FERTILIZER INDUSTRY ROUND TABLE (FIRT)
54TH ANNUAL MEETING
ANNAPOLIS, MARYLAND
27-28 OCTOBER 2004

Latest Developments Regarding Fertilizers and the Nitrogen Cycle: Implications for the Fertilizer Industry

by L.M. Maene
Director General
International Fertilizer Industry Association (IFA)
Paris, France

INTRODUCTION

Nitrogen is essential to the survival of all life forms, yet the natural availability of useable nitrogen is so limited that massive human intervention in the nitrogen cycle has been required to feed the world's population. The alteration has been made even greater by the release (and subsequent deposition) of nitrogen oxides to the atmosphere during fossil fuel combustion. These human-induced releases of large quantities of reactive nitrogen have raised a number of environmental issues, all of which have impacts on people and ecosystems.

As a response to growing concerns about these unwanted impacts, the International Nitrogen Unit was jointly established in 1978 by the Scientific Committee on Problems of the Environment (SCOPE) and the United Nations Environment Programme (UNEP).

In addition, knowledge about nitrogen biogeochemistry continued to advance at several major international conferences over the past six years. The First International Nitrogen Conference, with a focus on Europe, was held in the Netherlands in March 1998. Three years later, the Second International Nitrogen Conference was held in the United States in October 2001 with a focus on North America and Europe. The Third Conference, organized by the Chinese Academy of Sciences and related organizations in Nanjing, China two weeks ago focused on Asia.

One of the recommendations of the Second Conference was to establish the International Nitrogen Initiative (INI). In December 2002, both SCOPE and the International Geosphere-Biosphere Programme (IGBP) agreed to become founding sponsors. The overall goal of the Initiative is to optimize nitrogen's beneficial role in sustainable food production and minimize nitrogen's negative effects on human health and the environment from food production and fossil fuel consumption.

In September 2001, the International Fertilizer Industry Association (IFA) indicated its interest in being associated with the development of a project on nitrogen emissions from agriculture, particularly those resulting from the use of N fertilizers. Given that there are still major uncertainties regarding the fate of fertilizer N added to agricultural soils and the potential for reducing emissions to the environment by enhancing the efficiency of N fertilizer use, this was of interest and importance to SCOPE.

IFA has been associated with these efforts from an early stage both because the fertilizer industry recognizes that it shares responsibility for the impact of its products throughout their life cycle and

because initiatives to reduce negative impacts resulting from interference with the nitrogen cycle could have deleterious effects on the fertilizer industry's operating environment.

