

A Century of Synthetic Fertilizer: 1909-2009

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The Chemical Vision 1840

In 1840 Justus von Liebig (1803-1873) presented his vision for a new agriculture, “a rational system of Agriculture”, to be based on “the application of scientific principles”. He asserted that “This knowledge we must seek from chemistry” (Liebig, 1840, p.iiv-iv). It was not until seven decades later that two German chemists were on the threshold of realizing Liebig’s vision of chemical farming, and thereby transforming agriculture.

The Successful Experiment 1909

Fritz Haber approached German chemical company BASF in 1908 “with the suggestion to attempt the technical synthesis of ammonia from hydrogen and nitrogen under high pressure” (Bosch, 1932, p.197). The following year, with Carl Bosch as a witness (Leigh, 2004), Haber reported triumphantly that on the 2nd of July 1909: “we began operating the large ammonia apparatus ... and were able to keep its uninterrupted production for about five hours. During this whole time it had functioned correctly and it produced liquid ammonia” (Haber, quoted in Smil, 2001, p. 81).

Carl Bosch’s role was to extend Haber’s “high pressure synthesis” of ammonia from the laboratory proof-of-concept “to an industrial scale with a view to its economic application” (Bosch, 1932, p.197).

Haber and Bosch achieved the conversion of nitrogen and hydrogen to ammonia ($N_2 + 3H_2 \rightarrow 2NH_3$). They employed a cast of “hundreds of scientists”, pressures of “100 atmospheres and higher”, and “temperatures of not less than 400-450°C” (Bosch, 1932, p.197, 208). Theirs was a “brute force” method (Leigh, 2004, p.22). They had achieved what a variety of microscopic organisms can and do achieve at farmyard temperatures and pressures each day. The contrast between the industrial and the natural method is stark (Table 1).

Plants and animals cannot “fix”, capture, nitrogen directly from the air - of which nitrogen is the chief component. The web of life has heretofore relied primarily on the nitrogen capturing capabilities of micro-organisms, often in a symbiotic relationship with plants.

The ammonia produced by the Haber-Bosch process was not merely bio-available

Table 1: A comparison of two methods of nitrogen fixation.

NITROGEN FIXATION	Biological	Chemical
Temperature	Ambient temperature	450°C
Pressure	Atmospheric pressure	100+ atmospheres
Set-up costs	Free	\$millions
Scale	Microscopic	Hectares
Cost of output	Free	~\$80/tonne
Input	Air	Coal or natural gas
Timeline	Since billions of years ago	Since 1909
Process description	“natural”	“brute force”
Process knowledge	“mystery”	well understood
Annual Nitrogen Fixation	~100 million tonnes pa	~100 million tonnes pa

and capable of feeding food crops, it was also a product that could directly feed a war machine. Yes nitrogen is an essential ingredient for life and it is an essential component of amino acids, but it can also be used as a feedstock for ammunition. This dual-use process suited to both guns and grain, was rapidly commercialized in Germany. The nitrogen industrial complex at Oppau, employing the new Haber-Bosch process of converting nitrogen and hydrogen to ammonia opened in 1913 (Nobel Foundation, 1966).

WW1 (1914-1918)

Allied troops in WW1 nicknamed their German military adversary as “Fritz” and “the Bosch”. Perhaps it is just irony, or perhaps it was with chemistry-aforethought? In any event, it was the handiwork of Fritz Haber and Carl Bosch that contributed directly to some of the estimated 10 million lives lost in WW1. Writing just after the end of the war, Hall observed that “commercially great advances in the processes of manufacturing

synthetic nitrogen compounds from the atmosphere were stimulated by the war demand for explosives” (1920, p.x). Bosch related that “the Oppau works were bombed night after night” (Bosch, 1932, p. 224).

The 1918 Nobel Prize award for Chemistry to Fritz Haber for the synthesis of ammonia was both controversial and unpopular. It was not just that the Haber-Bosch process had prolonged the war - long after German ports were blockaded - but also because Haber had “developed a new weapon - poison gas, the first example of which was chlorine gas - and supervised its initial deployment on the Western Front at Ypres, Belgium, in 1915” (Bowden, 1997, p.20, 22). Haber was “considered in some circles to be a war criminal” (Leigh, 2004, p. 162). Haber’s “name appeared on the first list of war criminal sought for extradition by the Allies, and he hid for a short time in Switzerland” (Smil, 2001, p.228).

Intensive Agriculture

Haber has been described as “the progenitor of the basis for modern intensive agriculture” (Leigh, 2004, p.163). His process of fixing nitrogen underpins industrial scale agriculture by providing cheap fertilizer in abundance. “Since the 1930s the Haber-Bosch process has been the only significant industrial method of fixing nitrogen” (Leigh, 2004, p.157). The amount of nitrogen fixed by Haber-Bosch is now estimated to equate to the amount fixed by biological systems - both equal approximately 100 million tonnes per annum (Leigh, 2004).

Nitrogen in the form of synthetic fertilizers can be applied directly as ammonia (82.2% nitrogen) to fields, but mostly ammonia is further processed, and applied to fields as ammonia-derivative products. Synthetic nitrogenous fertilizers derived from Haber-Bosch ammonia include urea, ammonium nitrate, calcium ammonium nitrate, urea ammonium nitrate, ammonium chloride, and ammonium sulphate (listed here in order of nitrogen content, greater to lesser, 46% to 20%) (IFADATA, 2009a).

