Fritz Haber's Ammonia Process: The Effect on World War I and on Contemporary Agriculture

INTRODUCTION

Nitrates are indispensable for agricultural use and explosive manufacture. In 1898, William Crookes, a prominent English chemist and physicist in his time, warned the British Association for the Advancement of Science that the limit of global food production was on the horizon unless scientists developed a synthetic nitrogen fertilizer.[1] At that time, essentially all nitrates came from mines in Chile.

When World War I began, the British navy controlled of the seas, making it impossible for Germany to import Chilean nitrates. In addition to being vital for crop production during World War I, nitrates were also essential to manufacture explosives such as dynamite, varieties of gunpowder, high explosive bursting charges for shells, torpedoes and depth bombs using trinitrotoluene (T.N.T.), and nitro-starch used in hand grenades.[2]

THE HABER PROCESS (*Incomplete)*

Around 1910, Fritz Haber, a professor of chemistry at the University of Karlsruthe built a laboratory reactor for reacting nitrogen and hydrogen to make ammonia at high pressure. Nitrogen and hydrogen gas are combined at 450-500º Celsius and 250 atmospheres with porous iron catalyst Fe_3O_4. Under high pressure and medium temperature, nitrogen and hydrogen gas

PRAISED OUTCOMES OF THE HABER PROCESS – AGRICULTURAL FERTILIZERS

Nitrates derived from the Haber process have revolutionized agriculture in the past century. In the past, farmers used natural fertilizers such as manures and ground animal bones to boost crop growth. However, the decreasing availability of high-nitrogen natural fertilizes was ominous for the future of food production.

[1] Anthony N. Stranges, "Farrington Daniels and the Wisconsin Process for Nitrogen Fixation," *Social Studies of Science*, Vol. 22, No. 2, Symposium on 'Failed Innovations'. (May 1992), pp. 317-337.
[2] Grinell Jones, "Nitrogen: Its Fixation, Its Uses in Peace and War," *The Quarterly Journal of Economics,* Vol. 34, No. 3. (May 1920), pp. 391-431.

Fertilizers utilizing nitrogen fixed by the Haber process are indispensable for food production today and feed an estimated two billion people.[3] High nitrogen fertilizers benefit plant growth in several ways: "by replenishing nutrients used by growing plants, increasing the amount of biomass in the soil, which improves moisture retention and nutrient use efficiency, and by enabling the adoption of more productive varieties of cereal."[4]

Thirty years ago, China had could not yield more crop to feed her growing population by using natural fertilizers alone. When China opened to the West in the 1970's China embraced the Haber process and purchased thirteen of the world's largest modern ammonia plants. Today, China is the largest user of nitrogen fertilizers; Asia accounts for 50% of world fertilizer consumption.[5]

More recently, synthetic nitrogen fertilizers play an especially important role in the Green Revolution, an effort largely funded by the Ford Foundation and the Rockefeller Foundation to dramatically improve agriculture in developing countries in an effort to alleviate world hunger.[6] Scientists engineered "high yielding" strains of maize, wheat, and rice which outperform normal strains due to an engineered high nitrogen-absorbing potential. The high yielding strains of crops have increased cereal production in developing countries by over 80%, whereas expansion of cultivated land has only increased cereal production by 20%.[7] In the past four decades, developing countries have markedly increased fertilizer use, accounting for 12% of total fertilizer consumption in 1960 and 60% in 1999.[8]

The success of the Haber process is a global phenomenon – fertilizers use in 2000 400% greater than fertilizer use in 1940.[9] Currently fertilizer factories produce 100 million tons of nitrogen per year

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[3] Dan Charles, *National Public Radio*, "The Tragedy of Fritz Haber," 11 July 2002. <http://www.npr.org/programs/morning/features/2002/jul/fritzhaber/> (11 April 2007)
[4] Emily Matthews and Allen Hammond, "Nutrient Overload: Unbalancing the Global Nitrogen Cycle," *Critical Consumption Trends and Implications – Degrading Earth's Ecosystems,* 1999. <http://www.pdf.wri.org/critcons_food.pdf> (11 April 2007)
[5] Dan Charles, *National Public Radio*, "The Tragedy of Fritz Haber," 11 July 2002. <http://www.npr.org/programs/morning/features/2002/jul/fritzhaber/> (11 April 2007)
[6] Actionscience.org, "Interview with Norman Borlaug," *Biotechnology and the Green Revolution,* November 2002. <http://www.actionbioscience.org/biotech/borlaug.html> (25 April 2007)
[7] *Ibid.*
[8] Emily Matthews and Allen Hammond, "Nutrient Overload: Unbalancing the Global Nitrogen Cycle," *Critical Consumption Trends and Implications – Degrading Earth's Ecosystems,* 1999. <http://www.pdf.wri.org/critcons_food.pdf> (11 April 2007)
[9] Raymond Zmaczynski, "The Effect of the Haber Process on Fertilizers," n.d., <http://www.princeton.edu/~hos/mike/texts/readmach/zmaczynski.htm> (11 April 2007)

worldwide. Scientists estimate one half of the nitrogen found in water, soil, and human bodies come from ammonia made by the Haber process. [10]

