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The nitrogen emergency: How to fix our forgotten environmental crisis

Nitrogen pollution poisons our water and clogs our air – and it exacerbates other environmental problems. But if we organise now, we can fight back before it's too late

By **Andrew Zaleski**

Nitrogen is normally thought of as inoffensive stuff; after all, this colourless substance makes up 78 per cent of Earth's atmosphere. When you feel a refreshing breeze on your cheeks, it is mostly nitrogen molecules swishing past. Our ecosystems naturally cycle nitrogen from the air in and out of our soils, where it forms an essential nutrient for plants. The trouble is, this cycle is now dangerously out of whack because of human activity. The result is nitrogen in harmful forms swamping the wider environment.

Some of the effects of this crisis have been obvious for ages. We have long known, for instance, that pollution from nitrogen-bearing compounds prompts algal blooms that choke waterways. But other effects are now coming into focus too, like the way nitrogen pollution is killing peat bogs. Compounds of nitrogen are also damaging the delicate balance of the atmosphere.

A United Nations panel set up to assess the problem has revealed just how bad things have become. In fact, nitrogen pollution is one of the most dire crises we face. Fortunately, there are ways that we can dig ourselves out of this hole – but they will involve wholesale changes to how we grow our crops.

… For centuries, farmers have observed that plants grow better if the soil has been prepared with lots of nutrient-rich manure. So they forked in this natural fertiliser and grew legumes, with their symbiotic nitrogen-fixing bacteria, in rotation with other crops.

The trouble began in the early 1900s, when the German scientists Fritz Haber and Carl Bosch devised an industrial means of plucking nitrogen gas from the air and converting it to ammonia. Modern synthetic fertiliser was born.

But the Haber process, as the chemistry is called, has big downsides when carried out on industrial scales. The conditions required are punishing – a temperature of 450°C and a pressure about 200 times that at Earth's surface. This swallows huge amounts of power: worldwide, the Haber process is responsible for 1 per cent of human CO_2 emissions, about the same as the entire UK.

Worse, all the extra ammonia being produced has tipped the nitrogen cycle wildly out of balance… "We've completely disrupted the balance of where these nutrients sit

and what life forms they are accessible to," says biogeochemist Penny Johnes at the University of Bristol, UK.

Need a fix

Few know this better than Mark Sutton at the UK Centre for Ecology and Hydrology, who has been studying nitrogen pollution for decades. In 2011, the United Nations Environment Programme asked him to undertake the first global assessment of the problem, to determine how bad it was, what to expect in future and how to fix it. A few years later, Sutton became the head of a UN-backed project aiming to develop an International Nitrogen Management System (INMS).

The aim was to do for nitrogen what the Intergovernmental Panel on Climate Change (IPCC) had done for CO_2. Sutton and his team are drawing on the existing research to chart the full extent of well-documented problems like fertiliser pollution being washed into our oceans. They have also highlighted some previously unknown issues (see: "Five ways nitrogen is harming our planet"). "The INMS doesn't have to prove the existence of nitrogen pollution," says Sutton. "Rather, it's got to say how we get the world scientific community to work together."

Nitrogen based pollution can contribute to soil with higher acidity
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The IPCC has set a recognised goal of limiting global warming to 1.5°C by 2100 compared with pre-industrial temperatures. Sutton and his team wanted a similar rallying call for nitrogen use, but knew it would be politically tricky. He recalls one meeting at New York University in 2018, where he sat with a handful of nitrogen experts discussing what target they should set.

They realised that asking the world to cut nitrogen use in agriculture would meet a lot of resistance, notably from the powerful fertiliser industry. In the end, the scientists decided to call for nitrogen waste to be cut instead – after all, up to 58 per cent of the nitrogen in fertiliser isn't taken up by crops. It was an easier sell, they thought; who could object to cutting waste? And it was much needed. Research by Xin Zhang, now at the University of Maryland, and her colleagues shows that nitrogen use efficiency has fallen from 50 per cent in 1961 to 42 per cent today.

In October 2019, the UN held a meeting in Colombo, Sri Lanka, to discuss the nitrogen problem. Just beforehand, Sutton and 150 colleagues wrote to the UN secretary-general urging that their idea for a waste-cutting target was taken up.

It worked. The meeting adopted the Colombo Declaration, a road map for halving nitrogen waste by 2030. But with only 14 nations so far signed up, nitrogen remains a fledgling cause on the international stage. "It feels like the Paris Agreement is a massive 500-year oak tree and the Colombo Declaration is a little sapling," says Sutton.

That isn't to say that climate change and nitrogen woes can be treated separately. Nitrogen pollution makes a swathe of other environmental problems worse, from pollution of drinking water to smog in cities. "If we don't deal with our nitrogen challenge, then dealing with pretty much any other environmental or human health challenge becomes significantly harder," says David Kanter, vice-chair of the International Nitrogen Initiative.

