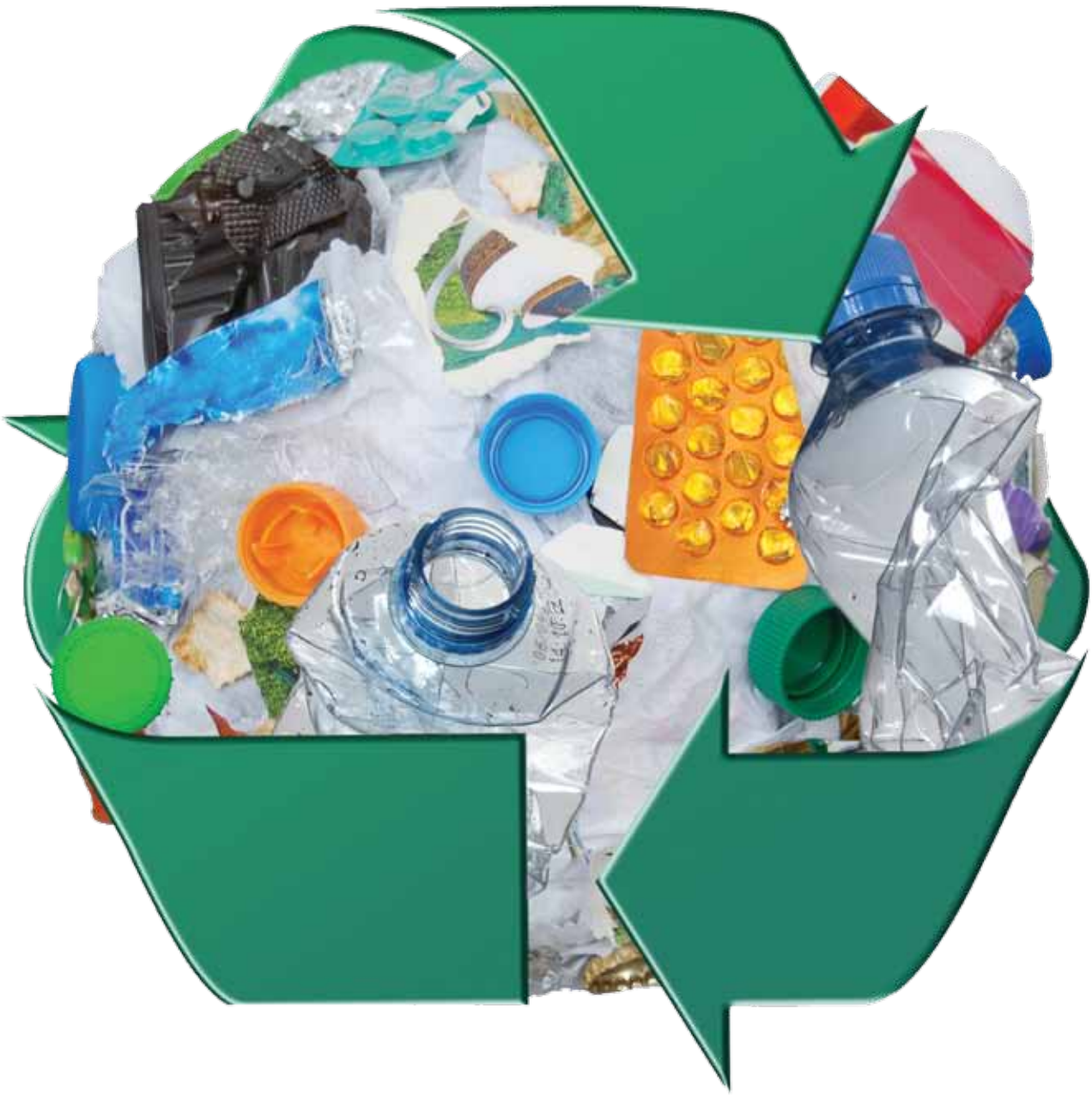
Plastic alchemy

Throwing away used plastics has environmental consequences – but is also wasting a valuable resource. Andy West looks at the ways chemists are turning a costly waste into a high grade raw material



For most of us, plastics have become an indispensible part of everyday life – from the cars we drive to the packets our sandwiches come in. However, our throw-away attitude to many plastics seems increasingly untenable.

