SCIENCE & TECHNOLOGY IN SOCIETY

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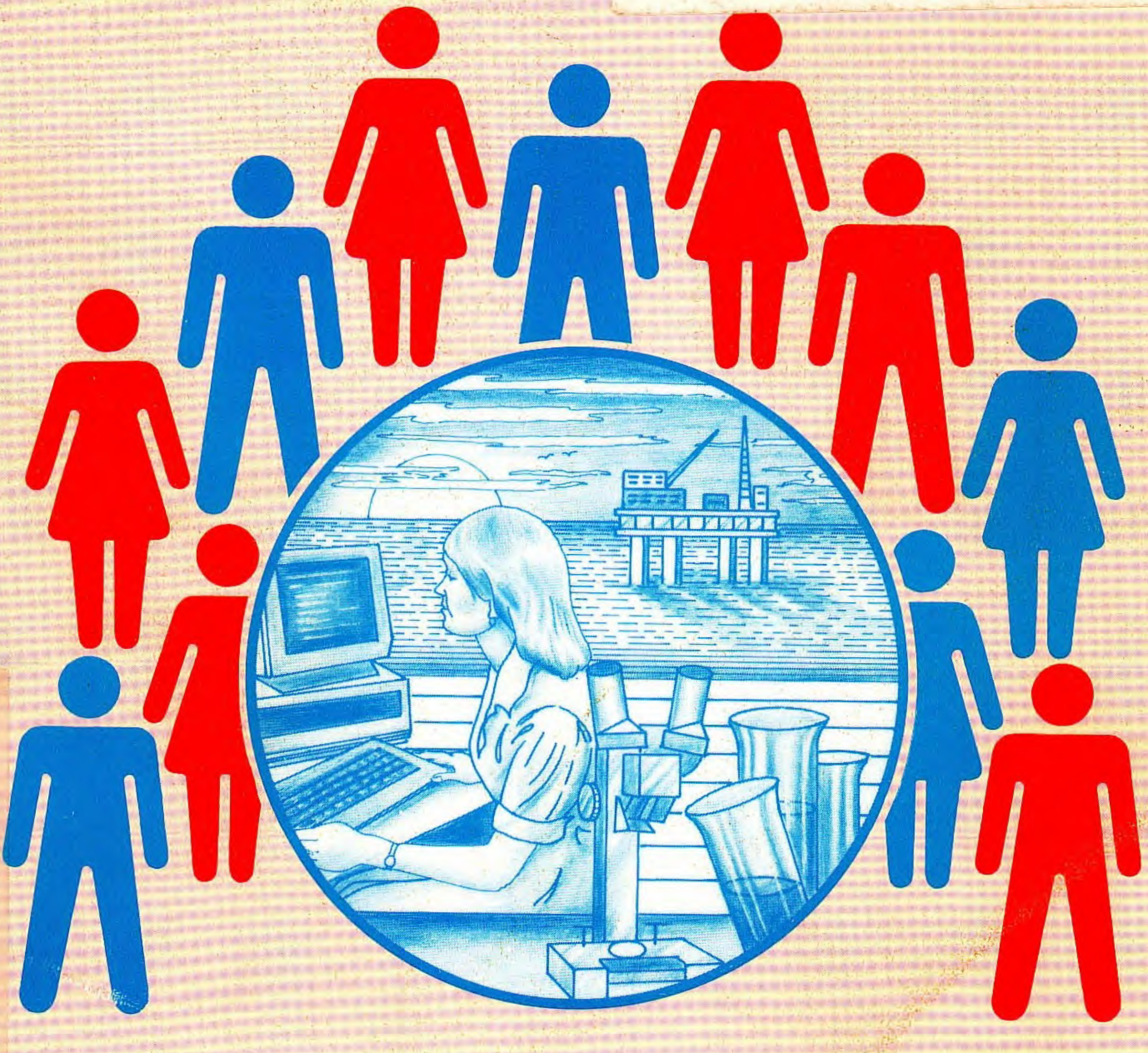

ASE

SATIS

ABOUT SATIS

Science and Technology in Society units are designed to be used in conjunction with conventional science courses, particularly those leading to GCSE examinations. Each unit has links to major science topics as well as exploring important social and technological applications and issues.

The units are self-contained and generally require about 2 periods (around 75 minutes) of classroom time. Each unit comprises Teachers' Notes (blue sheets) and Students' materials (white sheets). Full guidance on use is given in the Teachers' Notes accompanying each unit, which also include background information and suggest further resources.

Each SATIS book contains ten units. The units are numbered in a system giving the number of the book followed by the number of the unit within that book. Thus the first unit in the first SATIS book is numbered 101.

In addition to the SATIS books, a General Guide for Teachers is available, giving guidance on some of the teaching techniques involved as well as ideas for further activities.

Many people from schools, universities, industry and the professions have contributed to the writing, development and trials of the SATIS project. A full list of contributors appears in the General Guide for Teachers.

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SATIS 1

List of units in this book

Sulphurcrete

Contents: Reading, questions and experimental work on the use of sulphur as a building material.

Time: 2 periods.

Intended use: GCSE Chemistry and Integrated Science courses. Links with work on the properties, structure and allotropy of sulphur.

Aims:

- To revise and complement prior work on the properties, structure and allotropy of sulphur.
- To develop awareness of the importance of the recovery of sulphur from fuels as a measure for the control of acid rain.
- To show the dependence of choice of materials on the properties of those materials, to illustrate the search for new and better materials, and the ability of chemists to modify the properties of materials.
- To develop awareness of the need for careful use of resources.
- To provide an opportunity to practise reading and comprehension skills, and certain laboratory skills.

Requirements: Students' worksheets No. 101. For laboratory requirements, see below.

This unit follows on well from work on the allotropy of sulphur. If time is short, the practical work could be omitted, though students gain a good deal of satisfaction from making and testing their own sulphur concrete.

Requirements for experimental work

Each group of pupils will require:

3 hard-glass test tubes
a small metal container – an old crown bottle-cap is ideal, but the plastic inner liner must first be removed by heating
spatula
tongs
test tube holder
tripod, gauze, bunsen
access to pliers
access to fume cupboard
safety spectacles
clean sand
powdered roll sulphur
dilute hydrochloric acid
a small piece of ordinary concrete (for example, a chip off a concrete paving slab)

The sulphur must be heated *very* gently, otherwise it will ignite. The molten sulphur must *not* be allowed to reach the red, viscous stage – this will happen if it is heated too strongly.

Notes on some of the questions

Q.2 Acid rain has harmful effects on forests and fish in particular, and many forms of life in general. It damages buildings, particularly when these are made of limestone. However, the acid rain problem is extremely complex, and not all these effects are directly attributable to sulphur dioxide emission.

Q.7 The students' sulphur concrete is likely to be hard, but more brittle than ordinary concrete.

Qs.8,9 Sulphur concrete, unlike ordinary concrete, does not react with acid. This has led to its use in chemical works, particularly where acid is involved.

Q.10 After a few days, sulphur concrete tends to become yellow and powdery on its surface.

Q.11 The brittleness of sulphur concrete is due to the crystallization of monoclinic sulphur, which later changes to the rhombic form. This crystallization can be prevented by certain additives, for example, dicyclopentadiene. Such additives disrupt the regular shape of the S_8 rings, making crystallization more difficult.

