



Project Summary

Development and Selection of Ammonia Emission Factors

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This project compiles recent literature on ammonia (NH_3) emission factors for application in the United States. Most of the recent research supports acid deposition studies in the European community (specifically, the Netherlands, Great Britain, and Scandinavia), but some research has been conducted in Australia. The majority of NH_3 emissions in current inventories, (up to 90 percent or more of anthropogenic emissions) originates from livestock wastes with fertilizer applications providing a significant proportion. Some inventories exclude industrial emissions entirely because they are insignificant relative to agricultural sources. Global climate change research indicates that undisturbed soils and biomass burning may also have significant emissions, up to half of the global NH_3 budget. The recommended NH_3 emission factors are the following: European factors for agricultural sources; the *Pollutant Emission Factors—Volume I (AP-42)* for industrial sources; and National Acid Precipitation Assessment Program factors for combustion sources, human breath and perspiration, and publicly owned treatment works (POTWs). New factors are developed for beet sugar production, froth flotation in mineral processing, mineral wool (fiberglass) production, refrigeration, and selective catalytic and noncatalytic reduction for control of nitrogen oxide emissions. Additional discreet industrial sources of NH_3 are identified through the Toxic Release Inventory. Five future research projects are recommended: investigate global climate literature on NH_3 from undisturbed soils and biomass burning; use animal husbandry primary references to provide better linkage with United States Department of Agriculture statistics; develop temporal profiles for agricultural emissions; and conduct

additional research into emissions from refrigeration, POTWs, and selective catalytic and noncatalytic reduction.

This Project Summary was developed by EPA's Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Ammonia (NH_3) emissions are important in air quality models because NH_3 is the most important alkaline constituent in the atmospheric boundary layer. The fate of NH_3 released from the ground into the atmosphere is complex and varied, but NH_3 can have a significant effect on oxidation rates, particularly in clouds, and hence on deposition rates of acidic species. The effect is predicted not only by models for the heterogeneous chemistry of cloud droplets but has also been confirmed by observation and experimentation. The long range transport of atmospheric sulfur dioxide and nitrogen oxide and the products of their reactions have long been studied in relation to atmospheric deposition. However, much less research has been done on the effects of atmospheric NH_3 , although it is well known that over large areas of Europe, acid precipitation is falling in which up to 70 percent of the original acid is neutralized by NH_3 .

The importance of NH_3 in the atmospheric chemistry of air quality requires that accurate emission source inventory data be available for chemical and transport air quality modeling. Relatively little NH_3 emission data have been gathered and little effort expended in developing source-category specific NH_3 emission factors because NH_3 is generally not a regulated air pollutant. Also, it is not feasible to speciate NH_3 from volatile organic com-



ound (VOC) emission or particulate matter (PM) emission inventories because as an inorganic gaseous chemical NH_3 is not included in VOC emission estimates or PM emission estimates. Consequently, estimated inventories of NH_3 emissions provide very crude first-order information at this time.

This project compiled and reviewed recent (after 1985) literature on sources of NH_3 emissions and emission factors. The compilation contains the most recent research in the field of NH_3 emission factors. The primary focus of the project is on emission factors as opposed to estimates of total NH_3 emissions. Emission estimates are, however, made for some categories to determine the relative importance of the source category to overall NH_3 emissions and to assist in developing priorities for the NH_3 emission factor research.

Procedure

The project compiled and critically evaluated NH_3 emission information from recent literature with the objectives of 1) evaluating the quality of available emission factors, 2) recommending adoption of the factors where appropriate, 3) developing emission factors from data in the literature where possible, 4) recommending assignments of emission factors to specific U.S. Environmental Protection Agency (U.S. EPA) source category codes, and 5) arriving at a set of recommendations for future research likely to provide the greatest gain in knowledge of NH_3 emission factors.

The scope of the literature search included peer-reviewed books and journals and published and unpublished private and governmental laboratory reports. The search used computer-based library catalogs and personal contacts. The majority of available relevant literature was from North America and Europe. When the literature contained process activity data and information on the content of NH_3 in the emissions, an emission factor was computed and the scope of application (source category codes) determined.

Emission factors from or derived from the literature were assigned quality rating factors that depend on the quantity and rigor of underlying data and testing. The quality rating system is that used by U.S. EPA's Office of Air Quality Planning and Standards.

Results and Discussion

Recent research on NH_3 emissions as it relates to acid deposition, is concentrated in the European community (specifically,

in the Netherlands, Great Britain, and Scandinavia). In addition, there has been some research in Australia. The majority of the NH_3 emissions included in current inventories originate from agricultural sources. These agricultural sources are mainly livestock wastes, with fertilizer applications also providing a significant proportion. NH_3 emission estimate numbers vary widely between different studies, but the authors of recent European inventories all consider animal wastes and fertilizers to be responsible for 90 percent or more of the anthropogenic NH_3 emissions. Some of the more recent inventories in Europe even exclude contributions for industrial facilities entirely, noting that they are insignificant relative to the agricultural sources.

