2007

Assessment of In-Line Dust Filter Type and Condition on Ammonia Adsorption

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Abstract
Gas analyzers are commonly protected from impurities in air sampling via use of in-line dust filters to ensure operational performance and longevity of the instruments. This is especially true with extended periods of air quality monitoring in dusty environments. Prices for commercially available filters and monitoring needs vary considerably. A question that has often come up but has not received much investigation is how the filter media types (e.g., paper vs. Teflon) and operational conditions (clean vs. dirty) impact the integrity of gaseous concentration measurement. The study reported here was conducted toward addressing this issue. Specifically, the study assessed the magnitude of ammonia (NH3) adsorption for several types of in-line filters and conditions often used or encountered in animal feeding operation air emission studies, namely, Teflon (most expensive), paper (least expensive), and stand-alone automobile fuel filters, being either clean (new) or dust-laden. Three nominal NH3 levels (20, 45, or 90 ppm, generated with poultry manure) coupled with two nominal airflow rates (4 vs. 8 L/min or 8 vs. 16 L/min) through the filters were used in the evaluation. The types of dust used in the study included corn starch and broiler-house dust. Simultaneous measurements of NH3 concentrations before and after the tested filter were made with two photoacoustic gas spectrometers. The results revealed that NH3 adsorption was highest for the fuel filter initially but negligible for the Teflon filters. However, after 30 min exposure, relative NH3 adsorption by the filters mostly fell below 1%. The higher flow rate led to significantly lower relative NH3 adsorption for both the fuel and paper filters ($P < 0.001$) but made no difference for the Teflon filters ($P = 0.31$ to 0.49). During fresh-air purging of the fuel filters laden with broiler-house dust, NH3 was initially released but diminished after 15 min. The results suggest that when used properly (e.g., proper flow rate), the in-line dust filters tested in this study (fuel, paper, and Teflon) offer viable, performance-based options for air emissions (especially NH3) measurement applications.

Keywords
Air emissions, Air quality, Air sampling integrity, Ammonia adsorption, Dust filter

Disciplines
Agriculture | Bioresource and Agricultural Engineering

Comments
This article is from *Transactions of the ASABE* 50, no. 5 (2007): 1823–1830.

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Keywords. *Air emissions, Air quality, Air sampling integrity, Ammonia adsorption, Dust filter.*

Ammonia (NH_3) generation and emissions are associated with animal feeding operations (AFOs) due to the biological decomposition of manure. Because of its environmental impact, quantification and mitigation of NH_3 emissions for AFO systems continue to receive increasing attention from the animal industry, regulatory agencies, and the scientific community (Li et al., 2006; Liang et al., 2005, 2006; Wheeler et al., 2006; Xin, 2006). Estimates of NH_3 emissions from AFOs with reasonable accuracy are essential for evaluating the efficacy of potential emission mitigation techniques and for establishing fair and equitable regulations (Wathes et al., 1998). The two key elements in determining the magnitude of aerial emissions from a source are concentration of the aerial pollutant and air exchange or ventilation rate through the source. Though not the focus of this article, considerable research and progress has been made towards improved quantification of animal building ventilation rate (Demmers et al., 2000, 2001; Gates et al., 2004; Li et al., 2005; Muhlbauer et al., 2006; Xin et al., 2006).

Concentrations of atmospheric NH_3 may be measured with different types of instruments, including electrochemical sensors (Xin et al., 2002, 2003; Liang et al., 2004; Gates et al., 2005), chemiluminescence detectors (Phillips et al., 1998; Heber et al., 2001; Liang et al., 2004), and photoacoustic spectrometers (Zhang et al., 2005; Burns et al., 2006; Li et al., 2006). Regardless of the working principles of the gas analyzers, their operation must be protected from the dust-laden environments when sampling air streams from AFO facilities to ensure measurement performance and longevity of the instruments. Mukhtar et al. (2003) reported that NH_3 adsorption onto low-density polyethylene (LDPE) tubing was significantly higher than that of Teflon; and that tubing length was not significant in NH_3 adsorption onto Teflon. Capareda et al. (2005) reported the same result. It has also been reported that gaseous NH_3 adsorbs to dust particles (Takai et al., 2002; Lee and Zhang, 2006). However, research is meager that quantifies the impacts of media types and conditions of in-line dust filters on NH_3 adsorption.

Submitted for review in February 2007 as manuscript number SE 6898; approved for publication by the Structures & Environment Division of ASABE in August 2007.

