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Reactive Nitrogen in the Environment

Too Much or Too Little of a Good Thing

United Nations Environment Programme

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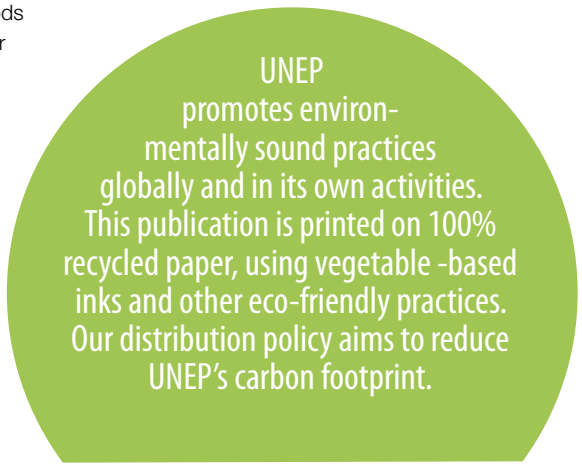

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UNEP DTIE
Sustainable Consumption and Production (SCP) Branch
15 rue de Milan
75441 Paris CEDEX 09
France
Tel: +33 1 4437 1450
Fax: +33 1 4437 1474
E-mail: unep.tie@unep.fr
www.unep.fr/pc

The Woods Hole Research Center
149 Woods Hole Road
Falmouth MA 02540-1644 USA
Tel: + 1 508 540 9900
Fax: + 1 508 540 9700
www.whrc.org

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Executive summary

Nitrogen is an essential, fundamental building block for life. It is the most plentiful element in the earth's atmosphere, yet in its molecular form (N_2), it is unusable by the vast majority of living organisms. It must be transformed, or fixed, into other forms, collectively known as reactive nitrogen (See Glossary), before it can be used by most plants and animals. Without an adequate supply of nitrogen, crops do not thrive and fail to reach their maximum production potential. In many ecosystems, nitrogen is the limiting element for growth. However, when present in excess, reactive nitrogen causes a range of negative environmental effects, poses risks to human health and consequently can have negative economic and social consequences. This non-technical review seeks to convey an understanding of the effects of reactive nitrogen in the environment, focusing mainly on those caused by excesses of reactive nitrogen. It also examines experience with some policies developed to address those effects, and offers recommendations to advance understanding and policy responses to them.

Natural production of reactive nitrogen includes nitrogen fixation by legumes, blue-green algae and a few other organisms and by lightning. Although substantial amounts of nitrogen are fixed through these naturally occurring processes, those rates are not sufficient to meet the food demands of an increasing world population. Because of this, scientists and technologists have found ways to increase its availability by artificially fixing nitrogen and producing synthetic fertilizers. Application of reactive nitrogen, in the form of synthetic fertilizers, plays a central role in modern crop production. These applications have a two-fold consequence: (1) the fertilizers enable increased crop production, supporting a larger human population; (2) at the same time this increases unintended releases of reactive nitrogen to the broader environment through agricultural runoff and additional sewage. These are important factors in the redistribution of reactive nitrogen, especially as it is introduced into groundwater, rivers and estuaries, causing overgrowth of algae in coastal zones, a process known as eutrophication.

Another major source of reactive nitrogen is associated with the growing use of fossil fuels for energy. Combustion of fossil fuels leads to the creation of nitrogen oxides (NO_X) in the atmosphere, and these emissions have increased dramatically since the beginning of the industrial revolution. In the last 150 years, the annual inputs of reactive nitrogen primarily from these agricultural, industrial and transportation sources to the earth's atmosphere, soils, and water bodies have increased by more than a factor of ten and now exceed the annual rate of production of reactive nitrogen from natural sources.

While the overall amount of reactive nitrogen production has increased, it is not evenly distributed around the world. In some areas, primarily industrialized nations, there is an excess of reactive nitrogen. It is accumulating in the air, the soil and the water, moving between each and causing subsequent environmental, human health and related economic problems. In areas where there is too little nitrogen, primarily in the developing world, agriculture cannot meet the basic

challenge of producing enough food to sustain the population, nor fulfill its potential contribution to economic development. Insufficient nitrogen and other agricultural nutrient inputs can also lead to land degradation, soil erosion, desertification and their attendant long-term environmental and economic consequences.

A single nitrogen-containing molecule can have a series of impacts on the environment because reactive nitrogen can so easily move among the different media of air, soil and water. In the air, it can contribute to higher levels of ozone in the lower atmosphere, causing respiratory ailments and damaging vegetation. From the atmosphere, it generally falls to the surface in atmospheric deposition, generating a series of effects — corrosion of buildings, bridges and other human-made structures, acidification of soils and water bodies, and inadvertent fertilization of trees and grasslands, creating unnatural growth rates, nutrient imbalances, and decreasing or altering biodiversity. Leaching out of the soils, reactive nitrogen can make groundwater and surface water unfit for human consumption. Reactive nitrogen also promotes eutrophication in coastal ecosystems, which can negatively impact fish stocks and biodiversity. Eventually, most reactive nitrogen is denitrified back to molecular nitrogen, but a portion is converted to nitrous oxide which contributes to both the greenhouse effect and to stratospheric ozone depletion.

The complex environmental, human health and economic issues surrounding reactive nitrogen (whether in excess or in deficiency) require monitoring, research and assessment of their effects, as well as broader information sharing to inform the design of specific policy responses at local, national and regional levels. Experience shows that well designed policy instruments can play a major role in rectifying reactive nitrogen imbalances and their resulting effects. However, developing effective policies is not a simple matter because the effects of reactive nitrogen are not limited to a single medium — air or soil or water — and a policy to remedy one issue may inadvertently aggravate another. Thus, a comprehensive and coherent understanding of the issue, and of the status of related policy initiatives, is an initial requirement for any action, regardless of scale. It is incumbent upon all the stakeholders — including scientists, policymakers and private sector leaders — both to broadly understand and to specifically address this range of concerns to work towards solutions.

The most successful policy initiatives that have been implemented reflect the integrated nature of the actions needed to address air, water and soil pollution resulting from the excessive release of reactive nitrogen