How does waste affect our environment?

Introduction

We discard many things every day ranging from ordinary rubbish to old newspapers, packaging, cleaning materials and many different kinds of junk. Large quantities of pesticides and fertilisers are also leached into the environment from farms, for example. Large volumes of the gaseous, liquid or solid wastes produced by manufacturing and other industrial processes are also quite legally released. These emissions are only partially controlled by pollution control methods. Some of this industrial waste is discharged into the environment in substantial quantities.

So what is the impact of all this and to what extent is it harmful to our health and environment? Do the various substances break down into simpler forms over time or do they remain largely unchanged? The answers to these questions require a large amount of scientific data and information on health, risk and safety. In this resource we begin to consider a few aspects of these broader questions and how green chemistry provides ways for us to improve our record on protecting the environment.

This is an example of principle 6 of green chemistry.

Activity 1: Rubbish, junk and refuse - solid wastes

Municipal solid waste

The Department for Environment, Food and Rural Affairs (DEFRA) gathers data each year on the quantities of municipal solid waste (MSW) generated throughout England and Wales. This type of waste is what goes in your dustbin or the local tip, and it consists of everyday items such as product packaging, garden rubbish, furniture, clothing, bottles, food scraps, newspapers, electrical appliances, paint and batteries to name but a few. Municipal waste makes up 7% of the 420 million tonnes of waste generated each year.

Around 28 million tonnes of municipal waste was generated in 2000/2001. This was an increase of 689 000 tonnes on the same period 12 months earlier. Around 78% of the waste generated in 2000/2001 was deposited in **landfill** sites – essentially burying it. This was 2% down on the previous twelve months, but recycling, composting or incineration with power generation all only increased very slightly.

Table 1 gives a breakdown.

Method	**Municipal waste generated in England / thousand tonnes**				
	1996/97	1997/98	1998/99	1999/00	2000/01
Total municipal waste	24 588	25 711	26 342	27 461	28 150
Incineration with energy from waste	1446	1624	2146	2326	2479
Incineration without energy from waste	614	66	17	8	20
Refuse-derived fuel manufacture	147	156	133	106	67
Recycled or composted	1750	2063	2530	3083	3454
Composted only	0	0	0.462	0.67	unknown
Total waste recovered	3343	3844	4809	5515	6000
Other	0	36	10	4	75
Landfill	20 631	21 765	21 506	21 933	22 055

Total discarded	20 631	21 801	21 516	21 937	22 130

Table 1 Treatment of municipal waste (Figures taken from the Digest of Environmental Statistics published by DEFRA on their web site at http://www.defra.gov.uk/environment/statistics/waste/index.htm (accessed August 2005))

Q 1.	Prepare a bar chart of total quantity of solid waste generated for each of the years indicated.
Q 2.	(a) What percentage of solid waste was recycled in 1996/97 compared with 2000/2001? (b) What are some possible reasons for the change?
Q 3.	(a) What is composting? Look up information if you are not sure. (b) Why would composting of garden and kitchen waste be a better method of disposal than burying these wastes underground in a landfill?
Q 4.	About 500 kg (half a tonne) of household waste per person was collected in 2000/01. This is an increase of nearly 10 % per person since 1996/97 and of 100 kg per person compared to 1983/1984. (a) What are the implications of continuing such a trend? (b) Suggest some ways of reducing the quantity of waste individuals generate.

Activity 2: How can packaging materials be formulated in 'greener', more environmentally friendly ways?

Commercial packaging seems to be everywhere in the western world. Our food, drinks, clothing, medicine, furniture, computers, cleaning materials, publications *etc* all come packaged in some form. The main function of packaging is to protect the contents from damage. The final package often incorporates several types of packaging materials to ensure that the product can be transported easily. One problem with packaging material is that by its nature it is designed to be thrown away once the product is put into use. If it is not possible to redesign the product to eliminate the packaging or to recycle the packaging, then the best alternative is to ensure the packaging does no harm to the environment once it is discarded.