The majority of the 100 million tonnes of plastic manufactured each year are made from oil, and as world stocks are depleted and the cost rises, supplies of affordable plastics produced from virgin chemicals are unlikely to be sustainable.

At the same time, disposal of waste plastic is becoming unsustainable. In Europe alone, around 25 million tonnes of plastic scrap were generated in 2008 – a figure that increases by around 5 per cent every year. In the UK, plastics typically account for 7 per cent of all rubbish thrown out in domestic refuse and what happens to this once it has left your bin very much depends on where you live. In Europe, 50 per cent at best is recycled, while the other half is sent to landfill or for incineration. As landfill sites fill up and new incinerators are not built due to public aversion, cost and environmental concerns, we are fast running out of disposal routes.

Faced with this problem, many governments have responded by sending their plastic waste abroad, to countries where labour and energy costs are cheaper and sorting and recycling can be achieved more profitably. Ethical concerns with this practice aside, the environmental impact can be enormous: contaminated plastic cannot generally be reused and so will still end up being burned; plastics are typically only recycled when the market value is high, so huge stockpiles of used plastic can be created, attracting pests and disease; current recycling methods usually do not produce high-grade plastic, reducing its resale value. Depending on the price of oil, this can still make recycling costs higher than resale profits, making it cheaper to dump plastic than to reprocess it.

'I would say many countries are dumping their rubbish in the name of recycling,' says Martin Baker, of Greenpeace China. 'It is not responsible recycling. The methods being used are still mostly rudimentary; on the whole it is small scale, done in backstreets with few environmental standards. People are sorting plastic by hand, burning it, and the water used for washing gets polluted and goes back into the rivers.'

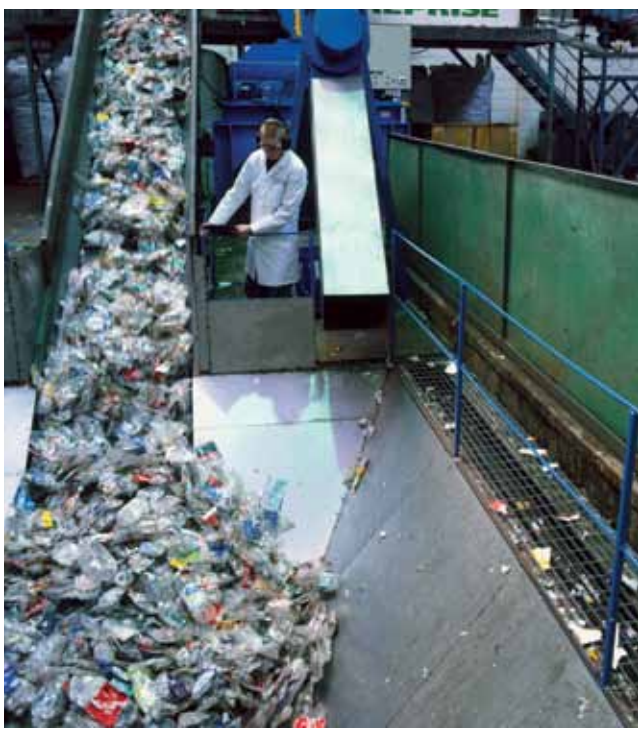
But aside from the environmental concerns, with advances in recycling technology and chemistry, it is becoming apparent that sending plastic waste abroad or to landfill could actually be giving away or disposing of very valuable raw materials. PET (polyethylene terephthalate) plastic bottles are a prime example of this: in the UK alone, it costs £100 million a year to dispose of these used items, while if correctly recycled and resold, the polymer materials could be worth up to £27 million. Similarly, if other plastics can be recycled at relatively low cost into high value, virgin-like materials and sold at a premium, companies could make large profits while reducing environmental impact and our dependency on oil.

