5. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

5.1 PRODUCTION

Ammonia is both a natural and a manufactured chemical. It is a key intermediate in the nitrogen cycle in nature, and microbial production is a major source of ammonia in the world. Recent reports, however, have emphasized the significant influence that humans are having on the global nitrogen budget. At the beginning of the 20th century, most nitrogen was fixed into usable forms (e.g., NH_3) by lightning strikes and microbial nitrogen fixation, with an estimated 90–130 teragrams (Tg; 1 teragram is equivalent to one million metric tons) fixed per year. Human production of fixed nitrogen (NH_3) is now estimated to be 140 Tg N per year, an amount that is similar to non-anthropogenic sources (NSF 1999; Socolow 1999). This increase in human-related ammonia emissions is considerably higher than earlier estimates of the total annual commercial production of ammonia, wherein the anthropogenic emission of ammonia represented approximately 1–5% of nature's global ammonia emission budget (ApSimon et al. 1987; Buijsman et al. 1987; Crutzen 1983; Galbally 1985; Rosswall 1981; Socolow 1999).

The largest amount of naturally produced ammonia is thought to arise from soil. Ammonia from decomposing animal excreta probably accounts for the largest proportion of the ammonia produced, with the decay of organic materials from plants, dead animals, and the like contributing significant amounts (Crutzen 1983; Dawson 1977; Dawson and Farmer 1984; Galbally 1985; Irwin and Williams 1988).

Manufacture of ammonia within the United States has declined steadily over the past several years, with one of the outcomes being the closure of several production plants. The U.S. annual commercial production capacity for ammonia was 16.6 million metric tons in 1999 (CMR 1999), 15.7 million metric tons in 2000 (SRI 2000), but only 9.5 million metric tons in 2001 (Kramer 2002). Production levels increased slightly to 10.8 million metric tons in 2002 (Kramer 2003). High natural gas costs, along with weather-related decreases in demands, contributed to the lower production output in the years leading up to 2002. However, natural gas prices became lower in 2002, and ammonia production increased that year. In 1999, four plant closings eliminated a combined production capacity of 1.2 million tons, some of which was replaced by new facilities (CMR 1999). In 2000, an additional seven plants were completely shut down, and five plants were partially closed due to market conditions (Kramer 2000). In 2002, the largest producer of ammonia in the United States filed for Chapter 11 bankruptcy, leading to the permanent closing of three large production plants (with a combined production capacity of just over 980,000 metric tons) (Kramer 2003).

While ammonia production decreased over the past few years and some ammonia plants were closed, the states and companies that have historically produced most of the ammonia remained relatively constant. In 2000, 2001, and 2002, Louisiana, Oklahoma, and Texas were the three major producing states, contributing over 50% of the total U.S. ammonia production. Six companies (Farmland Industries Inc., Terra Industries Inc., PCS Nitrogen Inc., Agrium Inc., CF Industries Inc., and Koch Nitrogen) produced 73% of the nation's ammonia in 2002 (Kramer 2003).

There are 2,338 facilities that manufacture or process ammonia in the United States (Table 5-1). The amounts manufactured or processed range from relatively small production activities (from 0 to 99,999 pounds) in Hawaii to very large formulation and processing activities (up to 499,999,999 pounds) in Alaska, Florida, Iowa, Kansas, Louisiana, Nebraska, and Texas (TRI01 2003). As mentioned previously, three states, Louisiana, Oklahoma, and Texas, produce more than 50% of the nation's total NH_3 output.

The major method for commercial production of anhydrous ammonia is a modified Haber-Bosch process. This process was first demonstrated in 1909 (Kramer 2000), and was commercially developed in 1913 in Germany. The first U.S. plant to use this process was built in Syracuse, New York, in 1921 (DOI 1985). The basic Haber-Bosch methodology was still responsible for 98% of the industrially produced ammonia in the United States in 1979 (EPA 1980; HSDB 2003). In this process, nitrogen (obtained from the atmosphere) and hydrogen (obtained from natural gas) are mixed together in a 1 to 3 ratio and passed over a catalyst at high pressure and high temperature. The ammonia thus produced is collected by various means, and any unreacted feed gases are recirculated through the reactor.