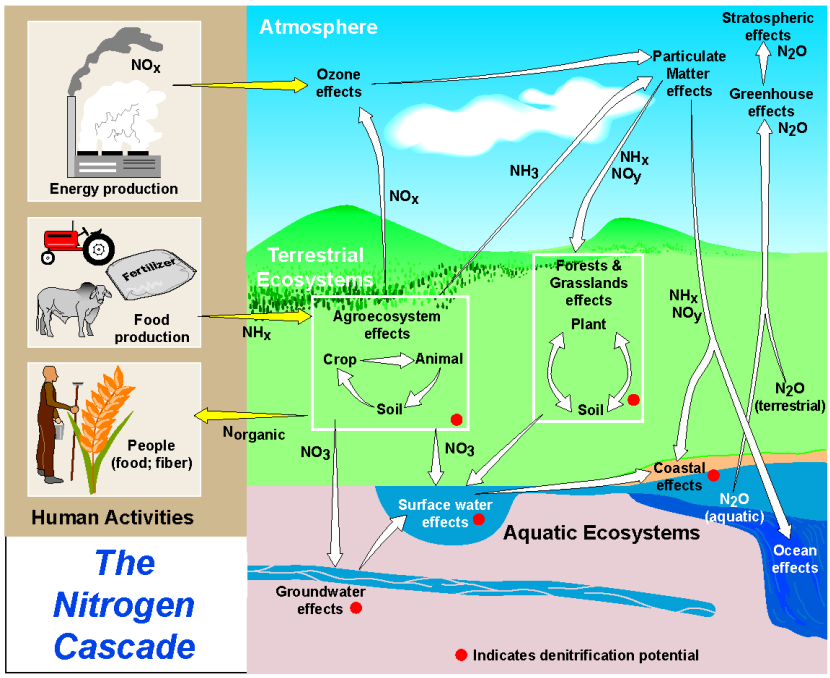
THE EVOLUTION OF HUMAN-INDUCED CHANGES TO THE NITROGEN CYCLE

Two related developments have been key in driving human impacts on the nitrogen cycle. The first is the global explosion in the human population since the dawn of the Industrial Revolution. Between 1900 and 2000, the population expanded by about sixfold, an exponential increase that is unparalleled in human history. Although this leap in population numbers is expected to level off within the next fifty years, the increase has outstripped a number of coping responses. However, contrary to all expectations, food production has not only kept pace, but also exceeded the population growth rate. Modern agriculture is even managing to fulfill demands stemming from a qualitative shift in human diets to include more meat. This being said, the Food and Agriculture Organization of the United Nations (FAO) estimates that some 800 million people still live in a chronic state of hunger[1] due to uneven distribution and other constraints.

One of the key elements of modern agriculture that has helped to meet expanding food demand has also opened the door to significant human impacts on the nitrogen cycle. The NH_3-producing Haber-Bosch process, developed in the early twentieth century is credited with supplying some 40 per cent of the protein consumed by humans around the globe today.[2] This technology captures inert atmospheric N and converts it into a form that plants can absorb; however, when supplied in excess this now reactive nitrogen can also have unwanted impacts on the environment. Reactive nitrogen can contribute to smog, acid deposition, climate change, coastal eutrophication and stratospheric ozone depletion.

The second development that contributes significantly to the release of reactive nitrogen is the burning of fossil fuels (mostly for energy and transport), which has also increased notably during the Industrial Age.

Human activities now fix some 165 million tonnes (Mt) of nitrogen annually. Natural terrestrial processes only fix about 100 Mt, so human activities have increased the global load by some 150 per cent. Since 1950, the sharply rising curves for the creation of reactive nitrogen and fertilizer use have run almost perfectly in parallel. The problem is



Source: Galloway, J.N., J.D. Aber, J.W. Erisman, S.P. Seitzinger, R.H. Howarth, E.B. Cowling, B.J. Cosby. "The nitrogen cascade". *Bioscience* 53, 341-356.

[1] *The State of Food Insecurity in the World 2003*. Food and Agriculture Organization of the United Nations. November 2003.
[2] Smil, V. "How many people does fertilizer nitrogen feed?". In *Enriching the Earth*. MIT Press. Cambridge, Massachusetts, USA. 2001: pp. 156-161.

compounded by the fact that nitrogen remains reactive in the environment for a long time before being reconverted to its inert state. Cascading through the environment, the nitrogen can have multiple negative impacts before biological processes eventually revert it to its inert form.

In the 1970s, scientists began to note the potential negative impacts associated with industrial nitrogen fixation, which had previously been considered an unquestionable success because it allowed farmers to meet global food needs. Since that decade, regulators have had some success in addressing the emissions of NO_x, largely because industrial releases are easier to pinpoint than those arising from agriculture. For example, following amendments to the US Clean Air Act in 1990, NO_x levels have been stabilized in the United States. Out of 25 signatories of the 1988 UN Protocol (to the Convention on Long-range Transboundary Air Pollution) concerning the Control of Emissions of Nitrogen Oxides or Their Transboundary Fluxes, only 19, including the United States have reached or surpassed the target of stabilizing emissions at 1987 levels.[3]

Reactive nitrogen in agriculture has proved much more difficult to control, because sources are diffuse, emanating from a large number of farms. As a result, a significant number of sampled streams in the United States have nitrogen levels that exceed the background amounts. Nitrate concentration in groundwater has increased in some parts of Europe. Asia is particularly concerned due to the political imperative of feeding burgeoning populations. Asia now consumes just over 50 per cent of synthetically produced nitrogen fertilizers, and the actual amount is expected to increase significantly during the next three decades.[4] Latin America has a mixed experience with agricultural nitrogen use, and Africa stands out as the only continent that totally defies this trend: Africa suffers from an alarming depletion of plant-available nitrogen and other nutrients in its soils.

At the same time, following a regulation-induced reduction of nitrogen fertilizer use in Denmark, the protein content of feed wheat has declined by almost sixteen per cent over the last decade. Both food quality and food quantity are closely linked with an adequate supply of plant-available nitrogen.

