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Fertilisers

GCSE key words
Fertiliser
Ammonia
Nitric acid
Eutrophication

As plants grow they remove compounds of nitrogen, phosphorus and potassium from soil. These essential elements must be replaced to maintain the soil's fertility. For centuries farmers have used organic manures, rotated their crops or ploughed in specially grown crops to enrich the soil. A more modern method is to use chemicals called fertilisers.

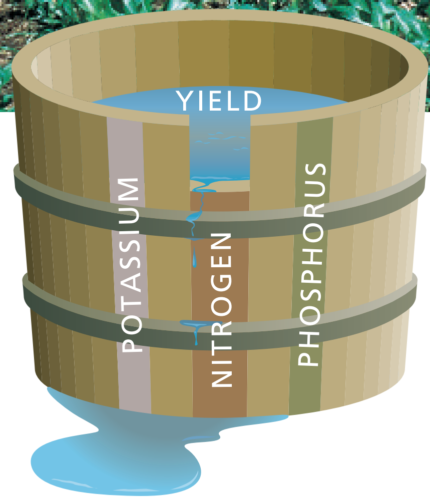


Figure 1 Liebig's barrel, a diagram he used to show how the loss of one nutrient decreases the overall yield of a crop

Justus Liebig, in 1842, was the first chemist to recognise that essential elements in the soil should be replaced (Figure 1). He patented and manufactured a manure — one of the first artificial fertilisers — containing these elements. The first permanent agricultural experimental station was set up in 1843 by John Lawes at Rothamsted in Hertfordshire, to study the effect of fertilisers on crops.

The huge growth in the use of fertilisers in developing countries during recent years is shown in Figure 2.

• **Find out about the life of Baron Justus von Liebig (1803–1873) and his other contributions to science.**

ESSENTIAL ELEMENTS

Nitrogen (**N**) is absorbed by plant roots as either nitrate (NO_3^-) or ammonium (NH_4^+) ions. A multistage reaction in the plant converts these ions to a form which can react with compounds derived from glucose (produced by photosynthesis) to make amino acids. These are the building blocks of proteins. Applying nitrogen fertiliser thus increases the protein content of plants and adds to their food value, as well as producing a bigger, lusher, crop.

Phosphorus (**P**) stimulates healthy root development, improves plants' ability to take up other nutrients and is important in crop ripening. Naturally occurring phosphate rock is insoluble and so is treated with sulphuric acid to produce soluble phosphoric acid.

BOX 1 AMMONIA MANUFACTURE

Ammonia is produced by reacting the elements nitrogen and hydrogen over an iron catalyst:

$$N_2 + 3H_2 \underset{}{\overset{\text{catalyst}}{\rightleftharpoons}} 2NH_3$$

Hydrogen is made by passing methane (natural gas) and steam over a catalyst in a reformer. Air is added to supply the nitrogen. The ratios of methane, steam and air are varied to ensure that hydrogen and nitrogen are in the correct ratio of 3:1. Carbon dioxide is a by-product which is sold or used to make urea ($CO(NH_2)_2$), another water-soluble fertiliser.

In modern manufacturing plants the mixture of hydrogen and nitrogen is compressed to 150–300 times atmospheric pressure and then circulated rapidly through a reactor containing the iron catalyst and various promoters (these enable the catalyst to work more efficiently). The reaction is exothermic and produces enough heat to maintain the temperature at between 350 and 500°C. The yield of ammonia is approximately 18%, and it is removed from the unreacted gases by condensation. Unused nitrogen and hydrogen are returned to the converter.

Ammonia plant

Terra Nitrogen

Even though **potassium** (**K**) compounds are soluble in water, potassium ions do not leach out of the soil as they are readily held within clay particles. Potassium is important for photosynthesis and other chemical reactions involving carbohydrates in plants.