Although the European inventories currently focus on agricultural sources, there is evidence that additional, significant sources of NH_3 may exist. Studies in the United Kingdom suggest that current estimates of NH_3 emissions are too small to explain the concentrations of ammonium in precipitation and that there may be other sources of NH_3 that have not been considered in budget studies. Other research, principally in support of global climate change research, suggests that there may be significant NH_3 emissions from undisturbed soils and biomass burning.

Much of the research obtained and reviewed by this project concerns the measurement of NH_3 in which results were generally reported as experimental rather than as emission factors. The majority of NH_3 emission factors available in the literature are discussed relative to the development of an emission inventory. In the development of an emission inventory, emission factors are often either developed for the experimental measurement literature or are borrowed directly from other bodies of work. The primary source for the emission factors reviewed by this project was the body of recent emission inventory literature. The experimental measurement literature was also reviewed to provide detail on how the measurements were made. This review contributes to understanding the uncertainty of the emission factors, addresses the extent to which the factors presented incorporate the most recent research, and identifies data gaps for future emission factor development.

The most recent NH_3 inventory prepared in the United States is the *Emissions Inventory for the National Particulate Matter Study*, which used Bureau of Economic Activity data to project the 1985 NAPAP inventory to the 1990 study year. There are several recent NH_3 emission invento-

ries for specific European countries, including Great Britain, the Netherlands, Denmark, and Germany. The most recent European inventory was published in 1992. Another NH_3 inventory was published for Australia in 1990.

Rough estimates of anthropogenic NH_3 emissions in the United States indicate that animal husbandry and fertilizer application dominate emissions (approximately 80 percent) as they do in Europe. Industrial emissions of NH_3 and NH_3 emissions from combustion are relatively insignificant (about 1 percent). NH_3 emissions from refrigeration and POTWs may be significant (perhaps 7 percent).

Estimates of NH_3 emissions for biomass burning and undisturbed soils were not made because of the unavailability of an emission factor for biomass burning and activity data for undisturbed soils. Recent research indicates that these two categories may contribute significantly (up to half) of the global budget of NH_3 emissions.

Conclusions and Recommendations

The NH_3 emission factors recommended for use in future U.S. inventories include the following: European factors for agricultural sources (animal husbandry and fertilizer application); the *Compilation of Air Pollutant Emission Factors—Volume 1 (AP-42)* for the majority of the stationary industrial sources; and the NAPAP factors for the majority of the combustion sources (including coal, oil, natural gas, and mobile sources), human breath and perspiration, and POTWs. New emission factors are developed for beet sugar production, froth flotation in mineral processing, mineral wool (fiberglass) production, refrigeration, and selective catalytic and noncatalytic reduction for control of nitrogen oxide emissions. Specific industrial sources of NH_3 with no corresponding emission factors are identified through the Toxic Release Inventory.

Five research areas are recommended to enhance the quality of NH_3 factors addressed by this project. The five research areas include completion of the following:

1. Investigate the recent global climate change literature on NH_3 from undisturbed soils. Merge the literature on emission fluxes with new land use and land cover data categories to develop emission factors for biogenic and mobile sources categories.
2. Investigate recent literature on NH_3 emissions for biomass burning. Integrate the data results with infor-

mation in the United States on naturally occurring fires to develop emission factors for the United States. Also, investigate all information on NH₃ emissions for the chemical agents used to fight these naturally occurring fires.

3. Research the primary references for the animal husbandry emission factors to provide more accurate linkages with the U.S. Department of Agriculture statistics. In addition, investigate the discrepancy in the

emission factors for sheep in the literature.

4. Develop temporal profiles for the larger NH₃ emission categories. Specifically, investigate the seasonal nature of the animal husbandry and fertilizer application emissions.
5. Conduct additional research on the NH₃ emission factors reported for refrigeration, POTWs, and selective catalytic and noncatalytic reduction (for control of NO_x emissions) to

improve confidence in their validity. Refrigeration contributes a significant portion of the NH₃ inventory (about 5 percent); however, this factor was developed based on a material balance. POTWs also contribute a significant amount of NH₃ (about 2 percent); additional research is ongoing in the United Kingdom and California that may improve the accuracy of the emission factor.

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The complete report, entitled "Development and Selection of Ammonia Emission Factors," (Order No. PB95-123915; Cost: \$27.00, subject to change) will be available only from

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