# Making Fertilizers

*Contents:* Reading, questions and optional experimental work on the production and use of fertilizers.

*Time:* 2 periods or more, depending on amount of experimental work attempted.

*Intended use:* GCSE Chemistry and Integrated Science. Links with work on ammonia, fertilizers, acids, bases and salts. Best used after students have been introduced to ammonia and its use in making fertilizers.

*Aims:*

- To consolidate and revise prior work on ammonia and fertilizers
- To outline the industrial manufacture of fertilizers
- To show some of the factors involved in the siting and organization of a large chemical plant
- To develop awareness of some of the environmental problems associated with fertilizer use
- To provide opportunities to practise skills in reading, comprehension, the application of knowledge, experimental design and certain practical skills.

*Requirements:* Students' worksheets No. 505. For experimental work requirements, see below.

## Notes on some of the questions

*Q.2* Developing countries frequently have rapidly growing populations and often an associated food supply problem. Fertilizers provide an important means of increasing food supply, and it is obviously preferable if the fertilizer can be made at home rather than imported. However, supply of raw materials presents a problem; in particular fertilizer manufacture requires a substantial energy input, and this must frequently be imported as fossil fuel.

*Q.10* Obviously, over-use of fertilizers must be avoided. It appears that the time of greatest fertilizer run-off is in autumn and winter, so it helps if fertilizer is not applied at these times. Normally, nitrogenous fertilizers are applied in the spring, when crops are growing fastest.

*Qs 11 and 12* Students should appreciate that in a natural, balanced ecosystem the processes of decay and excretion will replace nutrients as fast as they are used by growing plants. Agriculture, however, disturbs this balance because crops are harvested and removed from the habitat. It is of course possible to grow crops 'organically', without the use of fertilizers, but this requires that all dead, decayed and excreted material is eventually returned to the land.

## Further questions

For students who are familiar with the mole concept, quantitative questions could be set. For example:

A compound fertilizer contains ammonium nitrate, $NH_4NO_3$, ammonium dihydrogen phosphate, $NH_4H_2PO_4$, and potassium chloride, KCl, in the ratio 1 : 2 : 2 by mass.

(a) What is the mass of each compound in 100 g of fertilizer?

(b) Work out the percentages by mass of nitrogen, phosphorus and potassium in the fertilizer. (Relative atomic masses: N=14, H=1, O=16, P=31, Cl=35.5, K=39)

(Answers: (a) $NH_4NO_3$ 20g; $NH_4H_2PO_4$ 40g; KCl 40g. (b) N 11.9%; P 10.8%; K 20.9%)

## Making your own fertilizer

This is intended as a fairly open-ended exercise in experimental design. There is no 'right' answer, but the most successful approaches are likely to be based on some kind of titration, followed by evaporation.

Requirements for each group:

ammonia solution (approximately 2M)
sulphuric acid (approximately 1M)
glass stirring rod
conical flask (250cm$^3$)
burette and stand
measuring cylinder (50cm$^3$)
universal indicator paper.

## Testing your fertilizer

It is rewarding for students to test the fertilizer they have made, using cress seedlings.

Requirements for each group:

three Petri dishes
filter paper to fit the dishes
cress seeds
fertilizer made in previous experiment
commercial fertilizer from a gardening shop (optional)
distilled water
measuring cylinder or graduated flask to measure to 1 dm$^3$
three beakers (250cm$^3$)
access to a balance.

*Notes:* 1 Students may need guidance and help with making the fertilizer solutions to the right strength.

2 It is most important that the dishes are checked and watered each day, as they dry out very quickly.

## Further resources

There is a fuller account of fertilizer manufacture in the ICI publication *STEAM*, No. 3. Available from: ICI Education Publications, PO Box 96, 1 Hornchurch Close, Coventry, West Midlands, CV1 2QZ.

*Acknowledgements* Figures 1 and 2 supplied by ICI Agricultural Division; Figure 5 reproduced by permission from *STEAM*, No. 3.

# MAKING FERTILIZERS

*Figure 1 Applying fertilizer on farmland*

Plants need certain elements in order to grow heathily. They can get most of these elements from the soil, but three elements are sometimes in short supply. These are nitrogen, N, phosphorus, P and potassium K. Table 1 shows the effect on plants of a shortage of each of these three elements.

*Table 1 Effects of shortages of N, P and K*

| *Element lacking* | *Deficiency symptom* |
|---|---|
| Nitrogen, N | Harsh and fibrous leaves. Stunted growth. |
| Phosphorus, P | Grey and stunted leaves. Stunted growth. |
| Potassium, K | Premature death of leaves. Stunted growth. |

These elements can be obtained from manure or compost, or from artificial fertilizers. In order to grow more food, modern farmers are using more and more artificial fertilizers. For example, 300 kg of nitrogen fertilizer on a hectare (10 000 $m^2$) of ground can double the yield of grass. The plants produced on soils that have had fertilizers used on them are not only larger, but also contain more protein and so have better food value.

