

Feed the world: artificial nitrogen fertilisers

The problems caused by artificial fertilisers have had a fair amount of media coverage in recent years. Should we still use them? Should we all 'go organic'? What is best for the environment? What sustainable solutions are there to the problems associated with growing food?

This activity allows students to consider the benefits and drawbacks of using artificial fertilisers and encourages them to do so from a scientific, rather than an emotive point of view. Students will probably bring their own existing ideas and beliefs to the activity and they should be encouraged to think about whether the scientific data supports their views.

Overview

Students take on the roles of a number of experts. Some information is provided for each role and students can do their own research to find out more about the likely views of the expert they are playing.

One of three routes can be taken through the activity:

1. If video cameras are available, students could make a TV programme. This could either be done in the form of a TV debate in the style of programmes like 'Question time', or 'Richard and Judy,' or it could be a mini documentary in the style of 'Panorama,' 'Horizon' or another similar programme. Students would need to be in reasonably large groups and the activity would need careful management.
2. Alternatively, the whole class could prepare for a radio show on the subject. The final show will require a presenter with a reasonable grasp of the arguments both for and against the use of artificial fertilisers, three experts on each side of the debate and a group of listeners. Divide the class into seven groups to prepare for the show and give each group the information sheet for one of the possible roles.

Students should then discuss the information and the views their character might hold. Each group must nominate a spokesperson to take the role of the presenter or one of the experts in the final show. The remainder of the class becomes the listeners, who can phone the radio station during the show to state their opinions.

You could use a microphone to aid management of the discussion – students are only 'on air' when speaking into the microphone and must remain silent otherwise. It is important that a strong student plays the role of the presenter, who should hold the experts in line, take calls and facilitate discussion. If your presenter group is struggling with preparing for this role, you could discuss some of the arguments they might hear from the other students with them before the show starts.

Student sheets required:

- **Feed the world – general briefing sheet (TV)**
- **Feed the world – general briefing sheet (radio)**
- **Expert briefing – presenter**
- **Expert briefing – farmer**
- **Expert briefing – spokesperson for the charity 'Food for All'**
- **Expert briefing – spokesperson for the charity 'Action on Habitat Destruction'**
- **Expert briefing – 'Organic Food Producers and Consumers Association'**
- **Expert briefing – 'Green Earth' environmental charity**
- **Expert briefing – 'Water Quality Campaign'**

The teacher takes the role of the producer of the show, supporting the presenter in managing the discussion and taking calls.

3. Another alternative is to ask students to do some research then hold a class debate about the issues involved.

Experts

Neutral

Presenter

For artificial fertiliser use

Farmer

Spokesperson from the charity 'Food for All'

Spokesperson from 'Action on Habitat Destruction'

Against artificial fertiliser use

Spokesperson from the 'Organic Food Producers and Consumers Association'

Spokesperson from 'Green Earth' environmental charity

Spokesperson from the 'Water Quality Campaign' group

Each student will need a copy of the **General briefing** (either the TV or the radio version as appropriate) and a copy of the **Expert briefing** for the group to which they have been assigned. The **General briefing** includes some suggested websites for further research.

Note

Remind students that this debate/TV or radio programme is about fertilisers and not about the use of pesticides, antibiotics or genetic modification. If they do their own research to add to the information supplied in the notes they are given, then they should make sure they stick to the main point of the debate, ie 'Should we use artificial fertilisers?'

Follow-up

After the debate, each student could write a newspaper or magazine article about the issues raised. They should include arguments from both sides of the debate, as well as their own opinions

A more able group could be asked to research and present ideas for sustainable solutions to the problem of feeding 10 billion people. Possible starting points could include the websites listed on the General briefing sheet and perhaps also the following site:

<http://www2.essex.ac.uk/ces/default.htm#top> (accessed December 2005) – students will need a high level of reading and comprehension skills to use this site but it contains a lot of useful information.

Less useful agriculture

If students are up in arms at the environmental damage agriculture is causing, you may wish to point out that tobacco is also produced on farms. These farms cause habitat destruction and pollution from fertilisers and the final product does not even feed anyone!

References

G.J. Leigh, *The World's Greatest Fix: A history of nitrogen in agriculture*, Oxford: Oxford University Press, 2004.

N. Borlaug, *Feeding a world of 10 billion people*, Alabama, USA: IFDC, 2003 (available on the internet at <http://www.ifdc.org>).