Therefore, although excessive reactive nitrogen has negative effects at local, regional and global levels, it is clear that there is no one-size-fits-all solution. Nor would a policy of simply reducing global fertilizer use fulfill the double demand of producing enough high-quality and nutritious food for the world and reducing negative impacts.

THE INTERNATIONAL NITROGEN INITIATIVE

It is precisely with this double mandate that the scientific community created the International Nitrogen Initiative. Recognizing that humanity today cannot live without the nitrogen currently fixed by the Haber-Bosch process, scientists decided to make an interdisciplinary effort to learn how best to live with industrial nitrogen fixation. To date, the assessment of the nitrogen issue has been fragmented, creating a need for an integrated scientific effort to evaluate past research, to consider the implications of various future scenarios and to identify and assess potential mitigation

[3] Ramakrishna, Kilaparti. "Scientific Assessments for Policy Formulation–the Way to Move Forward on Nitrogen?" Presented at the workshop on Nitrogen Cycling and Environmental Impact at China Agricultural University. Beijing, China: 9 October 2004.

[4] Apparent consumption (Production + imports - exports) for 2001/02. IFADATA Statistics. IFA, Paris: November 2003.

strategies.[5] Successful nitrogen management will clearly involve a wide range of actors, and it is evident that the fertilizer industry has a significant place at the table.

The work of the International Nitrogen Initiative builds on efforts of the International Council for Science (ICSU) / Scientific Committee on Problems of the Environment (SCOPE) Nitrogen Project. During the past decade, experts have synthesized a mountain of knowledge on the nitrogen cycle, with a particular focus on East Asia, Europe, Latin America and North America. Some fifteen workshops and symposia as well as three major international conferences have been held. The results have been published in a number of books and special issues of scientific journals.

Nonetheless, substantial uncertainties remain about how to maximize food production and the efficiency of fossil fuel consumption while maintaining a healthy environment. This lingering doubt led to the creation of the International Nitrogen Initiative (INI) at the recommendation of the Second International Nitrogen Conference.

The Initiative is organized on a regional basis, with centres already established in Africa, Asia, Europe, Latin America and North America. The activities of any given centre will be determined by the maturity of both nitrogen science and policy for that region.

Each regional centre will use a three-phase approach:

1. Assessment of knowledge on nitrogen flows and related problems;
2. Development of region-specific solutions to the problems identified in Phase I;
3. The use of scientific, engineering and policy tools to implement these solutions, in cooperation with critical stakeholder groups.

Phase I is organized around cross-cutting themes at both global and regional levels. Initial themes are natural processes (e.g. biological N fixation, denitrification), agriculture, fertilizers, animal production, human waste and energy production/use. A preliminary assessment has been produced by the INI Steering Committee and is currently undergoing peer review before finalization.[6]

In addition to the regional centres that are responsible for promoting the Initiative's agenda and developing regionally tailored assessments, INI is managed by a Steering Committee that oversees the programme and ensures regional coordination. A Scientific Advisory Committee provides guidance to the executive group and acts as a sounding board for proposed activities.[7]

THE THIRD INTERNATIONAL NITROGEN CONFERENCE

Recognizing the importance of this issue to the fertilizer industry, IFA engaged in the process at an early stage. Although early meetings were sometimes difficult, the credibility and trust gained by persistence and open dialogue are beginning to bear fruit. The Nanjing Declaration (full text in

[5] A useful overview of the information synthesized to date can be found at the INI interactive Nitrogen Timeline found at www.iniforum.com/fileadmin/timeline/map.htm. It provides a brief review of nitrogen and the policies that have resulted from state-of-the-art knowledge at various points in history. Additions and suggestions can be sent to ntimeline@iniforum.org.

[6] International Nitrogen Initiative Steering Committee. "Changes in the Global Nitrogen Cycle as a Result of Anthropogenic Influences". Preliminary assessment presented at the Third International Nitrogen Conference. Nanjing, China. October 2004.

[7] Galloway, James. "The International Nitrogen Initiative". Presented at the Third International Nitrogen Conference, Nanjing, China. 12-16 October 2004.

annex) that emerged from the Third International Nitrogen Conference explicitly notes the vital role of reactive nitrogen in "the production of food, fibre and other societal requirements for the growing population". It also mentions the imperative to address the areas of the world suffering from a crippling deficiency of reactive nitrogen in the soil. The Nanjing Declaration calls for an integrated approach to optimize nitrogen use while preventing nitrogen pollution.

