The Crisis of Nitrate Fertilizer in Groundwater

The first modern chemical fertilizers were developed from calcium nitrate at the beginning of the twentieth century (Russel). Since this initial introduction, large-scale uses of chemical fertilizer have been implemented in the United States; although primarily used for agricultural purposes, chemical fertilizers are also credited to the development of the American social ideal of lush, green lawns. The impacts of chemical fertilizers are devastating to waterways. Fertilizer runoff is an enormous contributing factor to the pollution of groundwater, which then flows into the aquifers that millions of Texans rely on for survival (Lant). It is crucial immediate measures are taken to limit the amount of nitrate entering the groundwater and to consciously make the widespread switch to alternative fertilizer methods in order to decrease the depletion of healthy resources. Without these necessary changes, people and the environment will continue to suffer.

Nitrate (NO_3) is the main ingredient in fertilizers which cause the pollution of groundwater. It is used in agriculture and by private individuals to stimulate rapid and significant agricultural plant or lawn growth, containing between 25 and 40 parts per million in chemical fertilizers (Nicholson). Naturally, as groundwater flows on the surface of the earth as runoff and begins to sink underground, soil and outcrop act as geological filters to remove potentially-harmful resources from the water before it collects. However, the nitrates in chemical fertilizer are "completely soluble and highly mobile in soil" (Davies). Thus nitrates easily sink underneath the earth's surface and through the 'filters' along with the groundwater: leaching into the collection basins and contaminating the aquifers. An overabundance of nitrate and nitrate-containing compounds from agricultural practices are therefore significant contributors to the increase in hazardous pollution, destroying our natural resources at detrimental rates ("Groundwater Contamination").

The use of nitrate fertilizer has increased as much as eight times since the 1960s (Khan). Globally, the increased use has cultivated a demand for research on the effects of surplus nitrates that are polluting the groundwater. One research experiment, conducted to examine the retention of NO_3 in soil and groundwater, simulated rainfall over a period of eight days. Fertilizer was added to the rainfall over a series of 12 simulations. At the end of the trials the nitrate retention rate reached 50.53% in the soil. The study also concluded "NO_3 residues mainly existed at the surface and in the bottom soil layers that may lead to dangerous pollution for surface and groundwater" (Khan). The high retention of nitrate coupled with its location on the surface and subsurface of the soil leads to excessive pollution leaching into the groundwater.

To their detriment, organisms which survive in or by groundwater are affected by excess nitrates. Often, fertilizers accumulate and create "plumes" of concentrated pollutants. Eutrophication, the nutrient pollution process which depletes oxygen, is the "number-one threat to water quality worldwide" (Denchak). Algal blooms form and eliminate the oxygen necessary for the survival of marine wildlife and ecosystems. Lack of oxygen negatively impacts water quality for habitats and for its use as drinking water (Khan). The consequence of eutrophication is the fact that entire water-reliant environments become so oxygen depleted by nitrates they become categorized as "dead zones." Plants, wildlife, and most microorganisms cannot survive. Life near the water is forcibly displaced or subject to death.

An excess of fertilizer in groundwater has also been proven to cause substantial health issues in people. When nitrates are high in concentration in drinking water (a fairly common occurrence), health disorders such as gastric cancer and birth malformations can result (Majumdar). The exponentially-serious consequences of nitrate fertilizer are "often overlooked as a source of nitrate exposure that can result in serious health effects in infants" ("Nitrates/Nitrites Poisoning"). Alarmingly, in studies which tested the groundwater around locations where infant methemoglobinemia is evident, the levels of nitrates were below the "safe level" regulations set by the Environmental Protection Agency (EPA). Despite the Safe Drinking Water Act of 1974 many prenatal infants face the risk of limb deficiencies (Blaisdell). As a result it is clear once unhealthy levels of nitrate enter the groundwater, it is too late. Thus, preventative measures must be taken to stop groundwater pollution at the source.

