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Research report

Forum: UNEP

Issue: establishing rules to combat overfertilisation

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Introduction

At the start of the 20th century, German chemists Fritz Haber and Carl Bosch developed a method for taking nitrogen from the air and melding it with hydrogen. It would prove to be one of the great scientific advances of the century. Combined, the two elements made liquid ammonia, a key ingredient in **synthetic fertilisers**, which would drive an unprecedented agricultural expansion and help feed a fast-growing world. But there has been a downside. During the last 100 years, the amount of man-made nitrogen compounds in water, soil and the air has doubled – an increase driven in large part by the widespread use of synthetic fertilisers. Nitrogen is essential for life on Earth but in excess, it is a dangerous **pollutant** and is poisoning water bodies, plants, animals and humans, while driving climate change through emissions of the potent greenhouse gas, nitrous oxide. Though little known to the general public, experts call the flood of excess nitrogen one of the most severe pollution threats facing humanity today.

Definitions of key terms

Over-fertilisation

What is meant by 'overfertilization?' The central source of market failure is an environmental externality associated with leaching of nutrients into groundwater and/or runoff of nutrients into surface waters. Farmers do not confront the costs of these environmental consequences of their fertiliser management choices.

Synthetic fertilisers

Synthetic Fertilisers are "Man made" inorganic compounds - usually derived from by-products of the petroleum industry. Examples are Ammonium Nitrate, Ammonium Phosphate, Superphosphate, and Potassium Sulphate.

Pollutant

A pollutant is a substance that is present in concentrations that may harm organisms (humans, plants and animals) or exceed an environmental quality standard. The term is frequently used synonymously with contaminants.

freshwater and marine habitats

Freshwater habitats include ponds, lakes, rivers, and streams, while marine habitats include the ocean and salty seas. Ponds and lakes are both stationary bodies of freshwater, with ponds being smaller than lakes. The types of life present vary within lakes and ponds.

hydrological cycles

The hydrologic -- or water -- cycle is the continuous movement of water between the earth and the atmosphere. Water reaches land as precipitation such as rain and snow. Then the water evaporates, condenses in the atmosphere to form clouds, and falls to the earth again as precipitation, continuing the cycle.

Eutrophication

The process by which a body of water becomes enriched in dissolved nutrients (such as phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen.

General overview

At the beginning of the 19th century, there were almost no man-made nitrogen compounds in the environment. But in the years after the Haber-Bosch breakthrough, their levels began to skyrocket, driven by the massive uptake of synthetic fertilisers and other human activities like the manufacturing of munitions and the burning of fossil fuels, both of which create chemically reactive forms of nitrogen.

Nutrient run-off from farms laced with synthetic fertilisers has adversely affected land ecosystems, according to the United Nations-backed Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). But **freshwater and marine habitats** have been hit hardest, with recurrent algal blooms such as in Lake Erie, and “dead zones” bereft of aquatic life as in the Gulf of Mexico, it says.

Human health is also at risk. Agricultural ammonia emissions can combine with pollution from vehicle exhausts to create dangerous particulates in the air and exacerbate respiratory diseases, including COVID-19. One study has estimated that air pollution may increase mortality associated with COVID-19 by 15 per cent.

<u>Negative effects of over fertilisation</u>

Pollution

Problems for the plants include water pollution, e.g., through gold mining or oil search, the presence of herbicides or over fertilisation. Some species, like *Eichhornia crassipes*, have a high tolerance to pollutants and are used to clean polluted inland waters. However, the biomass accumulated by the species will retain the pollutants and may become a problem if well designed removal strategies and disposal are not used.

Alteration of hydric cycles

Altered hydric cycles arise with artificial water regulations where dams or river rectifications have been built. Dams and hydropower stations are being built all over, and their influence on the inland water networks is mostly disastrous. Changes which are linked to the presence of dams include the emergence of different flooding periodicities, which lead to disruptions of interactions and the asynchronicity of the plant life cycles and even change in species composition. Large-scale deforestation in catchment of rivers leads to changes in **hydrological cycles** and also alters hydrochemical parameters. In rectified rivers, such as all over Europe and N-America, many habitats along the river channels and wetlands were lost, and the concentration of hydraulic energy along a linear river channel increased bed erosion and consequently led to lowered groundwater levels. The results were fragmented river wetlands with reduced habitat and plant diversity, as well as the introduction of non-native **invasive species** (neophytes), which in turn endanger local species pools.