Q.12 The reversion of plastic sulphur to the hard solid form is due to the crystallization of the S_8 molecules which remain in considerable numbers even in the plastic form. Later, the long-chain polymers which give the sulphur its plasticity slowly revert to S_8 rings. Certain additives can prevent the crystallization of the S_8 form and also ensure that the polymeric form persists, giving a permanent plastic sulphur.

Q.14 Teachers might wish to explore the question of whether it is wise to use such an indispensable raw material as sulphur as a building material.

Q.15 There are of course many examples, such as the use of plastic instead of metal for buckets, drain pipes, etc.

Extension work

If time permits, teachers might like to attempt some more open-ended investigations of sulphur concrete. For example:

1 Try making sulphur concrete with different proportions of sand and sulphur. Devise a method for testing the concrete and so find out the mixture which gives the strongest product.

2 Try comparing the strength of sulphur concrete and ordinary concrete:

Make a beam-shaped mould about 2cm × 2cm × 10cm and line it with aluminium foil. Use an old tin to make sulphur concrete on a larger scale and cast it in the mould.

Re-line the mould. This time make normal concrete from cement (1 part) and sand (5 parts) mixed in an old yoghurt pot with enough water to give a creamy paste. Pour this into the mould and leave to set overnight.

Devise a method for comparing the strength of the sulphur concrete and concrete beams.

Acknowledgement Figures 1 and 4 supplied by The Sulphur Institute, Washington DC.

SULPHURCRETE

Part 1 Introduction: Sulphur and sulphur concrete

Read this, then answer questions 1 to 4.

You have probably seen sulphur and investigated its properties. You may have looked at the way sulphur's properties change when it is heated. But can we *use* sulphur in any way?

You may well know that a lot of sulphur is used to make sulphuric acid. But you might be surprised to discover that sulphur can also be used as a *building material*. In this unit of work you will find out why.

The story starts not with sulphur, but with coal and oil. These fossil fuels contain a lot of sulphur compounds – crude oil from the Middle East contains particularly large amounts of sulphur. When the fuels are burned, the sulphur turns to sulphur dioxide. Sulphur dioxide is an acid gas, and if it is allowed to get into the air, it causes pollution. Sulphur dioxide made by burning fossil fuels is one of the main causes of acid rain.

For many years, oil companies have had to 'recover' sulphur from crude oil before the oil can be used. As society becomes more concerned about acid rain, more and more sulphur is likely to be recovered from fuels, and from the chimneys of power stations where the fuels are burned. This means that more and more sulphur is becoming available, and sulphur has become quite cheap. For example, between 1968 and 1972, the price of sulphur fell from $70 a tonne to $6 a tonne. In Canada alone, stockpiles of sulphur increased from 3 million tonnes in 1970 to 25 millions in 1980.

All this is more than enough sulphur for making the sulphuric acid we need, and for other traditional uses of sulphur. Scientists and industrialists began to wonder if sulphur could be used for other things. So they began to explore sulphur's possibilities as a building material. They have found that sulphur can be used to make a kind of concrete. One of the trade names for this sulphur concrete is **Sulphurcrete**. Sulphur can also be used to make flexible surface coatings to protect fabrics.

Questions

1 *Why do oil companies have to recover sulphur from crude oil?*

2 *What kind of problems are caused by acid rain? (You may need to talk to your teacher about this, or consult a book.)*

3 *Why is more and more sulphur becoming available for us to use?*

4 *If you have done some experiments with sulphur, you will know it can exist in different forms. Which form would be most useful for:*

(a) Making sulphur concrete,
(b) Making surface coatings for fabrics?

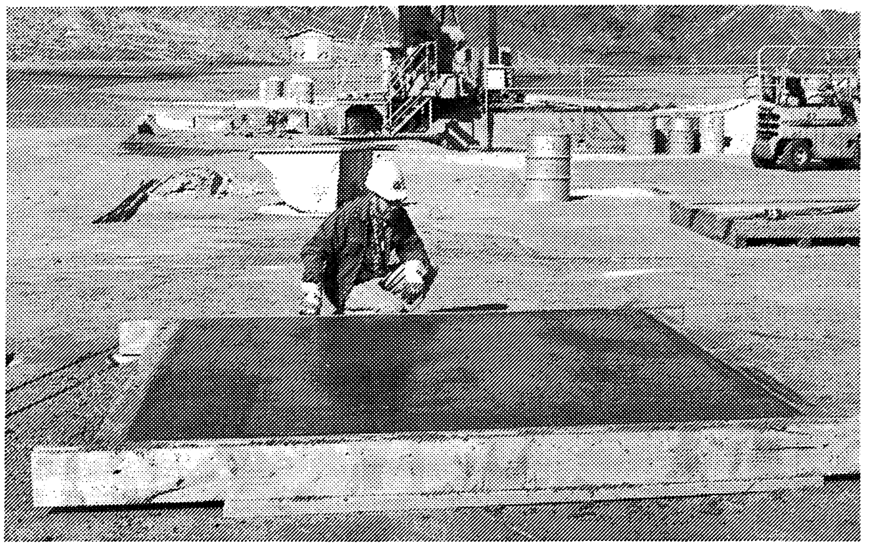

Figure 1 A slab of sulphur concrete

Part 2 Experiment

Making sulphur concrete

In this experiment you will be making a sample of sulphur concrete. In ordinary concrete, particles of sand, gravel and stone, called aggregate, are held together by cement, as shown in Figure 2.

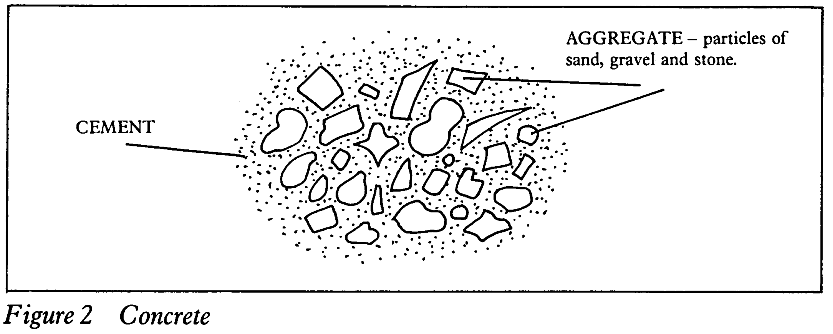

Figure 2 Concrete

In sulphur concrete, the aggregate is held together by sulphur instead of cement. The sulphur must first be melted before it is mixed with the aggregate. The aggregate needs to be warm, so the sulphur does not set too quickly.

What you do

Read the following detailed instructions before you start.

CAUTION – Sulphur sometimes catches fire when it is heated, burning with a blue flame. An unpleasant, choking gas, sulphur dioxide, is given off by burning sulphur. Work in a fume cupboard, and if your sulphur does catch fire, put it out at once by smothering. Wear safety spectacles throughout the practical.

A Half fill a hard-glass test tube with clean sand.

B Fill a small metal container with powdered sulphur. An old crown bottle-cap is ideal, but you must make sure the plastic seal has been removed. Put the container of sulphur onto a gauze resting on a tripod.

C Now heat the sulphur VERY, VERY GENTLY using a small bunsen flame, until the sulphur *just* melts. It should become a runny yellow liquid. Stop heating as soon as this happens.

