An Online Parallel-Plate Wet Denuder System for Monitoring Acetic Acid Gas

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ABSTRACT

In air environments, acetic acid gas may lead to irritations, generate pungent odor, and cause objects to corrode. This paper examines an online parallel-plate wet denuder system to monitor gaseous acid at ppbv concentration levels. Denuder surfaces which comprised frosted glass plates coated with a thin layer of TiO_2 nanoparticles were covered by a thin film made of ultrapure water or 0.5 mM H_2O_2 to absorb the test acetic gases that were generated from a small thermostatic evaporation tube. Denuder effluent was then injected automatically into an ion chromatography for real-time detection. The method was validated by comparing measured concentrations with those obtained simultaneously by using a well established impinger technique. Test results showed that the current technique is an efficient collector for gaseous acetic acid, achieving the collection efficiency between 93.8% to 96.4% by using ultrapure water film. It can monitor 0.9–698.0 ppbv gaseous acetic acid accurately in real-time with response time of 10 minutes, a detection limit of 1.2 ppbv and a time resolution of either 10 minutes or 20 minutes, depending on the concentration of the eluent used in the ion chromatography. The technique was applied successfully to measure the exposure concentration of acetic acid gas leaking from a fume hood in a laboratory.

Keywords: Impinger; Ion chromatography; Air quality monitoring; Acidic gas; Indoor air.

INTRODUCTION

Acetic acid gas is one of the major indoor air contaminants (OSHA, 1999), common sources of which include treated wood products in museums, hospital X-ray development equipment, industrial silicone caulking compounds, and etching processes employed by semiconductor and optoelectronic industries (Berndt, 1987; OSHA, 1999; Shu, 2003). It has been reported that high concentrations of acetic acid gas in indoor environments can cause eye, respiratory, and mucous membrane irritations (OSHA, 1999), while low indoor concentrations of acetic acid gas generate pungent odor (threshold odor limit of 74 ppbv) (AIHA, 1989), corrode metal (> 0.43 mg/m³ or > 172 ppbv, exposure for 12 months under 75% RH) (Tétreault *et al*., 1998) and decrease fiber strength in paper (> 3 mg/m³ or > 1.2 ppmv, exposure for 40–80 days) (Dupont and Tétreault, 2000). Therefore, developing a sensitive air monitoring method for gaseous acetic acid is important for the protection of human health and preservation of objects.

Several air-sampling methods have been previously applied to collect gaseous acetic acid, however none were designed to monitor short-term concentration fluctuations. Complicated pre- and post-sampling procedures required for some of the methods (e.g., the impinger absorption, glass nebulizer and dry diffusion denuder techniques) (Schultz Tokos *et al*., 1992; Amati *et al*., 1999; Zervas *et al*., 1999; Tsai *et al*., 2001a, 2001b, 2003) could lead to sampling errors. The solvent-free technique solid-phase microextraction (SPME) is noted for its simplicity and ease of operation, but it is unable to monitor short-term concentration changes since the SPME collection efficiency depends on the equilibrium time and the distribution of acetic acid gas concentration between the fiber coating and air. In addition, the SPME desorption efficiency decreases as sampling time and acetic acid gas concentration in the air decrease (Godoi *et al*., 2005).

A wet diffusion denuder technique coupled with an ion chromatography (IC) system and used as an online denuder system to minimize sampling artifacts, was developed to enable automatic sampling and analysis of water-soluble gaseous acetic acid (Löflund *et al*., 2001; Boring *et al*., 2002; Fisseha *et al*., 2006). Löflund *et al*. (2001) utilized a wet effluent parallel plate denuder (WEPPD) designed by Simon and Dasgupta (1993) and an ion chromatography system to detect concentrations of gaseous acetic acid in field environments. The 140 cm² glass plate surfaces of the WEPPD were chemically etched and coated with a thin layer of silica powder (2–25 μm) via chemical bonding with the $NaOH/Na_2SiO_3$ solution. Plate