Through the Declaration, participants at the Nanjing conference called on national governments to support further assessment of the nitrogen cycle; to increase the efficiency and effectiveness of agricultural production and energy use; to promote the exchange of information and technology; to enhance the availability of reactive nitrogen to ensure adequate supplies of food, fibre and other basic needs; to develop codes of site-specific good practices for agriculture, forestry and aquaculture; to establish strategies for sustainable energy use; and to apply emissions-reducing technologies.

Another significant contribution of the Third Nitrogen Conference was a better understanding of the interactions between environmental and economic considerations concerning the nitrogen cycle. William R. Moomaw from the Fletcher School at Tufts University presented an economic cascade, based on the chemical nitrogen cascade for the Cheasapeake Bay area in the United States. In so doing, he tried to estimate relative costs and benefits of intervention to better manage the cycle. His conclusions were that reducing the quantity of reactive nitrogen would have many benefits but at a significant cost from the loss of food, feed, fibre and other goods coming from the use of fertilizers.[8]

THE NITROGEN FERTILIZER RAPID ASSESSMENT PROJECT (NFRAP)

Given the important uncertainties regarding the fate of fertilizer N added to agricultural soils and the potential for reducing emissions to the environment by enhancing the efficiency of fertilizer N use, it is natural that fertilizers are an initial focus of the International Nitrogen Initiative. Therefore, at the XIth General Assembly of SCOPE in September 2001, the International Fertilizer Industry Association (IFA) indicated its interest in being associated with a project on nitrogen emissions from agriculture.

The following issues were identified as priorities:

- Develop a better understanding and quantification of the fate of fertilizer N added to different farming systems in diverse environments (a regional need);
- Elaborate the concept of reactive N in agricultural systems and put this in context with other sources of N to water and the atmosphere (a conceptual and contextual need);
- Identify and assess the technological and management strategies for enhancing the agronomic efficiency of fertilizer N and reducing emissions to the environment, with positive benefits to the economic efficiency of fertilizer N use (a management and societal need).

A workshop was held in Kampala, Uganda on this subject in mid-January 2004, and the final report was completed for the Third International Nitrogen Conference, held earlier this month in China.[9] Kampala was chosen as the site of the NFRAP meeting to emphasize that management of the global

[8] Moomaw, William R. "Cascading Costs: An Economic Nitrogen Cycle". Presented at the Third International Nitrogen Conference, Nanjing, China. 12-16 October 2004.
[9] Mosier, Arvin et al. Agriculture and the Nitrogen Cycle: Assessing the Impacts of Fertilizer Use on Food Production and the Environment. Washington, DC, USA. Island Press: 2004.

nitrogen cycle is not just about reducing fertilizer use, a statement that seems totally absurd in an African context. Proper management of nitrogen globally will mean rebalancing its use across regions, according to local needs.

The starting point for the NFRAP workshop was the importance of nitrogen, in general, and fertilizers, more particularly, for meeting global food, feed and fibre needs. Nonetheless, scientists noted that about half of the agricultural nitrogen applied is lost to the environment. One of the working groups examined the pathways of nitrogen loss and the related impacts on human health and the environment. Decision makers have a tendency to lump all nitrogen losses together, often leading to poorly targeted and ineffective policy responses. Discussions at the NFRAP meeting highlighted the differing impacts arising, depending on the given pathway. Local impacts primarily come from leaching and immobilization, whereas offsite effects are more likely to result from gaseous emissions, runoff, erosion and the transport of agricultural produce. Denitrification is the most complex process and the most influenced by environmental variables.

The use and subsequent impacts of nitrogen fertilizers varies widely, so participants in the Kampala workshop stressed the need to regionally adapted societal responses. In Africa and some areas of Latin America and Asia, inadequate application of agricultural nitrogen has triggered significant soil degradation.

Participants also discussed the importance of combining enhanced efficiency fertilizer products and improved management techniques in a mixture tailored to local conditions. Site-specific nutrient management within an integrated soil fertility framework shows significant promise to improve nitrogen fertilizer use efficiency (NFUE).