D Take away the bunsen from under the sulphur and use it gently to warm the sand in the test tube. You will need to work quickly, otherwise the sulphur will have solidified before you finish.

E Carefully pour the warm sand into the molten sulphur. The liquid sulphur will soak into the sand. Go on pouring until all the liquid sulphur is soaked up. You have now made liquid sulphur concrete. Figure 3 summarizes the procedure.

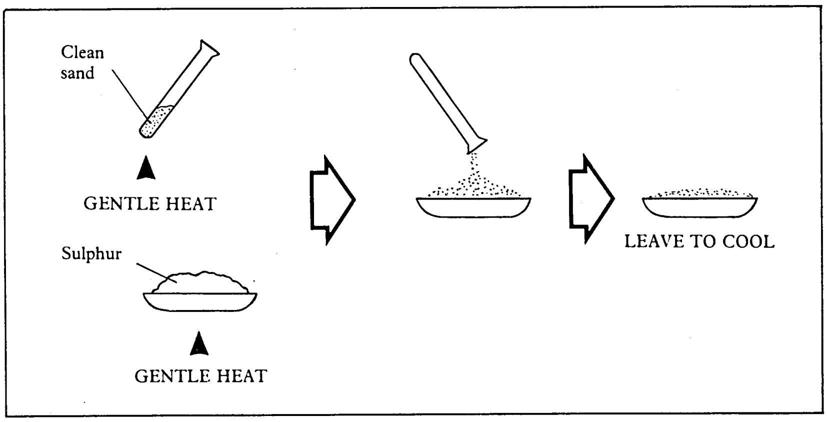

Figure 3 Making sulphur concrete

F Leave the sulphur concrete to solidify and cool.

G When the sulphur concrete is cool, remove it from the container. To do this, you will probably have to bend the container using pliers. The sulphur concrete will break, but this does not matter.

H Examine your sulphur concrete. Compare it with a piece of ordinary concrete.

I Put a piece of sulphur concrete and a piece of ordinary concrete into two separate test tubes. Add a little dilute acid to each. Observe what happens.

J Examine your piece of sulphur concrete after a few days. Has it changed?

Answer questions 5 to 10.

Questions about the experiment

5 *Why was it important to heat the sulphur very gently?*

6 *Why did the sand have to be warmed before adding it to the sulphur?*

7 *How does sulphur concrete compare with ordinary concrete for hardness?*

8 *How does sulphur concrete compare with ordinary concrete for resistance to acid?*

9 *Why is sulphur concrete sometimes used instead of ordinary concrete in chemical factories, particularly where acid is used?*

10 *What changes happened to your sulphur concrete when it was left for a few days?*

Part 3 Sulphur as a building material

Read this, then answer questions 11 to 15.

You have just made sulphur concrete. You will have found that, unlike ordinary concrete, sulphur concrete does not react with acid. For this reason it is used for floors and walls in chemical factories where acid is likely to get spilt. It is also used to make parking kerbs, lamp-post bases, etc.

However, you may have noticed that although your sulphur concrete was hard, it was also brittle. This is because the sulphur crystallizes into a brittle form, similar to the sulphur before you melted it. Chemists have found that certain substances can be added to sulphur to stop it crystallizing. This helps to make the sulphur concrete less brittle.

Sulphur can also be used to make a flexible coating for fabrics. For this purpose, the normal, solid form of sulphur would be far too brittle. But if you have investigated the different forms of sulphur you will probably remember what happens to sulphur when it is heated strongly, then cooled by pouring into cold water. It forms a flexible, rubbery solid called plastic sulphur. Unfortunately, plastic sulphur quickly turns back to its hard, brittle form. But chemists have once again found substances that can be added to the sulphur to keep it in its plastic form. In this form it makes a flexible, acid-resistant coating.

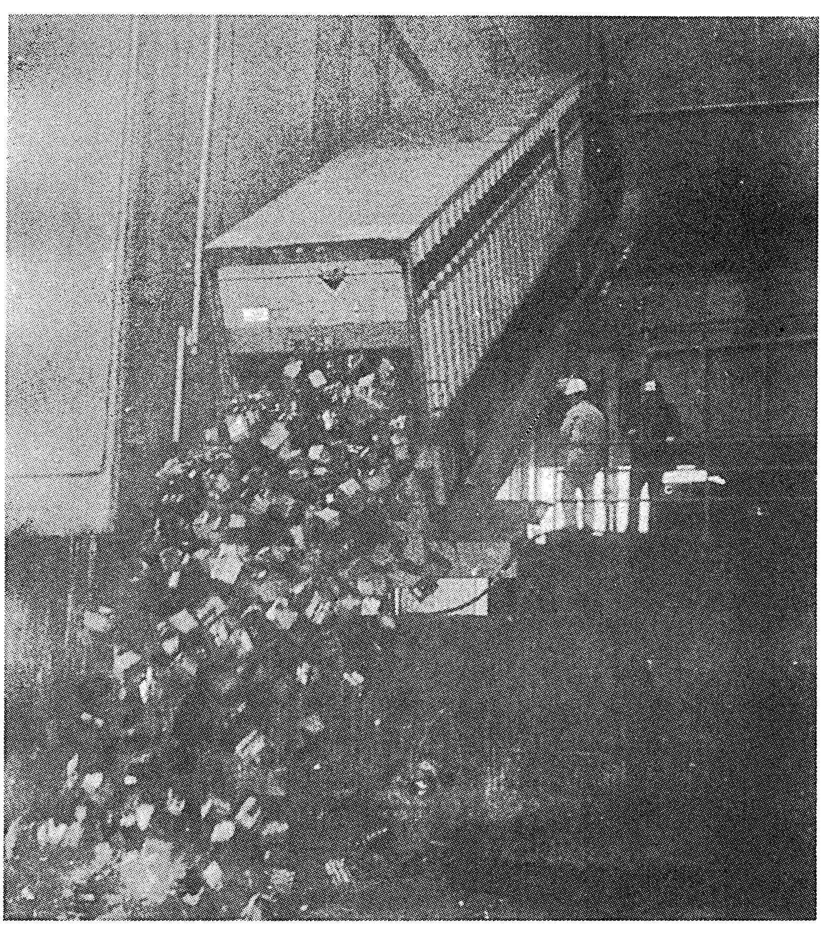

Figure 4 Tipping used car batteries onto a sulphur concrete floor

Questions

11 *The sulphur concrete you made was brittle. How have chemists managed to overcome this problem?*

12 *Why is ordinary plastic sulphur on its own not suitable for coating fabrics? What can be done to overcome this problem?*

13 *Figure 4 shows used car batteries being tipped onto a concrete floor in order to break open the casing. Why is sulphur concrete particularly useful for making this floor?*

14 *Sulphur concrete is a useful building material. But sulphur is also an important raw material. It is particularly important for making sulphuric acid. What problems might there be if we use more and more sulphur concrete?*

15 *Scientists and industrialists are always interested in new materials that may be cheaper and better than traditional ones. What other examples can you think of?*

Food from Fungus

Contents: Information, questions and decision-making exercise concerning the production and marketing of a novel food.

Time: 2 periods plus homework or a further single period.

Intended use: GCSE Biology, Chemistry and Integrated Science. Links with work on food, food production, fungi, nutrition and health.

