# Fact Sheet: Reactive Nitrogen



Nitrogen is literally all around us, including nearly 80 percent of each breath we take. Though it is the most plentiful element in the earth's atmosphere, it's unusable in its inert state and must be transformed into reactive nitrogen before plants and animals can use it to make protein, DNA, and other compounds essential for life.

100 years ago, chemists invented a process to turn the inexhaustible resource of inert nitrogen gas in the atmosphere into reactive, biologically available nitrogen in the form of ammonia. A few decades later, the widespread use of synthetic nitrogen to fertilize croplands had boosted global food production and helped to catapult world population from 1.6 billion to six billion during the 20th century.

More than half of the synthetic fertilizer ever produced has been made since 1985. Production of reactive nitrogen for chemical fertilizer has jumped from 10 million metric tons in the late 1950s to just over 100 million metric tons in 2008.

While the US, Western Europe, and Asia suffer the consequences of the release of too much reactive nitrogen into the environment, other regions like Africa suffer from limited access to chemical fertilizer, resulting in poor crop yields and worsening malnutrition.

## *Higher crop yields – a mixed blessing*

In the last 50 years, a dramatic increase in the use of chemical fertilizer and fossil fuels has been matched by an equally dramatic rise in nitrogen pollution. Reactive nitrogen helps grow food and biofuel crops. And almost all of it eventually escapes to the environment. While some ends up in the food we eat, most ends up in the atmosphere or in groundwater, freshwater, or ocean ecosystems, where it can cause a suite of environmental and health problems.

## *Growing impacts on human health and the environment*

A single molecule of reactive nitrogen can pack a wallop as it moves, or 'cascades' through the environment. It can worsen climate change, air and water pollution, coastal dead zones, and cause biodiversity loss.

## *Waterborne nitrogen*

The runoff of reactive nitrogen into water supplies creates aquatic dead zones where life is much diminished. These so-called "dead zones" occur because algae flourish in the presence of reactive nitrogen; algal blooms in turn deplete oxygen supplies as the algae eventually die, sink, and decompose, starving shrimp and fish of needed oxygen. Chemical fertilizer runoff from the Mississippi River watershed is the chief cause of an 8,000 square-mile "dead zone" in the Gulf of Mexico.[1] Fish, shrimp and other shellfish that are the mainstay for commercial fishing operations along the Gulf cannot survive in the dead zone's oxygen-deprived conditions. In addition to causing dead zones, nitrogen runoff poses a threat to human health. Drinking water with elevated nitrate levels may cause cancer.

## *Airborne nitrogen*

Reactive nitrogen is present in the atmosphere in gaseous and particulate form. These compounds can

[1] NASA Satellite Images of Dead Zone, 2004 http://www.nasa.gov/vision/earth/environment/dead_zone.html

cause a number of environmental problems, including:

- *Ground-level ozone* – When nitrogen oxides react with volatile organic compounds in the presence of sunlight, they form ground level ozone – or smog. Smog damages lung tissue and reduces lung function, especially among children, people who work or exercise outdoors and those with lung diseases like asthma. In addition, ozone can damage forests and reduces crop yields.
- *Acid rain* – Nitrogen oxides contribute to acid rain. Even ammonia, when deposited to ecosystems, will act as an acidifying agent. Acid rain damages water supplies and fisheries, as well as cars, buildings and other structures.
- *Air pollution* – Nitrogen oxides react with ammonia, other compounds and moisture in the air to form particles such as ammonium nitrate. When these particles are breathed into the lungs, they affect breathing and respiratory systems, damage lung tissue and cause premature death. Breathing particles can exacerbate respiratory ailments like emphysema and bronchitis and aggravate existing heart disease.
- *Climate change* – Nitrous oxide ($N_2O$) is a greenhouse gas 300 times more potent than carbon dioxide. Agriculture is responsible for about 80 percent of human-caused N2O. Fertilized fields, livestock operations, wetlands and coastal ecosystems that receive anthropogenic Nr all emit nitrous oxide to the atmosphere. Recent studies have shown that corn-ethanol production has aggravated, not lessened global warming.[2] Other minor human-caused sources of nitrous oxide emissions include vehicle emissions and fossil fuel combustion.

