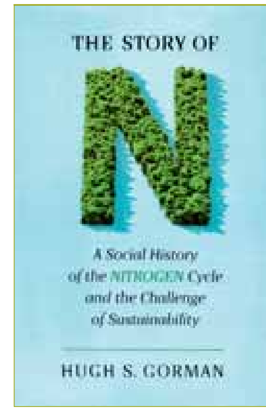
GAiA

3 | 2015

ECOLOGICAL PERSPECTIVES FOR SCIENCE AND SOCIETY
ÖKOLOGISCHE PERSPEKTIVEN FÜR WISSENSCHAFT UND GESELLSCHAFT

oekom verlag

GAIA is available online at *www.ingentaconnect.com/content/oekom/gaia*
www.oekom.de | B 54649 | ISSN 0940-5550 |
GAIAEA 24/3, 145–216 (2015)



Nitrogen – A Crucial Element in a Complex World

Wilfried Winiwarter

Nitrogen is an essential element to living organisms. Thus it is indispensable in agriculture, and it also is the primary ingredient of fertilizers. Nevertheless, an excess of this boost to plant growth leads to several environmental problems.

Gorman, H. S. 2013. *The story of N: A social history of the nitrogen cycle and the challenge of sustainability.* New Brunswick, NJ: Rutgers University Press. 260 pp., 49.95 USD, ISBN 978-0-8135-5438-9

We have seen many attempts to use a single explanatory parameter for a whole set of effects. Identifying a unique and common cause for a suite of consequences undoubtedly contributes to scientific developments, providing a simplification, a guidance to the otherwise overly complex reality. Such mono-dimensional explanations are much easier to communicate, important also when relating to environmental problems, and offer a straightforward pathway to solutions.

The concept developed by Hugh S. Gorman (2013) in *The Story of N* thus is convincing: to describe a whole range of environmental issues via one single element, nitrogen (N). Originally brought forward by biogeoscientists (e. g., Galloway et al. 2003), the idea is rooted in the principle of mass conservation. Nitrogen in its reactive form – chemically fixed nitrogen in compounds like nitrate, ammonia, urea, or organic compounds – is known to transfer between different environmental pools, thus contributing to a range of unintended effects. The fact that humans spend considerable efforts (and fossil energy) to fix atmospheric (molecular) nitrogen in order to obtain the plant-accessible reactive nitrogen forms amplifies the dichotomy of immense benefits and considerable environmental damage caused by the identical substance.

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No Growth without Nitrogen

Nitrogen is an essential element to living organisms, as a key compound in amino acids that form proteins needed in the metabolism. Thus it is indispensable in agriculture, and it also is the primary ingredient of fertilizers. As much as carbon represents energy, nitrogen stands for life. It has been argued that mineral nitrogen fertilizers nourish more than 50 percent of the world's population (Erisman et al. 2008). Nevertheless, an excess of this boost to plant growth leads to eutrophied and depleted soils, to algal blooms in inland waters as well as in the coastal area, suppresses plant species that also could flourish on little nitrogen supply (thus affecting biodiversity) and can be harmful to drinking water as well as to the atmosphere, where nitrogen compounds are found as air pollutants or affecting the global climate (Sutton et al. 2011).

Gorman's choice of this multi-faceted element to describe human reactions on problems with the environment is therefore very well justified. The relevance of nitrogen to agriculture was discovered not long after discovering the element itself. But it did not take very long until first problems (primarily on water quality) became evident. Gorman describes the impact of urbanization and waste water systems on the need to treat effluents, and how the technical facilities that allow such treatment were developed. Likewise, his account of the historical development, the increased agricultural use of the element and its consequences on the Mississippi basin and delta is an exciting piece of evidence (compensating for some lack of precision and editing errors in his introductory part on natural and prehistoric nitrogen cycles).

Complaints about a given situation, here drinking water quality or eutrophication of fishing water, lead to investigation of its causes. Science is called upon finding solutions, and the potential to monitor improves. Instrumental development flourishes such that the relevant compounds (in aqueous phase as well as in the atmosphere) can be routinely quantified. This development, according to the author, finds considerable support from all stakeholders: each group involved contributing to the call for more and better information – the main limitation being the costs of development of such devices which has to be taken by the customers, often the general public or the taxpayer.

