U.S. Environmental Protection Agency
Environmental Technology Verification Program

Ambient Ammonia Monitors

The U.S. EPA Environmental Technology Verification (ETV) Program's Advanced Monitoring Systems (AMS) Center, operated by Battelle under a cooperative agreement with EPA, has verified the performance of seven ambient ammonia monitors[1] for use at animal feeding operations (AFOs). The current standard method for measuring ambient ammonia is time consuming, labor intensive, and not well-suited for conducting continuous measurements. The verified monitors can provide a quick and convenient way of measuring ammonia. These monitors were verified in collaboration with the U.S. Department of Agriculture (USDA).

Technology Description and Verification Testing

The AMS Center verified the seven ambient ammonia monitors (**Table 1**) in two phases of testing, each at separate AFOs. Phase I was conducted at a swine finishing farm, and Phase II was conducted at a cattle feedlot. These sites were selected to provide realistic testing conditions and a wide range of ammonia concentrations. **Table 2** summarizes some of the performance data for the individual technologies. The full verification reports can be found at http://www.epa.gov/nrmrl/std/etv/vt-ams.html under ambient ammonia sensors category. Ambient ammonia monitors utilize a wide range of analytical methods. These methods include direct detection by spectroscopic techniques or indirect detection of ammonia using selective membrane permeation with conductivity detection, catalytic conversion with chemiluminescence detection, treatment with a chemical dopant followed by ion mobility detection, or other techniques. Ambient ammonia monitors also can provide specialized features that can be valuable in specific uses, such as long-term monitoring or determining ammonia fluxes and emission rates.

For example, monitors that collect high-speed (sub-second response time) ammonia concentration data can be used with simultaneous three-dimensional windspeed/direction data to determine ammonia flux. Alternatively, open-path monitors can be used to calculate emission rates from AFOs, since these monitors measure the average ammonia concentration over a 1-to-100 meter path. Some monitors also are suitable for long-term monitoring, since they can be operated without user intervention for weeks at a time.

AFOs and Ammonia at a Glance

Animal husbandry operations, which include AFOs, are regarded as representing the largest single source of ammonia in the United States, emitting 2,200 thousand metric tons in 2002 alone. Approximately half of the ammonia from the ponds and lagoons used to manage animal wastes at AFOs falls to the surface within 50 miles of these sources, where it can contribute to eutrophication of surface waters and result in fish kills and reduced biodiversity. The remainder is transformed into particulate matter, which can have significant adverse human health effects.

The Clean Air Act; Comprehensive Environmental Response, Compensation, and Liability Act; and Emergency Planning and Community Right-to-Know Act include requirements for monitoring and reporting ammonia releases that are applicable to some AFOs. In 2003, the National Academies of Science identified the methods used to estimate ammonia emissions from these sources (i.e., that apply generic emission factors to estimates of live stock population) as generally inadequate, and they recommended improvement in measurement protocols for ammonia. EPA recently issued an Air Quality Compliance Agreement (AQCA) with the animal producers industry to improve ammonia emissions measurements and promote compliance with federal regulations. Some ETV-verified technologies utilize the analytical methods identified in the AQCA study protocol.

Table 1. Verified Ambient Ammonia Monitors

Technology Name	Description
Aerodyne Research, Inc. QC-TILDAS	An infrared laser spectrometer, based on pulsed quantum cascade laser technology; continuous measurement
Bruker Daltonics OPAG 22 Open-Path Gas Analyzer	A broadband, open-path, Fourier transform infrared spectrometer for remote sensing continuous measurement
Molecular Analytics IonPro-IMS Ammonia Analyzer	An ion mobility spectrometer; continuous measurement
Omnisens SA TGA310 Ammonia Analyzer	A trace gas analyzer that uses photoacoustic spectrometry; continuous measurement
Pranalytica, Inc. Nitrolux™ 1000 Ambient Ammonia Analyzer	A resonant photoacoustic spectrometer with a line-tunable carbon dioxide (CO_2) laser; continuous measurement
Mechatronics Instruments BV AiRRmonia Ammonia Analyzer	A single-point monitor composed of a membrane diffusion sampler, a detector block with a diffusion membrane, and two conductivity cells; continuous measurement
Thermo Electron Corp. Model 17C Ammonia Analyzer	A chemiluminescence analyzer that uses nitric oxide (NO) and ozone (O_3) reactions; time-averaged measurement