## US Environmental Impacts

- Coastal dead zones like those in the Gulf of Mexico threaten the Chesapeake Bay and Lake Erie, and are spreading rapidly worldwide. The number of known dead zones has risen steadily from 39 at the end of the 1960s to 405 in 2009.[3]
- Atmospheric deposition of nitrogen from fossil-fuel combustion is the largest single source of nitrogen pollution in much of the northeastern United States, leading to acid rain that contributes to the Chesapeake Bay dead zone.
- In the Mojave and Sonoran deserts of the southwestern U.S. deserts, non-native grasses like red brome thrive on atmospheric nitrogen pollution. The grasses provide dangerous fuel for wildfire and threaten native plant survival.[4]
- In California, invasive European grasses spurred by increased nitrogen emissions from auto exhaust are wiping out native wildflowers that don't adapt to nitrogen-rich soil. [5]

## Health Impacts

- Nitrogen oxides formed by fossil fuel combustion create ozone, otherwise known as smog. Tiny particles in smog damage lung tissue, increase the risk of cancer and cause heart disease. A recent 18-year study shows that long-term, low-level exposure to ozone can be lethal, increasing the

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[2] Biofools, Apr 8th 2009, The Economist, http://www.economist.com/science/displaystory.cfm?story_id=13437705
[3] Spreading Dead Zones and Consequences for Marine Ecosystems by Robert J. Diaz and Rutger Rosenberg, Science, August 15, 2008 http://www.sciencemag.org/cgi/content/abstract/321/5891/926
[4] Alien grasses in the Mojave and Sonoran Deserts, ML Brooks, TC Esque, Proceedings California Exotic Plant Pest Council Symposium, 2000, http://www.werc.usgs.gov/lasvegas/pdfs/Brooks_Esque_2000_Alien%20grasses%20in%20the%20Mojave%20and%20Sonoran.pdf
[5] UCR, the magazine of UC Riverside, Spring 2008: Volume 3, Number 2, A Global Warning, link at http://ucrmagazine.ucr.edu/cgi-bin/display.cgi?id=120

yearly risk of death from respiratory diseases by 40% to 50% in heavily polluted cities like Los Angeles, California.[6]
- Health impacts from increased nitrogen pollution include the consequences of ozone pollution on asthma and respiratory function, and potentially increased allergies and asthma. High nitrate levels in drinking water elevate the risk of blue-baby syndrome and may also spell increased risk of cancer and other chronic diseases.[7]

## *Global Impacts*

- In Asia, the growing use of coal and other fossil fuels results in the growing release of nitrogen oxides to the atmosphere. China is now the world's top user of synthetic fertilizers, applying 41 million tons in 2004, an 8 million-ton jump in just ten years. The number of dead zones along the Chinese coastline now equals those in North America and Western Europe.[8]
- In Latin America, the release of nitrogen into water supplies from inadequate sewage treatment threatens public health, while more rural areas grapple with agricultural runoff and the impacts on freshwater supplies and air quality that follow.
- Africa faces crises resulting from nitrogen deficiencies, as population growth and agricultural demands exceed the land's ability to provide. But even in Africa, there are highly localized areas that suffer sewage disposal problems or runoff from synthetic fertilizer.

## Solutions

International Nitrogen Initiative (INI) scientists say that by targeting key points in the creation, transport and use of reactive nitrogen, its benefits can be enhanced while its problems reduced. These key 'control' points include decreasing NOx emissions from fossil-fuel combustion, increasing nitrogen-uptake efficiency of crops, improving animal manure management strategies, and implementing advanced sewage treatment in selected regions.[9]

## *Farm Practice Solutions*

*Buffer strips* – Farmers who install buffer strips and trees between crops and waterways can filter reactive nitrogen and prevent it from seeping into groundwater or rivers and streams. The Conservation Security Program, which is part of the U.S. Farm Bill, provides incentives to farmers to do so.

*Winter cover crops* – Crops planted in the fall can capture nitrogen left over from the summer crop before it can be washed into the surrounding watershed by fall and winter rains or spring snowmelt. The next crop can use the captured nitrogen when the cover crop is killed prior to spring planting. Some grain crops such as winter wheat can also be planted in the fall.

*Precision farming* – New global positioning system (GPS) technologies allow farmers to vary the rate of fertilizer application across a given field precisely, tailoring the amount applied to a particular portion of a field to the amount needed by the plants growing there.

*Conservation tillage* – With conservation tillage, farmers grow crops with little or no plowing. Crops grown without tillage tend to lose less nitrate to the environment.