The fertilisers that farmers apply make good the gap between the minerals available from the soil and the nutrients the plants need. Although soils may contain reserves of NPK, every time a crop is

BOX 2 NITRIC ACID MANUFACTURE

To make nitric acid, ammonia is oxidised to nitrogen monoxide, helped by using a catalyst. Further oxidation to nitrogen dioxide, followed by absorption in water, gives nitric acid.

The three main reactions are:

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$$
$$2NO + O_2 \longrightarrow 2NO_2$$
$$3NO_2 + H_2O \longrightarrow 2HNO_3 + NO$$

The oxidation is very rapid and yields of 96–98% are achieved by passing the ammonia and air over a platinum/rhodium gauze catalyst. The reaction is highly exothermic and so the temperature has to be controlled to maintain it at 800–900°C.

The manufacturing processes are strictly controlled to limit the amount of noxious gas released from the tall waste-gas chimney.

Nitric acid plant

Terra Nitrogen

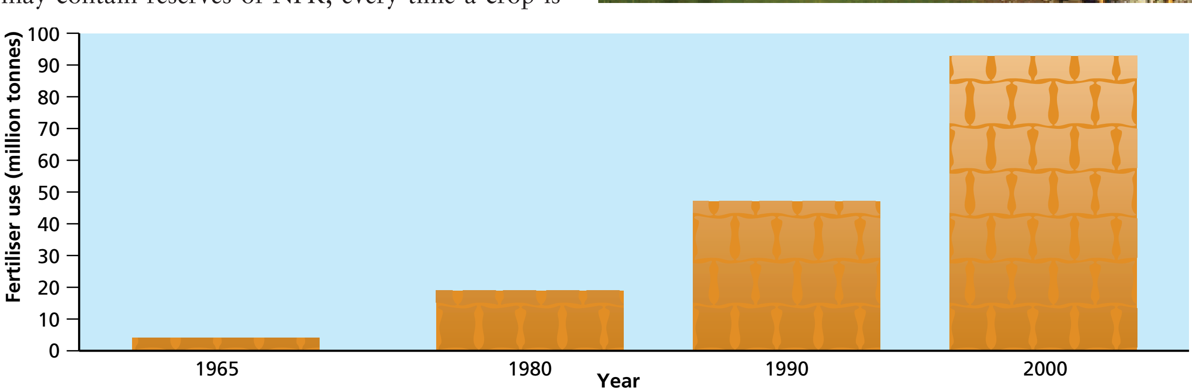
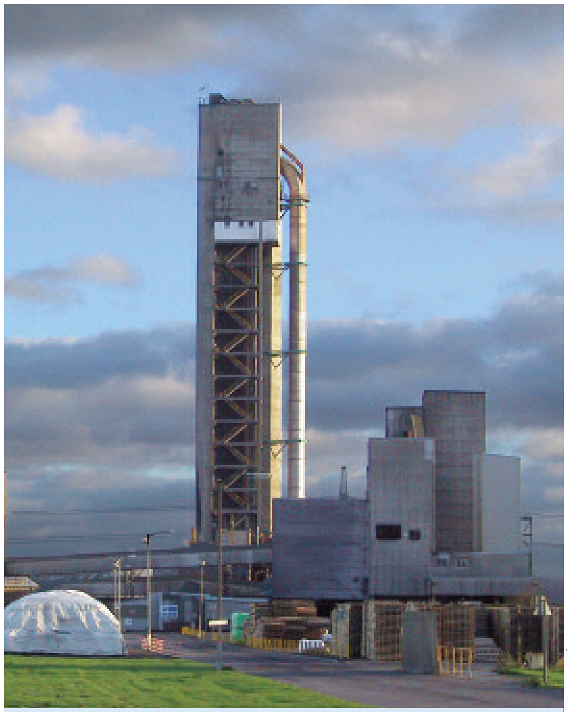


Figure 2 *Changing use of fertilisers worldwide. This increase has come about as developing countries adopt the more intensive farming practices of the developed world*

● In which other countries can minerals containing potassium chloride be found?