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  ISSN 0001–2351

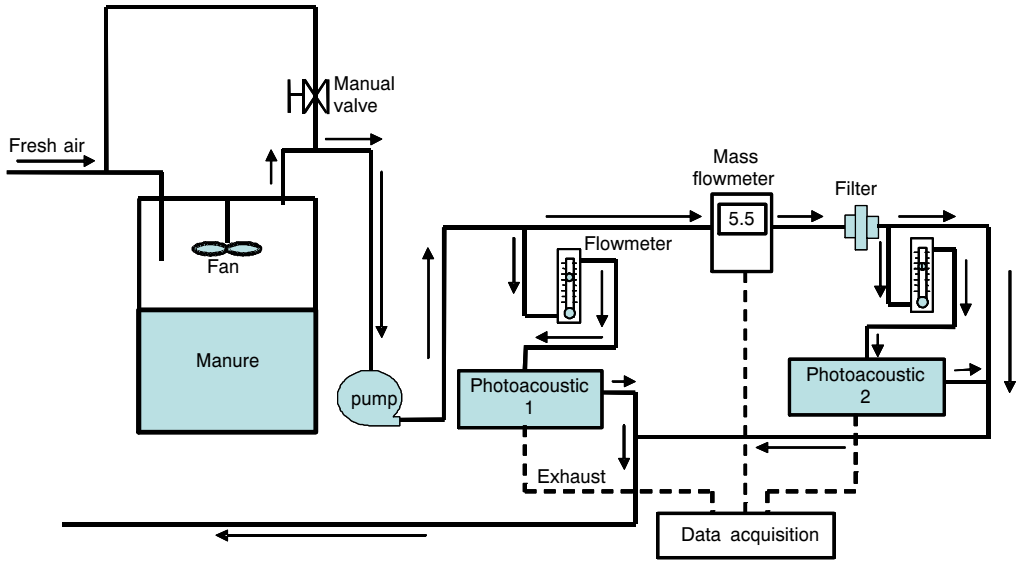

Figure 1. Schematic representation of the experimental apparatus for evaluating impact of in-line filters on ammonia adsorption.

The objective of this study was to evaluate the magnitude of NH_3 adsorption onto Teflon, paper, or automobile fuel type filters under clean or dust-laden conditions over a range of NH_3 concentrations and in-line airflow rates.

Materials and Methods

Measurement System Setup

Ammonia concentration before and after the dust filter under evaluation was measured simultaneously using two photoacoustic multi-gas spectrometers (model 1412, Innova AirTech Instruments, Ballerup, Denmark). The evaluation system (fig. 1) was located inside an environmentally controlled room where the air temperature was maintained at 21.1°C ±1.1°C throughout the experiment. Prior to each evaluation trial, zero (99.999% N_2) and span (22.6 ppm $NH_3 + N_2$ balance, ±2% accuracy) calibration gases (Matheson Tri-Gas, Inc., La Porte, Texas) were used to check and calibrate, if needed, both gas analyzers to ensure their specified performance and exchangeability. The checking results throughout the testing period (fig. 2) revealed that the mutual differences were within the detection limit of the instrument (0.2 ppm).

For the filter evaluation trials, laying hen manure held in a sealed 19 L container with a top-mounted stirring fan was used to generate NH_3 (fig. 1). Different NH_3 concentrations from the source were achieved by controlling the amount of fresh air into the manure container. Selection of the testing NH_3 levels was based on the typical concentrations encountered in winter and summer in commercial broiler and high-rise laying hen houses in either manure storage or exhaust air (Liang et al., 2005; Wheeler et al., 2006). Teflon tubing (0.64 mm OD, 0.32 mm ID) was used throughout the system. The airflow rate through the filter was measured using one or two (parallel) stainless-steel mass flowmeters (10 L/min capacity per meter, McMillan Co., Georgetown, Texas). A programmable data acquisition system (model CR10X, Campbell Scientific, Inc., Logan, Utah) was used to record the analog output from the gas analyzers, the mass flowmeter, and an ambient temperature and relative humidity probe. The output readings were sampled at 20 s intervals and stored as 1 min averages.

The testing conditions for the study are listed in table 1 and are described below. Selection of the flow rate for each filter was based on its likely placement in the sample lines. Note that the air sampling pumps used in AFO air emissions studies typically have an operating capacity of 8 to 16 L/min. The sampling lines may have two intake ports with coarse filters to eliminate or minimize the intake port blockage.

Dust Filters

Four types of in-line dust filters that may be used in air sampling were tested in this study, including two varieties of

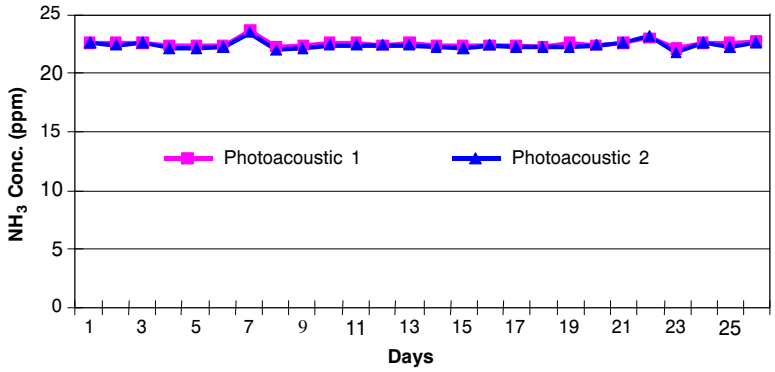

Figure 2. Responses of the two photoacoustic gas analyzers to daily ammonia span (22.6 ppm) check.

Table 1. Filter types, flow rates, and ammonia concentrations used in the ammonia adsorption tests.