Most packaging is not harmful to the environment in terms of toxicity. However, because many common packaging materials do not degrade easily once they are discarded, they keep on adding to the large volume of solid waste that we produce. If packaging can decompose quickly it will be recycled naturally. For example, some companies are designing plastics that will break down through the action of microbes (bio-degradation) or light (photo-degradation) into harmless products.

It is estimated that the equivalent of 1.5 billion dustbins of packaging waste is produced in the UK each year, most of which ends up in landfill sites. Industry and commerce generate 150 million tonnes, and households about 3.2 million tonnes of packaging waste a year. Since much packaging ends up as litter on streets, it is a very visible form of waste.

In the USA it is estimated that approximately a quarter of landfill space is occupied by discarded packaging. In England and Wales, packaging accounts for about a third by weight of household waste.

In this activity you will investigate some of the different types of packaging materials used to protect products and note how some are able to decompose by enzyme action.

You will need to obtain samples of typical packaging materials used for cushioning such as shredded paper, bubble wrap, polystyrene packing (including pellets and moulded blocks), similar materials made of starch, and any other types of packaging you can find. Think about the similarities and differences you observe in these materials. Based on your observations of these, and any other knowledge you may have of packing materials, compile a brief list of ideal properties of packing materials.

Comparison of enzyme action on different packing materials

One of the characteristics of packaging that designers evaluate is **biodegradability**, a property that indicates the ease with which micro-organisms and other natural agents can break down these materials into the chemicals from which they are made. This process can vary greatly in the time required, from a considerable length of time for some substances to almost immediately for others. However, biological catalysts, called **enzymes**, can speed up the process considerably. Enzymes control nearly every metabolic process of living things. For new synthetic materials it is less likely that enzymes will be found in nature that can act upon them.

Synthetic plastics and polymers often remain unchanged in landfills for decades because there are no natural decomposers with the ability to break them down. In this investigation you will investigate how enzymatic degradation affects materials.

What you will need

- Eye protection
- Samples of typical packaging materials used for cushioning such as shredded paper, bubble wrap, polystyrene packing, including pellets and moulded block, and starch-based packaging granules
- Six 100 cm^3 beakers
- Dropping pipettes
- Access to a top pan balance
- A 24-well plate
- Glucose test strips
- A little amylase
- Distilled or deionised water
- Iodine solution (0.01 mol dm^{-3} in potassium iodide)

Safety

- Wear eye protection

What to do

1. Weigh two pieces each of samples of paper, polystyrene pellets and starch pellets. Trim each as necessary so that each sample is of approximately equal mass.
2. Take six 100 cm^3 beakers and place a piece of each sample into each.
3. Label the beakers so that one piece of each sample is Group A and the other Group B.
4. Break up the samples into small pieces.
5. Add 10 cm^3 of distilled or deionised water to each beaker and stir thoroughly. Make a note of any changes that occur in the samples.

6. To each sample in Group B add a small amount (about 0.05 g) of amylase powder and stir. Allow the sample to stand for 10-15 minutes.

Starch test

This test is based on the principle that iodine reacts with dissolved starch to produce a dark blue colour.

7. Use a 24-well plate to carry out the tests described below.
8. Using a pipette, transfer approximately 2 cm^3 of the liquid for each of the six samples to separate wells in well plate. (Be sure to rinse your pipette well after each transfer to avoid cross-contamination of samples.)
9. To each of the samples in the well plate, add 4-5 drops of iodine solution and mix by gently shaking the well plate.
10. Note any colour changes in each, let samples stand for 10 minutes and make final observations.

Test for glucose

11. With a clean 24-well plate, repeat step 8 above.
12. Using glucose test strips measure the glucose concentration of each sample and record it.