The Birth of Bio-Dynamic (1924) & Organic Agriculture (1940)

An early response to the proliferation of chemical agriculture was Rudolf Steiner’s Agriculture Course. The course was a series of eight lectures, delivered in June 1924 to a group of Anthroposophic farmers, at their invitation, at Koberwitz (Poland) (Steiner, 1924). The year prior to the course, Steiner “for the first time gave the procedures for making the bio-dynamic fertilizer preparations” in Switzerland (Pfeiffer, 1956, p.3). These events in Switzerland and Poland initiated the foundational stirrings of “a world-embracing agricultural movement” (Pfeiffer, 1956, p.3). The Agriculture Course was delivered only once. Steiner died just nine months later on 30 March 1925 (Hemleben, 1963). Ehrenfried Pfeiffer comments that “At the time of the Agriculture Course the bio-dynamic direction of thought, and agricultural chemistry, stood opposed (Pfeiffer, 1956, p. 6).

Across the English Channel, at the outset

of WW2, Lord Northbourne coined the term “organic farming” and endorsed the bio-dynamic method. Northbourne wrote that “the ‘bio-dynamic method’, evolved in accordance with the recommendations of the late Dr Rudolf Steiner. The ... method has been highly developed in the course of some fifteen years' work on the Continent, and its effectiveness may be said to be proved” (Northbourne, 1940, p.173)

Northbourne identified a contest of “organic versus chemical farming” (Northbourne, 1940, p.81). He proposed that “The main weakness of [the chemist’s] position as the farmer’s adviser” is that “no chemist has ever analysed or described in chemical terms a living creature, however humble; and there is not the slightest chance that he ever will” (p. 159-160).

In his call for action, Northbourne expressed his version of what is now

termed the precautionary principle: “if we waited for scientific proof of every impression before deciding to take any consequential action we might avoid a few mistakes, but we should also hardly ever decide to act at all. In practice, decisions about most things that really matter have to be taken on impressions, or on intuition, otherwise they would be far too late” (Northbourne, 1940, p.41).

Synthetic Fertilizer - Final Solution or New Problem?

The amount of synthetic nitrogenous fertilizer applied to agriculture is growing exponentially (Fig.1). It has been asserted that the world’s population expansion of the twentieth century “would not have been possible without the synthesis of ammonia” (Smil, 2001, p.xiiv). Smil may be right, but since he does not produce his evidence the claim remains just that. By way of contrast, a meta-analysis of many

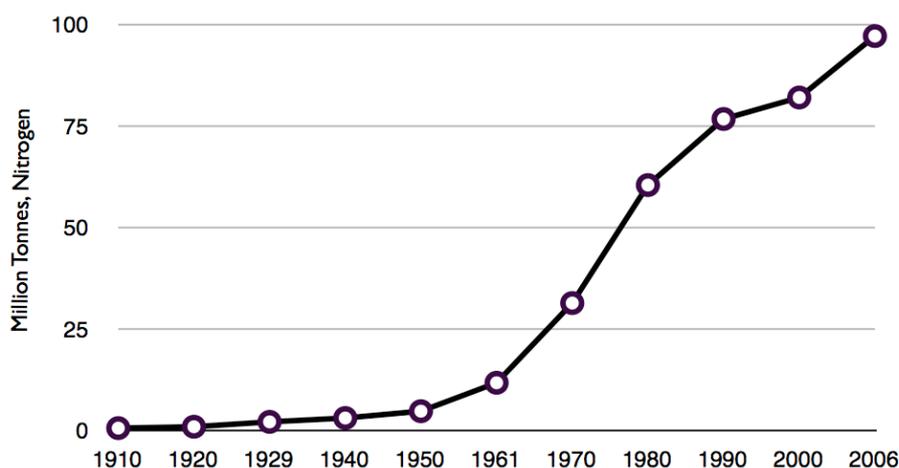


Figure 1: Global consumption of nitrogen fertilizers, in million tonnes of nutrient. (Data sources: Smil (2004) data 1910 to 1950; (IFADATA, 2009b) data 1961 to 2006).

comparative studies reveals that a global switch to organic agriculture would increase the world's food supply (Badgley, et al., 2007).

The early concerns, of Steiner's Koberwitz farmers in 1924, of Lord Northbourne in 1940, of Herbert Koepf in 1965 and in 1977, were concerns for the health of the soil, seeds, plants, animals, humans and the environment. These concerns remain live issues today. There is a long litany of knock-on effects from pumping massive amounts of synthetic nitrogen products into the food chain. In the shadow of massive algal blooms in waterways, and the proliferation of ocean dead zones, concerns about synthetic nitrogenous fertilizers now have a greater immediacy than ever.

When Fritz Haber collected his 1918 Nobel Prize for Chemistry he conceded that "it may be that this solution is not the final one. Nitrogen bacteria teach us that Nature, with her sophisticated forms of chemistry of living matter, still understands and utilizes methods which we do not as yet know how to imitate" (Haber, 1920, p. 339). Carl Bosch also won a Nobel Prize for that work on nitrogen fixation, his being a 1931 award. Meanwhile, despite two Nobel Prizes and much further research, "What is sure is that the chemistry of biological nitrogen fixation is almost as much a mystery as ever it was" (Leigh, 2004, p.183).

"I will solve the Nitrogen Problem" Bosch declared (cited by Smil, 2001, p.86). However Bosch's 'solution' runs headfirst

into the Law of Unintended Consequences. Leigh observes that "in the long run, the 'solution' was going to bring problems of a different kind that could not have been envisaged" (2004, p.157). Did Haber and Bosch solve a problem, or did they create a problem - in this the centenary year of the Haber-Bosch process, the question persists.

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