Filter Type and Condition	Nominal Flow Rate (L/min)[a]	Nominal NH_3 Conc. (ppm)[b]	Dust Type/Source
New fuel filter	4, 8	20, 45, 90	None or corn starch
Dust-laden fuel filter	4, 8	20, 45, 90, fresh air	Broiler-house dust
New Teflon filter[c]	8, 16	20, 45, 90	None or corn starch
Dust-laden Teflon filter	8, 16	20, 45, 90, fresh air	Broiler-house dust
New paper filter	8, 16	20, 45, 90	None or corn starch

[a] The actual range of flow rate corresponding to the nominal values of 4, 8, and 16 L/min were 4.0 to 4.2, 7.9 to 8.3, and 14.0 to 15.7 L/min, respectively.
[b] The actual range of NH_3 concentration corresponding to the nominal values of 20, 45, and 90 ppm were, respectively, 18.5 to 26.7, 36.8 to 59.0, and 62.0 to 97.0 ppm. Fresh air had nearly zero NH_3.
[c] Pore size of 5 μm or 20 μm.

Teflon filter, an automobile fuel filter, and a paper filter. The two varieties of Teflon membrane filters featured: (1) 47 mm O.D., 5 to 6 μm pore size, and 0.10 mm thick membrane (model 1141); and (2) 47 mm O.D., 20 to 30 μm pore size, and 0.14 mm thick membrane (model 1151) (Savillex, Minnetonka, Minn.). The paper filter had a 47 mm O.D. and 20 to 25 μm pore size (model 41, Whatman International, Ltd., Maidstone, U.K.). Finally, the fuel filter was a stand-alone, NAPA automobile fuel filter (model 3011, made in Israel) that was made of silicone-treated cellulose with a surface area of approximately 45.6 cm^2. All filter membranes were held in a Teflon filter holder (model 401-22-47-10-22-1, Savillex, Minnetonka, Minn.). Photographs of the filters are shown in figure 3.

Dust Generation and Measurement

To determine the NH_3 adsorption of dust on filters, two types of dust were examined: (1) new filters laden with NH_3-free corn starch, and (2) used filters that had been in operation (as the first-stage filtration) in air sample lines for one week in a broiler house for air emissions monitoring (Burns et al., 2006), hence containing some amount of broiler-house dust. To load the new filters with the NH_3-free starch dust, corn starch was put in a sealed, 19 L bucket and a mixing fan was used to facilitate the dust generation. A new fuel filter or paper/Teflon filter assembly was connected via Teflon tubing between the dust source and a vacuum pump that drew air from the dust-generating bucket. The new filters were oven-dried at 105°C for 24 h before and after dust loading, and weighed using an electronic balance (accuSeries II, model accu-224, Fisher Scientific International, Inc., Hampton, N.H.) to determine the amount of dust on the filter. The used filters were weighed before the test and again after a good shake-out of the dust to estimate the amount of dust carried on the filters. Reduction in NH_3 concentration after the filter represented the NH_3 adsorption onto the filter.

Results and Discussion

Ammonia Adsorption by Different Filters

Fuel Filter

The NH_3 adsorption profiles for the new, dust-free automobile fuel filter over a 60 min exposure to the combinations of different NH_3 concentrations and flow rates are shown in figure 4. It can be noted that for a given NH_3 concentration, higher flow rate through the filter generally led to less NH_3 adsorption, a result of shorter residence time. For the lower flow rate (4 L/min), higher concentration (90 ppm) tended to yield greater NH_3 adsorption. In comparison, for the higher flow rate (8 L/min), the adsorption was rather independent of the NH_3 concentrations (20 to 90 ppm). Ammonia adsorption by the fuel filter was ≤1 ppm after 10 min exposure for all the concentration-flow rate combinations except for the 90 ppm, 4 L/min regimen, in which NH_3 adsorption approached ≤1 ppm after approximately 50 min exposure.

Ammonia adsorption profiles for the fuel filter laden with corn starch dust over a 60 min exposure to various NH_3 concentrations and flow rates are shown in figure 5 and are further summarized in table 2. Ammonia adsorption by the "dirty" filters was similar for the concentrations of 20 and 45 ppm, but was higher for 90 ppm ($P < 0.05$) under both flow rates. The adsorption, however, did not differ between the two flow rates ($P = 0.8$). Initially, NH_3 adsorption by the corn starch dust-laden filter was high (up to 9.0 ppm for the 90 ppm, 4 L/min regimen), but the difference decreased rapidly with time. After a 30 min exposure, the difference was reduced to 1 ppm or less for all the testing regimens.

Similar behaviors for the used fuel filter laden with broiler-house dust were observed (fig. 6 and table 3) when NH_3-laden air passed through the filters. However, when fresh air passed through the used filters, there was an initial release of NH_3, and the magnitude somewhat depended on the flow rate. The 8 L/min flow rate led to smaller difference (nearly zero after 20 min) than the 4L/min flow rate (<0.5 ppm after 20 min) due to more dilution.