Discussion and questions

Q 1.	(a) What observations did you note for each sample after water was added?
	(b) Which samples contain starch?
Q 2.	Did the enzyme amylase make any difference to the degradation of the samples?
Q 3.	(a) Find out the chemical structures of glucose, starch, cellulose and polystyrene molecules.
	(b) What do the last three have in common?
	(c) What is the relationship between glucose and starch?
Q 4.	Use the chemical structures to help you suggest an explanation for your experimental results.
Q 5.	The principles of green chemistry encourage us to consider the environmental impact of a substance before it is designed and manufactured. Explain why the production and use of starch pellets rather than polystyrene pellets for packaging could be considered an example of green chemistry.

Activity 3: Using the web to investigate toxic wastes

The principles of green chemistry relevant to this material deal with returning safe substances to the environment. The solid wastes we considered in the first two activities are mostly non-toxic. The major problem they present is that they take up an increasingly large amount of space in landfills and represent an inefficient use of the Earth's resources. The toxic wastes released into the environment by various industrial operations present a much greater threat. In this activity we will attempt to find out how great this problem is.

The Pollution Inventory (PI) is published by the UK Environment Agency and is an annual record of pollution in England and Wales from regulated activities. It records the release of toxic chemicals into the air, discharged into rivers or the sewerage network, or disposed of as waste on land. The PI includes three years of data from major industrial sites and is being gradually extended to cover sewage treatment works and sites licensed to work with radioactive substances. Interestingly, during the year 2000, the chemical industry has shown some of the greatest reductions in emissions. In fact for most chemicals the trend over the past three years is for a reduction in pollution.

The Pollution Inventory currently contains details on large industrial sites, with the greatest potential to cause pollution, as designated in the Environmental Protection Act 1990. The smaller, less hazardous, but more numerous, processes are regulated by Local Authorities. Many other sources of pollution are not included, such as the significant contribution made from transport. For further details on national pollution levels to air visit the UK National Air Quality Information Archive (formerly the National Atmospheric Emission Inventory) www.airquality.co.uk (accessed September 2002), published by DEFRA and the Department of the Environment (DOE). Indications of the levels of pollution to air from sources not included in the PI are indicated in the Figure 1 which can also be found at http://www.environment-agency.gov.uk/commondata/103196/131122?referrer=/business/255244/255281/259778/259798/ (accessed September 2002).

Notes on Figure 1

- VOCs are volatile organic compounds.
- PM_{10} refers to particulate matter in the air with an aerodynamic diameter of less than 10 µm.
- Dioxins are a group of 210 similar chlorinated organic chemicals produced naturally from volcanoes and forest fires and from the by-products of smelting, bleaching of paper pulp and manufacture of some herbicides and pesticides. Dioxins myt cause adverse health effects.