Eliminating excess nitrates is costly and inefficient after the initial introduction and subsequent infiltration of chemical fertilizer after it reaches surface water. According to the National Resources Defense Council, "once polluted, an aquifer may be unusable for decades, or even thousands of years" (NRDC). Yet according to EPA estimates, "our nation's aging and easily overwhelmed sewage treatment systems also release more than 850 billion gallons of untreated wastewater each year" (Denchak). Thus it is crucial for regulations to be strengthened to stop the heavy pollution of groundwater before it can enter the stream of water systems. One current regulation in place is the Clean Water Act, originally established in 1972 to oversee and reduce the pollution in major bodies of water. The act establishes standards to regulate the amount of pollution flowing into surface water by making it illegal for certain parties to discharge pollutants directly into water streams ("Federal Water Pollution"). Although the law has been beneficial in reducing pollution from point-source industrial manufacturers, it does not specify limitations on the amount of nitrate pollution in surface runoff. As a result, significant amounts of pollution due to fertilizer still flows unrestricted into groundwater. Subsequently, the contamination is spread to small rivers, streams, and larger bodies of water. Regulation must be advanced to ensure the individual's pollution of nitrate fertilizer is limited and more regulated in the location of discharge in order to make groundwater safe.

Alternative methods of fertilizer are also needed to decrease nitrate pollution by shifting away from chemicals. As stated by the United Nations, "policies to change farmer behaviour and incentivize the adoption of good practices are key to preventing pollution at the source" ("Water Pollution from Agriculture"). Changing agricultural practices and using alternative methods to traditional fertilizer, such as controlled-release formulations, would significantly decrease the amount of nitrates entering the groundwater (Carbeck). Controlled-release systems lessen the need for farmers to use large quantities of chemical fertilizer and it limits the excess from flowing into surface water. Another sustainable option is using "set-asides;" the transferring of developed farming land into more sustainable and natural applications. This kind of sustainable farming limits the need for mass use of chemical fertilizers ("Water Pollution from Agriculture"). Individual acts are also important. Small, personal changes can assist in protecting groundwater, such as composting and utilizing grass clippings rather than chemical fertilizers (Kanuckel). Lush lawns can also still be achieved by growing plants native to the garden's location.

The use of nitrate chemical fertilizer detrimentally affects the health of groundwater and spreads to hurt both people and wildlife. However, the devastation can be decreased with more stringent regulations and the promotion of alternative agricultural methods. Moving away from the use of chemical fertilizer will take time and effort, but it's absolutely essential in order to conserve the health of groundwater. Small changes within our communities will add up to make a big difference -- which is exactly what is needed to protect our groundwater and the organisms which rely on it.

Bibliography

Blaisdell, Julie. Prenatal exposure to nitrate in drinking water and the risk of congenital anomalies, Environmental Research, Volume 176, 2019, 108553, ISSN 0013-9351, https://doi.org/10.1016/j.envres.2019.108553. (http://www.sciencedirect.com/science/article/pii/S0013935119303500)

Carbeck, Jeff. "Smarter Fertilizers Can Reduce Environmental Contamination." *Scientific American*, 1 July 2019, www.scientificamerican.com/article/smarter-fertilizers-can-reduce-environmental-contamination/.

Davies, Sara, et al. "Environmental Impacts of Lawn Fertilizer." *Vermont Legislative Research Shop*, The University of Vermont, 22 Feb. 2001, www.uvm.edu/~vlrs/doc/lawnfert.htm.

Denchak, Melissa. "Water Pollution: Everything You Need to Know." *Natural Resources Defense Council*, 13 Mar. 2020, www.nrdc.org/stories/water-pollution-everything-you-need-know.

Dowell, Tiffany. "Clean Water Act Application to Groundwater: Keeping Score." *Texas Agriculture Law*, 20 Mar. 2019, agrilife.org/texasaglaw/2018/12/10/clean-water-act-application-to-groundwater-keeping-score/.