[1]The ETV Program operates largely as a public-private partnership through competitive cooperative agreements with non-profit research institutes. The program provides objective quality-assured data on the performance of commercial-ready technologies. Verification does not imply product approval or effectiveness. ETV does not endorse the purchase or sale of any products and services mentioned in this document.

Selected Outcomes of Verified Ambient Ammonia Monitors

An ambient ammonia monitor at an AFO

The potential market for verified ambient ammonia monitors includes AFOs. EPA estimates that there are approximately 450,000 AFOs in the U.S. Larger facilities (more than 1000 animal units[2]) with higher emissions are more likely to implement monitoring technologies. The verified monitors could:

- be used under EPA's Voluntary Air Compliance Agreement to improve ammonia emission estimates
- help address the research needs identified by the National Academies of Science and others
- be applied potentially at up to 975 large AFOs (out of an estimated potential market of 3,900) to verify their compliance with current or potential future state and federal regulations and to avoid potential multimillion dollar penalties
- identify operational changes to improve ammonia control and reduce emissions from AFOs; a 10% reduction in livestock ammonia emissions can lead to over $4 billion annually in particulate-related health benefits (McCubbin et al).

[2] An animal unit is equal roughly to one beef cow.

Table 2. Selected Performance of Verified Ambient Ammonia Monitors

Vendor[a]	Testing	Average Relative Accuracy[b]	Relative Precision[b]	Response Time (95%)	Linearity			Comparability[c]		
					Slope	Intercept	r^2	Slope	Intercept	r^2
A	Phase I & Phase II	3.7 to 10.5%	0.3%	3 to 76 min	0.90 to 1.03	-24 to -0.6	1.000	0.86 to 1.20	-0.5 to 16	0.984 to 0.990
B	Phase I & Phase II	2.4 to 34%	0.7 to 2.1%	8 to 20 min	1.02 to 1.28	-2.4 to 136	0.9957 to 0.9999	0.41 to 1.18	-1.4 to 58	0.538 to 0.9755
C	Phase I & Phase II	10 to 44%	0.2 to 1.3%	1 to 32 min	0.716 to 1.25	-58.5 to 167	0.9854 to 0.9997	0.646 to 1.83	-6.7 to 21.6	0.9794 to 0.9842
D	Phase II	2.2%	0.9%	2 to 2.6 min	0.966	15.9	1.000	1.15	-4.1	0.994
E	Phase II	18.3%	1.0%	2.5 to 17 min	0.815	1.08	1.000	1.565	-16.5	0.994
F	Phase II	26%	1.8%	4 to 14 sec	0.583	24.9	0.9144	Not reported	Not reported	Not reported
G	Phase I & Phase II	4.7 to 10%	1.9 to 2.5%	0.8 to 66 sec	0.840 to 0.962	-8.8 to 35	0.9989 to 0.9998	0.984 to 1.09	-9.5 to 14.4	0.9943 to 0.9982

[a] Because the ETV Program does not compare technologies, the performance results shown in this table do not identify the vendor associated with each result and are not in the same order as the list of technologies in Table 1.
[b] A result of 0% indicates perfect accuracy or precision.
[c] The comparability of the verified technology with a standard reference method was established by comparing the average ammonia sensors readings with time-integrated NH_3 samples collected using citric-acid-coated denuders. The reference samples were collected based on procedures described in the EPA Compendium Method IO-4.2, Determination of Reactive Acidic and Basic Gases and Acidity of Fine Particles (<2.5 µm). Comparability between the ammonia sensors results and the reference method results with respect to ambient air was assessed by linear regression using the reference method NH_3 concentrations as the independent variable and results from the ammonia sensor as the dependent variable.

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