It should be noted that because the amount of dust on the "dirty" filters was not uniform among the concentration levels within or between the flow rates, the statistical differences or lack thereof should be used only as a supplement to the results, as opposed to delineating a cause–

(a) (b) (c)

Figure 3. Photographs of (a) automobile fuel filter, (b) Teflon or paper membrane filters, and (c) Teflon filter holder used in this study.

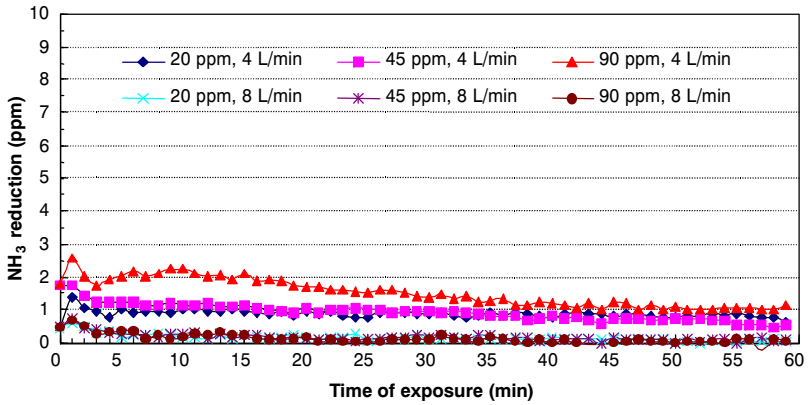

Figure 4. Ammonia absorption by dust-free new fuel filter at different combinations of NH_3 concentrations and flow rates (mean of four replicates per regimen).

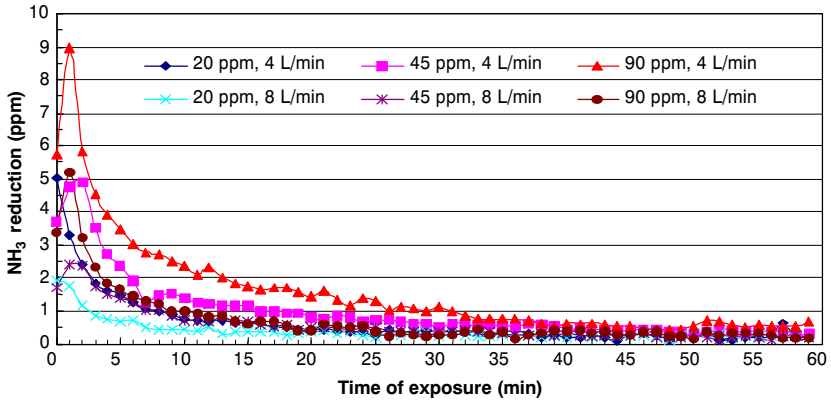

Figure 5. Ammonia absorption by starch dust-laden new automobile fuel filters at different combinations of concentration and flow rates (mean of four replicates per regimen).

effect relationship (not the focus of this study). To truly quantify the relationship between NH_3 adsorption and the amount of dust on filters, future studies should consider equalizing the amount of the dust laden on the filters across the levels of concentration and flow rate. However, this would require screening a large number of dirty/used filters from field monitoring to obtain enough testing filters with the same amount of dust on them.

Paper Filter

Ammonia adsorption profiles for the new, dust-free paper filter over a 60 min exposure to the combinations of different NH_3 concentrations and flow rates are shown in figure 7. The adsorption profiles for the new paper filter resembled those of the new fuel filter, although the paper filter had much lower initial adsorption (fig. 7). Nonetheless, the reduction decreased to <0.5 ppm after 30 min exposure for all except the 90 ppm, 8 L/min regimen.

Teflon Filters

Figures 8 and 9 show the NH_3 adsorption profiles for new, dust-free Teflon filters with a pore size of 20 µm or 5 µm. The differences in NH_3 concentration between the inlet and the outlet air in all cases were well within the measurement sensitivity (0.2 ppm) of the gas analyzer. Similar results were observed for the used Teflon filters laden with broiler-house dust (fig. 10). Since the pore size of 20 µm or 5 µm did not impact the NH_3 adsorption characteristics of the Teflon filters, they were not differentiated. The filters had been in operation in our broiler air emission sampling lines for 14 days (Burns et al., 2006). However, no attempt was made to determine the amount of dust collected on the filters due to its very small amount and the inherent large uncertainty that would be involved with such determination.

The NH_3 adsorption or release characteristics of the tested filters are further summarized in table 4. In addition to the absolute changes in NH_3 concentration between the inlet and outlet of the filter, relative changes with reference to the inlet concentration were expressed. As can be noted from the data in table 4, the relative reduction caused by the filter media

Table 2. Ammonia adsorption by new fuel filter laden with corn starch dust (n = 4; mean ±SEM).