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surfaces were wetted continuously with ultrapure water at 10 mL/h to absorb gaseous acetic acid in the counter-flow air at 5 L/min. Results showed that the sampling efficiency for gaseous acetic acid approached 99% with a detection limit of 2–4 pptv and a time resolution of 1 hour. Following the above design, Fisseha *et al.* (2004, 2006) altered water and air flow rates to 1.5 mL/min and 4 L/min, respectively, to detect concentration changes at parts per trillion by volume (pptv) level every 30 mins for gaseous acetic acid in urban environments. However, they noted that collection efficiency for acetic acid gas fell to 85%, which might reflect sampling loss in the sampling line and uncertainties due to aging of the acetic acid gas permeation source. Boring *et al.* (1999, 2002) applied larger silica particles (74–127 μm) and larger denuder plates (273 cm^2 per plate) on the WEPPD to detect gaseous acid concentrations (including acetic acid gas) in field environments. Rather than being bonded chemically with the NaOH/Na$_2$SiO$_3$ solution, silica particles were coated onto plates by thermal bonding. The absorbing liquid was hydrogen peroxide (0.5 mM) operating at 0.5 mL/min. The airflow rate was 5 L/min and the ion chromatography cycle was 10–15 min. However, the collection efficiency and response time were not reported. Tsai *et al.* (2008) designed a parallel-plate wet denuder (PPWD) and applied TiO$_2$ nanoparticles (P25, Degussa, Germany) on glass plates that were sand-blasted to give a microscaled surface roughness to further increase plate wettability. The accuracy of this method is excellent for capturing and detecting strong acids (Tsai *et al.*, 2008). However, the accuracy of the PPWD coupled with an ion chromatography remains to be investigated for weak acids.

This study was designed to assess the accuracy of the online PPWD system (PPWD and IC) for on-line semi-continuous measuring the acetic gas concentrations with time resolution/cycle time of 10–20 minutes. Measured concentrations were compared with those obtained by using an established impinger method. The system response time was also evaluated. Finally, the online PPWD system was applied to determine the exposure concentration of acetic acid gas in front of a laboratory fume hood in which acetic acid liquid was being heated.

EXPERIMENTAL

Online PPWD System
PPWD

PPWD (Fig. 1) consists of two sand-blasted plates (17 cm × 7.5 cm, L × W) coated by the calcination process at 300°C with a thin layer of TiO$_2$ nanoparticles (Tsai *et al.*, 2008), which were generated by the sol gel method. The gap between the two plates was 4 mm, providing a channel through which an upward gas stream flowed at a rate of 5 L/min (Fig. 1). Observation of the water film on the plates for over 2 months showed the nanoparticle coating remained intact and the water film was uniform throughout the period. A peristaltic pump (Watson-Marlow, 313FD, UK) was used to deliver the denuder liquid at a flow rate of 1 mL/min per denuder plate to wet the microstructured
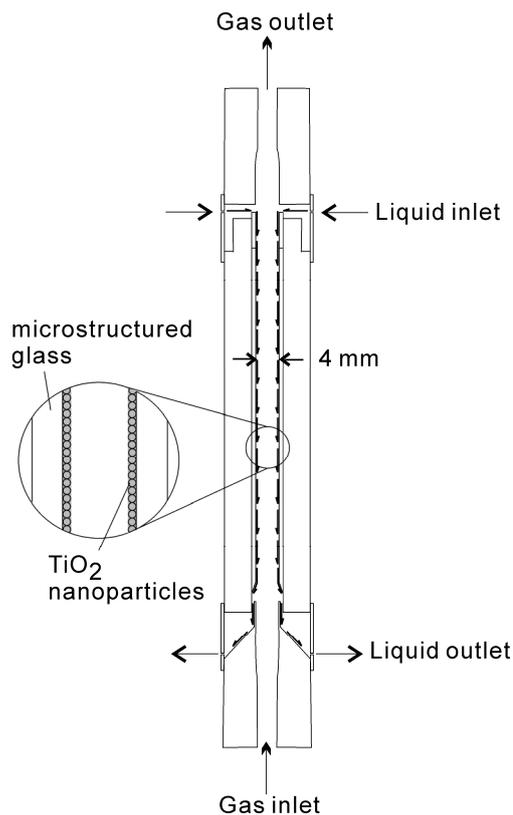
Fig. 1. PPWD: schematic diagram.

denuder plates via capillary attraction that attained. Water-soluble gas was absorbed by the denuder liquid on the plate surfaces. The denuder effluent was collected in reservoirs at the bottom of the PPWD and continuously pumped through the connecting Marprene tubing line either into a sample loop of the IC system or into a drain. The flow direction was controlled by an injection valve. Transportation time required for denuder effluent to travel between the PPWD and the injection valve is 2.47 minutes, as estimated by tubing volume and solution flow rate. The PPWD has a theoretical collection efficiency of 96–98% for acetic acid gas, as calculated using the gas penetration theory by Gormley and Kennedy (Tsai *et al.*, 2008) with a diffusion coefficient of 0.103–0.133 cm^2/sec (Bennett and Myers, 1982; Staudt *et al.*, 1995; Bird *et al.*, 2002).