Aims:

- To complement and revise prior work on food, food production, nutrition and health.
- To develop appreciation of an application of biotechnology and of the potential of novel food sources.
- To develop awareness of the techniques needed to market a novel product.
- To develop skills in reading, comprehension, communication and problem-solving.

Requirements: Students' worksheets No. 102.

Background information

The idea of using microorganisms to produce single-cell protein (SCP) has been around since the 1960s. Companies invested millions of pounds in such ventures but many of them failed because of difficulties in getting their products accepted. The production of myco-protein is one of the few ventures that looks like being successful.

The organism used in the process described here is a micro-fungus called *Fusarium graminearum*. It is grown on a glucose syrup which can be prepared from a wide range of starchy crops, particularly cereals and potatoes.

If wheat is the source of glucose syrup, the wheat flour is first separated into starch and gluten. The latter represents the protein part of wheat and is used in animal feed. The starch is then hydrolyzed to give glucose syrup.

The final section of Part 1 includes some reference to conversion efficiency. It will be noted that myco-protein represents a far more efficient conversion of carbohydrate to protein than the same conversion performed by domestic farm animals. However, it is worth noting that even myco-protein is wasteful compared to direct consumption of plant foods. For example, wholemeal flour contains 11% protein and 70% carbohydrate. This means that there are 157g of protein for every 1000g of carbohydrate in wholemeal flour. This is even more than the 136g of protein that would be obtained by using the same 1000g of wheat carbohydrate as a substrate to grow myco-protein.

Notes on questions 6 and 7 in Part 2

The advantages of myco-protein might include its versatility, its more efficient conversion of carbohydrate to protein and its nutritious qualities, particularly compared with meat. Disadvantages might include the fact that additives have to be used to make it palatable, its relatively high price and the problem of getting it accepted.

Notes on Part 3

In this decision-making simulation, students are asked to develop a marketing strategy for myco-protein. They should be encouraged to work in groups and discuss the questions fully before coming to a decision. It might be interesting for the different groups to compare their marketing strategies at the end of the exercise.

Myco-protein was in fact first test-marketed as a filling for a savoury pie.

Acknowledgement Figures 1a, 1b supplied by Countrywide.

FOOD FROM FUNGUS

In this unit you will learn about a new food called **myco-protein**. It is a high-protein food made from a microscopic fungus. The unit is in three parts.

Part 1 Information about myco-protein
Part 2 Questions
Part 3 Decisions – how would you market myco-protein?

Part 1 About myco-protein

Eating fungus isn't new

The fungi are a large group of organisms which includes mushrooms, moulds and yeast. Many fungi are micro-organisms. This means they are very small and can only be seen under a microscope. Fungi are quite often used as food. About 40,000 tonnes of mushrooms are eaten each year in Britain. Yeast is eaten in bread and is used to make yeast extracts such as Marmite. Some cheeses have blue or green veins which contain moulds. In Japan and Indonesia a delicious food called *tempeh* is made by growing fungus on soya beans.

All these fungus foods are traditional and have been eaten for thousands of years. Myco-protein, though, is a new, not a traditional food. One of the problems with myco-protein is persuading people to eat it for the first time.

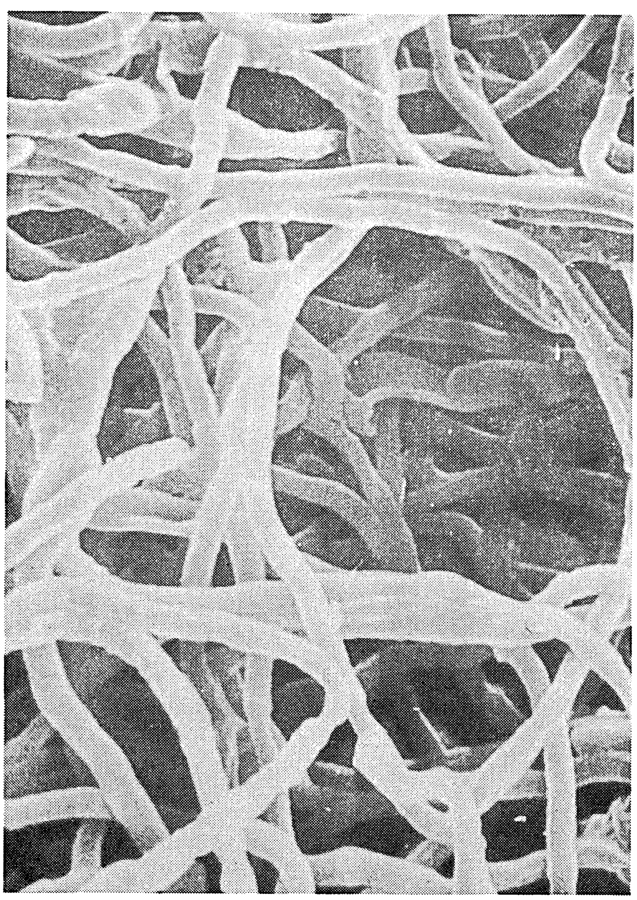

Fig 1a Magnification of myco-protein

Fig 1b Selection of products made with myco-protein

How was myco-protein discovered?

The story begins in the 1960s when a food company decided to look for a way to turn cheap carbohydrate into high-protein food. They decided to use a fungus to produce the food. Fungi need their own food supply in order to grow, and the company started looking for one that would grow in a solution of sugar. The fungus had to

- be safe to eat
- be nutritious
- grow quickly
- have the right taste and texture for using as a food.

Three thousand different fungi from all over the world were collected and tested. In the end, the best fungus was found in the back garden of a house in Buckinghamshire – just four miles from the company's research laboratories. It was a microscopic fungus that grows rapidly in a solution of sugar.

The process of growing and testing the fungus then started. It was tested on animals and human volunteers to make sure it had no harmful effects. It took ten years of careful testing before the myco-protein food was proved safe to put on the market.

How is myco-protein made?

The microscopic fungus is grown in a syrupy solution of sugar inside a big vessel called a fermenter. The sugar needed for the process is obtained by breaking down starch from cereals such as wheat or maize. Ammonia is added to supply the nitrogen the fungus needs to make protein. Air is also needed so that the fungus can respire. The temperature is kept at 32°C. Everything in the fermenter, except the fungus, is sterilized.

The fungus grows quickly, doubling its weight every five hours or so. It is continuously removed from the fermenter, then heated to break down some materials which may be harmful. Finally, the fungus is filtered off from the solution and used to make myco-protein food. Figure 2 illustrates the process.