Right: *A prilling tower*



Terra Nitrogen

BOX 3 AMMONIUM NITRATE MANUFACTURE

Ammonium nitrate is most useful as a fertiliser in the form of prill — dense spheres, 1–3 mm in diameter. Gaseous ammonia and 55–65% w/w nitric acid are reacted to give ammonium nitrate solution:

$$NH_3 + HNO_3 \longrightarrow NH_4NO_3$$

After neutralisation, the concentrated ammonium nitrate solution is sprayed down a 100-metre high tower. The solution crystallises on the way down and is further agitated and cooled by a flow of air. The prill forms a fluidised bed. It is then sieved before weighing and packaging.

● Find out what eutrophication and algal bloom are, and how they can be related to fertiliser use.

1 hectare = 100 m × 100 m

harvested, nutrients are removed from the soil (Table 1) and probably need replacing.

MANUFACTURING PROCESSES

Nitrogen in fertilisers is in the form of nitrates, made from ammonia and nitric acid. Phosphorus is added in the form of phosphoric acid (see above) and potassium in the form of potassium chloride, obtained from the ore sylvinite. This is mined at Boulby near Whitby in North Yorkshire.

The manufacturing processes are illustrated in Figure 3. The compounds described above, and others, are blended to make compound fertilisers (Box 4) which contain varying proportions of nitrate, phosphate and potassium (described as the N:P:K ratio), according to the needs of particular crops. A typical fertiliser might contain 15% N, 7% P and 17% K by mass. Fertilisers are made 24 hours a day all year round, in order to meet the huge demands of the growing season, and have to be stockpiled in vast storage areas.

Farmers have to be careful when using fertilisers. Excess nitrate is not held by the soil and can be leached into groundwater and streams. The problem is worst in the autumn and winter after the fertiliser has been applied. Leaching can lead to serious pollution problems but farmers can take measures to prevent it, such as leaving an uncultivated buffer strip between the edge of the field and a river or stream.

Table 1 The nutrients removed when a typical crop of 50 tonnes of sugar beet is harvested off 1 hectare of ground

Element	Amount removed when roots are harvested and leaves ploughed back in to rot (kg/hectare)	Amount removed when roots are harvested and leaves removed as well (kg/hectare)
Nitrogen (N)	65	170
Phosphorus (P)	30	65
Potassium (K)	90	235

BOX 4 BLENDING PLANT

The blending plant is used to produce fertilisers which contain other nutrients in addition to the nitrate provided by ammonium nitrate. Terra Nitrogen, for example, produces Nitram (mostly ammonium nitrate) which contains 34.5% N. Addition of ammonium sulphate gives Sulphur Gold — a spring fertiliser for arable crops; addition of sodium nitrate produces Grazemore — especially suited for grassland grazed by cows; and potash (potassium carbonate) is blended with Nitram to form Kaynitro — an early top-dressing fertiliser for cereal and oil seed rape.

The blended fertiliser is packaged in bags of up to 1 tonne in mass.

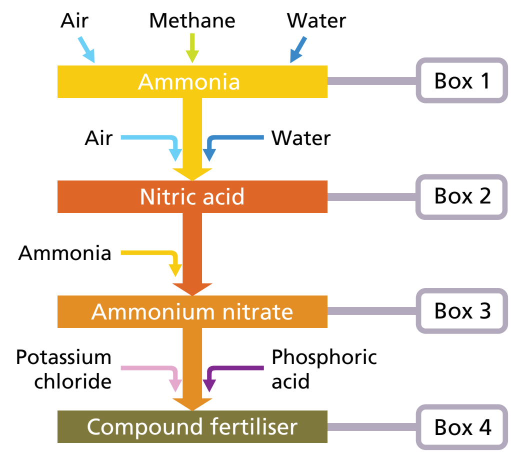


Figure 3 *Flow diagram for a fertiliser plant*

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