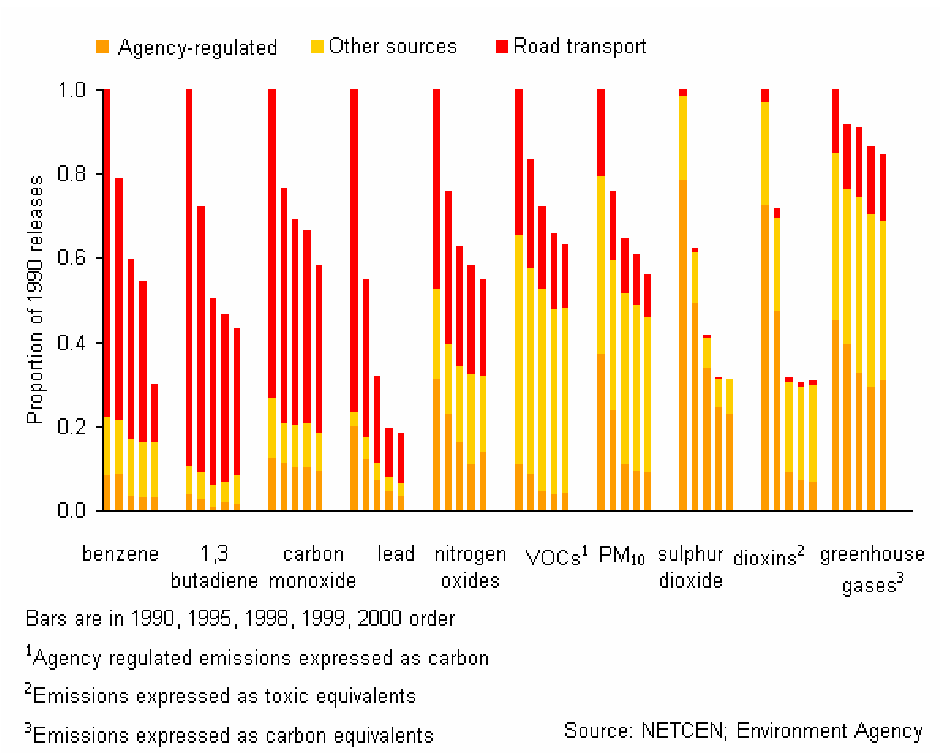

Figure 1 Emissions to Air from Agency-regulated industrial processes, other sources and road transport, 1990 to 2001 (Reproduced with permission of The Environment Agency)

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Discussion and questions: the pollution inventory

Q 1. Access the 'What's in your backyard?' website at www.environment-agency.gov.uk/maps/ (accessed August 2005). Look at where you live by putting in your home postcode in 'What's in your backyard?'. Click on one of the yellow squares and look at the chemicals they release. Then look up one of these chemicals in the two Excel© spreadsheets on the Environment Agency web site (go to http://www.environment-agency.gov.uk/pi and then navigate to 'Pollution Inventory data' (accessed September 2002)).

(a) What industry is mostly responsible for emissions of the chemical you chose?

(b) How high are average emissions in your area?

(c) Can you offer any suggestions about why the levels are as they are by looking at the other industries in your area and the gases they emit? Include any information you can find on the toxicity of the chemical. You may find this information in Material Safety Data Sheets. You will find a searchable database at: http://physchem.ox.ac.uk/MSDS/msds-searcher.html (accessed September 2002).

(d) How does the area you live in compare with other regions around the country?

(e) Can you explain why some regions have much higher pollution levels for some chemicals than others? Look at the industry in each area to help you answer this question. Again use the two spreadsheets on the Environment Agency website to help you answer these questions. http://www.environment-agency.gov.uk/pi (accessed September 2002). Navigate to 'Pollution Inventory Data' and open the two Excel spreadsheets. These can be saved to your computer for ease of use.

Discussion and questions: pollution Inventory data by region

Table 2 shows the total amounts of toxic pollutants released in each UK region for 2000.

Region	**Pollutants released / kg**		
	Air	**Water**	**Sewer**
Anglian	32 134 751 036	145 993	1664
Midlands	45 117 017 111	6229	8093
North East	60 629 210 593	108 780	27 194
North West	18 776 771 647	43 006	134 771
South West	3 382 892 214	11 046	2100
Southern	14 824 449 163	5980	4377
Thames	17 175 988 664	1936	7528
Wales	30 288 856 366	23 848	18 034

Table 2 The total amounts of toxic pollutants released in UK regions in 2000

Q 1. The total pollutants released to air, water and sewer in 2000 was over 222 330 million kg. In fact the emissions to air make up 99.9998% of the total emissions.

(a) Using this total figure, which is the highest-polluting region in total?

(b) Is it also the highest polluter by air, water and sewer?

Q 2.	Discuss how the following principles of green chemistry, if widely applied in industry, would reduce the amount of toxic chemicals released into the environment. (a) Methods of making chemicals should be designed to make products that cause no harm to human health or to the environment and that do not cause accidents such as explosions and fires. (b) Methods of making chemicals should be monitored to prevent the formation of hazardous substances. (c) Processes should be designed to incorporate the maximum amount of the raw material into the final product, thus reducing waste products. (d) Chemical products should be designed so that they break down at the end of their useful life to form harmless products.