Nominal Flow Rate (L/min)	Nominal Inlet NH_3 (ppm)	NH_3 Adsorption (mg over 1 h)	Starch Dust on Filter (g)	Specific NH_3 Adsorption by Dust (mg·g dust^{-1} over 1 h)[a]
4	20	0.12 (±0.01)	0.19 (±0.02)	0.61 (±0.05) b
	45	0.18 (±0.02)	0.34 (±0.07)	0.60 (±0.11) b
	90	0.29 (±0.04)	0.24 (±0.02)	1.20 (±0.12) a
8	20	0.14 (±0.01)	0.23 (±0.03)	0.62 (±0.04) b
	45	0.21 (±0.05)	0.35 (±0.12)	0.69 (±0.03) b
	90	0.26 (±0.06)	0.27 (±0.07)	1.01 (±0.16) a

[a] Within each flow rate, values followed by different letters are significantly different ($P < 0.05$). No significant differences were found in adsorption between flow rates ($P = 0.80$).

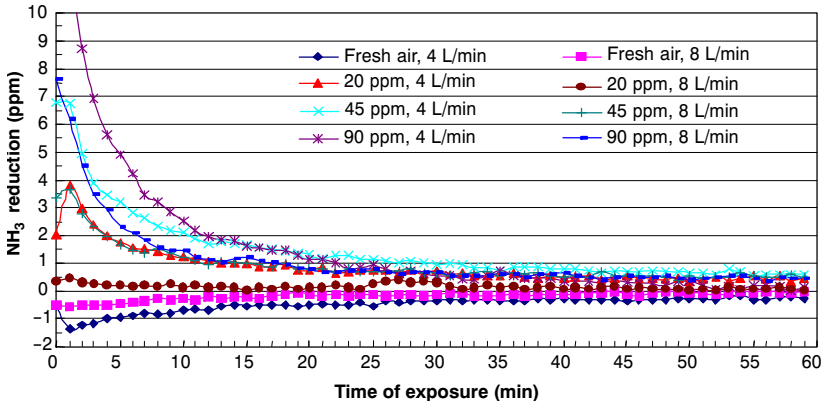

Figure 6. Ammonia (NH_3) absorption by used fuel filter laden with broiler-house dust for different combinations of NH_3 concentration and flow rate (mean of four replicates per regimen). Note that the used fuel filters containing broiler-house dust released NH_3 initially when fresh air passed through.

Table 3. Ammonia adsorption by used fuel filter laden with broiler-house dust (n = 4; mean ±SEM).

Nominal Flow Rate (L/min)	Nominal Inlet NH_3 (ppm)	NH_3 Adsorption (mg over 1 h)	Broiler Dust on Filter (g)	Specific NH_3 Adsorption by Dust (mg·g dust^{-1} over 1 h)[a]
4	20	0.16 (±0.05)	0.11 (±0.06)	2.32 (±0.99) a
	45	0.27 (±0.03)	0.11 (±0.04)	2.72 (±0.53) a
	90	0.31 (±0.01)	0.20 (±0.03)	1.60 (±0.10) a
8	20	0.06 (±0.04)	0.15 (±0.06)	0.68 (±0.14) c
	45	0.21 (±0.10)	0.14 (±0.03)	2.48 (±0.14) a
	90	0.41 (±0.02)	0.24 (±0.30)	1.75 (±0.15) b

[a] Within each flow rate, values followed by different letters are significantly different (P < 0.05).

and operating condition was mostly less than 1% and occasionally as high as 3% following a 60 min exposure. Hence, for practical purposes of monitoring AFO air emissions, all the in-line filers tested in this study and their typical operating conditions are expected to function well when used properly.

Assessment of the Experimental Factors on Filter Adsorption of NH_3

To assess the impact of exposure time, inlet concentration, and airflow rate on NH_3 adsorption onto the filters, regression analysis was performed for the fuel and paper filters. Because NH_3 adsorption for the clean or dirty/used Teflon filters was lower than the sensitivity of the gas analyzer (<0.2 ppm), its regression analysis was omitted. Moreover, since differences in NH_3 concentration approached stabilization and were mostly less than 1% of the inlet value after 30 min exposure for the tested filters and conditions, regression was only performed for the first 30 min exposure. The regression equations for the fuel and paper filters are shown below. All constants and coefficients in the equations are significant at a 0.05 level.

For new, dust-free fuel filter:

$$NH_{3\,diff} = 2.30 - 0.014 \cdot t + 0.0067 \cdot C_{inlet} - 0.28 \cdot F \quad (1)$$

$$(R^2 = 0.85)$$

For new fuel filter with NH_3-free, corn starch dust:

$$NH_{3\,diff} = 2.93 - 0.090 \cdot t + 0.015 \cdot C_{inlet} - 0.19 \cdot F \quad (2)$$

$$(R^2 = 0.62)$$

For used fuel filter with broiler-house dust:

$$NH_{3\,diff} = 3.66 - 0.12 \cdot t + 0.024 \cdot C_{inlet} - 0.25 \cdot F \quad (3)$$

$$(R^2 = 0.51)$$

For new, dust-free paper filter:

$$NH_{3\,diff} = 1.16 - 0.026 \cdot t + 0.0070 \cdot C_{inlet} - 0.060 \cdot F \quad (4)$$

