocks during the manufacture of products that have been designed using materials data from well characterised, homogeneous virgin materials. The main problem reported with the use of bought-in recyclate is contamination, which could result from the lack of suitable measurement techniques for the quality control of recycled polymers. There is also a need for increased understanding of the effects of contaminants on the properties of polymers in service and how much contamination can be tolerated before performance is significantly reduced.

The respondents to the NPL questionnaire did not see legislation as a significant driving force in plastics recycling, although this situation is likely to change in the very near future as new EC Directives in the packaging, automotive and electrical/electronic sectors begin to take effect. Indeed, the panel involved in the Delphi survey, which was focused on future aspects of recycling, predicts that legislation will be a greater driving force than at present and will continue to be the main factor affecting the use of recycled plastics until around 2010.

Enhanced competitiveness and profitability achieved through lowering manufacturing cost is seen as the current main drive for companies to recycle plastics. Currently there is little difference in cost between recycled and virgin materials and therefore manufacturers prefer to use virgin feedstocks. The relatively high price of recyclate is due to the cost of extracting plastics from the waste stream, which reflects the current lack of efficient separating technologies. It may be difficult to sell products manufactured from recycled materials at a premium price due the often low customer perception of the value of recycled materials. This low customer value of recyclate may hinder the development of new markets.

10. FURTHER WORK

A number of potential project areas have been identified by those who participated in this survey. Some of which are required to provide the necessary underpinning metrological characterization of the behaviour of recyclates that will facilitate their use in the future.

The project areas that have been ranked in terms of their popularity are as follows;

- Improve methods of detecting contamination in recycle feedstocks,
- Investigate the long term environmental behaviour of products manufactured wholly from or containing recycle coupled and assess the effects of already degraded material on performance,
- Study the time and processing dependent properties of additives such as fire retardants.
- Investigate what influence the number of reprocessing cycles has on the properties of plastics,
- Develop new technology for segregating mixed plastic waste,
- Assess the potential for using recycled plastics in a wider range of products,
- Improve customer confidence in the use of recycled plastics - some companies reported that their customers would not accept recycle in their products.

11. FURTHER SOURCES OF INFORMATION

Information on EC Directives

A substantial amount of information about EC policy and a history of the Directives can be found on the Internet site <http://www.europa.eu>.

General Information on Plastics Recycling (economics, technology etc.)

BRANDRUP J et. al. (eds.) *Recycling and Recovery of Plastics* Hanser Press, 1996.

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12. ACKNOWLEDGEMENTS

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APPENDIX 1: QUESTIONNAIRE

Recycling of Thermoplastics - Questionnaire

Please amend address details if required

The National Physical Laboratory is surveying the requirements for research in the area of recycling of thermoplastics by companies such as yourselves. We would appreciate it if you would take the time to complete this questionnaire which will enable us to:

identify problems associated with the use of recyclates

- identify areas where new standards or accepted codes of best practice are required
- improve the quality control of recyclates
- improve customer confidence in products containing high levels of recyclates
- identify areas of research that are required in order to fully exploit process and post-consumer scrap
- identify the most appropriate routes for feedback in order for you to derive maximum benefits

We will be forwarding the results of this survey back to the companies that participate in order for you to derive the maximum benefits from the survey.

If you would like to discuss the questionnaire before completion or have any questions, please do not hesitate to contact:

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 National Physical Laboratory
 Queens Road
 Teddington
 Middlesex TW11 0LW

Telephone: 0181 977 3222 (Main Switchboard)
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Materials and Markets

1. Which thermoplastics does your company deal with?

Tick all that apply

- | | | |
|--------------------------------|------------------------------|---|
| ☐ ABS | ☐ SAN | ☐ POM |
| ☐ HDPE | ☐ PET | ☐ PS |
| ☐ LLDPE | ☐ PBT | ☐ PP |
| ☐ PVC | ☐ SBR | ☐ Other, please specify: |

2. Do you use any form of recycled thermoplastic material in your products?

- ☐ Yes
☐ No

If Yes, why do you use recyclates?

If No, what are the main reasons for not using recyclates?