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[6] Low-level ozone exposure found to be lethal over time, by Thomas H. Maugh II, Los Angeles Times, March 12, 2009, http://articles.latimes.com/2009/mar/12/science/sci-ozone12

[7] Townsend, A. R., R. Howarth, F. A. Bazzaz, M. S. Booth, C.C. Cleveland, et al., 2003: Human health effects of a changing global nitrogen cycle, Frontiers in Ecology & Environment, 1, 240 – 46.

[8] UNEP and WHRC. Reactive Nitrogen in the Environment: Too Much or Too Little of a Good Thing. United Nations Environment Programme, Paris, 2007.

[9] Galloway et al., 2008—Science

*Biofuels developed with switchgrass* and other perennial crops can provide a less-polluting source of energy than corn grain-ethanol. Perennial crops store nitrogen in their roots over winter and thus require less nitrogen fertilizer, and they can also capture soil nitrogen over a greater part of the year than can annual crops. Moreover, after initial planting they require no tillage. Plantations of small trees like willow and poplar provide another source of fuel more environmentally benign than growing corn.[10]

*Burning solid biofuels* like switchgrass or small trees directly to create heat in buildings and factories provides an even more energy-efficient alternative to producing liquid ethanol. The energy gains from burning switchgrass are impressive—nine times more than by producing liquid corn-ethanol, with fewer environmental impacts. Sweden already heats a third of its homes and commercial businesses in this way, using biofuels grown on willow plantations.[11]

## Regional solutions and contacts

### *California*

Dairy farmers in the Central Valley are using a new tool that helps them improve groundwater quality and reduce chemical fertilizer use. The project includes installing flow meters in dairy lagoons to allow the controlled application of nitrogen-rich wastewater at beneficial levels, and using an in-field nitrogen test that tells farmers how much of this key nutrient they are applying to avoid water quality impacts. They then time applications to maximize crop uptake of nitrogen and prevent nitrate and salt migration into surface water or groundwater. In addition to improving water quality, farmers have reported saving tens of thousands of dollars annually by not having to purchase commercial nitrogen fertilizer for their crops, because they get all the nitrogen they need with their own dairy's manure. The University of California (UC) Cooperative Extension, the non-profit Sustainable Conservation, and dairy trade associations are overseeing the project. For more info go to www.suscon.org
Contact: Alex Karolyi, Associate Director of Communications, Sustainable Conservation
415-977-0380 ext. 317

### *Iowa*

The Iowa Soybean Association On-Farm Network® is comprised of growers who work together to study and improve nitrogen management and increase crop production profits. They compare current nitrogen management practices with alternatives in replicated strip trials across their fields, using precision technology such as GPS and combine yield monitors. They pool and share their data in local and statewide groups to learn what works - and what doesn't – to minimize nitrogen losses. Most growers involved have learned ways to reduce N use by 50 lbs. per acre or more without reducing profits. For more info, go to http://www.isafarmnet.com.
Contact: Mick Lane, On-Farm Network Communications Manager
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### *Montana*

While municipalities, including the Inland Empire Utility District in Southern California (http://www.ieua.org/departments/org/protection.html), and larger dairy operations have installed methane

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[10] Proceedings of the Scientific Committee on Problems of the Environment (SCOPE) International Biofuels Project Rapid Assessment, 22-25 September 2008, Gummersbach, Germany. R.W. Howarth and S. Bringezu, editors. 2009, p. 10
[11] ibid

digesters, the Huls Dairy in Corvallis, Montana shows how smaller farms are using the technology to cut their solid wastes in half. The 750-cow farm, Montana's largest dairy, is the first agricultural operation in the state to turn the usable methane gas from manure into electricity. Sewage lagoons are covered, reducing the amount of nitrous oxide that escapes.

### *Pennsylvania*

Farmers in the Chesapeake Bay region are tackling water quality challenges and rising chemical fertilizer and fuel costs. In southeastern Pennsylvania, 135 farmers taking part in the On Farm Network are using tools like the end-of-season cornstalk nitrate test, aerial imagery and replicated strip trials to learn whether too little, excess, or optimal nitrogen fertilizer was applied and to fine tune nitrogen management. Fertilizer application rates and timing, as well as conservation practices such as cover crops are also utilized to allow farmers to conserve nitrogen.
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