V. Smil, *Scientific American*, 1997, 227, 76.

Feed the world – general briefing sheet (TV)

Should we use artificial fertilisers?

Early in the history of humankind, people began to plant crops and harvest them rather than simply hunting and gathering their food. This helped to ensure a reliable supply of the chosen food and meant that individuals no longer had to rely on their own skills and luck to find enough to eat. After a while, the land being used for growing crops began to become less productive. Initially, people just moved to another plot of land when this happened and began growing their crops there instead. Once the population reached a certain size, however, that became impossible and farmers had to look for ways to keep their soil productive.

Various methods were used, including putting manure and dung on the ground, growing crops in rotation and allowing a plot of ground to lie fallow (have nothing grown on it) for a year or growing something on it then digging the plants back into the ground. Until the middle of the 1800s it was not known how these methods worked, but they had been found to do so by careful observation.

Eventually it was discovered that the factor that usually limited the growth of plants was the availability of nitrates (NO_3^-) in the soil. The air is about 80% nitrogen (N_2) gas but plants cannot use this nitrogen as it is virtually insoluble in water and very unreactive. Adding extra nitrates to the soil improves its fertility and makes it possible to achieve better yields of crops. Spreading manure and animal waste on soil adds nitrates to it, as does growing beans and peas. Unfortunately, these methods did not provide enough of the essential nitrates to allow farmers to feed the increasing numbers of people in the world. Famines like the ones in Africa you may have seen reported on the news were fairly common in Europe only 150 years ago. People were dying of starvation so another supply of nitrates was needed.

In the early 1900s Carl Bosch and Fritz Haber from Germany succeeded in turning nitrogen from the air into ammonia. This ammonia could in turn be reacted to form nitrates, which could be spread on fields and used to fertilise the soil. The process developed by Bosch and Haber remains in use today and very few changes have been made to it.

Now and the future

The world population is increasing. At the moment it is about 6 billion and it is estimated that it will rise to about 10 billion by the end of the 21st century. There is increasing pressure on the land to produce enough food to feed all those mouths.

Why do we need nitrogen?

Nitrogen is an important part of our bodies. Amino acids all contain nitrogen and these are the building blocks that make up the proteins in your hair, muscles, skin and other important tissues.

Nitrogen is an important part of your DNA, which defines what you are like in many ways. We cannot survive without nitrogen in our diet – we get it in the form of protein.

Meat or veg?

Growing vegetables for protein takes less energy and uses a smaller amount of fertilisers than raising animals. Animals need to eat plants but they also use up energy in moving,

excreting and digesting food. As populations get richer they tend to increase the amount of meat in their diet and this requires more fertilisers for growing animal feed.

Documentary

You are going to make a mini TV documentary about the issues surrounding the use of artificial fertilisers.

You will need

- A presenter or two
- Three experts in favour of using artificial fertilisers – a farmer, a spokesperson from the charity 'Food for All' and a spokesperson from 'Action on Habitat Destruction'
- Three experts against the use of artificial fertilisers – someone from the 'Organic Food Producers and Consumers Association', a spokesperson from 'Green Earth' environmental charity and a spokesperson from the 'Water Quality Campaign'
- A camera operator (you could take turns with this so everyone gets in front of the camera)
- A producer
- Perhaps some 'people on the street'.

What to do

- Each expert will have a briefing sheet, but you will also need to do your own research to add to the information they have.
- Your programme could be done as a TV debate in the style of a programme like 'Question time' or even 'Richard and Judy,' or you may prefer to make a documentary more like 'Panorama,' 'Horizon' or similar shows. You could also include 'vox pops' – quick interviews with 'people on the street.'
- You must ensure your video includes plenty of scientific arguments, not just people's opinions and feelings.

Further information

You will need to make sure you understand the issues involved and you may want to add some arguments to the ones on your Expert briefing sheet. The following books and websites may be helpful:

Salters' Advanced Chemistry: Chemical Storylines, 2nd edition, Oxford: Heinemann, 2000, 184–199.

<http://www.foe.org.uk>

<http://www.greenpeace.org.uk>

<http://www.soilassociation.org.uk>

<http://www.newscientist.com> – If your school is a subscriber you will be able to access all the articles on this site; if not, you will be able to read the introductions of the articles.