$$(R^2 = 0.67)$$

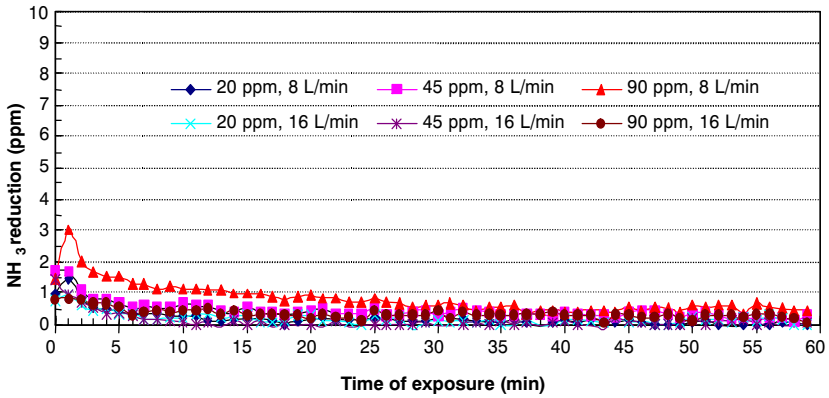

Figure 7. Ammonia (NH_3) absorption by new paper disk filter for different combinations of NH_3 concentration and flow rate (mean of three replicates per regimen).

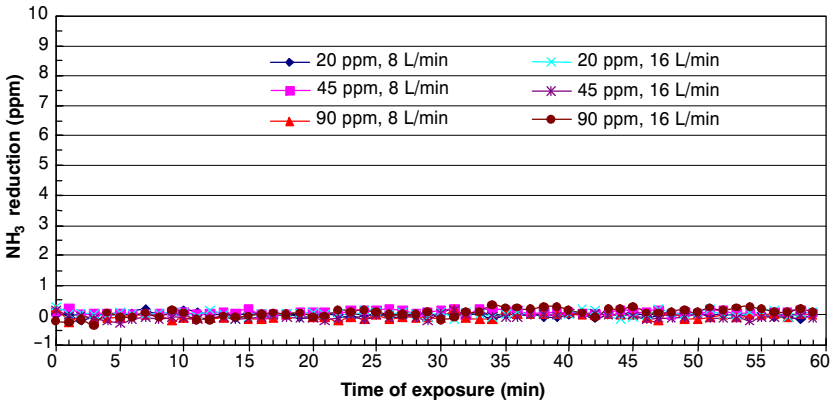

Figure 8. Ammonia (NH_3) absorption by dust-free Teflon filter (pore size of 20 µm) at different combinations of NH_3 concentrations and flow rates (mean of three replicates per regimen).

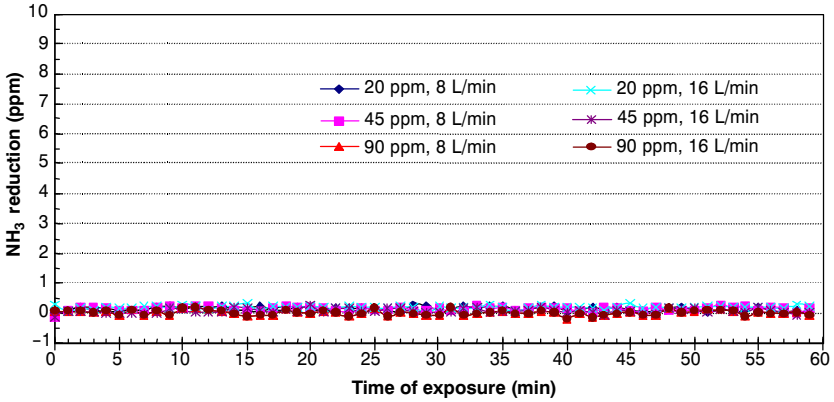

Figure 9. Ammonia (NH_3) absorption by dust-free Teflon filter (pore size of 5 µm) at different combinations of NH_3 concentrations and flow rates (mean of three replicates per regimen).

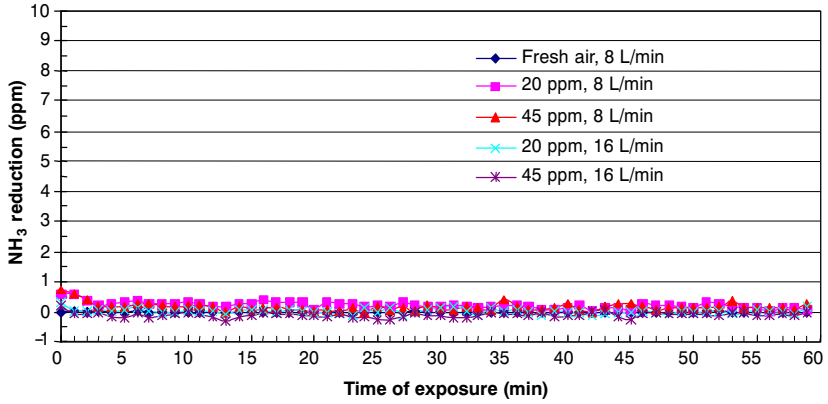

Figure 10. Ammonia (NH_3) absorption by used Teflon filter (pore size of 20 µm) laden with broiler-house dust for different combinations of NH_3 concentration and flow rate (mean of three replicates per regimen).

where

$NH_{3\ diff}$ = difference in NH_3 concentration between inlet and outlet (ppm)

t = exposure or run time (0 to 30 min)

C_{inlet} = actual NH_3 concentration at the inlet of filter (ppm)

F = actual airflow rate through the filter (L/min).