Ion Chromatography

Ion chromatography was used for sample analysis. The ion chromatograph was a Metrohm IC 861 equipped with a METROSEP ASUPP5-150(6.1006.520) column and a conductivity detector. The eluent was an aqueous solution of 3.2 mM Na$_2$CO$_3$ and 1.0 mM NaHCO$_3$ delivered at a flow rate of 0.7 mL/min. The suppressor was regenerated using 7.5 × 10^{-2} N H$_2$SO$_4$ solution and 19.9 MΩ × cm ultrapure water. The sample loop used 0.25 mL PEEK (poly ether ether ketone) tubing. The ion chromatography system had a 20-minute analysis cycle (1-min equilibration time in the sample loop and 19-min analysis time). Fig. 2 displays a typical 19-min analysis of the acetic acid at different concentrations with acetate ion retention time of 4.4 min. In
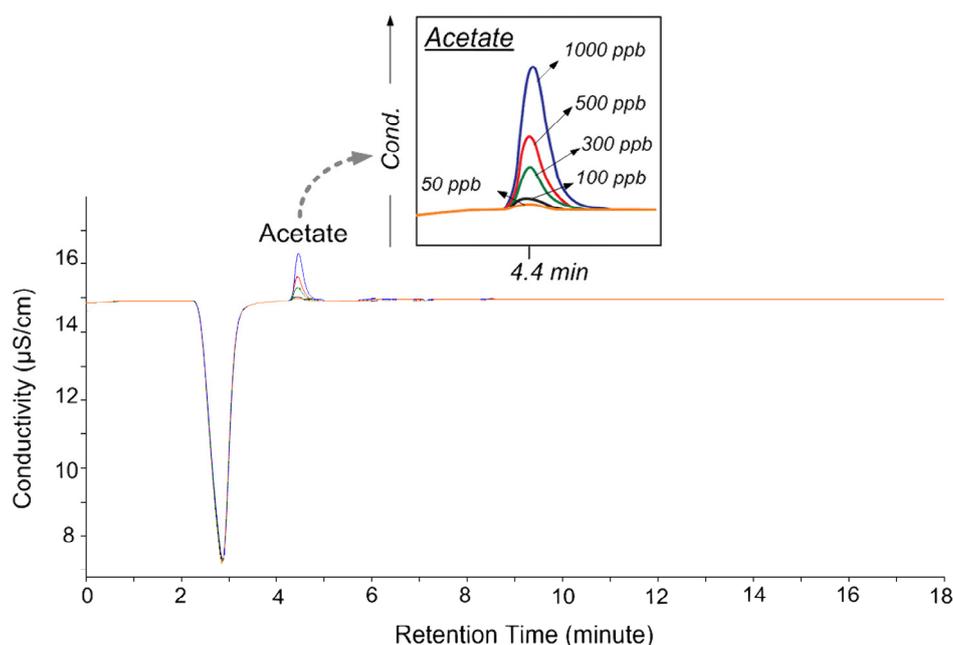
Fig. 2. Representative chromatogram.

another tests (data not shown), the cycle time of 20 minutes was reduced to 10 minutes (1-min equilibration time and 9-min analysis time) by using high eluent concentration of 10.0 mM Na_2CO_3 and 3.1 mM $NaHCO_3$, which shortened the retention time of acetate ion to 3.3 min.

The method detection limit (MDL) for the acetate ion was found to be below 7.5 ppb in liquid phase in accordance with the procedure outlined in 40 CFR 136. In terms acetic acid gas sampling at 5 L/min by the online PPWD, the MDL is 1.2 ppbv. Blanks were analyzed before each test and found to be below the detection limit.