Industry and Environmental Threats

In contrast, any action impacting on economic activities (in terms of nitrogen in river systems, this is predominantly agriculture and waste water treatment; for air, combustion at high temperatures to drive vehicles or run power plants) is a tedious task relying on long-winding legal confron-

http://dx.doi.org/10.14512/gaia.24.3.12

tation. Gordon shows in much detail for the U.S. situation, how such battles are being performed, and how water and air quality, on the long run, are being improved. Systems that have been devised to implement a continuous improvement process are taken advantage of in form of quality standards (e.g., ISO 14000 series). While being effective in the beginning, also the shortcomings of the concept become visible. The "best-available technology", a level to which industry is expected to adopt as soon as quality standards are implemented, does not pick up on technological improvement. With the lack of other incentives, Gordon describes in this most exciting part of the book, industry has little reason to provide the technology to further remove or mitigate pollution. He rather observes a hesitance of such improvement. This is in stark contrast to the abovementioned monitoring devices, which seem to fully profit from technological advancement as there seems to be no risk of consequential abatement cost hitting the very industry.

Where will we move further, regarding environmental threats caused by nitrogen? And can action be limited to just one dimension, as laid out in the book's concept? Many individual pathways seem possible, strongly depending on the respective actors, and experience can differ strikingly from the U.S. examples. In Europe, Denmark and The Netherlands probably feature the most intensive agriculture. Both industry and the related research are highly developed in both countries – allowing these countries also to be forerunners in reducing emissions from these sources. High population density and in consequence public pressure against pollution (e.g., visible eutrophication of shorelines along the Baltic Sea in Denmark, a consequence of leaching exacerbated by the predominantly sandy soils) triggered strict regulation on fertilizer application, enforced by detailed reporting requirements – despite of resistance of the farming industry (which nevertheless remains highly competitive on the European market). Also air quality standards and emission ceilings were introduced as legal action, triggered by the public pressure to safeguard ecosystems and human health, but based on sound scientific evidence (Reis et al. 2012). Again another characteristic becomes apparent from successful mitigation of nitrous oxide from chemical industry (nitric acid and adipic acid production), which in 2007 caused twelve percent of the emissions of this greenhouse gas in the EU (EEA 2014). Since then, these emissions have decreased by a factor of four over five years – in response to the introduction of the EU emission trading scheme, indeed a success story of emission trading.

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Perspectives for Environmental Nitrogen

Despite some success, considerable challenges in limiting nitrogen-related pollution remain. In his conclusions, Gorman suggests an "adaptive management" approach to be taken. Considering such an approach in connection with the available tools as described by Gorman, the lengthy process of court decisions typical for the U.S. system, one starts to wonder whether that is such a good idea – especially as the author demonstrates adaptive management not to achieve much when the continuous-improvement standards fall short of their expectations. However, one could regard adaptive management as well in a much wider sense, as a system where new steps are explored as soon as the old approaches tend to fail.

In this respect, it is highly interesting to observe a new initiative from Germany. The German Advisory Council on the Environment (Sachverständigenrat für Umweltfragen, SRU) recently provided a treatise on nitrogen pollution (SRU 2015), suggesting a national nitrogen strategy to be adopted. A set of 40 specific recommendations have been developed, targeting agriculture as well as biogas production, while also addressing food consumption patterns. Transportation and the power sector are explicitly mentioned, with interrelations between the respective actions fully attended to. The further fate of this move is yet to be seen, but anyway the perspective to think in terms of one single pollutant, nitrogen, is maintained. Germany, as the largest EU member, can play a central role in the further development of the whole continent's environmental policies. Policies may take different shapes (regulation, trading, or litigation), and positive impacts have yet to be demonstrated. This is not a question of technology availability – this technology exists, both in devices for combustion exhaust, and in the high-tech agricultural industry.

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