*Questions*

1 *In 1900 the world's population was 1700 million. In 1984 it was 4800 million. In 1900 farmers used very little artificial fertilizer. In 1984, about 100 million tonnes of artificial fertilizers were used throughout the world.*

*Explain why the use of artificial fertilizers has increased so much.*

2 *Why is it particularly important for developing countries to develop their own fertilizer manufacturing industries?*

## Types of fertilizers

There are several different types of fertilizer. The main ones made by ICI, one of Britain's largest manufacturers, are shown in Table 2. Look at the table then answer questions 3 and 4.

*Table 2 Some of the main types of fertilizer*

| *Name of fertilizer* | *Elements it provides* | *What it contains* |
|---|---|---|
| NITRAM | N | Ammonium nitrate, $NH_4NO_3$ |
| NITRO-CHALK | N | Ammonium nitrate absorbed in chalk, $NH_4NO_3/CaCO_3$ |
| COMPOUND FERTILIZERS | N,P,K in varying amounts | Ammonium nitrate, ammonium dihydrogen phosphate, potassium chloride. $NH_4NO_3/NH_4H_2PO_4/KCl$ in varying amounts |

*Questions*

*Remember that the major elements needed for plant growth are nitrogen, N, phosphorus, P and potassium, K.*

3 *Which type of fertilizer would you use on soil that was short of all three elements?*

4 *Which type of fertilizer would you use on soil that was short of nitrogen, and too acid?*


*Figure 2 Some ICI fertilizers*

## How are fertilizers made?

Fertilizers are manufactured in enormous quantities. On a huge site at Billingham on Teesside, ICI Agricultural Division make a range of different fertilizers. The raw materials used for making the fertilizers are shown in Table 3.

*Table 3 Raw materials for fertilizer manufacture*

| *Raw material* | *Where it comes from* | *Used to make* |
|---|---|---|
| nitrogen | the air | ammonia for all fertilizers |
| water | reservoirs in Teesdale | ammonia for all fertilizers |
| natural gas | North Sea | ammonia for all fertilizers |
| potassium chloride | mines at Boulby | compound fertilizers |
| phosphate rock | imported from overseas | compound fertilizers |
| sulphur | imported from overseas | sulphuric acid for compound fertilizers |

*Question*

5 *Billingham is particularly well situated for the manufacture of fertilizers. Use Table 3 and the map in Figure 3 to explain why.*