Test Setup

Fig. 3 shows the experimental setup. Both the online PPWD system and the impinger method were tested. Two types of denuder liquids were used: ultrapure water (19.9 MΩ × cm) and 0.5 mM H_2O_2, both were used previously to sample acetic acid gas (*e.g.* Löflund *et al.*, 2001; Boring *et al.*, 2002; Fisseha *et al.*, 2006). The 0.5 mM H_2O_2 solution was preserved in a 2L plastic tank covered by an aluminum foil to prevent exposure to light prior to use. The absorbent liquid for the impinger technique was ultrapure water.

In the experimental setup, the test gas was drawn simultaneously through the impinger and PPWD systems via a three-way valve. Two glass impingers (Impinger 1 and Impinger 2), which were connected in series and placed beside the PPWD, were used to determine the collection efficiency of the impinger technique, which was calculated as the percentage of acetic acid gas collected by Impinger 1 of that collected by both Impingers 1 and 2. The gas flow rate of the impinger system was 2.5 L/min. The other single glass impinger placed in series after the PPWD operated at 5 L/min was used to collect the gas that penetrated the PPWD. The PPWD collection efficiency was calculated as the percentage of the acetic acid gas

collected by the PPWD over the total acetic acid gas collected by both the PPWD and the glass impinger.

In each glass impinger, the distance between jet orifice and impinger vessel bottom was about 2 cm. The capacity of the impinger vessel was 300 mL and the liquid volume was 150 mL. The sampling period for the impingers technique was 90 min. After sampling, the samples were extracted from the glass impingers with three different clean plastic syringes, which were sealed by parafilm and analyzed by the offline IC within 2 hours.

The test acetic acid gas was generated by using a small evaporation tube containing 300 μL aqueous acetic acid solution, as shown in Fig. 3. The evaporation tube was placed in a temperature-controlled tubular furnace. Acetic acid vapor, evaporated and released through an orifice (1 mm in diameter) on the tube, was carried by zero air generated from a zero air supply (Model 111, thermo environmental instruments Inc. U.S.A) at 0–80 cc/min out of the furnace and diluted by another zero air at a specific flow rate (7920 cc/min) to obtain desired test concentrations. A mass flow controller (Model 146, thermo environmental instruments Inc. U.S.A.) was used to control the gas flow rates.

In the evaporation tube, nine concentrations ranging between 99.7–5.9% (w/w) diluted from 99.7% (w/w) purity glacial acetic acid (PA-ACS-ISO 131008, Panreac Quimica S.A., Spain) were used as aqueous solutions. Five constant temperatures ranging between 298–328 K regulated by the tubular furnace were used. The gas-phase acetic acid with specific concentration can be generated via the control of carrier and dilution gas flow rates. Alternatively, when carrier gas flow rate was fixed at a constant value, the gas-phase acetic acid with specific concentration could be generated using either different concentrations of the aqueous solution in the evaporation tube or different controlled temperatures of the thermostatic tubular furnace,
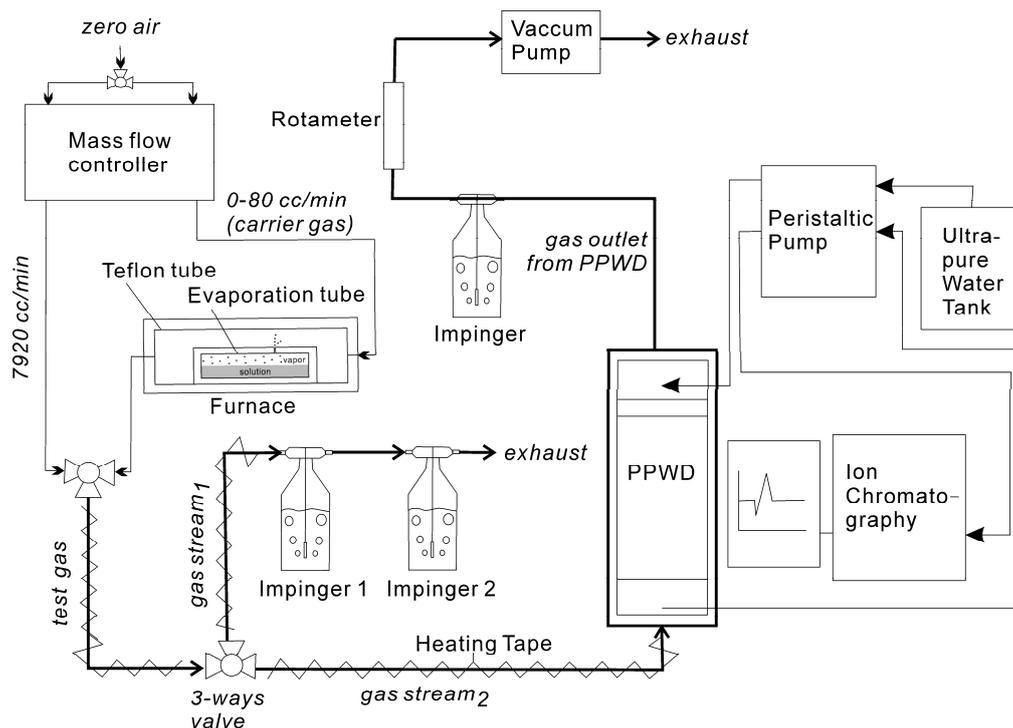
Fig. 3. Test setup: schematic diagram.