<http://www.efma.org>

<http://www.environment-agency.gov.uk>

<http://www.rothamsted.ac.uk/>

<http://www.sendacow.org.uk> – the newsletters, in particular, have information about the effect organic farming techniques can have in poor parts of the world.

http://www.ifdc.org/Publications_Catalog/Lecture_Series/index.html – these documents are long, but they are indexed and contain some very useful information; 'Feeding a world of 10 billion people' is particularly worth a look.

(All sites accessed December 2005)

If you use information from the internet, remember to think carefully about who posted that information and what their bias is likely to be. Is the information reliable?

Feed the world – general briefing sheet (radio)

Should we use artificial fertilisers?

Early in the history of humankind, people began to plant crops and harvest them rather than simply hunting and gathering their food. This helped to ensure a reliable supply of the chosen food and meant that individuals no longer had to rely on their own skills and luck to find enough to eat. After a while, the land being used for growing crops began to become less productive.

Initially, people just moved to another plot of land when this happened and began growing their crops there instead. Once the population reached a certain size, however, that became impossible and farmers had to look for ways to keep their soil productive.

Various methods were used, including putting manure and dung on the ground, growing crops in rotation and allowing a plot of ground to lie fallow (have nothing grown on it) for a year or growing something on it then digging the plants back into the ground. Until the middle of the 1800s it was not known how these methods worked, but they had been found to do so by careful observation.

Eventually it was discovered that the factor that usually limited the growth of plants was the availability of nitrates (NO_3^-) in the soil. The air is about 80% nitrogen (N_2) gas but plants cannot use this nitrogen as it is virtually insoluble in water and very unreactive. Adding extra nitrates to the soil improves its fertility and makes it possible to achieve better yields of crops. Spreading manure and animal waste on soil adds nitrates to it, as does growing beans and peas. Unfortunately, these methods did not provide enough of the essential nitrates to allow farmers to feed the increasing numbers of people in the world. Famines like the ones in Africa you may have seen reported on the news were fairly common in Europe only 150 years ago. People were dying of starvation so another supply of nitrates was needed.

In the early 1900s Carl Bosch and Fritz Haber from Germany succeeded in turning nitrogen from the air into ammonia. This ammonia could in turn be reacted to form nitrates, which could be spread on fields and used to fertilise the soil. The process developed by Bosch and Haber remains in use today and very few changes have been made to it.

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The world population is increasing. At the moment it is about 6 billion and it is estimated that it will rise to about 10 billion by the end of the 21st century. There is increasing pressure on the land to produce enough food to feed all those mouths.

Why do we need nitrogen?

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Meat or veg?

Growing vegetables for protein takes less energy and uses a smaller amount of fertilisers than raising animals. Animals need to eat plants but they also use up energy in moving, excreting and digesting food. As populations get richer they tend to increase the amount of meat in their diet and this requires more fertilisers for growing animal feed.

What to do

Work in a group to prepare for a radio show about artificial fertilisers – should we use them or not? You will have an expert briefing sheet to help you but everyone in the group must contribute to further research on the topic. On the day of the show, one or two of you will present the views of your group ‘on air.’ The rest of the group will be part of the listening public and will be able to call in to the show to have their say if they wish. There will be seven groups. Each group will represent one of the following people:

- Presenter of the show – needs to have an idea of the arguments for and against using artificial fertilisers
- Three experts for the use of artificial fertilisers:
 - a) Farmer
 - b) Spokesperson from the charity ‘Food for All’
 - c) Spokesperson from ‘Action on Habitat Destruction’
- 3 experts against the use of artificial fertilisers:
 - a) Spokesperson for the ‘Organic Food Producers and Consumers Association’
 - b) Spokesperson from ‘Green Earth’ environmental charity
 - c) Spokesperson from the ‘Water Quality Campaign.’

After the show, write a report for a newspaper or magazine detailing the arguments for and against using artificial fertilisers and giving your own opinions. It does not matter which group you were in for this part of the work.

Further information

You will need to make sure you understand the issues involved and you may want to add some arguments to the ones on your Expert briefing sheet. The following books and websites may be helpful:

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Expert briefing – presenter

You are the presenter of a television programme or radio phone-in show. You will need to interview each of your six expert guests, three of whom are for the use of artificial fertilisers and three of whom are against it.

For artificial fertiliser use:

- Farmer
- Spokesperson from the charity 'Food for All'
- Spokesperson from 'Action on Habitat Destruction.'
-

Against artificial fertiliser use:

- Spokesperson from the 'Organic Food Producers and Consumers Association'
- Spokesperson from 'Green Earth' environmental charity
- Spokesperson from the 'Water Quality Campaign' group.