PET project

So if plastic recycling appears to make good economic sense, why isn't more of it being recycled? There are a number of reasons why domestic plastic recycling isn't as easy as it first appears, the biggest issue often being that no commercial process exists to recycle the plastic. 'It's a chicken and egg situation,' says Claire Wilton, of Friends of the Earth. 'There aren't many reprocessors, so it's not worth collecting plastics. And because there's not much used plastic available, there aren't many reprocessors.' Also, there are around 50 different types of plastics that can be found in domestic waste, making sorting and separation an often prohibitively expensive task if only low-value recycled plastic is produced. In short, to encourage industry to recycle more, profit margins need to be increased.

In short

- **Dumping plastics after use is looking increasingly untenable, and it being increasingly seen as a waste of a valuable resource**
- **Different plastics need recycling differently – and sorting can be costly**
- **Colour impurities dramatically affect the resale value of recycled plastic, so waste often also needs to be sorted by colour**
- **Scientists are researching ways to strip out the colour during reprocessing**



The first step in plastics recyling is sorting and separation

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The way to achieve those higher profits depends on the plastic. PET is widely used for making plastic bottles and can be recycled by a mechanical process to produce low-grade products such as carpet fibre and non-food containers. However, PET waste comes in such a variety of shades that it can't be separated by colour, so the recycled plastic cannot be exactly re-coloured according to the buyer's requirements – reducing its value by over 95 per cent in comparison to PET made from virgin chemicals (see box p54).

To increase the value of the recovered PET, a range of chemical processes can be undertaken. Treating the waste with superheated methanol depolymerises the PET into dimethyl terephthalate and ethylene glycol. These raw materials can be purified and repolymerised to yield what is classed as virgin PET. In the US, the Eastman Chemical company has been operating a small scale plant that can process around 25 000 tonnes per annum in Rochester, New York, for over a decade. Japan's Mitsubishi Heavy Industries also use a proprietary version of this technology that employs supercritical methanol to depolymerise the PET. Alternatively, glycolysis can be used, where PET flake is reacted with ethylene glycol to produce bishydroxyethyl terephthalate or low molecular weight oligomers. Again, these can be purified and re-polymerised to make high value PET. Shell and DuPont operate glycolysis plants, almost all of which are located in the US and Germany.

The main reason more PET is not recycled in this way is down to economics and a lack of guaranteed supply. Significant infrastructure and investment are required, which will only be made if a consistent volume and quality of waste can be obtained. In addition, such recycling facilities cannot be located near the homes that create the waste to begin with, which increases transport miles and reduces the profit margin for the recycled PET.

To overcome this, Closed Loop Recycling has developed a less treatment-intensive way to recycle PET that produces material that is pure enough for use in food containers. 'Until now there has been no facility in the UK to recycle

ANDREW FOX/CORBIS

bottles back into plastic food packaging,' explains Chris Dow, managing director of Closed Loop Recycling. After sorting, cleaning and pelletising, PET flakes are treated with sodium hydroxide solution, which removes the surface layer of the flake and any contamination along with it. The flake is then treated at high temperature in a rotating furnace to ensure the top layers have been removed before being washed and packaged for reuse. The company already sells recycled PET to the drinks giant Coca-Cola, and in June this year the UK-based Marks and Spencer supermarket chain began to sell salad in PET boxes recycled by Closed Loop. 'The industry and consumer are now viewing recycled plastic in a completely new light. It is no longer waste, it is a valuable resource,' continues Dow. The success of the process has led the company to begin construction of a second plant in North Wales.