Conclusions from the Kampala meeting included the recommendation that developing countries support fertilizer use as appropriate, especially where soil degradation is at the root of environmental damage. Under such conditions, the unwanted impacts associated with excessive nitrogen use in other locales are unlikely to appear. In these cases, any direct support should be just one element of an overall enabling framework that includes such things as vital infrastructure, secure land tenure and access to rural credit.

Even in some developing countries, local hotspots of excessive nitrogen use need to be addressed. In these areas, the imperative to increase NFUE is strong. Participants in Kampala noted that improved management techniques must be simple and cost-effective, provide consistent and adequate gains in efficiency, involve little extra time investment and entail little additional risk, or farmers will not adopt them. Technologies that enhance efficiency without a higher economic return may require transitional support in order to be adopted.

Regulations and incentives were considered by those attending the NFRAP meeting to be the most appropriate policy instruments to address the environmental impacts of excess nitrogen use. Regulations were often considered to be too blunt to increase fertilizer use efficiency. Incentives to increase efficiency were therefore put forward as the preferred option. For example, it was suggested that levies or taxes on N surpluses measured at the farm gate are more likely than straight taxes on N fertilizers to have the desired effect.

A number of concrete suggestions for the fertilizer industry came out of the meeting:

- The creation of education programmes targeting farmers on enhanced efficiency products, integrated plant nutrient management, balanced fertilization and site-specific nutrient management (SSNM);

- The development and dissemination of best agricultural practices through decision support

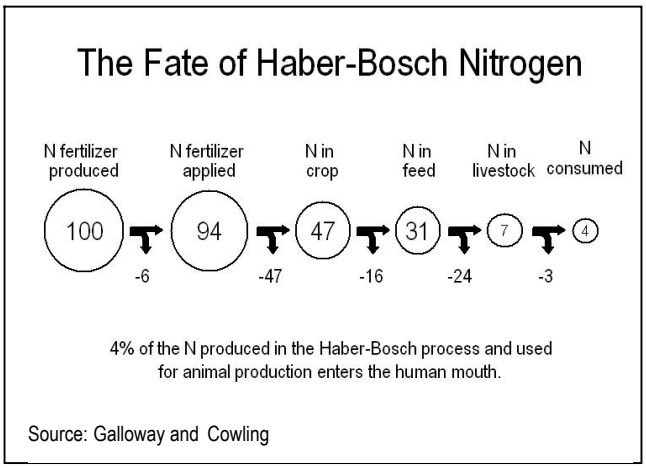
systems, tools facilitating SSNM, mechanisms for the deep placement of supergranules as appropriate;

- The commercialization of enhanced efficiency fertilizer products with little price differential from conventional products;

- Where N fertilizer use is adequate to prevent soil degradation, the industry should proactively engage policy makers to draw attention to the imperative for creating an enabling framework. The fertilizer industry should also propose solutions tailored to the needs of farmers in these countries, such as smaller packages.

THE FERTILIZER INDUSTRY AND THE NITROGEN CONUNDRUM: THREATS, OPPORTUNITIES AND RESPONSIBILITIES

Concerns regarding the nitrogen cycle pose potential policy and economic challenges to the fertilizer industry. Although scientists have been careful to underline the vital role of the industry in efforts to feed the world, a number of them frequently highlight the inherent inefficiency of the delivery of nitrogen fertilizer products, most of which have remained virtually unchanged since industrial nitrogen fertilizer production began. The industry itself often cites a figure of 30 to 40 per cent maximum uptake by the plant of the nitrogen applied in fertilizer to rice grown under tropical conditions. Other crops grown under temperate conditions may use as much as 80 per cent of the applied nitrogen. One estimation [10] puts the rough average at about 47 per cent. However, carrying the analysis further, because losses occur at harvesting and in food production, we find that a vegetarian consumes some 14 per cent of the nitrogen fixed in the fertilizer. For a meat-based diet, end consumption drops to a mere four per cent.



It is puzzling that farmers, who are often squeezed between the relatively high cost of inputs and low prices for their crops, tolerate such inefficiency, when simple management practices could make a significant improvement. By developing products that favour an efficient uptake, the industry could reduce the overall cost of raw materials, with a positive impact on per unit margins. A number of other industries have discovered that increasing the eco-efficiency of production methods and their final products often pays for itself by reducing production costs significantly. Society has probably tolerated this performance in part because of the essential role of fertilizers in helping feed humanity. Furthermore, scientists have only begun to understand the consequences of introducing excessive reactive nitrogen into the environment fairly recently. However, there are strong signals that this state of affairs will not last. The industry therefore has the choice of adopting a voluntary, proactive response or of assuming the unpredictable and likely high costs of a response designed by policymakers rather than fertilizer experts.