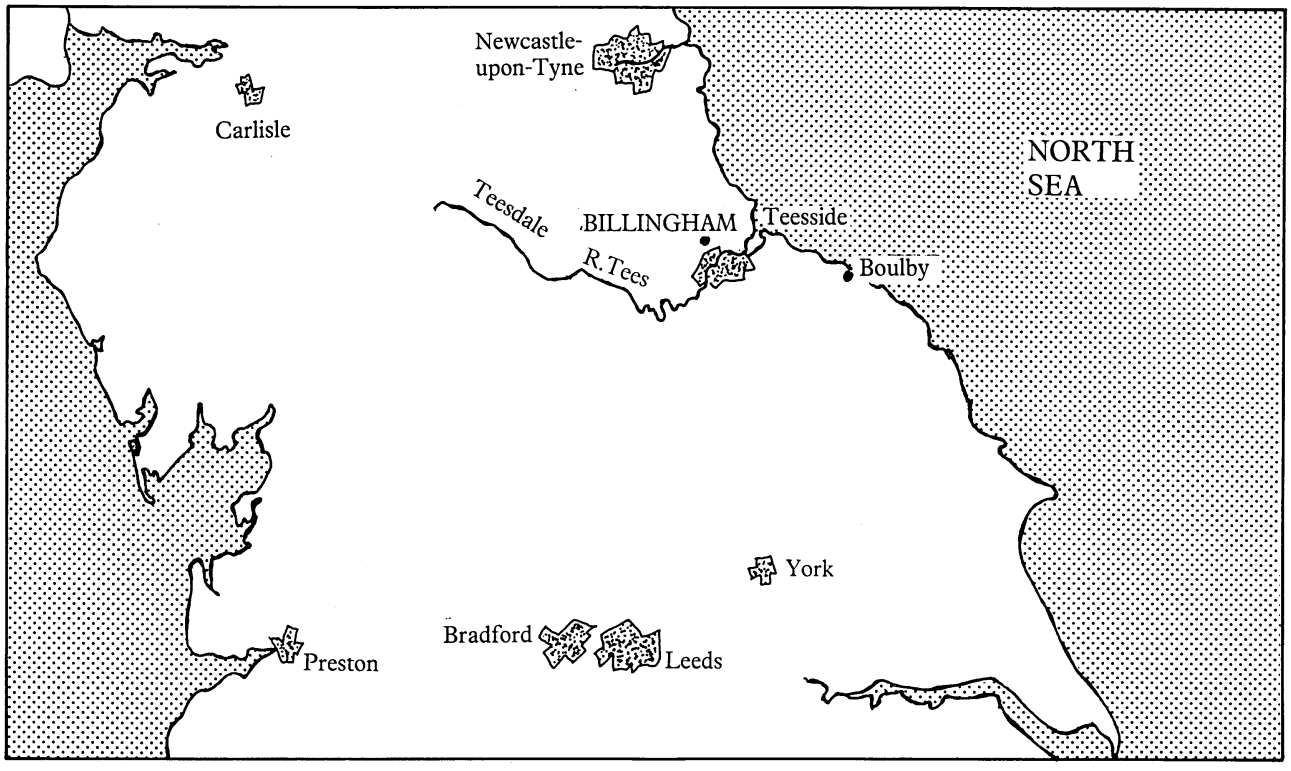


*Figure 3 Map showing the location of Billingham*

The fertilizer manufacturing site at Billingham is huge and complicated. Figure 4 on the next page shows the most important parts, though it is very simplified.

Look at figure 4, then answer questions 6 to 9.