Gao, Yang. "Groundwater Nitrogen Pollution and Assessment of its Health Risks: a Case Study of a Typical Village in Rural-Urban Continuum, China." *PloS one* vol. 7,4 (2012): e33982. doi:10.1371/journal.pone.0033982. (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3326077/)

"Groundwater Contamination." *The Groundwater Foundation*, www.groundwater.org/get-informed/groundwater/contamination.html.

"History of the Clean Water Act." Laws & Regulations, Environmental Protection Agency, 8 Aug. 2017, www.epa.gov/laws-regulations/history-clean-water-act.

Kanuckel, Amber. "8 Best Homemade Garden Fertilizers." *Farmers' Almanac*, 10 Jan. 2020, www.farmersalmanac.com/8-homemade-garden-fertilizers-24258.

Khan, M. (2017). Fertilizers and Their Contaminants in Soils, Surface and Groundwater. Reference Module in Earth Systems and Environmental Sciences. 10.1016/B978-0-12-409548-9.09888-2. https://www.researchgate.net/publication/315607995_Fertilizers_and_Their_Contaminants_in_Soils_Surface_and_Groundwater/citation/download.

Lant, Karla. "Managing and Studying Texas's Edwards Aquifer." *Environmental Monitor*, Fondriest, 2 Jan. 2019, www.fondriest.com/news/managing-and-studying-texass-edwards-aquifer.htm.

Majumdar, Deepanjan, and Navindu Gupta. *Nitrate Pollution of Groundwater and Associated Human Health Disorders.* file:///media/fuse/drivefs-eb6685752e65f5f6b13f4a2bc96c3e6e/root/Nitrate_pollution_of_groundwater_and_ass.pdf.

Vidal, M. Spatial and temporal hydrochemical changes in groundwater under the contaminating effects of fertilizers and wastewater, Journal of Environmental Management, Volume 60, Issue 3, 2000, Pages 215-225, ISSN 0301-4797, https://doi.org/10.1006/jema.2000.0379. (http://www.sciencedirect.com/science/article/pii/S0301479700903797).

Nitrate Accumulation and Leaching in Surface and Groundwater Based on Simulated Rainfall Experiments. Wang H, Gao Je, Li Xh, Zhang Sl, Wang Hj (2015) Nitrate Accumulation and Leaching in Surface and Groundwater Based on Simulated Rainfall Experiments. https://doi.org/10.1371/journal.pone.0136274.

(https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0136274)

"Nitrates/ Nitrites Poisoning."

www.atsdr.cdc.gov/csem/nitrate_2013/docs/nitrate_patient-education.pdf.

Rinkesh. "Causes, Effects and Solutions of Groundwater Pollution." *Conserve Energy Future*, 18 Mar. 2019,

www.conserve-energy-future.com/causes-effects-solutions-groundwater-pollution.php.

Russel, D. A., and G. G. Williams. 1977. History of Chemical Fertilizer Development 1. doi:10.2136/sssaj1977.03615995004100020020x. (https://dl.sciencesocieties.org/publications/citation-manager?action=prev&program=zt&ids[]=sssaj/41/2/SS0410020260).

Serpil, Savci. Investigation of Effect of Chemical Fertilizers on Environment, APCBEE Procedia, Volume 1, 2012, Pages 287-292, ISSN 2212-6708, https://doi.org/10.1016/j.apcbee.2012.03.047. (http://www.sciencedirect.com/science/article/pii/S2212670812000486)

Steven S. Nicholson, CHAPTER 68 - Nitrate and Nitrite Accumulating Plants, Veterinary Toxicology, Academic Press, 2007, Pages 876-879, ISBN 9780123704672, https://doi.org/10.1016/B978-012370467-2/50165-6. (http://www.sciencedirect.com/science/article/pii/B9780123704672501656)

"Water Pollution from Agriculture: a Global Review." *International Water Management Institute*, Food and Agriculture Organization from the United Nations, www.fao.org/3/a-i7754e.pdf.