Efficient recycling schemes are needed to reliably supply recycling plants

Colourful solutions

It is also already possible to recycle both polyethylene (PE) and polypropylene (PP) into high quality products, by shredding and then melting the plastics by heating above 200°C at reduced pressure. This removes any contamination from the plastics before they are extruded into pellets for reuse. A study on the recycling of PP buckets by Recoup, a network promoting the reuse of plastics, concluded that depending on the price of crude oil, a European recycler could make between £35 and £95 profit per tonne of recycled PP and PE. This profit varies from country to country depending on labour rates, electricity costs and other factors, but clearly shows that recycling both PP and PE makes good economic sense.

However, this melt and reform process is only effective for very clean, colourless waste plastics. If any colour contamination remains, the value of the recycled plastics can be reduced by as much as 15 per cent, quickly cutting profits. As a result, costly sorting techniques are

Jazzy Plastics

While there are often straightforward methods for recycling colourless plastics, coloured waste, known as 'jazz', can be a real problem to reuse. While mixing carbon black in with the jazz can hide the colours, this produces low-value plastic with low profit margins. However, a number of processes can use mixed coloured waste to make medium-value products – for example, used coloured PET bottles are already turned into a range of products including fleece-type clothing, carpets and strapping for cargo loads. Coloured mixed plastics can also be used in products such as garden benches, fence posts and coat hangers.

Since the late 1990s, a process called solid-state shear pulverisation has been under development that can convert mixed plastic waste in assorted colours into a uniform, light-coloured powder that can be used in direct-melt conversions. Numerous non-food products have been produced using this feedstock, including automotive and appliance parts, electrical housing and furnishings. The plastics formed often have enhanced mechanical properties, but have unusual colours that are difficult to control.

Another use for jazz that has recently entered the commercial market is in the production of building site hoardings. Millions of sheets of plywood are used around the world during construction projects as temporary barriers and most of these are burnt or sent to landfill after just one use. A consortium of companies, including international building contractor Bovis Lend Lease, has developed a process whereby coloured mixed waste plastic can be converted into boards of a similar thickness and weight to plywood, using powder impression moulding (PIM). Unlike wood, the boards do not absorb water and do not produce splinters, making handling, storage and reuse much easier. They cost around the same as plywood boards to produce and once they have worn out, they can simply be recycled again using the same PIM process.

A wide range of other novel uses for mixed-colour plastic waste are being investigated.

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Coloured waste can often only be used in low grade applications

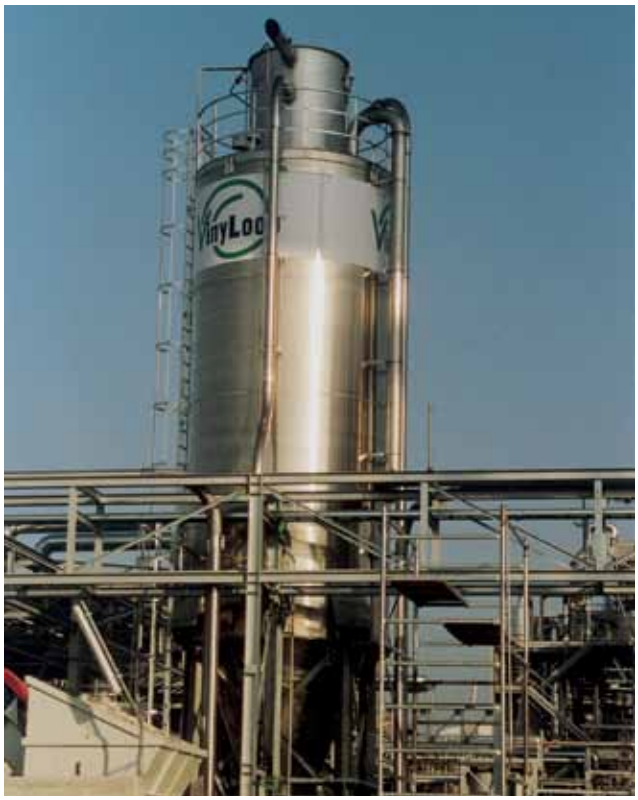
required to separate the colourless PE and PP from the coloured plastic. While this allows the colourless material to be recycled, it produces a coloured mixed waste stream. This is either sent to landfill or has carbon black added to it to mask the colour and can then only be used in low-grade applications.

