NEWSWATCH

The nitrogen bomb

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For the last 40 years or so, world food output has grown faster than demand. The reason is that the 'green revolution' of the 1960s produced high-yielding varieties of rice and wheat that enabled the countries of Asia, including Pakistan, India, China and others, to increase production sharply. Looking ahead, the world will need another revolution of similar scale, but of a rather different nature.

The capacity of the world to produce enough food to feed a much larger population than today's 6bn is not really in doubt, provided people are prepared to eat a smaller proportion of meat in their diet. Growing grain or grass and then feeding it to animals is an inefficient use of land, for animals are inefficient at converting plant energy into human food. At present, in countries like Pakistan, where meat forms a very small proportion of the diet of most people, the total plant energy consumed (actual plant food eaten, plus seed, plus animal feed) is about 3,000 calories a day. By contrast, North Americans, Australians, New Zealanders and the Europeans consume an average of 15,000 calories a day; thanks largely to the amount of meat in their diet. The world's average is some 6,000 calories a day.

Some calculations of the world's ability to feed a larger population have been done by the economist Bernard Gilland. He estimates that with some increase in the area of land under crops, and more than a doubling of average yields, the world could feed about 8bn people (the level of population likely to be reached by 2020) with a 'completely satisfactory' diet of 9,000 calories of plant energy a day.

There are two difficulties with these calculations, as Hamish McRae points out in his seminal study *The World in 2020*. Firstly, whatever happens to total food production, such growth as takes place will not be evenly distributed. Some countries are already facing chronic shortages. These will get worse, for most of them are in Africa, where population growth is fastest. Food production per head in Africa has declined since the 1960s, in contrast to every other region in the world. The little we know about long-term climate change suggests that sub-Saharan Africa will suffer more from drought in the future than it has over the last three decades.

Second, it is not clear that another green revolution is imminent. Without one, it may not be possible to increase yields by the amount needed. Some further advances will of course be made, but, as McRae points out, they will have to be in a different form from those of the past. The success of the green revolution depended on having suitable land, the right climate and enough water. Given these, it proved possible to achieve enormous increases in yields. But these higher yields were often achieved at a cost that is only now becoming evident. These costs include soil erosion, salination and other environmental damage. As a result, the sustainability of the advances is now being questioned.

Looking ahead, it is quite possible that genetic engineering will bring a green revolution of a different sort. Such engineering could produce more varieties of staple crops that do increase yields. But genetically modified crops are not without controversy, with some critics arguing that they are recipes for disaster. Also, the environmental consequences of pushing yields yet higher are not yet known, and of course, as McRae points out, the smaller the rise in yields, the greater the increase that will have to occur in the amount of land taken into cultivation.

If farming spreads to land that has up to now been considered unsuitable for agriculture, this may lead to further environmental damage, as has been happening in Brazil's Amazon basin, where millions of acres of rain forest are being cut down each year to make way for farming. Rain forests serve as the 'lungs' of the world, converting carbon dioxide into oxygen. So their large-scale destruction could have very serious consequences for the global ecosystem.

In 1898, Sir William Crookes called on science to save Europe from impending starvation in his presidential address to the British Association for the Advancement of Science. At that time the world's supply of wheat was produced mainly by the US and Russia. As those countries' populations grew, their own demands would outpace any increase in production. What then would happen to Europe? "It is the chemist who must come to the rescue of the threatened communities," Crookes cried. "It is through the laboratory that starvation may ultimately be turned into plenty," he said.

As David E Fisher and Marshall Jon Fisher point out in an article in *Discover* magazine, the crux of the matter was a lack of nitrogen. By the 1840s, agricultural production had declined in England, and famine would have ensued if not for the discovery that the limiting factor in food production was the amount of nitrogen in the soil. Adding nitrogen in the form of nitrate fertiliser raised food production enough to ward-off disaster.

Today nitrogen-based fertilisers help feed billions of people, but they are also poisoning ecosystems, destroying fisheries, and sickening and killing children throughout the world. In ensuring our supply of food, they are wreaking havoc on our water and air.

As David and Marshall Fisher point out, nitrogen is essential to the chemistry of life, and sometimes, its destruction. It winds its way through all living things in the form of amino acids, which are chains or rings of carbon atoms attached to the clusters of nitrogen and hydrogen atoms.

German physical chemist Franz Haber's invention of industrial nitrogen fixation in 1909 and its scaling up to commercial levels by 1912, Haber and German engineer Carl Bosch made the production of nitrogen-based fertilisers viable. Haber and Bosch would later receive Nobel prizes for their efforts, the threat of famine was averted, and the world lived happily ever after. Well, not quite.

In trying to feed humankind, we may yet starve it. The paradox of nitrogen remains. First it was all around us and we could not use it. Now we know how to use it and it is suffocating us.

The planet's 6bn humans (and counting) rely more than ever on fertiliser to augment the natural nitrogen in soils. In fact, we now produce more fixed nitrogen than the soil's natural microbial processes do. Farmers tend to apply more fertilisers rather than take a chance on less, so more nitrogen accumulates than the soil can absorb or break down. Nitrates from automobile exhaust and other fossil fuel combustion add appreciably to this overload.

The excess either gets washed off by rainfall or irrigation, or else leaches from the soil into groundwater. An estimated 20% of nitrogen that humans contribute to watersheds eventually ends up in lakes, rivers, oceans, and public reservoirs, opening a virtual Pandora's Box of problems.

At the end of the 19th Century, there were around 1.5bn people in the world, and they were already beginning to exhaust the food supply. Today, as the population surges past 6b, there is no way humanity could feed itself without nitrogen fertilisers. As Stanford University ecologist Peter Vitousek said recently, "We can't make food without mobilising a lot of nitrogen, and we can't mobilise a lot of nitrogen without spreading some around." Nitrogen also contaminates drinking water, making it especially dangerous for infants. It interferes with the necessary transformation of methemoglobin into hemoglobin, thus, decreasing the blood's ability to carry oxygen and causing methemoglobinemia, or 'blue baby syndrome'.

Beefing up agriculture not only contaminates our water, it corrupts the air. As fertilisers build up in the soil, bacteria convert more and more of it into nitrous oxide. Nitrous oxide is best known as 'laughing gas,' a common dental anesthetic, but it is also a powerful greenhouse gas, hundreds of times more effective than carbon dioxide, and a threat to the ozone layer. As David and Marshall Fisher note, our ecosphere can apparently withstand little tinkering. They write: "Bend one little pole the wrong way, and the whole interlocking mechanism goes out of whack."

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