Small amounts of ammonia are produced industrially as a by-product of the coking of coal. The largest proportion of industrial ammonia production occurs in areas where natural gas is cheap and plentiful because ammonia is synthesized using natural gas. Large pipelines stretching from Louisiana to Nebraska and from Texas to Minnesota carry anhydrous ammonia from its site of production to agricultural areas where it is used as fertilizer (LeBlanc et al. 1978). These pipelines are capable of transporting or storing 3 million metric tons of ammonia per year, and have a storage capacity of 1.5 million metric tons (Kramer 2000, 2003). Ammonia can also be shipped in large refrigerated, low

Table 5-1. Facilities that Produce, Process, or Use Ammonia

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
AK	6	1,000	499,999,999	1, 3, 4, 5, 6, 10, 11, 12
AL	69	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13
AR	45	100	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
AS	1	10,000	99,999	11
AZ	16	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
CA	161	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
CO	15	0	999,999	1, 5, 6, 7, 9, 11, 12
CT	24	0	999,999	1, 2, 3, 5, 6, 7, 8, 10, 11, 12
DC	2	100,000	999,999	12
DE	14	0	999,999	1, 3, 5, 6, 7, 11, 12
FL	54	100	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
GA	87	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
HI	6	0	99,999	1, 3, 5, 6, 10, 12, 13, 14
IA	54	100	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
ID	16	100	49,999,999	1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13
IL	108	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
IN	72	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
KS	36	100	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14
KY	34	100	9,999,999	1, 2, 3, 5, 6, 7, 9, 10, 11, 12, 13, 14
LA	73	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13, 14
MA	34	0	999,999	1, 2, 3, 5, 6, 7, 10, 11, 12
MD	16	1,000	999,999	1, 3, 5, 6, 7, 8, 10, 11, 12, 13, 14
ME	13	0	999,999	1, 2, 3, 5, 6, 10, 11, 12, 13
MI	72	0	999,999	1, 2, 3, 5, 6, 7, 8, 10, 11, 12, 13, 14
MN	39	0	9,999,999	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13
MO	50	1,000	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
MS	44	100	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
MT	12	0	9,999,999	1, 3, 5, 6, 10, 11, 12
NC	86	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
ND	7	0	999,999	1, 3, 5, 6, 10, 11, 12
NE	35	100	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
NH	14	0	9,999,999	1, 3, 4, 5, 6, 7, 10, 11, 12
NJ	58	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
NM	6	100	99,999	1, 5, 7, 11, 12
NV	11	100	9,999,999	1, 2, 3, 4, 5, 6, 10, 11, 12, 13
NY	63	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
OH	123	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
OK	26	100	99,999,999	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14

Table 5-1. Facilities that Produce, Process, or Use Ammonia

State[a]	Number of facilities	Minimum amount on site in pounds[b]	Maximum amount on site in pounds[b]	Activities and uses[c]
OR	46	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
PA	108	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
PR	15	100	999,999	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12
RI	13	0	9,999,999	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12
SC	64	0	999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
SD	4	1,000	999,999	1, 5, 10, 11
TN	56	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
TX	191	0	499,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
UT	28	100	9,999,999	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12
VA	57	0	49,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
VI	1	100,000	999,999	1, 2, 3, 5, 6, 10, 12
VT	2	1,000	99,999	1, 5, 11, 12
WA	38	0	99,999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13
WI	68	100	999,999	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
WV	33	0	49,999,999	1, 3, 5, 6, 7, 9, 10, 11, 12, 13
WY	12	0	99,999,999	1, 3, 4, 5, 6, 7, 10, 13

Source: TRI01 2003 (Data are from 2001)

[a]Post office state abbreviations used
[b]Amounts on site reported by facilities in each state
[c]Activities/Uses:

1. Produce
2. Import
3. Onsite use/processing
4. Sale/Distribution
5. Byproduct
6. Impurity
7. Reactant
8. Formulation Component
9. Article Component
10. Repackaging
11. Chemical Processing Aid
12. Manufacturing Aid
13. Ancillary/Other Uses
14. Process Impurity

pressure tanks (holding between 4 and 30 thousand tons) or smaller (holding approximately 210 tons), pressurized tanks (Farm Chemicals Handbook 1987). Barges are often used for refrigerated shipments because of their lower cost. Ammonia can be stored in refrigerated tanks holding up to 36,000 tons for use in the ammonia market. Smaller amounts of ammonia are stored in pressurized tanks.