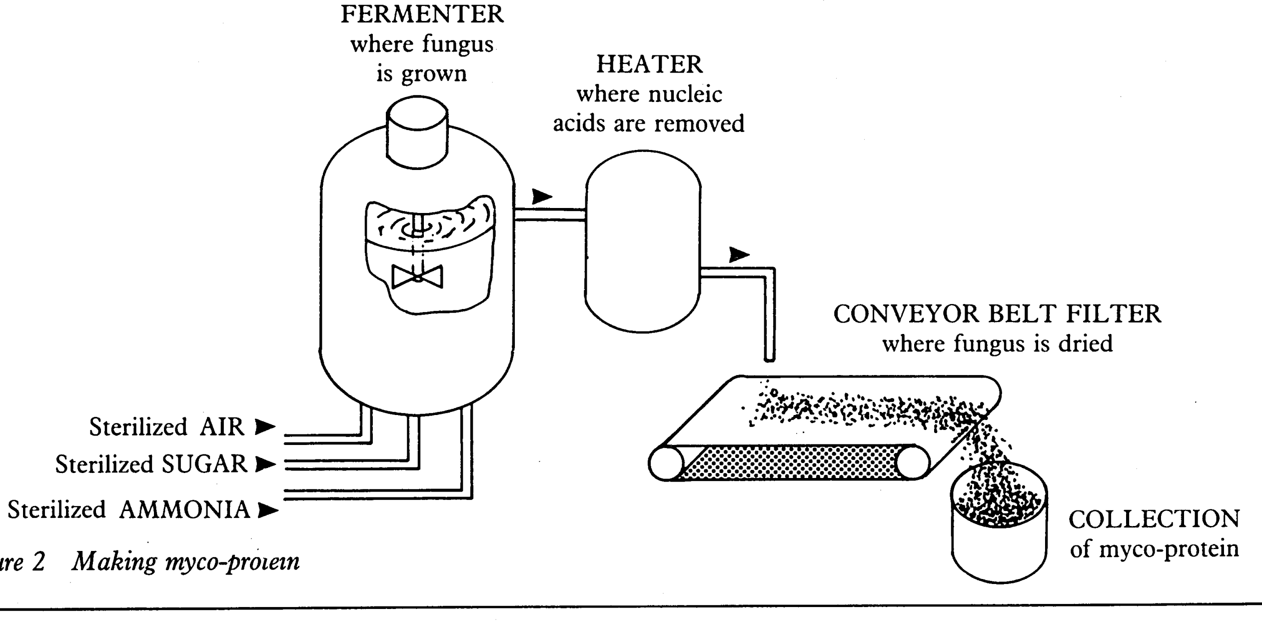

Figure 2 Making myco-protein

What is myco-protein like?

Myco-protein is a pale yellow solid with a faint taste of mushrooms. It is not very suitable for eating on its own because it has hardly any flavour. But it can be flavoured and coloured to make it taste like almost anything.

The texture of myco-protein can also be altered to make it resemble different foods. Myco-protein contains fibres, and the longer the fibres are allowed to grow, the coarser the texture. By lining up the fibres together, myco-protein can be given the 'chewy' texture of meat. Slightly different treatments give it the texture of chicken or fish. Pies, burgers, 'meat' slices and 'fish' fingers can all be made from myco-protein.

Myco-protein can also be ground into a kind of flour. This flour can be used to make all sorts of different foods including savoury snacks and even sweets.

Myco-protein is therefore very versatile and can be made into many different foods. In Part 3 of this unit, you will be trying to decide the best form in which to sell it.

Myco-protein normally costs about the same, weight for weight, as average quality meat.

Is myco-protein good for you?

Myco-protein is a high-protein food, so it makes sense to compare it with other high-protein foods like beef or chicken. Animals such as cows, chickens and pigs are fed mainly on carbohydrate, just as the fungus which produces myco-protein is. But as Figure 3 shows, myco-protein is more efficient than animals at turning carbohydrate into protein.

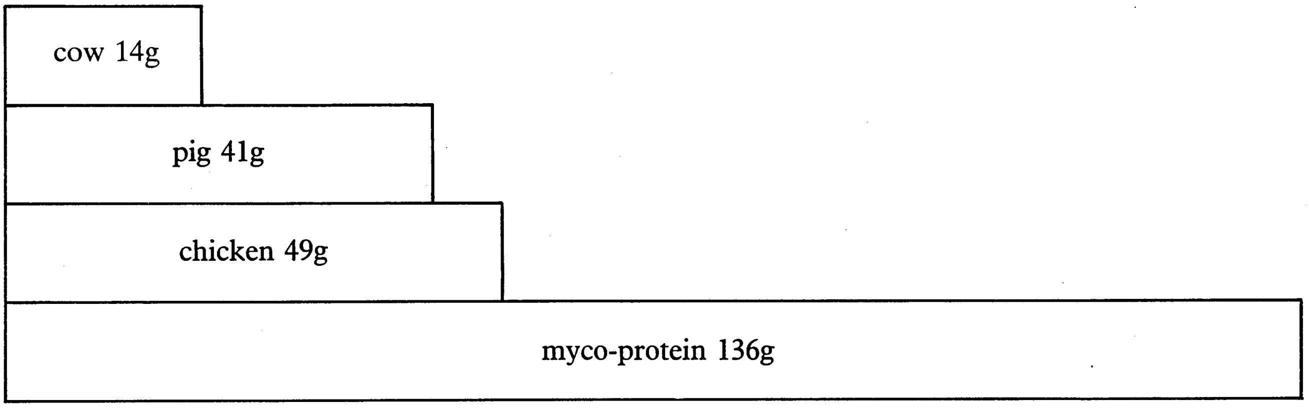

Figure 3 Mass of protein produced from 1000g of carbohydrate by different organisms

Myco-protein is probably also a healthier food than animal protein. Figure 4 compares the nutrients in myco-protein and in beef.

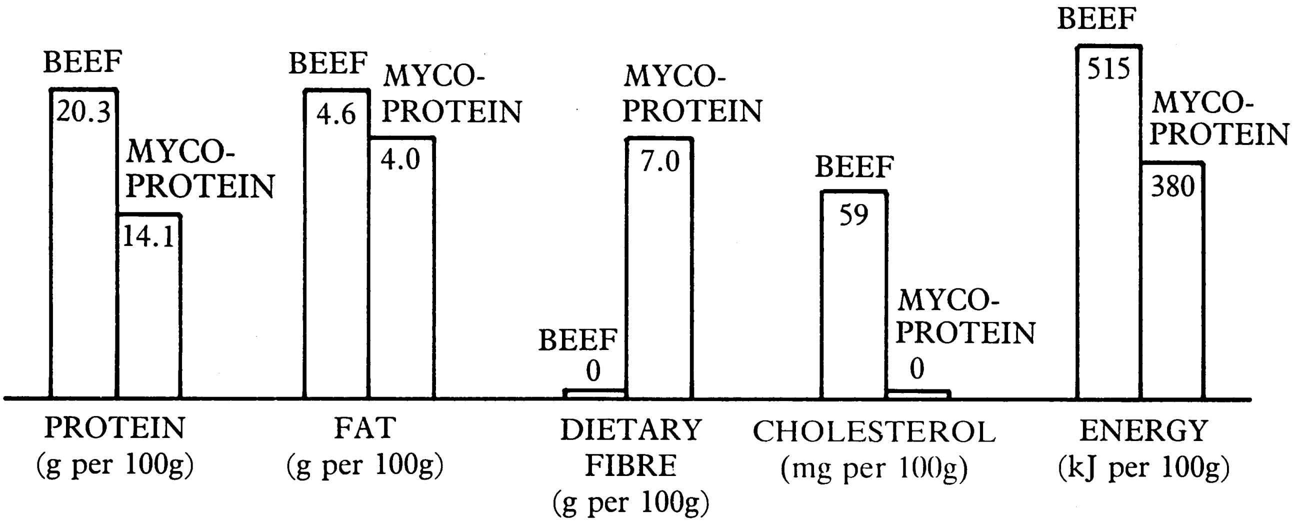

Figure 4 Comparing the nutrients in myco-protein and beef

Fat and cholesterol Doctors believe that both fat and cholesterol are unhealthy if eaten in large amounts. In particular, they are thought to increase the risk of heart disease. Compare the amounts of fat and cholesterol in beef and in myco-protein.