Changes of precipitation

Climatic changes lead to changed precipitation at a local and global level. Thus, the natural patterns of floods and droughts are undermined. Increased length and height of flooding has strong impacts on plant survival. Increased or less frequent floods and droughts can have devastating effects on plant life and species composition. Disruptions of networks and asynchronicity of life cycles are a consequence.

Fires following exceptional droughts are emerging ecological constraints. Since wetland plants of most inland water systems are usually not subjected nor adapted to fires, they may become a major concern in wetlands under climatic change scenarios.

Rivers – the lifeblood of coastal waters

Coastal waters are among the most productive regions of the oceans. The greatest numbers of fish, shellfish and seafood in general are caught here. The high productivity is a result of nutrients that are transported by rivers from the land into the sea. These mainly comprise phosphate and nitrogen compounds, which plants require for growth. Phytoplankton in the ocean, microscopically small algae in particular, also utilizes these substances. Because of the high availability of nutrients, phytoplankton grows exceptionally well in coastal regions. It is consumed by zooplankton, small crustaceans, fish larvae, and other creatures, and thus forms the base of the food web in the ocean. The high productivity of coastal waters also makes them increasingly attractive areas for aquaculture. The output of the aquaculture industry increased worldwide by a factor of fifteen between 1970 and 2005. But rivers are not the only source of nutrients for coastal areas. On the west coast of Africa, for instance, ocean currents from greater depths bring nutrient-rich water up to the surface, where light can penetrate. In these upwelling regions, the nutrients also promote a rich growth of algae, increase productivity through the entire food web, and ultimately produce a greater yield for fisheries. A natural level of nutrients is therefore a positive factor and is essential for marine organisms in the coastal waters.

Too much of a good thing

In many densely populated regions of the Earth, however, excessive amounts of nutrients are finding their way into the coastal waters. A large proportion of these nutrients come from the intensive agricultural application of chemical fertilisers, which are washed by rain into the rivers. Between 1970 and 2005 the amount of nitrogen fertiliser alone, applied globally, increased by almost a factor of three. Nitrogen and phosphate compounds are also transported to the sea by untreated wastewater, and via the atmosphere from the burning of fossil fuels. The production and decay of organic material are unnaturally intensified by the huge amounts of nutrients in coastal waters. Scientists call this process **eutrophication**. The availability of nutrients is so great that the phytoplankton population grows beyond normal levels, producing a classic algal bloom. In the North Sea and in the Wadden Sea, massive algal occurrences are occasionally whipped into a foam by the surf. These sometimes form piles up to a metre high, resembling giant meringues. A serious threat is presented by the propagation of toxic algae.