as shown in Fig. 4. It shows that test gas concentration increases with either increasing furnace temperature or solution concentration when the tubular furnace was preheated up to 1–2 hours. The concentration range of the test gas stream covers the acetic acid gas odor threshold of 74 ppbv reported by American Industrial Hygiene Association (AIHA, 1989). The relative standard deviation (r.s.d.) of each generated gas stream is less than 12% in the concentration range of 0.9 to 698.0 ppbv (Fig. 4).

Response Time Test

Acetic acid gas response time at different concentrations

was measured for the online PPWD system. The response time includes both the rise time and fall time. The rise time represents the time required by the online PPWD to detect 90% concentration of the acetic acid gas when it is first introduced into the system. The fall time is the time for the PPWD to detect 10% of the original acetic acid gas concentration after the concentration at the PPWD inlet is reduced to zero.

The response time was measured in eight steps that lasted for more than 200 minutes with the procedure shown in Fig. 5. These eight steps included: (1) At 0 minutes (0:00) a stable gas stream of a specific concentration generated

Fig. 4. Characteristics of test acetic acid gas generated from the evaporation tube depend on (a) furnace temperature and (b) aqueous solution concentration. Dilution and carrier gas flow rates were, respectively, fixed at 7920 and 80 cc/min. The error bar represents one standard deviation.

Test Gas			Denuder Effluent			
Step	Time (min : sec)	Type	Step	Time (min : sec)	Procedure	Schematic Diagram of Collection
1	0:00	Acetic gas	2	0:00	collected by a syringe	peristaltic pump, PPWD, syringe
				1:00	drained	
				2:00	collected by a syringe	
				3:00	drained	
				4:00	collected by a syringe	
				5:00		
					repeated step 2	
			3	20:00	collected by the sample loop	peristaltic pump, PPWD, IC (cycle time: 20 min)
				21:00	drained	
				40:00	collected by the sample loop	
				41:00	drained	
				60:00		
					repeated step 3	
4	140:00	zero air	5	140:00	collected by a syringe	peristaltic pump, PPWD, syringe
				141:00	drained	
				142:00	collected by a syringe	
				143:00		
					repeated step 5	
			6	160:00	collected by the sample loop	peristaltic pump, PPWD, IC (cycle time: 20 min)
				161:00	drained	
				180:00	collected by the sample loop	
				181:00	drained	
				200:00		
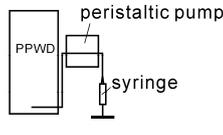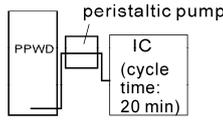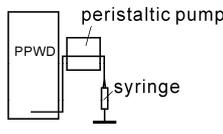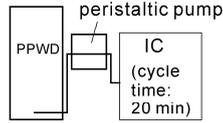
Fig. 5. Procedure for the response time test.