3. What is the source of your recycled material?

Tick all that apply

- | | |
|--|---|
| ☐ Process scrap (in-house) | ☐ Post-consumer waste (single grade) |
| ☐ Process scrap (bought in) | ☐ Post-consumer waste (mixed) |
| ☐ Other, please specify: | |

4. Do you have, or have you had, any specific problems with using recycled thermoplastics?

- ☐ Yes
☐ No

If Yes, please provide details:

5. In which products do you use recycled material?

6. In which of the following sector(s) are your product customers?

Tick all that apply

- | | |
|---|--|
| ☐ Aerospace | ☐ Food/Drink |
| ☐ Automotive/Transport | ☐ Medical |
| ☐ Chemical/Petrochemical | ☐ Packaging |
| ☐ Civil engineering/Construction | ☐ Plastics processing |
| ☐ Electrical/Electronics | ☐ Services (gas/water supply) |
| ☐ Other, please specify: | |

7. What do you consider to be the main drives encouraging plastics processing companies to use recycled material?

Tick all that apply

- | | |
|--|---|
| ☐ UK legislation | ☐ Waste disposal costs |
| ☐ European legislation | ☐ Public demand |
| ☐ Raw material costs | |
| ☐ Other, please specify | |

8. How do you perceive the value of recyclate changing in the next five years?

Tick all that apply

- ☐ increasing
☐ staying the same
☐ decreasing

9. How do you perceive the market for recyclates changing in the next five years?

Tick all that apply

- ☐ expanding
☐ staying the same
☐ contracting

Testing and Processing of Materials

10. What facilities do you have for testing plastics?

11. When using a recycled plastic, do you conduct any of the following quality control tests on the raw material?

Tick all that apply

- | | |
|---|--|
| ☐ Tensile modulus | ☐ Fatigue (shear) |
| ☐ Tensile strength | ☐ Creep |
| ☐ Elongation to break | ☐ Impact (Charpy) |
| ☐ Fatigue (tensile) | ☐ Impact (Izod) |
| ☐ Fatigue (compressive) | ☐ Impact (falling weight) |
| ☐ Fatigue (flexural) | ☐ Melt flow index |
| ☐ Viscosity - by which method? | ☐ Other, please specify: |

12. Which processes do you use?

Tick all that apply

- | | |
|---|---|
| ☐ Extrusion | ☐ Film blowing |
| ☐ Blow moulding | ☐ Injection moulding |
| ☐ Other, please specify: | |

13. Do you conduct any tests to assess how many times the material has been recycled?

- ☐ Yes
☐ No

If Yes, please provide details:

14. Do you conduct any tests to assess the level of degradation in the material?

- ☐ Yes
☐ No

If Yes, please provide details

15. Do you conduct any tests to assess the type and level of additives in the material?

- ☐ Yes
☐ No

If Yes, please provide details

16. Before using a recycled material, do you clean the recyclate in any way?

- ☐ Yes
☐ No

If Yes, please provide details:

17. Before using a recycled material, do you separate the plastics or grades?

- ☐ Yes
☐ No

If Yes, please provide details:

18. Before using a recycled material, do you separate the colours?

- ☐ Yes
☐ No

If Yes, please provide details:

19. Before using a recycled material, do you recompound with other material?

- ☐ Yes
☐ No

If Yes, please provide details:

20. Before using a recycled material, do you use any further additives?

- ☐ Yes
☐ No

If Yes, please provide details:

21. Typically, what level of concentration of recyclate is used in your feedstock?

Tick one box only

- | | | |
|-----------------------------------|-----------------------------------|-----------------------------------|
| ☐ 0 - 10% | ☐ 41 - 50% | ☐ 81 - 90% |
| ☐ 11 - 20% | ☐ 51 - 60% | ☐ 91-100% |
| ☐ 21 - 30% | ☐ 61 - 70% | |
| ☐ 31 - 40% | ☐ 71 - 80% | |

How did you determine this level?

22. How is the recyclate added to your feedstock?

Tick all that apply

- ☐ Dry blending
☐ Melt compounding
☐ Other, please specify:

Further Work

23. What sort of research would you like to see carried out in this area?

24. What would be the best route(s) for dissemination of results to your company?

Tick all that apply.

- ☐ Papers in academic journals?
 ☐ Newsletters?

- | | |
|--|---|
| ☐ A code of best practice? | ☐ Seminars held at |
| ☐ New or revised International standards? | major trade exhibitions? |
| ☐ Articles in the trade press? | ☐ The Internet |
| ☐ Other, please specify: | |

Any other comments:

Name of person completing questionnaire:

Position held within company:

Thank you for completing this questionnaire. Please return it to the address stated on Page 1. A business reply envelope has been provided for your convenience.

Articles tailored to specific sectorial audiences are being prepared for publications such as 'The CARE Newsletter' (the dissemination vehicle for companies involved in automotive recycling). These articles will describe the aims of the feasibility study and invite companies to discuss specific problems with the NPL.