Dietary fibre (roughage) Fibre cannot be digested, but passes straight through the digestive system. This helps keep the contents of the gut moving. Doctors believe fibre in the diet is healthy because it helps prevent diseases of the bowel and stops people overeating.

So you can see that myco-protein is healthier than animal protein, and it is also less wasteful in turning carbohydrate to protein. However, it is also worth comparing myco-protein with other non-animal foods like beans and cereals. These are also healthier than meat, and contain quite a lot of protein. What is more, producing them involves hardly any waste, and they are much cheaper than either beef or myco-protein.

Part 2 Some questions about myco-protein

You may need to look back over Part 1 when you answer these questions.

1 *Why was it necessary to test many different fungi before choosing the one to use for making myco-protein?*

2 *Why did the myco-protein have to be tested for years before it could be sold?*

3 *Proteins contain the elements carbon, hydrogen, oxygen and nitrogen. Where does the fungus get each of these elements from?*

4 *Suppose 10kg of fungus are put in a fermenter and left for 15 hours. What mass of fungus would there be by the end of this time?*

5 *Why does everything in the fermenter, apart from the fungus itself, have to be sterilized?*

6 *List some of the advantages of myco-protein compared with other foods.*

7 *Suggest some disadvantages of myco-protein compared with other foods.*

8 *Would you be prepared to eat myco-protein yourself?*

9 *The public is often reluctant to try out new foods like soya bean or myco-protein. Why do you think this is? What can be done about it? (More about this in Part 3.)*

Part 3 Decisions – Marketing Myco-protein

It is best to work in groups for this part.

Suppose you are working for the company that produces myco-protein. You are certain you have a good product, but your problem will be convincing the public that it is worth buying. Your group task is to put together a marketing strategy for the product. Read through the following points before you start.

- Myco-protein is a versatile food that can be made into many different forms. What form or forms will you sell? (Look back at 'What is myco-protein like?' if you need ideas.) You could market it in several different forms at once, or you might decide to launch one form first, and follow it up later with others.
- You will need to 'test-market' the product first. This means trying it out in a small number of shops. Which shops, and which parts of the country, will you choose?
- What will you tell the customers about the product? Which features of myco-protein will you emphasize? Remember, the customers will know very little, if anything, about what myco-protein is. They may be suspicious of it.
- What kind of advertising campaign will you plan when you get to the stage of full-scale marketing? Remember you have radio, TV, newspapers, magazines, posters, etc., to choose from. If you decide on radio and TV, at what times will you advertise?
- Design an advertising poster for your product, suitable for displaying in a shopping precinct.

Controlling Rust

Contents: Information, questions and decision-making exercises concerning rusting and its prevention, in particular its economic aspects.

Time: 2 periods.

Intended use: GCSE Chemistry and Integrated Science. Links with work on rusting, iron and the reactivity series of metals.

Aims:

- To complement and revise prior work on rusting, iron and the reactivity series.
- To develop awareness of the economic impact of corrosion, and factors involved in selecting an appropriate method of corrosion control.
- To develop awareness of some of the factors involved in commercial decision-making.
- To provide an opportunity to practise reading, comprehension and data-handling skills.

Requirements: Students' worksheets No. 103.

This unit is in four parts:

Part 1 Information on rusting and prevention methods
Part 2 Decisions – which method to use?
Part 3 More decisions – protecting the school bridge
Part 4 More points to discuss.

It is assumed that this unit will be used in conjunction with more conventional class work on rusting, probably including some experimental work. If so, Part 1, which is only a summary, could be omitted, or perhaps covered for homework. Nevertheless, students should cover the short introductory section on the cost of rust, to put the problem in perspective.

Part 4 could also be omitted if time is short, though it raises some interesting discussion points.

For simplicity, no mention is made in the unit of the use of *alloying* to prevent rust. The teacher may want to mention this, and to refer to stainless steel.

Less able students may need some guidance when tackling the decision-making exercise in Part 3. It might help them to draw up a table like the one below, in which to enter the various costs year by year.

Year	*Option 1*	*Option 2*	*Option 3*	*Option 4*
0				
1				
2				
.				
.				
Total				

Other resources

The National Corrosion Service of the National Physical Laboratory have produced a booklet called *Corrosion and Protection of Metals – Information for Use by Teachers*, and a set of slides. Available from:

National Corrosion Service
National Physical Laboratory
Teddington
Middlesex TW11 0LW

Acknowledgement Photo on page 1 Chris Ridgers Photography

CONTROLLING RUST

This unit is about the rusting (or corrosion, as it is sometimes called) of iron and steel. Why does rusting occur? How much does it cost – and how can it be prevented?

The cost of rust

It is thought that rusting costs Britain about £5000 million each year. This is more than the total amount spent by the Government on secondary education!

Look at these examples

- 40% of the steel made in the USA is used to replace steel lost by rusting.
- The steelwork on the Spaghetti Junction motorway interchange has to be painted continually to prevent rust. This costs about £2 million over an 18-month period.

Question

1 How many tonnes of steel are lost by rusting per year in Britain?

It is thought that one tonne of steel is lost by rusting every 90 seconds in Britain.

Cars are particularly badly affected by rust.

Part 1 Information

You may already have done quite a lot of work on the causes of rust, and how it can be prevented. If so, you could miss this part and go straight on to Part 2.

What causes rust?

You may have done experiments to investigate what causes rust. These experiments will have shown you that two things are needed:

WATER and AIR

Without both of these, rusting does not occur. If the water contains dissolved impurities, such as salt, rusting is faster.

Rusting is a very complicated reaction, but the end result is simple. Iron is oxidized to form iron oxide, Fe_2O_3, which is rust.

$$\text{IRON} + \text{OXYGEN} \xrightarrow{\text{water}} \text{IRON OXIDE (RUST)}$$

When iron is manufactured, it is made by taking away oxygen from iron ore. This is reduction. So rusting is really just returning iron to its naturally-occurring form, iron oxide (Figure 1). This is a neat way of getting rid of unwanted iron, but it can be a real nuisance!

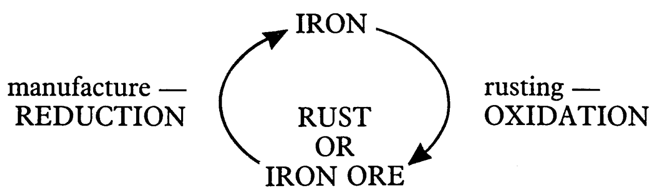

Figure 1 Iron, rust and iron ore.

> *Questions*
>
> *2 Why does painting the surface of iron prevent rust?*
>
> *3 Why does iron rust especially badly in seaside areas?*

Preventing rust

There are many different ways of preventing rust, and some are better than others. The different methods also vary a lot in cost.

1. *Surface protection*
   Rusting needs air and water. If these can be kept away from the metal surface, rusting will not occur. Surface protection can be given in several ways.

   (a) *By covering with oil or grease* This is not very effective, because the oil or grease soon rubs off.

   (b) *By painting* Paint keeps out water and air, but as soon as the paint cracks or peels off, rusting begins (Figure 2).