The supply of ammonia for domestic uses has been historically met by domestic production. The ability to meet the ammonia demand depends on the amount of crop acres planted, the price of imported fertilizers, the cost of natural gas, and the availability of ammonia via import from abroad. In 2000, 3.9 million metric tons of anhydrous ammonia were imported; in 2001, this amount increased to more than 5.5 million metric tons. In 2000, domestic sources supplied 15.7 million metric tons of ammonia, whereas international sources provided 3.9 million metric tons; imports represented 20% of the total supply. In 2001 by comparison, domestic production dropped to 9.5 million metric tons, while imports increased 5.5 million metric tons; imports in 2001 represented almost 37% of the supply of ammonia (Kramer 2002). The amount of ammonia imported in 2002 held steady—the amount imported was just under 5.7 million metric tons (Kramer 2003)—while domestic production rose slightly to 10.8 million metric tons. Imports in 2002 represented 35% of the domestic need. The increases in imported ammonia, along with decreased domestic production, resulted in a substantial increase in reliance on foreign sources during these 3 years.

5.2 IMPORT/EXPORT

The import and export of ammonia have fluctuated slightly over the last few years. In 2000, the amount of ammonia imported into the United States was slightly less than 3.9 million metric tons. In both 2001 and 2002, the amount of ammonia imported into the United States was slightly more than 5.5 million metric tons (Kramer 2003). These years reflect a 41% increase in the amount of ammonia imported compared to 2000. U.S. exports of ammonia fell during the years following the change in domestic production and import from abroad. Exports in 2000 were approximately 0.66 million metric tons, and in 2001, 0.65 million metric tons were exported. Exports then dropped to 2/3 of those reported in the previous years. In 2002, when domestic production dropped and imports increased, only 0.44 million metric tons of ammonia were exported.

5.3 USE

The largest and most significant use of ammonia and ammonium compounds is the agricultural application of fertilizers. Ammonia and ammonium compounds used as fertilizer represent 89–90% of the commercially produced ammonia, with plastics, synthetic fibers and resins, explosives, and other uses accounting for most of the remainder (Kramer 2002, 2004). Direct uses of ammonia as fertilizer can be broken down into the following categories (percentages based on mass of nitrogen in each compound): anhydrous ammonia, 26%; urea/ammonium nitrate solutions, 23%; urea, 20%; ammonium nitrate, 4.5%; ammonium sulfate, 2%; other forms, 3%; and multiple nutrient forms, 21% (Kramer 2003). Most ammonium compounds and nitric acid, which are produced from anhydrous ammonia, are used directly in the production of fertilizers.

The small proportion of commercially produced ammonia not incorporated into fertilizers is used as a corrosion inhibitor, in the purification of water supplies, as a component of household cleaners, and as a refrigerant. It is also used in the pulp and paper, metallurgy, rubber, food and beverage, textile, and leather industries. Ammonia is used in the manufacture of pharmaceuticals and explosives, and in the production of various chemical intermediates (LeBlanc et al. 1978; Sax and Lewis 1987).

5.4 DISPOSAL

Solutions of ammonia can be highly diluted with water, or alternatively, diluted with water and neutralized with HCl and then routed to the sewer system. The amount released to the receiving stream should not exceed the established limits for ammonia. Limited amounts of gaseous ammonia may be discharged to the atmosphere. Federal, state, and local guidelines should be consulted before disposal.

Disposal of liquefied ammonia or of large quantities of gaseous or aqueous ammonia directly into water is not desirable, because of the large amount of heat generated. This generation of heat could increase exposure to personnel involved in the process. Recovery of ammonia from aqueous waste solutions is a viable option for many industries (HSDB 2003).