Take nitrous oxide, a gaseous by-product of denitrification carried out by soil bacteria. It is a greenhouse gas with about 300 times the warming impact of CO_2. More and more of it is being produced as we cram too much fertiliser into soils. Kanter says it simply won't be possible to keep global warming below the IPCC's target of 1.5°C unless we do something about the nitrogen problem.

The way out of this mess begins with more intelligent management of fertilisers, by far the worst source of nitrogen pollution. Many farmers blanket their fields in fertiliser several times each growing season. This guarantees a great yield – but also a lot of nitrogen waste.

Better options already exist. Take the "smart nitrogen" fertiliser produced by businesses such as Nutrien. This comes as pellets of nitrogen encased in a polymer. Water leaches into the pellet, dissolves the nitrogen, which then seeps out gradually. This drip-feeds crops with a gradual supply, ensuring more gets absorbed and less runs into streams and so on.

Smart fertilisers are too expensive for most farmers, though, so some people are trying a low-tech equivalent called urea deep placement. Urea is a widely used and cheap nitrogen fertiliser. Its disadvantage is that once applied, it converts quickly to ammonia, creating such a build-up in the soil that ammonia gas escapes into the air.

"If we don't deal with nitrogen, then dealing with any other environmental challenge gets a lot harder"

The deep placement approach involves pushing granules of urea much further into the soil. This means that as urea turns into ammonia, it is already close to the roots and can be absorbed more readily.

The International Fertilizer Development Center (IFDC), a global non-profit organisation, is conducting field trials of the strategy in countries including Ghana, India, Rwanda and Vietnam. Its researchers say the farmers in the trials are achieving nitrogen use efficiencies as high as 80 per cent. “The single most important thing that can enhance nutrient efficiency is controlling nitrogen,” says Latha Nagarajan at the IFDC.

Nitrogen pollution can kill peat bogs in Northern Ireland
scenicireland.com/Christopher Hill Photographic/Alamy

In wealthier places, a precision agriculture revolution promises even greater rewards. The idea is to use satellites, drones and remote sensors to get an up-to-the-minute picture of how crops and soils are faring. Does this corner of a field need an extra few grams of nitrogen? Would that stretch benefit from a little more water? Armed with this information, farmers can give each area exactly what it needs. In its ultimate realisation, robots fed with the data will do the farming while humans monitor from afar. This could be a game changer for nitrogen pollution, says Johnes.

One US company, PrecisionHawk, uses drones for overhead crop inspection. These have cameras to spot signs of blight or stress, an indication that more fertiliser is needed. The firm found that during the 2016 growing season, corn farmers using the system saved $4 a hectare on nitrogen fertiliser, meaning they were buying, and applying, less.

Perhaps the most ambitious solution is to reimagine what Haber and Bosch did all those years ago. Rather than extract nitrogen from the air in industrial quantities and slather it on fields, might we be able to convert nitrogen gas to ammonia where and when plants need it? A slew of biotech start-ups are starting to show that the answer is yes.

Root of the problem

Regular nitrogen fixing bacteria can only form symbiotic relationships with certain plants, like soya beans and legumes. But firms such as Pivot Bio in California are re-engineering these bacteria so they can nuzzle up to other crops, like wheat. Farmers spray the bacteria onto seeds before planting. After germination, the bacteria live symbiotically with plant roots and fix nitrogen into nutrients the roots can absorb. The firm carried out field trials of its system in 2018 across 47 US states, comparing the harvest from fields treated with their product and ordinary synthetic fertiliser. This showed that the bacteria-treated fields yielded about 480 kilograms more crop per hectare than those treated with ordinary fertiliser.

It is the symbiotic relationship between the bacteria and the roots that seems to be crucial. “Our data shows that the microbes are producing nitrogen right around the time that the corn is calling for that nitrogen,” says Richard Broglie at Pivot Bio. The upshot is that the nitrogen gets absorbed from the soil more quickly, leaving less scope for it to escape into watercourses or the air. Several other US start-ups are working in this space, such as Joyn Bio in Boston and Intrinsyx Bio in Silicon Valley.

All these methods will go some way to reducing nitrogen pollution. The INMS is pushing 76 ideas for reducing nitrogen waste in a UN report published in December. But the mix of measures that will be most feasible and effective in any given place isn’t yet known; the soil type and many other factors all make a difference. For now, it is up to farmers and governments to decide the best methods.

Meanwhile, Sutton is keen to rally support for the goal of halving nitrogen waste by 2030. Whether it is achievable will depend largely on the buy-in the INMS secures from countries by 2022, when its UN funding ends. By then, the hope is to have what Sutton calls the “godfather of pollution” firmly on the global agenda.

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