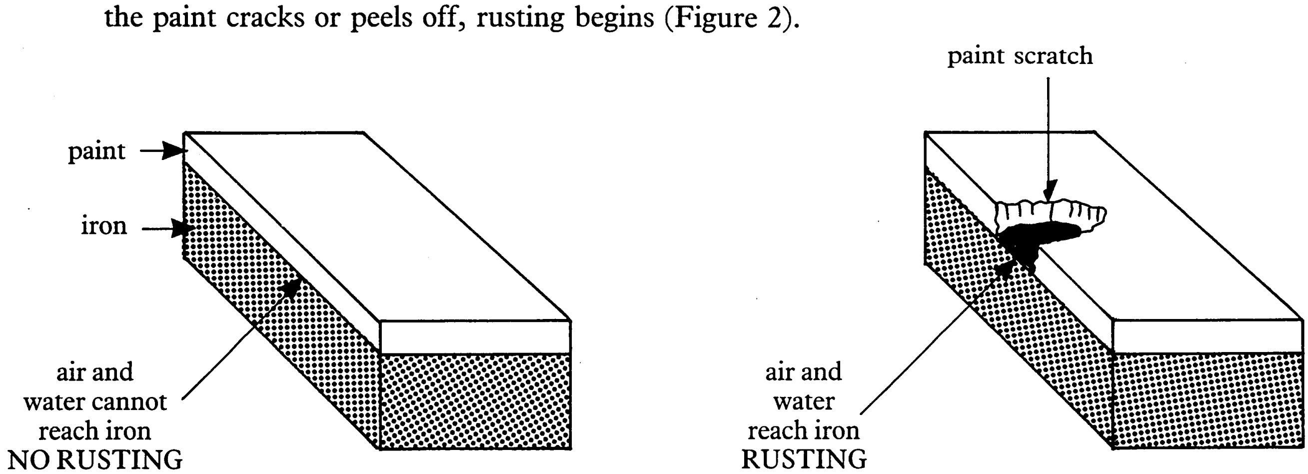

Figure 2 Protecting iron by painting

Then the metal must be painted again. Paint lasts longer if it is put on a really clean surface. Any traces of water, oil or rust make the paint peel off more easily. The best way of cleaning a metal surface for painting is by sand-blasting.

   (c) *By covering with plastic* Wire is often protected this way.

   (d) *By plating with metal* Iron can be coated, or plated, with another metal to prevent rust. If the metal is less reactive than iron, it just protects it like a coat of paint. Metal plating often looks decorative: for example, iron is chromium plated to make it look shiny.

2. *Sacrificial protection*
Some metals are more reactive than iron. Zinc and aluminium are examples of such metals. If iron is covered with a reactive metal like zinc, it gets extra rust protection. Oxygen prefers to react with the zinc, and this stops it reacting with the iron. Because the zinc is sacrificed to protect the iron, it is called a **sacrificial coating.** Even if some of the zinc gets scratched off, the iron is still protected (Figure 3). However, if iron is coated with a *less* reactive metal, like tin or chromium, it loses its protection once the coating is scratched.

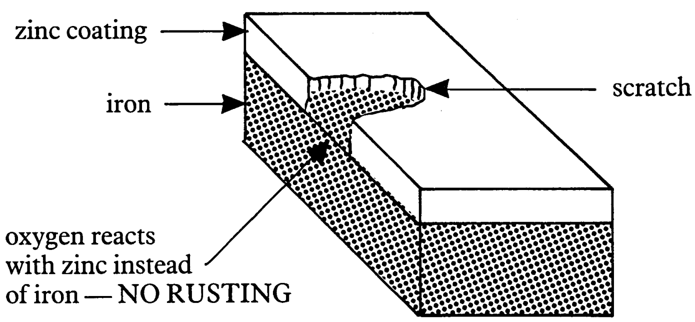

Figure 3 Protecting iron by sacrificial coating

Questions

This list shows some of the metals used to protect iron, in order of reactivity.

magnesium
aluminium
zinc
cadmium
(iron)
tin
nickel

4 *Which metal in the list do you think would give the best sacrificial protection? Explain your answer.*

5 *Which metals in the list would give no sacrificial protection at all?*

Part 2 Decisions – which method to use?

The chart in Figure 4 compares the effectiveness of different ways of stopping rust. It also gives their costs, though these are very approximate.

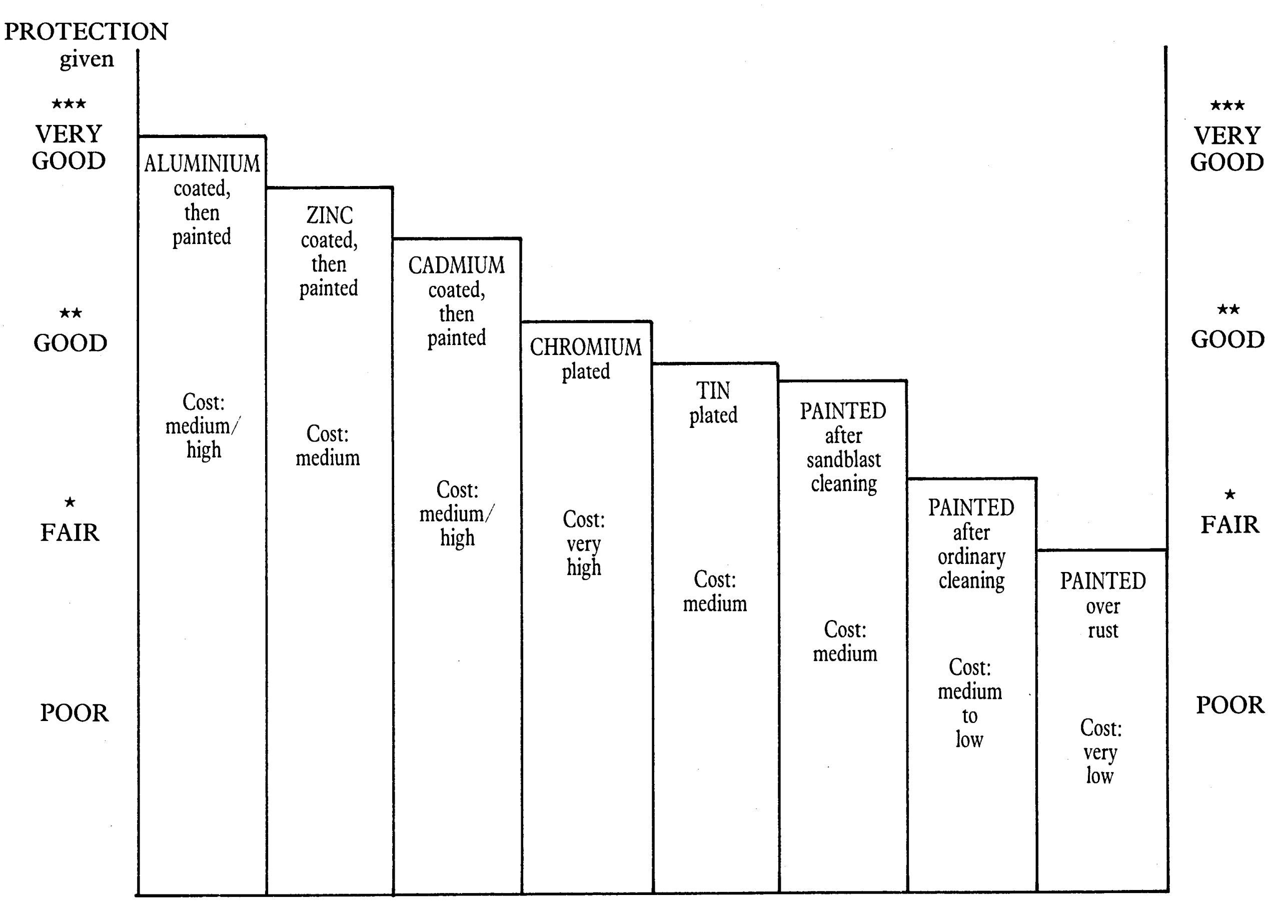

Figure 4 Comparing the effectiveness and cost of different rust prevention methods

In questions 6 to 12 you are asked to decide which rust prevention method to use in different cases. It is best to work in small groups on these questions. These are some of the facts you should bear in mind.