Scientists involved in the International Nitrogen Initiative suggest that there are two major ways to reduce the unwanted effects arising from the human disruption of the nitrogen cycle. The first is to

[10] Galloway, J.N., and E.B. Cowling, "Reactive nitrogen and the world: 200 years of change", *Ambio, 31*, 64-71.

create less reactive nitrogen by increasing the N use efficiency in food production and recycling reactive N within agroecosystems. The second is to convert unused nitrogen back to N_2 before it is lost to the environment.

For the fertilizer industry, there are three potential points of action.

The first is in the nature of its fertilizer products. Although some enhanced efficiency fertilizers exist, this market remains underdeveloped, and the use of foliar applications is in an early stage and restricted at present time to high-value crops grown under particular conditions. Research on such "advanced" products is concentrated in a handful of companies. The usual argument is that markets will not bear the extra cost of research and development because margins on fertilizers are extremely small. Even scientists note the economic challenges posed by the current situation, where farmers have no economic incentive to demand products with an enhanced performance. However, such calculations only hold in a short-term perspective. Considering the issue more strategically, stricter regulation of crop nutrient use is quite likely to be imposed within the next decade unless efforts succeed in reversing the growing negative impacts arising from nutrient leaching and loss to the environment. Compliance is likely to be costly for companies that have not previously increased the efficiency of their products. At the end of the day, the decision to continue producing low-efficiency commodity fertilizers or high-performance products could be a major factor deciding the viability of nitrogen fertilizer producers over the long term.

The second opportunity to improve the efficiency of nitrogen fertilizer use and, therefore to reduce regulatory pressure, is in the field. No matter how advanced the technology used in the factory, excessive application or bad timing of fertilizer use could still trigger negative environmental impacts. It is therefore vital to continually improve on-farm fertilizer use management, an objective that is complicated considerably by the almost limitless combinations of soil types, agroclimatic conditions, crop varieties and other site-specific factors that together define the best practice. Biotechnology may help support this goal by producing stress-tolerant crops and plants that have enhanced abilities to acquire and use nitrogen.[11]

Better integrating crop and animal production favours more efficient nutrient management by increasing the opportunities to use manure as the initial source of nitrogen, supplemented by manufactured fertilizers. IFA advocates integrated plant nutrient management, which seeks to optimize nutrient uptake by managing all available sources of nutrients together. Crop residues are another important source to take into account in this context, as are possibilities for biological nitrogen fixation, atmospheric deposition and indigenous supplies.

Again, although the industry dedicates some resources to supporting agronomic research, there is some reluctance to expand this support both because of small profit margins and because increasing fertilizer use efficiency could be interpreted as detrimental to sales within a short-term perspective. Taking into account that fertilizer use is likely to continue growing in developing regions to meet increasing food demands, the long-term costs of supporting more agricultural research are probably lower than the eventual adaptation costs of responding to stringent regulations. IFA endorses site-specific nitrogen management and supports crop nutrient research to the extent possible. However, current resources are only a drop in the bucket of what would be necessary to dramatically accelerate progress in this area, given the number of variables that can affect performance in the field.

[11] Freney, John R. "Options for Reducing the Negative Effects of Nitrogen in Agriculture". Presented at the Third International Nitrogen Conference. Nanjing, China. 12-16 October 2004.

