

Plastics

An insoluble problem

DAVID
MOORE

Emmanuel Viale/Still Pictures

GCSE key words

Polymer
Polyethene

As part of your GCSE course you will be looking at plastics and their uses — but have you wondered what happens to them once they are discarded?

Imagine the *Time Team* excavating a site at some time in the future. What will they make of large holes in the ground which have been filled with tonnes of plastic before being covered with soil? Unlike discarded metal washing machines, waste paper and cardboard, plastic does not decompose once it has been thrown away. What can be done to change this, how can we recycle plastics, and can we make plastics that dissolve?

PLASTICS WHICH WASH AWAY

To start at the end, yes, plastics which will dissolve in water have been known for quite some years. They are used in hospitals to make laundry bags. Panels within the bag are made of dissolving plastic. Soiled sheets and clothes can be put in the bag and the whole bag placed in a washing machine without handling the dirty laundry again. Once the hot water is in the machine the plastic dissolves and simply washes away, leaving the clothes and sheets free to be washed. How does this happen?

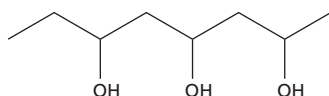


Figure 1 The structure of poly(ethenol).



Peter Frischmuth/Still Pictures

OH groups (%)	Solubility in water
Below 90	Soluble in cold water
90–96	Soluble in warm water
97–98	Soluble in hot water
99–100	Insoluble

Table 1 Relationship between percentage of OH groups on alternate carbons of the polymer chain, and solubility of the plastic

Top: Plastic bags cause a serious litter problem because they blow about and do not decompose.

Above: Plastic bottles for recycling.

The plastic is made from chains of polymer called poly(ethenol) which has OH groups on every other carbon of the polymer chain (Figure 1). These can form a special type of bond, called a **hydrogen bond**, with water, and so dissolve. Table 1 shows how the percentage of OH groups affects the dissolving properties of this type of plastic. Some shops now offer these ecologically-friendly plastic bags in an attempt to reduce the litter problem caused by waste plastics.

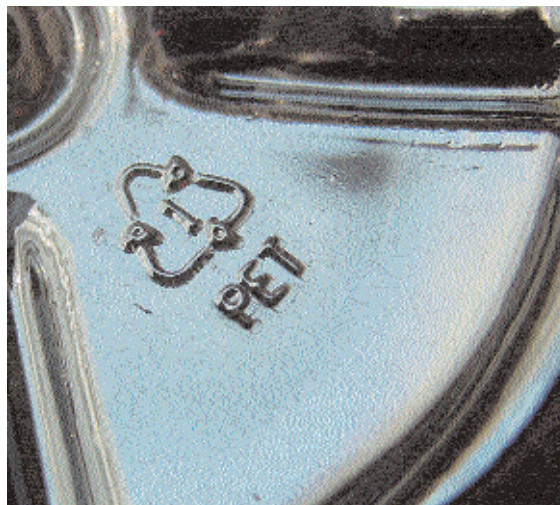
BOX 1

Polymers (or plastics) are long molecules made up of chains of carbon atoms. These polymers are made by joining many thousands of small molecules — called monomers — together:



Polymers which are soft and springy and will regain their original shape after being stretched are called **elastomers**. Polymers which remain deformed after being stretched are called **plastics** while those which can be made into strong thin threads are called **fibres**.

High-density polyethene is made up of long chains of carbon atoms. These chains are not branched, so they can lie close to each other. This allows strong interactions to occur between the chains and the polymer becomes strong and tough. Low-density polyethene is made up of branched chains which cannot lie close to each other. The forces between chains are therefore weaker and the polymer is more flexible and not tough.



The triangle on the bottom of a plastic bottle tells you what it is made of (see Table 2).

The first polyethene produced melted just above the boiling point of water. It wasn't until 1953 that a German chemist, Karl Ziegler, refined the manufacturing process to produce high-density polyethene (see Box 1), which was far more stable to heat and very durable.

Nowadays the starting materials for plastics manufacture come from the petrochemical industry. The ethene is obtained from distillation and cracking in oil refineries. Most plastics can be readily moulded, are chemically inert, have good strength properties and, weight for weight, are both more flexible and stronger than steel.

CAN WE RECYCLE PLASTICS?

To a limited extent, yes, we can. If you look at the bottom of a plastic drinks bottle you will find an embossed triangle with a number in it. The number, which varies between 1 and 7, tells you what plastic the item is made from (see Table 2).