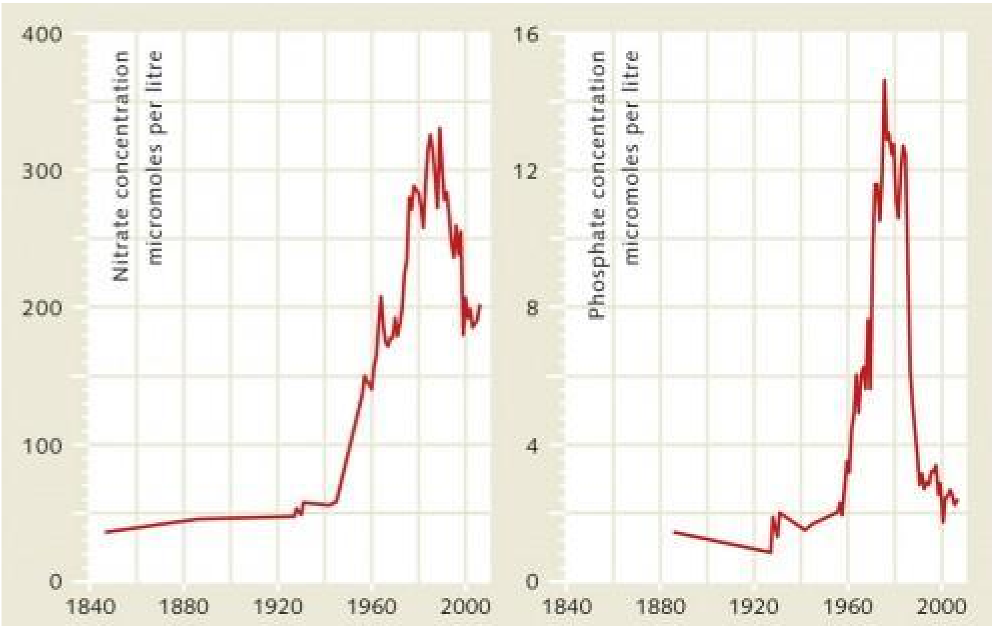
These are poisonous to various organisms in the sea, such as fish and clams and if they enter the food chain, they may also be ingested by humans. Numerous cases have been reported of people dying after eating poisoned shellfish. Scientists have also verified the deaths of marine mammals from algal toxins that they ingested with their food. These toxic algal blooms occur along the coast of Texas, for example. Because they discolour the water they are commonly called “red tides” or “brown tides”.
The blooms of non-toxic algae can also create problems when the algae die. The dead algae sink to the bottom where they are broken down by microorganisms through a process that depletes oxygen in the seawater. Low oxygen concentrations in the water can lead to large-scale mortality of fish and crustaceans. When the oxygen levels begin to drop, the animals that can actively move, such as fish and crabs, leave the area first. Within the seafloor, the population of animals that require a healthy oxygen supply diminishes at the same time. If the oxygen concentration continues to drop, then most of the other species living in the sea floor also disappear. Only a few species that can tolerate low oxygen levels remain. If the bottom water finally becomes completely depleted of oxygen, even these organisms will die off.
But **eutrophication** also causes blooms of other organisms besides phytoplankton. It has a significant effect on larger plants, and can often change entire coastal ecosystems. One example of this was the formation of a vast carpet of green algae on the Chinese coast at Qingdao in 2008, which disrupted the Olympic sailing competition. In other cases, **eutrophication** leads to the disappearance of seagrass beds (Chapter 5) or to changes in the species composition in certain habitats. In short, **eutrophication** is an illustration of how changes onshore can impact the

ocean, because the oceans are connected to the land masses by rivers and the atmosphere. To counteract the negative effects of **eutrophication**, serious efforts are being made to reduce the input of phosphate and nitrogen compounds into coastal waters.

Reversing the trend

The Rhine River and North Sea present a good example illustrating how the input of nutrients by rivers into the ocean has evolved through time in European regions, because extensive data are available for both of these water bodies. The first observations were made as early as the mid 19th century. Water samples from the Rhine near the border of Germany and Holland were taken and analysed over several decades. Near the border town of Lobith, researchers documented a strong increase in phosphate and nitrate concentrations from the mid-20th century. Appropriate measures were taken that have succeeded in consistently reducing the concentrations since the mid-1980s.

The causes of the increase included a growing input from agriculture and industry as well as the discharge of untreated urban sewage. Laundry detergent with phosphate additives to decalcify the wash water was a significant source of phosphates. As early as the 1970s, a ban on this type of detergent had already begun to reduce the phosphate concentrations in the Rhine. Then, in the 1980s, the nitrogen levels in the river also began to drop. This can be attributed in part to improved fertilising methods in agriculture that resulted in lesser amounts of nutrients being washed from the fields. Another reason is the improved treatment of industrial and domestic wastewater. In 1987, environmental ministers from the North Sea countries finally agreed to a goal of halving the amounts of phosphate and nitrogen transported by rivers. For phosphates this goal was reached quickly. For the nitrogen compounds it took almost 25 years. Despite decreasing phosphate and nitrogen concentrations in the water, however, the Rhine River still carries large amounts of nutrients to the North Sea, because it flows through a highly developed and intensively used agrarian region. The present nitrate loads are still higher than in the pre-industrial age 150 years ago. Similar situations exist in other European river regions and in the USA.



In some parts of Europe, political decisions have thus led to a reversal of the trends and a reduction of nutrient input into the oceans. But the opposite trend can be observed globally. Computer models indicate that the use of fertiliser is increasing in many regions due to population growth and the intensification of agriculture. Accordingly, in many coastal regions, the amounts of phosphate and nitrogen being washed into the sea by the rivers are increasing. Particularly in Southeast Asia, rivers are carrying more and more nutrients to the sea, and experts expect this trend to continue.