Equations 1 to 4 show that NH_3 adsorption was positively related to inlet concentration but negatively related to exposure time and flow rate. It should be noted that the above empirical equations are only valid for the exposure time of 0 to 30 min, NH_3 concentration of 20 to 90 ppm, and flow rates of 4 vs. 8 L/min or 8 vs. 16 L/min, as used in this experiment.

It should be further noted that in the case of the fuel and paper filters, the higher flow rate of the pair (8 vs. 4 L/min and 16 vs. 8 L/min) led to significantly lower relative NH_3 reduction or adsorption ($P < 0.001$), even though the magnitude of adsorption has little practical implications. In the case of the Teflon filters, the flow rate showed no impact on the relative reduction ($P = 0.31$ to 0.49).

Table 4. Ammonia (NH_3) adsorption by in-line filters of different types and operating conditions (new vs. dust-laden), expressed as relative concentration changes before and after the filter. Negative values resulted from differences within the measurement sensitivity of the gas analyzer (0.2 ppm).

Filter Type and Condition	No. of Reps	Flow Rate (L/min)	Nominal NH_3 Level (ppm)	Relative Change (% ±SEM) in NH_3 Concentration after Exposure Time of:					
				1 min	5 min	10 min	20 min	40 min	60 min
Fuel filter: new, dust free	4	4	20	2.6 ±1.0	4.0 ±0.5	4.5 ±0.9	4.2 ±0.8	4.2 ±0.9	3.3 ±0.5
	4	4	45	3.9 ±1.7	2.8 ±0.8	2.7 ±1.0	2.1 ±1.3	1.6 ±1.0	1.2 ±0.5
	4	4	90	2.0 ±0.5	2.1 ±1.2	2.5 ±1.3	2.0 ±1.2	1.4 ±0.8	1.3 ±0.9
	4	8	20	2.2 ±0.5	1.8 ±0.3	1.1 ±0.4	1.0 ±0.3	0.4 ±0.3	0.2 ±0.3
	4	8	45	1.2 ±0.8	0.7 ±0.3	0.6 ±0.4	0.5 ±0.3	0.1 ±0.1	0.2 ±0.2
	4	8	90	0.5 ±0.4	0.3 ±0.1	0.2 ±0.1	0.1 ±0.1	0.1 ±0.1	0.04 ±0.1
Fuel filter: new, laden with starch dust	4	4	20	25.2 ±2.8	7.9 ±0.9	4.4 ±0.6	2.3 ±0.2	1.2 ±0.3	0.9 ±0.3
	4	4	45	8.2 ±4.1	6.0 ±0.5	3.3 ±0.3	2.1 ±0.1	1.2 ±0.1	0.7 ±0.3
	4	4	90	6.4 ±3.4	4.3 ±0.6	2.8 ±0.2	1.7 ±0.1	0.6 ±0.3	0.8 ±0.3
	4	8	20	9.5 ±1.4	3.7 ±0.2	2.2 ±0.3	1.5 ±0.1	1.1 ±0.5	1.0 ±0.1
	4	8	45	3.8 ±1.3	3.4 ±0.8	1.8 ±0.6	1.0 ±0.4	0.6 ±0.2	0.4 ±0.1
	4	8	90	3.7 ±1.1	2.0 ±0.5	1.1 ±0.2	0.5 ±0.2	0.4 ±0.1	0.2 ±0.1
Fuel filter: used, laden with broiler-house dust	4	4	20	10.3 ±4.0	9.9 ±1.6	6.4 ±1.2	3.8 ±0.8	2.8 ±0.7	2.3 ±0.5
	4	4	45	15 ±3.7	7.7 ±0.3	4.8 ±0.1	3.0 ±0.2	1.8 ±0.2	1.4 ±0.1
	4	4	90	17.2 ±2.6	6.2 ±0.2	3.2 ±0.04	1.4 ±0.2	0.5 ±0.1	0.1 ±0.2
	4	8	20	1.7 ±0.4	1.2 ±0.6	1.2 ±0.6	0.3 ±0.3	0.8 ±0.3	0.1 ±0.3
	4	8	45	7.4 ±2.4	4.3 ±0.4	3.0 ±0.2	1.8 ±0.2	1.2 ±0.2	1.1 ±0.1
	4	8	90	8.5 ±1.4	3.3 ±0.2	1.6 ±0.1	0.9 ±0.1	0.6 ±0.1	0.53 ±0.04
Paper filter: new, dust free	3	8	20	4.8 ±2.5	2.4 ±0.1	1.3 ±0.1	0.6 ±0.1	0.2 ±0.2	0.1 ±0.8
	3	8	45	3.9 ±0.7	1.8 ±0.1	1.1 ±0.1	0.9 ±0.2	0.6 ±0.1	0.6 ±0.1
	3	8	90	1.6 ±0.1	1.7 ±0.5	1.3 ±0.4	0.9 ±0.2	0.5 ±0.2	0.5 ±0.2
	3	16	20	3.7 ±1.0	2.5 ±0.7	1.0 ±0.4	1.3 ±0.3	-0.2 ±0.3	-0.1 ±0.9
	3	16	45	3.1 ±1.0	0.7 ±0.2	0.2 ±0.4	-0.1 ±0.1	0.2 ±0.3	0.2 ±0.4
	3	16	90	0.8 ±0.4	0.7 ±0.2	0.4 ±0.02	0.3 ±0.1	0.4 ±0.1	0.06 ±0.02
Teflon filter: new, dust free, 20 μm pore size	3	8	20	-0.2 ±0.3	-0.1 ±0.3	0.3 ±0.3	-0.3 ±0.2	-0.4 ±0.1	0.03 ±0.5
	3	8	45	0.2 ±0.1	0.1 ±0.1	0.2 ±0.2	0.2 ±0.04	0.3 ±0.2	0.2 ±0.2
	3	8	90	0.3 ±0.8	-0.1 ±0.04	-0.2 ±0.1	0.1 ±0.1	0.0 ±0.1	-0.01 ±0.1
	3	16	20	1.3 ±0.9	-0.1 ±0.4	0.6 ±0.6	0.3 ±0.1	-0.2 ±0.3	0.6 ±0.1
	3	16	45	0.3 ±0.4	-0.5 ±0.2	-0.2 ±0.4	-0.2 ±0.3	-0.1 ±0.3	-0.2 ±0.02
	3	16	90	-0.2 ±0.1	0.05 ±0.2	0.2 ±0.2	0.1 ±0.03	0.3 ±0.2	0.1 ±0.1
Teflon filter: new, dust free, 5 μm pore size	3	8	20	-0.1 ±1.0	0.4 ±0.4	1.1 ±0.4	1.0 ±0.4	1.3 ±0.4	0.2 ±0.7
	3	8	45	-0.3 ±0.3	0.3 ±0.2	0.5 ±0.2	0.4 ±0.1	0.3 ±0.04	0.4 ±0.1
	3	8	90	0.1 ±0.4	0.1 ±0.1	0 ±0.04	0.05 ±0.1	0.01 ±0.1	-0.05 ±0.1
	3	16	20	1.5 ±0.6	0.1 ±0.1	0.6 ±0.2	0.3 ±0.3	-0.2 ±0.4	0.6 ±0.2
	3	16	45	0.3 ±0.6	-0.5 ±0.3	-0.2 ±0.1	-0.2 ±0.3	-0.1 ±0.2	-0.2 ±0.2
	3	16	90	-0.2 ±0.4	0.05 ±0.1	0.2 ±0.04	0.1 ±0.1	0.3 ±0.1	0.1 ±0.1
Teflon filter: used, laden with broiler-house dust	3	8	20	2.9 ±0.6	1.4 ±0.1	0.05 ±0.1	1.5 ±0.2	0.3 ±0.1	0.3 ±0.2
	3	8	45	1.6 ±0.9	0.4 ±0.1	0.3 ±0	0.2 ±0.3	0.2 ±0.1	0.6 ±0.1
	3	16	20	1.6 ±1.1	0.04 ±0.7	-0.2 ±0.4	0.06 ±0.4	0.03 ±0.5	0.7 ±0.2
	3	16	45	0.5 ±0.4	-0.4 ±0.1	-0.1 ±0.2	-0.3 ±0.3	-0.3 ±0.1	-0.02 ±0.2