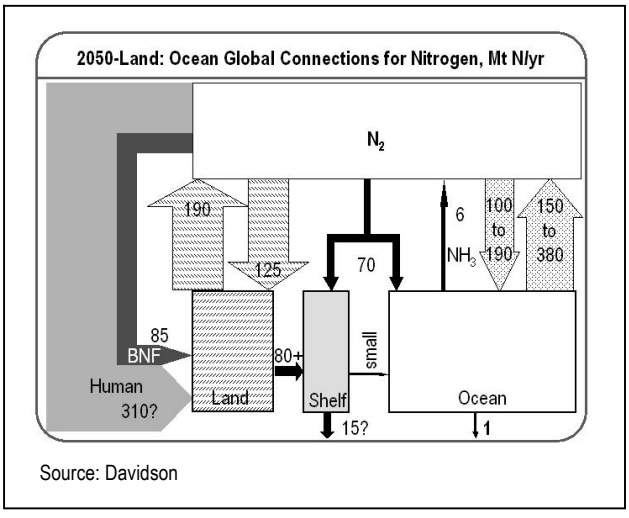
The third area for potential action is the conversion of "lost" nitrogen back into its inert state. Within an industrial context, it is easier to imagine possible solutions for this problem: systems similar to chimney scrubbers could be developed to reconvert NO_x to N_2 as it is emitted. Doing this in the agricultural sphere is less obvious, precisely because the release of reactive nitrogen is intentional, since crops cannot take up inert nitrogen. However, it might be possible to develop mechanisms in buffer zones around fields that reconvert nitrogen in run-off water, therefore reducing the loss of reactive nitrogen, especially into waterways. This would require a combination of technology and management adjustments.

CONCLUSIONS

Until recently, human interference in the nitrogen cycle has not attracted the same level of global attention as chlorofluorocarbons (CFCs) that damage the ozone layer or contribute to global warming, but experts increasingly warn that the nitrogen issue is also problematic. Scientists have become more active on this issue, and it is likely that policy efforts to address the topic will multiply in the coming decade. Indeed, interest in the topic seems to have increased during the past year. The International Fertilizer Industry Association (IFA) already participates in the International Nitrogen Initiative with a number of objectives:

- To ensure that the perspective of the industry is taken into account during deliberations, an effort that has borne fruit by ensuring that the Initiative considers regions that lack reactive nitrogen as well as those dealing with an excess;
- To monitor potential regulations on reactive nitrogen that could have negative impacts on the fertilizer industry's operating environment;
- To identify areas where voluntary efforts by the industry could contribute to the alleviation of demonstrated problems, thus creating goodwill on the part of other stakeholders, such as regulators.

The scientists addressing the nitrogen issue note that managing the N cycle presents a dilemma: the Haber-Bosch process that led to the production of manufactured nitrogen fertilizers has been a major success by allowing global food production to meet the needs of a burgeoning population. However, this success has not been unqualified: the fixation of such a large quantity of reactive nitrogen has some negative environmental impacts as it cascades through an ecosystem, triggering an entire chain of impacts. Solutions lie in finding the balance between meeting the nitrogen requirements of global agriculture and limiting the losses of reactive nitrogen to the environment. This means greatly increasing the efficiency of nitrogen fertilizer use. Techniques for reconverting escaped nitrogen into its inert form will also play a role.



Source: Davidson

The technological improvement of nitrogen fertilizers and better agricultural management practices both have an important role in meeting this challenge. The global nitrogen fertilizer industry is now faced with a strategic decision and must weigh the costs of voluntary, proactive action against the costs of the imposition of heavy-handed regulation.

In fact the industry has the opportunity to be a leader by proactively reshaping its future to

prevent a restrictive operating environment that could result from the business-as-usual scenario pictured above[12]. Heavy regulation is not inevitable, but a careful examination of possible future scenarios shows that a business-as-usual response would increase the chances that government authorities would be the primary architects of a future nitrogen management system. The chances of an optimal outcome increase if the fertilizer industry adopts a proactive stance that seeks solutions in partnership with scientists to increase fertilizer use efficiency and to reduce the amount of fertilizer N that can cascade through the environment.

The participation of IFA in the International Nitrogen Initiative constitutes a first step towards industry engagement in finding ways to feed the world without endangering the global ecosystem through the introduction of excess reactive nitrogen. Experts in science do not set policy goals, but without rigorously prepared inputs about technical issues and tradeoffs, poor policy will result.[13] By taking part in the debate, the fertilizer industry can bring its significant expertise to the table as well as creating goodwill with important stakeholders. The credibility of the industry as being sincerely concerned about minimizing unwanted impacts throughout the fertilizer life cycle has been increased significantly by the participation of IFA and other fertilizer-industry groups.

All fertilizer producers must take up this challenge individually and as a community.

[12] Davidson, Eric A. "Human Alteration of the Global Nitrogen Cycle: Scale and Scope of the Problem". Presented at the open meeting of the Ad hoc Group of Experts on Nitrogen Management for Food Security and Ecosystem Security held in the context of the World Summit on Sustainable Development. Johannesburg: August 2002.
[13] Ramakrishna, 2004.