A global problem

The effects of **eutrophication** have been coming to light since the 1960s. Researchers have noted more abundant algal blooms, oxygen-poor zones in coastal regions, and changes in coastal ecosystems. The causes of **eutrophication** have been thoroughly analysed in numerous studies, and there is certainly a direct connection between environmental changes and nutrient input. But for a long time researchers were in disagreement as to how the phosphates and nitrates interact as nutrients. Some experts accepted that the "law of the minimum", formulated by the agronomist Carl Sprengel in 1828, was valid for algal growth. According to this theory, a plant requires several nutrients in order to thrive. If one nutrient is missing, then it cannot grow. This means that the growth of plants would always be limited by the one substance that is not available in sufficient quantity. This would suggest that it is sufficient to remove one nutrient, either phosphate or nitrogen, from the wastewater and rivers in order to stop the growth of algae. This

would also significantly reduce the costs of water treatment.
This assumption, however, now appears to be too simplistic. Continuing experiments and observations show that multiple factors acting in concert are often responsible for limiting plant growth. Experts call this phenomenon co-limitation. **Eutrophication** can only be combated successfully if both phosphate and nitrogen are reduced. However, this is fraught with difficulty, primarily because nitrogen released by agricultural activity is not easily contained. This is also true of nitrogen released into the atmosphere by the burning of natural gas, oil or coal. **Eutrophication** is therefore likely to continue to occur in coastal waters in the future.

One example of a strongly eutrophic area is the German Bight. In the 1980s the oxygen concentration in its deep waters dropped to alarming levels. At the same time an increase in primary productivity in the form of enhanced algal growth was observed in the Wadden Sea. Seagrass, a plant that is the foundation for a unique habitat in the North Sea and Wadden Sea, disappeared. It was displaced by an excessive proliferation of green algae. All over the world, bays with limited water exchange are affected by **eutrophication** because nutrients are not effectively dispersed. These include Tokyo Bay, Long Island Sound in the USA, the Baltic Sea, and several of the fjords in Norway.
Eutrophication with an excessive growth of phytoplankton has also been observed in some areas in the Mediterranean Sea, such as the north-eastern Adriatic Sea or the bay at Athens. The Gulf of Mexico is a special case: here the Mississippi River discharges such a large volume of nutrients that an extensive low-oxygen area has formed along the coast.

Previous attempts to solve the issue

To stem the tide of nitrogen pollution, a growing number of governments, companies and international bodies, including the United Nations Environment Programme (UNEP), have been working with scientists to better understand the risks associated with human use of nitrogen, and to raise awareness.

To that end, almost exactly a year ago United Nations Member States endorsed the Colombo Declaration on Sustainable Nitrogen Management, which sets an ambition to halve nitrogen waste from all sources by 2030.

UNEP also recently established the global “Halve Nitrogen Waste” campaign, highlighting the fact that improving nitrogen use efficiency not only supports climate, nature and health goals but also saves US$100 billion globally annually (an estimate based on half the value of global synthetic fertiliser sales).

Possible solutions

Globally, synthetic fertilisers are behind the bulk of global food production and they're especially important in developing countries. That, experts say, will make a transition away from them challenging. However, initiatives to stake out a more sustainable way of growing food are plentiful. A recent study from the Soil Association, a United Kingdom-based charity and advocate of organic farming, calls for much greater attention to nitrous oxide emissions in global greenhouse gas accounting; more integrated efforts to tackle nitrogen excess as a climate, nature and health issue; and incentives for better nitrogen management at farm level. But organic farming methods are not the only example of sustainable nutrient management: agroecological approaches, including conservation, low-input, and minimum tillage agriculture, are all recognized as "nature-positive" and regenerative practices. From farm to fork, 80 percent of nitrogen is wasted and lost to the environment, according to a study by the Centre for Ecology & Hydrology in the United Kingdom. More efficient use of animal manure and greater use, in rotations, of nitrogen-fixing crops – such as legumes which convert nitrogen from the air into a form that is biologically useful – will be crucial to replace synthetic nitrogen as part of the process of rebuilding soil fertility.

Further reading/ Bibliography

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