To overcome this limitation, new research is underway to generate high quality colourless PE by removing the coloured dyes and pigments before the plastic is recycled. Funded by the EU and involving industrial and academic partners from across Europe, the ClearPlast project aims to use supercritical carbon dioxide to selectively remove the colour from PE while leaving the plastic properties unchanged. 'The prospect of a technology enabling removal of pigments and selected additives from waste PE opens up a huge range of possibilities for recycled PE material and would have a large impact on the need for virgin polymer and thus raw material consumption,' says Camilla Lien, project manager of the ClearPlast project from Nor-Tek in Norway. The market potential for the process promises to be huge. 'If we only processed 10 per cent of the world's mixed colour PE waste each year, we could create products with a market value of around €300 million [£260 million] annually,' continues Lien. The project technology could also be applied to PP and is due to conclude in 2010.

Separation science

Polystyrene is a more difficult polymer to recycle economically due to its very low initial cost and low density. There is no technological reason why uncontaminated waste polystyrene cannot be melted down and re-extruded as new products. However, when transport, storage and reprocessing costs are factored into the price of new products from recycled material, it is almost always cheaper to use virgin material. Most countries around the world simply break up used polystyrene and dispose of it in landfill.

However, changes in public attitude to landfill and recycling are making a difference. 'The biggest problems are lack of weight and subsequent transport costs, and there's little support for the scheme from local authorities,' says Peter Fox from Kay-Metzeler, a company set up in 2006 to recycle expanded polystyrene (EPS). The company gets around the problem of transport costs impacting their profits by asking people to drop off their unwanted EPS. 'We're getting very good feedback from customers about our service and there has been a lot of interest from the general public and commercial sectors,' Fox continues. 'We have more than doubled the amount of EPS we recycle since we opened and more and more people are using us.' The company is now looking for more applications for their recycled material.



SOLVAY

Vinyloop is a pioneering approach to PVC recycling

PVC (polyvinyl chloride) is the final major contributor to household waste plastic volumes and is possibly the most difficult polymer to recycle due to the way it is made. As pure PVC is not very stiff and is quite reactive, a large number of stabilisers and additives are included during its manufacture. These compounds typically contain heavy metals including lead, tin and cadmium and there are significant environmental concerns about the disposal of PVC in landfill or by incineration; it is estimated that 45 000 tonnes of lead are released into the atmosphere globally each year this way. An added complication is that very rigid PVC, such as the type used in window frames, is difficult to grind and cannot be recycled by any current commercial means into new, high-grade products.

Commercial recycling of less rigid PVC is possible, thanks to the Vinyloop process developed by Solvay. In this process, waste material containing PVC in any proportion is washed and chopped before being dissolved in butanone, known more widely in the chemical industry as methyl ethyl ketone (MEK). Materials such as polyester fibres, textiles and rubber are then separated, washed with further MEK, and the solvent fractions combined. At this point, steam is injected to completely evaporate the MEK, leaving PVC microgranules suspended in water. These are recovered and dried before being reused as replacements for virgin PVC, while 99.9 per cent of the MEK is recovered and reused.

A small-scale industrial plant has been in operation in Ferrara, Italy, since 2002, which has allowed further development of the process. This plant is now producing 10 000 tonnes of recycled PVC per year and, having proved the validity and commercial viability of the process, numerous plants are now planned across Europe, Japan, China and the US.

Plastic recycling has clearly come a long way in a relatively short period of time as public opinions have changed and governments have acknowledged the need for recycling. As recycling technology improves, it is also becoming evident to industry that used plastic is not just a waste material but also a valuable resource that can reduce expenditure and increase profits. These profits should drive industrial acceptance of recycling technology and recycled materials, reducing demands for raw materials and on the environment, which can only be good for everyone.

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Stripping out the colour would make recycled plastic pellets far more valuable

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