ANNEX 1: NANJING DECLARATION ON NITROGEN MANAGEMENT

The participants of the Third International Nitrogen Conference, held in Nanjing, People's Republic of China, 12–16 October 2004

AFFIRM the principles of the Millennium Development Goals and the World Summit on Sustainable Development to speedily increase access to basic human needs such as energy, water, food security and the protection of human health and biodiversity.

AFFIRM the scientific findings of the International Nitrogen Conferences and the International Nitrogen Initiative (INI).

ACKNOWLEDGE that reactive nitrogen plays a vital role as a nutrient in the production of food, fiber, and other societal requirements for the growing population.

RECOGNIZE that, although anthropogenic production of reactive nitrogen exceeds natural creation in many regions of the world, other areas suffer from the opposite problem - a deficiency of reactive nitrogen in the soil, contributing to food insecurity and malnutrition.. These areas include most of Africa and parts of South America and Asia.

RECOGNIZE that, although many people suffer from malnutrition, a growing proportion of the world's population consumes excess protein and calories, which may lead to human health problems. The associated production of these dietary proteins (especially animal products) leads to further disturbance of the nitrogen cycle.

ACKNOWLEDGE that reactive nitrogen is a by-product of fossil fuel combustion that contributes to the welfare of humanity by supplying electricity, transportation and energy.

NOTE WITH SERIOUS CONCERN that in many parts of the world, significant amounts of reactive nitrogen are lost to the environment in agricultural and industrial production and fossil fuel . combustion. This has lead to disturbances in the nitrogen cycle, and has increased the probability of nitrogen-induced problems such as pollution of freshwaters, terrestrial and coastal ecosystems, decreasing biodiversity and changing climate and pose a threat to human health.

ARE FURTHERMORE CONCERNED that, with the rapidly increasing world population, the disturbance of the nitrogen cycle will become worse unless adequate measures are taken.

AFFIRM that since the different forms of reactive nitrogen can be transformed into one another . and are very mobile in the environment, an integrated approach to optimize nitrogen use whilst preventing nitrogen pollution, is necessary.

ARE KEENLY AWARE of the urgent need for international cooperation to decrease the disturbance of the nitrogen cycle.

ENCOURAGE countries to coordinate their research, exchange solutions, and work together with the International Nitrogen Initiative and its Regional Centers, including participating in the International Nitrogen Conferences as recurrent opportunities to discuss scientific progress and issues related to policy.

CALL UPON the United Nations Environment Programme, as the environmental conscience of the United Nations system, to promote understanding of the nitrogen cycle, assess consequences of its disturbance, provide policy advice and early warning information, and catalyze and promote international cooperation. This should be done in conjunction and close cooperation with: the

Consultative Group on International Agricultural Research, the Food and Agriculture Organization, the World Health Organization and other appropriate United Nations organizations, stakeholders, the International Nitrogen Initiative and its Regional Centers, and other relevant organizations.

WELCOME the new International Assessment on Agricultural Science and Technology for Development and recommend that it should fully consider agricultural nitrogen issues.

Hereby declare their commitment to facilitate the optimization of nitrogen management in food and energy production, and environmental protection.

Call upon their national governments to optimize nitrogen management on a local, regional and global scale by:

Supporting further assessment of the nitrogen cycle, its benefits *for* humankind, and its consequences on human health and the environment.

Focusing efforts on increasing the efficiency and effectiveness of agricultural production and energy use, while decreasing the adverse effects of reactive nitrogen.

Promoting exchange of information and technology, raising public awareness, encouraging research and development of solutions to reactive nitrogen problems, and monitoring disturbances of the nitrogen cycle.

Taking action to enhance availability to reactive nitrogen as food, fiber and other basic needs in regions of nitrogen deficiency and avoid nitrogen pollution. This can be done by continual development and promotion of:

A code of good agricultural, forestry, and aquacultural practices, recognizing the needs for specific practices to be tailored to specific conditions and improving utilization of nitrogen in food production;

Strategies for sustainable energy use to prevent the formation of nitrogen oxides in fossil fuel combustion, and

Application of emission reduction technologies (e.g. wastewater treatment, selective catalytic reduction).