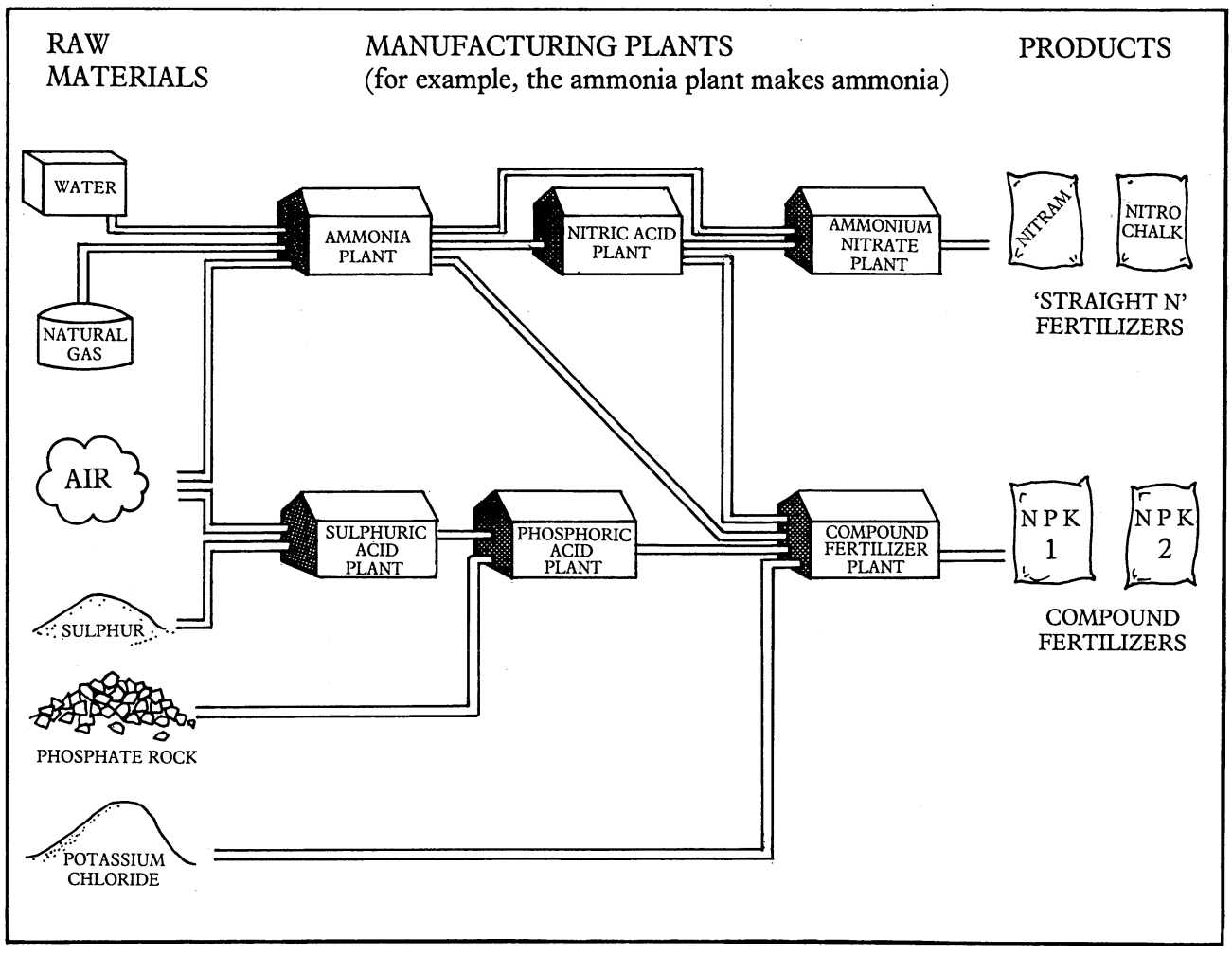


*Figure 4 A simplified scheme of fertilizer manufacture*

*Questions*

6 *Which plants use the ammonia from the ammonia plant?*

7 *What substances go into the compound fertilizer plant?*

8 *Why is it useful to have all the manufacturing plants on a single site?*

9 *What are the advantages and disadvantages for a community of having an industrial complex like Billingham nearby?*

*Figure 5 Billingham complex*

## Problems with fertilizers

Fertilizers are important if we are to grow enough food for the world's huge and growing population. However, fertilizers can cause environmental problems.

Rain can wash fertilizers out of the soil and into streams, rivers and lakes. Once in the water, the fertilizers encourage bacteria and algae to grow rapidly. As they grow, they use up the oxygen in the water. In bad cases, the concentration of oxygen in the water can become very low. Without oxygen, many of the organisms die. The water becomes murky and smelly. This is called **eutrophication**.

*Questions*

*10 What could farmers do to try to avoid the environmental problems caused by fertilizers?*

*11 In a natural, undisturbed habitat such as a forest or moorland, plants grow perfectly well without fertilizers. Why, then, do plants grown for food crops often need fertilizers?*

*12 What changes would be necessary in modern farming in order to grow enough food* without *using fertilizers?*

## Making your own fertilizer

You can make a nitrogenous fertilizer quite easily in the laboratory. The fertilizer is ammonium sulphate, and it is made from ammonia solution and dilute sulphuric acid.

$$\underset{\text{ammonia}}{2NH_{3(aq)}} + \underset{\text{sulphuric acid}}{H_2SO_{4(aq)}} \rightarrow \underset{\text{ammonium sulphate}}{(NH_4)_2SO_{4(aq)}} + 2H_2O_{(l)}$$

You will be provided with the following:

ammonia solution (approximately 2 M concentration)
sulphuric acid (approximately 1M)
glass stirring rod
conical flask (250cm$^3$)
burette and stand
50 cm$^3$ measuring cylinder
universal indicator paper.

You are to use these to make a pure, dry sample of ammonium sulphate crystals. Bear these points in mind:

- Ammonia solution and dilute sulphuric acid react together to make a solution of ammonium sulphate. The concentrations of the solutions are such that approximately equal volumes will react together.
- You should not use less than about 10 cm$^3$, or more than about 30 cm$^3$, of either of the two solutions.
- Ammonia is alkaline and sulphuric acid is acidic. Your ammonium sulphate fertilizer must be as near neutral as possible, otherwise it will damage the plants.
- Ammonium sulphate crystals decompose if heated too strongly.

Decide the method you will use, and discuss it with your teacher before going ahead with the experiment.

## Testing your fertilizer

You can test the fertilizer you have made by trying its effect on cress seedlings. Grow the cress on filter paper watered with fertilizer solution. That way you can be pretty sure the only nutrients the cress is getting have come from your fertilizer.

You will need to grow at least two sets of cress — one for your fertilizer, and one for a control. You might also like to test a commercial fertilizer. You can buy these in small quantities from gardening shops.

### What you do

1 Make a solution of your fertilizer in water. You must be sure to use the right concentration — only tiny amounts are needed. 0.5g of fertilizer dissolved in 1 dm$^3$ of water is about right.

2 Put a piece of filter paper in a clean glass dish.

3 Moisten the filter paper with your fertilizer solution so it is wet, but not swimming.

4 Sprinkle the filter paper **thinly** with cress seeds.

5 Set up a similar experiment as a control, using water instead of fertilizer solution. You could also set up a third experiment using commercial fertilizer. (Make sure you use the concentration recommended by the makers.)

6 Make sure the paper is always kept wet with fertilizer solution (or plain water for the control).

7 Compare the growth of the different sets of seedlings.