When the experts have made their presentations/answered your questions, you will take questions and comments from your listeners, who will phone in. Your job is to keep the show interesting and informative, to allow those who wish to speak to do so – one at a time – and to keep the discussion based on the central question: 'Should we use artificial fertilisers?'

Your aim is to make a programme that will demonstrate the benefits and the drawbacks of using artificial fertilisers and will allow listeners to hear a balance of arguments so that they can make up their own minds on the issue.

You should have an idea of the main arguments you think the six experts might make prior to the show. Prepare some suitable questions to ask them.

Expert briefing – farmer

You are a farmer and your aim is to make a living from your land. To do this you need to grow crops, harvest them and sell them at a fair price. You also need the land to remain in good condition or else you will not be able to make a living year on year.

Some points you might want to make

- If you do not put fertiliser of any kind on your land, it will eventually produce low yields and poor quality crops.
- Fertiliser costs money so you do not want to use a lot more than you need.
- Some of the fertiliser will leach into rivers and streams, but this also happens when natural fertilisers such as manure are used.
- Experiments done at research farms have shown that it is essential to use some kind of nitrogen-containing fertiliser to maintain high yields of crops but it makes no difference to the plants whether the fertiliser is natural or artificial.
- Research has also helped tell farmers when is the best time to put fertiliser down and how much should be used – this has helped reduce the amount of excess fertiliser used by one third compared to 20 years ago and leaching has been reduced by one-fifth.
- Everyone eats the food produced on farms and it is not possible to produce food without causing some change to the environment.
- If we tried to convert all the farms in the world to 'organic' farming and they all used manure as fertiliser, we would need to have a lot more cows to produce all that manure – the number would need to increase from about 1.5 billion to 6 or 7 billion, which would cause environmental damage by overgrazing, erosion and destruction of wildlife habitats (and it would smell really awful!).

Expert briefing – spokesperson for the charity ‘Food for All’

The aim of ‘Food for All’ is to ensure that every person on the planet has enough to eat.

Some points you might want to make

- Prior to the introduction of fertilisers in Europe, famine was all too often a problem and people starved to death. The most recent European famine was in the 1850s and many people died. After that, various sorts of fertiliser were introduced, which helped to prevent the problem.
- There are 800 million malnourished people in the developing world.
- Today there are about 1.5 billion hectares of farmland worldwide. Using pre-20th century agricultural practices – so no artificial fertilisers – this land could be made to feed about 3.2 billion people.
- There are 6 billion people in the world today so without fertilisers we could only feed just over half of them – and this with a basic, mainly vegetarian diet.
- So, about 40% of the world’s population is dependent on artificial nitrogen fertilisers and would starve to death without them.
- If there was an even distribution of food all round the world and everyone adopted a simple but adequate diet of mainly cereals and legumes (beans and peas) we could all survive – even if harvests were a bit lower than they are today. Even in the very unlikely event that this were done, we would still be dependent on artificial fertilisers for about 1/3 of our food.
- The world population is still rising and is likely to reach around 10 billion in the next 100 years.
- We may not like it, but we are dependent on nitrogen fertilisers to survive.

Expert briefing – spokesperson for the charity ‘Action on Habitat Destruction’

The aim of your charity is to preserve natural habitats in the UK and overseas. You do not want the remaining rainforest to be cut down to provide extra farmland. You think keeping habitats is important to help preserve the biodiversity of our planet.

Some points you might want to make

- Everyone in the world has to be fed and most of this food comes from farms.
- As the world population increases, either the land must produce a higher yield of crops or more land must be used for farming.
- Using fertilisers can more than double the yield of crops, which in turn can halve the amount of land used for farming.
- In many places no extra land for farming is available. In the UK, for instance, there is very little land that is not used for something and in parts of Asia the situation is more extreme – there is virtually no land left that could be farmed where it is not already being done.
- If more land is used for farming it is likely to be environmentally sensitive land so there will be problems with soil erosion and loss of forests and grasslands.
- Some of the only fertile land left uncultivated in South America is the rainforests. Without the use of fertilisers, these would be cut down at an even faster rate than they are at the moment. Once the trees have been cut down, the soil is washed away and the land becomes ‘exhausted’ very quickly. It is then no use for growing crops – it is not good agricultural land.
- In the 7 years from 1997 to 2004 an area of the Amazon rainforest the size of Great Britain was cleared for producing soya (an important food crop).
- Without suitable habitats to live in, many animal and plant species will become extinct and the biodiversity of the planet will be severely reduced.