by the gas generation system was introduced into the PPWD; (2) At the same time, 1 mL of denuder effluent was collected over a 1 min time period (0:00–1:00) using a syringe. After collection, the effluent was then drained for one minute (1:00–2:00). Collection of the sample with a new syringe for one minute (2:00–3:00), followed by another one minute time interval during which the effluent was not collected. Thereafter, one-minute collections followed by one-minute non-collection intervals were repeated until elapsed time reached 20 minute (20:00). All syringes containing sample solutions were stored in a refrigerator and later analyzed by an offline IC; (3) Over the next 120-minute period (20:00–140:00), the gas stream was monitored by the online PPWD system with a cycle time of 20 minutes (1-min equilibration time in the sample loop and 19-min analysis time for the ion chromatography); (4) At 140 minutes (140:00), the incoming gas stream was stopped and replaced by zero air; (5) At the same time, denuder effluent was collected for one minute (140:00–141:00) by a syringe. This one-minute collection period was followed by another one–minute period (141:00–142:00) during which the effluent was not collected. Thereafter, one-minute collections followed by one-minute non-collection intervals were repeated until elapsed time reached 160-minute. Syringes with the sample solution were then stored in a refrigerator and later analyzed by an offline IC; (6) Over the next 40-minute period (160:00–200:00), the gas stream was again monitored by the online PPWD with a cycle time of 20 minutes; (7) The online PPWD system was shut down at 200-minute; (8) Absolute concentrations obtained in steps 2, 3, 5 and 6 were further represented by relative concentrations in percentage of to the mean absolute concentrations obtained in step 3.

Exposure Measurement in Front of a Laboratory Fume Hood

A fume hood is one type of the local exhaust ventilation system to control operator's exposure to toxic, offensive or flammable vapors, gases and aerosols in the laboratory. An improperly used and poorly functioning fume hood leaks air pollutant from the hood leading to potential inhalation exposure of operator(s) and pungent odor as well as invisible corrosion of the objects in laboratory. The online PPWD system can be used as an on-line and real-time monitor to measure the air pollutants that are leaking in the laboratory. Fig. 6 shows the schematic diagram of a by-pass fume hood (Hong Tai laboratory equipment, Taiwan) and the measurement positions (left, middle and right) in front of the hood with different sash heights of 15, 30, 45 and 60 cm, respectively. Totally, there were 12 measurements for acetic gas concentration, each was repeated 3 times. The air speed was measured by an anemometer at three different heights of a sash opening and the average was calculated. In the hood, 150 mL of 99.7% (w/w) acetic acid solution (PA-ACS-ISO 131008, Panreac Quimica S.A., Spain) was contained in a stainless dish heated by a hot plate (333 K) in the middle of the working platform inside the hood. A Teflon tube with 5.28 mm inner diameter was connected with the online PPWD system, whose inlet opening was fixed at 150 cm above the ground and faced toward the hood to mimic potential personal exposure. Horizontal distance between the tube and opening was kept at 17 cm.
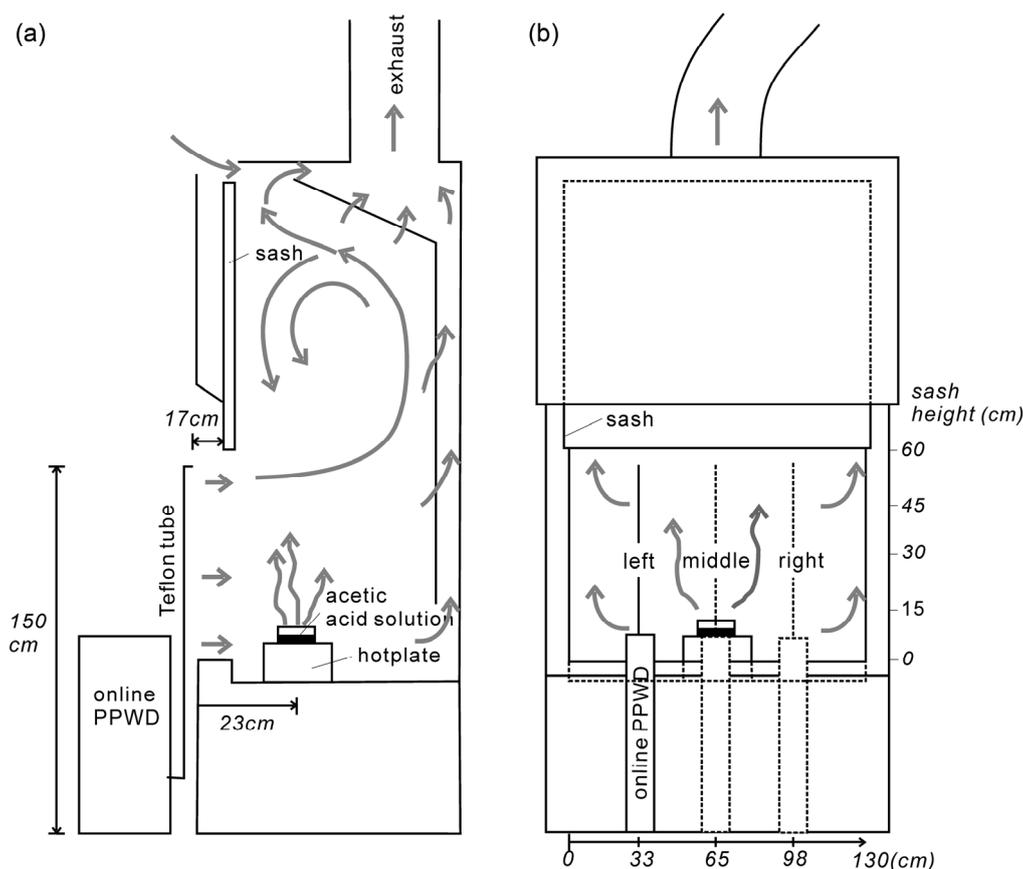
Fig. 6. Laboratory flume hood and experimental setup for exposure measurement of acetic acid gas (a) side view and (b) front view.