A normal household can use more than 1000 carrier bags a year. Britain's annual plastic bag mountain weighs over 145 000 tonnes.

The Irish government has introduced a tax on plastic carrier bags (about 9p a bag). How much would your family spend a year on bags if we had such a tax here?

See how many of the different types of plastic in Table 2 you can find around the home. Sort them and work out whether there are any relationships between their code number and the use to which they are put.

WHERE DID PLASTICS FIRST COME FROM?

Polyethene — the main material from which plastic bags are made — was first invented in 1933 by Eric Fawcett and Reginald Gibbon who worked for ICI in Cheshire. Polyethene was discovered accidentally. Both men were trying to make a totally different compound, but kept obtaining a white waxy solid. At first they couldn't find anything to do with it and so it remained a curiosity. However it was found to be both chemically and electrically inert and so was used in the Second World War to shield the circuitry in radar apparatus from stray electrical fields. It was also used as a protective sheath to prevent water attacking undersea cables.

Table 2 Recycling numbers

Number	Plastic	Uses
1 PETE	Polyethylene terephthalate	Drinks bottles, water bottles, vinegar bottles, medicine containers, backing for photography film
2 HDPE	High-density polyethene	Containers for laundry/dishwashing detergent, fabric softeners, bleach, milk, shampoo, conditioner, motor oil. Newer bullet-proof vests, various toys
3 V	Polychloroethene (PVC)	Pipes, shower curtains, meat wraps, cooking oil bottles, shrink wrap, clear medical tubing, coffee containers
4 LDPE	Low-density polyethene	Wrapping films, grocery bags, sandwich bags
5 PP	Polypropene	Tupperware®, syrup bottles, yogurt tubs, outdoor carpet
6 PS	Polystyrene	Coffee cups, disposable cutlery and cups (clear and coloured), bakery shells, meat trays, 'cheap' hubcaps, packing peanuts, insulation
7 OTHER	Other	Products labelled 'other' are made of any combination of 1–6 or another, less commonly used, plastic



Above: How many of the different types of plastic in Table 2 can you spot here?

The main problem with recycling is that in a batch of household waste there may be plastics with many different numbers. A bottle top may be made from a different plastic to the bottle itself. An article of clothing may be made from mixtures of many types of polymer fibre, each with its own properties to enable the clothing to function properly. The difficulty comes with separating all the plastics into their different types before or after they are collected — some plastics may not even have a recycling number on them.

Councils that do separate plastics from other household waste often leave them mixed — once cleaned and re-melted they produce a low-quality plastic which may be used for packaging purposes. Plastic has to be heated carefully during recycling to stop it decomposing and releasing carbon particles that would contaminate and weaken it.

ARE THERE ALTERNATIVES TO PLASTICS?

Yes, there are many, but they may not have all the desired properties of a plastic. Extruded cellulose is

A woman in the market in Minsk, Belarus, selling Western carrier bags to shoppers.



Jane Buekett

now commonly used as a packaging material for fragile objects, but if it gets wet the cellulose softens and the structure collapses to a paste. A strong composite of laminated wood and reclaimed plastic has been made using a special chemical called a **graft copolymer** to join the two together. In the past objects made from fusing together wood and plastic have often failed to last. This is because plastics are essentially oily substances while wood consists of water-loving molecules, and the two don't easily coexist.

PLASTIC, PLASTIC, EVERYWHERE

Plastic carrier bags were first introduced into shops in 1968 and are now found all over the world — quite literally! In some of the poorest countries they are a status symbol and are re-used many times. But when it comes to litter they are a major problem because they tend to last for ever. They weigh so little that they blow about and are both a visual eyesore and a hazard to wildlife.

Perhaps we should be more like the Swedish, who have large resources of wood and tend to use far more paper bags than plastic ones. Surprisingly this is also true of Americans who tend to use the potentially more fragile paper sack instead of the plastic carrier bag. Even if the paper of the bag is not recycled, at least it will decompose once it is in the ground — unlike plastic.

It is up to all of us to try and cut down on the use of plastic, in particular plastic bags, or in the future we will be submerged in a sea of plastic. The alternatives are out there — it is up to us to use them.

David Moore teaches chemistry at St Edward's School in Oxford and is an editor of CATALYST.

An average carrier bag will hold more than 10 kg of food without breaking.

99% of all carrier bags are used twice: once to put shopping in and then to put rubbish in, before being thrown away.

● **Take a bag with you when you go shopping and try to avoid collecting any more carrier bags. See how difficult it is!**