CONCLUSIONS

Ammonia adsorption characteristics of selected common in-line dust filters at different operating conditions were investigated. The filter types tested included an automobile fuel filter, a paper membrane filter, and two kinds of Teflon membrane filters (5 or 20 μm pore size), either new or laden with corn starch dust or broiler-house dust. All the tested filters were subjected to combinations of three nominal inlet NH_3 concentrations (20, 45, and 90 ppm) and two nominal flow rates (4 vs. 8 L/min or 8 vs. 16 L/min). In addition, the fuel and Teflon filters laden with broiler-house dust were evaluated for NH_3 release during fresh-air purging. The following conclusions were drawn:

- Ammonia adsorption by the fuel and paper filters was positively related to inlet concentration but negatively related to exposure/run time and flow rate. Relative NH_3 adsorption was generally less than 1% for the fuel and paper filters after 30 min exposure.
- The used fuel filter laden with broiler-house dust showed NH_3 release during the first 15 min (at 8L/min flow rate) of fresh air purging.
- Ammonia adsorption by the Teflon filters was negligible regardless of the inlet NH_3 level (20 to 90 ppm) or flow rate.
- The fuel filter and the paper membrane filters tested in this study offer viable, performance-based options for in-line dust filtration of air samples in NH_3 emissions monitoring.

ACKNOWLEDGEMENTS

Funding for the study was provided in part by the Iowa State University College of Agriculture and Life Sciences Air Quality Initiative and a USDA Special Project on Air Quality Research.

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