- How long does the article need to last? Obviously if it has a short lifetime, there is no point in giving it long-lasting protection.
- Where will the article be used? If it is to be used a lot outside, it will need better protection.
- What is the article to be used for? Different kinds of protection are suitable for different jobs. For example, paint is no use for an article that will get very hot.
- Is appearance important? Some kinds of protection are also decorative (chromium plating, for example).

Questions

Decide which method you would use to protect each article against rust. Look back at the chart in Figure 4 to find out costs and effectiveness before you decide which method to choose.

If you think there are other possibilities as well as rust prevention, say so. (For example, in question 6 you might say 'replace it with a plastic gutter'.)

6 A cast-iron gutter on a house
7 Steel railings on a seaside pier
8 An iron badge
9 The base of an electric iron
10 A steel knife blade
11 An iron key
12 The steel frame of a swing in a children's playground.

Part 3 More decisions – protecting the school bridge

You work for the Bridges Department of the local council. You have to build a footbridge across a river so children from a housing estate can reach the local school (Figure 5).

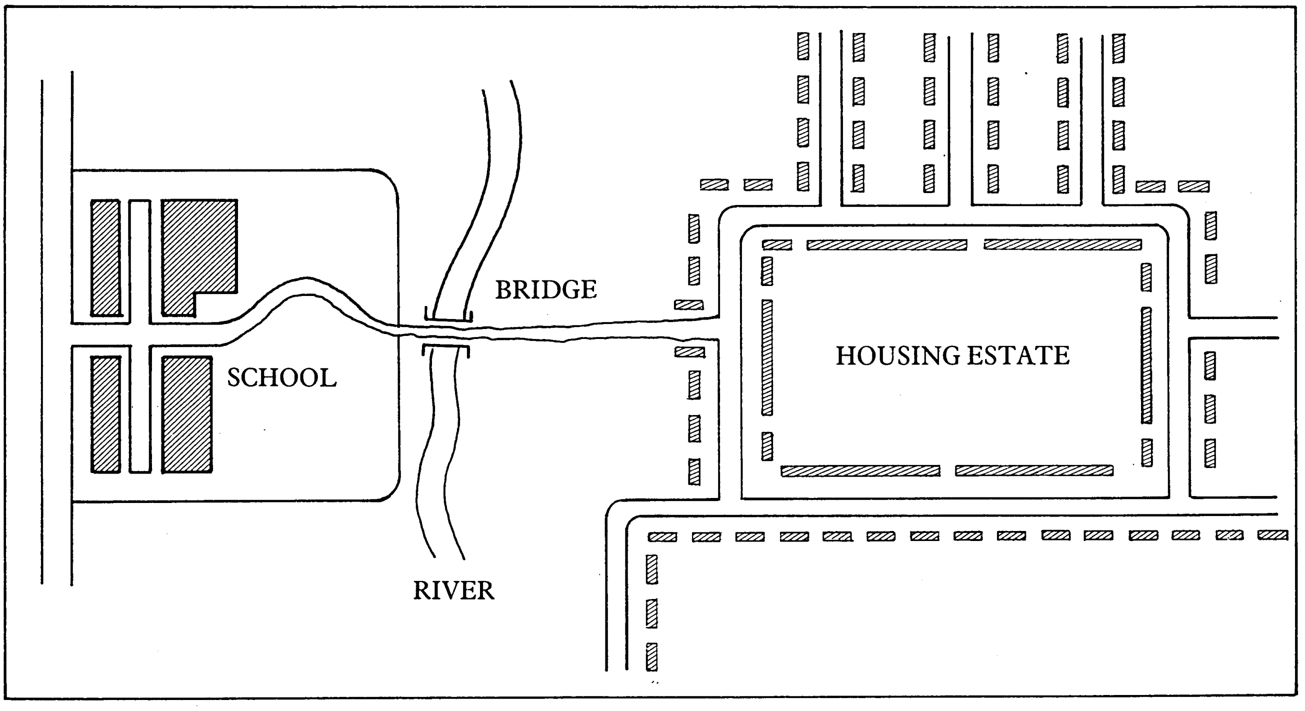

Figure 5 Map showing location of bridge

The bridge is to be made of iron, and you have to decide how to protect it against rust. It does not need to last more than 16 years, because after that time the school is due to move to a new site.

You have four options concerning rust protection:

Option 1: No protection. With no protection the bridge will need replacing after 10 years due to dangerous corrosion.

Option 2: Paint the bridge, after ordinary cleaning of the metal. It will need cleaning and repainting every 3 years.

Option 3: Paint the bridge, after cleaning the metal by sandblasting. It will need sandblasting and repainting every 6 years.

Option 4: Clean the metal by sandblasting, then zinc coat it, then paint it. This protection will last 18 years.

Table 1 gives information about the costs of these options.

Questions

13 For each option, work out the cost of building and maintaining the bridge for 16 years.

14 Apart from cost, are there any other factors you should consider before you decide?

15 Which option would you choose?

Table 1 Costs of the four options

	Option 1 (no protection)	*Option 2* (ordinary cleaning and painting)	*Option 3* (sandblasting and painting)	*Option 4* (sandblasting and zinc coating and painting)
Cost of the basic bridge	£40 000	£40 000	£40 000	£40 000
Cost of installing the bridge	£ 5000	£ 5000	£ 5000	£ 5000
Rust protection costs:	None			
1. Cleaning the surface		£ 600	£ 2000	£ 2000
2. Coating the surface		£ 3000	£ 3000	£ 5000
Value of the bridge as scrap	£ 800	£ 800	£ 800	£ 800

Part 4 More points to discuss about rusting

- Only iron and steel suffer from rust. Many other metals exist which hardly corrode at all – aluminium and copper, for example. Yet we go on using iron and steel more than any other metals. Why?
- Suppose someone invented a cheap, easy-to-use method which stopped rusting for good. Obviously it would have many advantages. Can you think of any *disadvantages* there might be?

Car exhaust systems are badly affected by rust. An exhaust system made from ordinary steel costs £80 for a particular car. It lasts about 2 years before it has to be replaced due to rust. It is also possible to buy a stainless steel exhaust system for the same car. This is much less affected by rust, and lasts over 6 years. The stainless steel system costs £155.

- Which is cheaper in the long run: the ordinary steel system or the stainless steel one? Explain your answer.
- Less than 10% of car-owners buy stainless-steel exhausts. Comment on this fact.