Fritz Haber received the Nobel Prize 1918 for his contribution to agriculture.[11]

CRITICIZED OUTCOMES OF THE HABER PROCESS

The Nobel Prize awarded to Fritz Haber was met with criticism. Many believed awarding Haber, the inventor of chemical gas warfare, the Nobel Prize for developing a process for the purposes of creating nitrates for explosives manufacture was particularly untimely and "ill-advised" so soon after World War I.[12]

The Haber process initiated a century of tremendous nitrate use. However, plants are limited to the amount of nitrogen they can absorb due to availability of other essential nutrients (this is termed 'nitrogen saturation), as much as half of the reactive fertilizer nitrogen added to fertilizers is released back into the environment, which is easily transferred between terrestrial, freshwater, and marine ecosystems, as well as the atmosphere. Fecal matter from humans and livestock is also a formidable nitrate source; an estimated 32 million tons of nitrogen is deposited into the environment from livestock manure alone.[13] Today, these excess nitrates are a major cause of "every environmental issue,"[14] including: pollution in drinking water; plant life damage; and pollution in lakes, rivers, and estuaries.

Reduced forms of nitrogen such as ammonium ions are an overly-effective fertilizer. Grasslands greatly decrease in species diversity as nitrogen-responsive out-compete less-responsive plants. Nitrates and other oxidized forms of nitrogen acidify natural ecosystems; this leaches soils of calcium, potassium,

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[10] Dan Charles, *National Public Radio*, "The Tragedy of Fritz Haber," 11 July 2002. <http://www.npr.org/programs/morning/features/2002/jul/fritzhaber/> (11 April 2007)

[11] *Nobelprize.org*, "Fritz Haber –Nobel Prize in Chemistry 1918," n.d., <http://nobelprize.org/nobel_prizes/chemistry/laureates/1918/haber-bio.html> (19 April 2007)

[12] Jerome Alexander, "The Award of the Nobel Prize to Professor Haber," *Science,* New Series, Vol. 51, No. 1318. (2 April 1920), p. 348.

[13] Emily Matthews and Allen Hammond, "Nutrient Overload: Unbalancing the Global Nitrogen Cycle," *Critical Consumption Trends and Implications – Degrading Earth's Ecosystems,* 1999. <http://www.pdf.wri.org/critcons_food.pdf> (11 April 2007)

[14] Charles, *National Public Radio*, "The Tragedy of Fritz Haber," 11 July 2002. <http://www.npr.org/programs/morning/features/2002/jul/fritzhaber/> (11 April 2007)

and magnesium, and impairs soil ability to bind heavy metals, all of which are essential plant nutrients. Acidification of soil also makes plants vulnerable to insects and mildew.[15]

Excess nitrogen also dramatically changes aquatic ecosystems through eutrophication. Nitrogen is utilized by nitrogen fixing organisms such as algae and phytoplankton, without nitrogen as a limiting nutrient, algae and phytoplankton utilize surrounded dissolved oxygen and possibly develop into huge algal and phytoplankton blooms (also known as red tides or brown tides) that block sunlight from deeper waters. The blooms sink to the ocean floor when dead and their decomposition consumes oxygen in deeper waters. Hypoxia causes widespread marine death that harms the ecosystem as well as local fishing industries. One of the most severe instances of hypoxia is the infamous "Dead Zone" in the Gulf of Mexico, the cause of which has been traced back to excess nitrogen and phosphorous from human activities washed into the Mississippi River. The dead zone not only exhibits an extreme lack of biodiversity, but also poses a threat to the four billion dollar per year seafood economy of the gulf.[16]

Excess nitrogen also contaminates drinking water supplies through eutrophication – water in eutrophication systems is not suitable for drinking or recreation. Nitrates in drinking water pose the threat of "blue-baby" syndrome – infants with nubile red blood cells cannot deliver oxygen sufficiently in significant presence of nitrates.[17]

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[15] Matthews and Allen Hammond, "Nutrient Overload: Unbalancing the Global Nitrogen Cycle," *Critical Consumption Trends and Implications – Degrading Earth's Ecosystems,* 1999. <http://www.pdf.wri.org/critcons_food.pdf> (11 April 2007)
[16] Sierra Club, "The Dead Zone in the Gulf of Mexico," n.d., <http://www.sierraclub.org/cleanwater/waterquality/deadzone.asp> (23 April 2007)
[17] Matthews and Allen Hammond, "Nutrient Overload: Unbalancing the Global Nitrogen Cycle," *Critical Consumption Trends and Implications – Degrading Earth's Ecosystems,* 1999. <http://www.pdf.wri.org/critcons_food.pdf> (11 April 2007)