Expert briefing – ‘Organic Food Producers and Consumers Association’

You want to promote organic food as a safer and more environmentally friendly way of producing food. Organic food is produced without the use of artificial fertilisers.

Some points you might want to make

- When you buy and eat organic food you are supporting sustainable farming that produces healthy animals and plants with minimum environmental damage.
- There is greater biodiversity on organic farms than on conventional ones.
- It is possible to increase yield on small, poor farms in developing countries without the use of artificial fertiliser. Some of the methods that have been successful include:
 - a) Planting a variety of vegetables – this means that a variety of minerals are taken up from the soil
 - b) Owning a cow because it produces natural fertiliser
 - c) Having a fish pond because it attracts helpful wildlife that eat pests
 - d) Planting trees on the farm boundary to protect the soil from erosion
 - e) Changing the variety of plant grown every so often
 - f) Including legumes (beans or peas) in a crop rotation system – rotation is useful because it helps to build the fertility of the soil and can break the life cycle of pests and disease organisms. Legumes are particularly helpful because they have nodules in their roots containing bacteria that can fix nitrogen and produce nitrates.
- Use of these simple organic techniques has led to major yield increases of 46–150% on farms in developing countries without the use of artificial fertilisers.
- According to the Soil Association, organic food generally contains 10–50% more vitamin C, iron, magnesium, phosphorus and chromium than food produced using artificial fertilisers. All of these substances are essential for a healthy body.
- Using manure as a fertiliser encourages the growth of small animals like earthworms and soil microorganisms, which keeps the soil healthy and encourages biodiversity.

Expert briefing – ‘Green Earth’ environmental charity

You are a spokesperson for ‘Green Earth’, a charity that raises awareness of a number of environmental issues.

Some points you might want to make

- Agriculture causes environmental damage. It causes habitat destruction and the loss of species of many kinds, from soil bacteria to large mammals and fish. The question is not whether the environment will be affected by agriculture (as it certainly will be) but how much it will be affected.
- Fertiliser that is put on the ground and is not taken up by plants can be turned into nitrous oxide (N_2O) by denitrifying bacteria. Although the levels of nitrous oxide in the air are still low, it can contribute to two key environmental problems:
 - a) Nitrous oxide high up in the atmosphere can react with and help to destroy ozone. This contributes to the growing hole in the ozone layer. Harmful UV rays can reach the surface of the Earth through this hole and cause skin cancer.
 - b) In the lower atmosphere nitrous oxide is a ‘greenhouse gas’ and contributes to global warming. Although there is not much of it in the atmosphere at the moment, just one molecule of nitrous oxide can cause as much global warming as 200 molecules of carbon dioxide.
- The production of fertilisers starts with the Haber process. This takes place at high temperatures and pressures. It takes a lot of energy to create these conditions. The energy usually comes from burning fossil fuels, which contributes to global warming and other environmental problems – even before the fertiliser has got to the farm.
- The hydrogen used in the Haber process is made from natural gas. Altogether fertiliser production worldwide uses about 5% of all the natural gas produced.

Expert briefing – ‘Water Quality Campaign’

The ‘Water Quality Campaign’ group is concerned about the damage artificial fertilisers can do to water sources.

- Not all the nitrates spread on farmland are taken up by plants. Those which are not used by plants can leach into rivers and streams and raise the nitrate levels in the water. This can cause a number of problems.
- Nitrates can end up in drinking water. It is thought that they contribute to an increase in the number of cases of stomach cancer and cause ‘blue baby’ syndrome in new born babies.
- Nitrates in water can cause excessive growth of algae. This is known as ‘eutrophication.’ As the algae decompose they use up the oxygen in the water, which causes fish and other animals to die. This can kill off the life in a river or stream and leave it toxic and smelly.
- Algal growth increases even more if phosphates are also present in the water. Most fertilisers contain phosphate as well as nitrate, which makes this problem worse.
- Up to 200 rivers and streams in the UK are affected by nitrate pollution annually.
- The European Union has set a limit on the level of nitrates allowed in drinking water at 50 mg per dm³. Many countries (including the UK) have to spend a lot of money removing nitrates from drinking water so that it contains no more than the approved level.