RESULTS AND DISCUSSION

Collection Efficiency and Accuracy of the Online PPWD System

The impinger technique exhibits a high collection efficiency of 98–99% for acetic acid gas as shown in Table 1. Therefore, acetic acid concentrations obtained by the impinger technique were used as the reference values in this study. The collection efficiency of PPWD wetted by ultrapure water was measured to be between 93.8% and 96.4%, with acetic acid gas concentrations ranging between 56.3 ppbv and 174.6 ppbv as shown in Table 2. The experimental collection efficiency is close to the expected theoretical value of 96–98% and higher than the reported value of 85% by Fisseha *et al.* (2004, 2006).

Acetic acid gas concentrations measured by the PPWD wetted by ultrapure water are shown to be nearly the same as those of the impinger for the acetic acid gas in the 0.9–698.0 ppbv range in Fig. 7. Linear regression of the concentrations of the PPWD with those of the impinger shows the correlation coefficient r^2 of 0.998, the slope of 1.026 and the intercept of 0.961 ppbv. Independent t test (t = 0.101, degree of freedom = 60, P value = 0.920) indicates the difference between the two methods is not statistically significant. Accordingly, the PPWD technique coupled with ion chromatography is considered to be an accurate, semi-continuous monitoring technique for detecting gaseous

acetic acid with the time resolution/cycle time either of 10 minutes or of 20 minutes depending on the concentration of the eluent used in IC.

Table 1. Collection efficiency of the impinger technique at the acetic acid gas flow rate of 2.5 L/min.

Concentrations (ppbv)				Collection Efficiency (%)
Impinger [1]				
Impinger 1		Impinger 2		
Mean	1std	Mean	1std	
42.3	± 0.9	1.0	± 0.4	98
59.0	± 1.1	0.9	± 0.3	98
61.5	± 1.4	0.9	± 0.1	99
68.6	± 1.5	1.2	± 0.3	98
114.0	± 3.3	1.9	± 0.3	98
146.1	± 1.5	1.5	± 0.6	99
189.6	± 0.3	1.7	± 0.1	99
200.8	± 4.2	3.6	± 1.8	98
286.1	± 1.5	4.0	± 0.5	99
375.5	± 2.9	4.1	± 0.5	99
481.9	± 5.7	5.2	± 0.9	99
553.2	± 7.8	3.4	± 1.2	99
693.9	± 17.1	4.7	± 0.9	99

Note. for each data point, the average ± standard deviation is based on three samples.

Table 2. Collection efficiency of the online PPWD system.

Concentration (ppbv)				Efficiency (%)
Online PPWD		Impinger after PPWD		
Ultrapure water		Ultrapure water		
56.3	± 2.4	2.6	± 0.2	95.6
95.1	± 3.5	6.2	± 0.2	93.8
101.8	± 1.8	4.1	± 3.4	96.2
126.9	± 6.6	4.7	± 2.6	96.4
174.6	± 5.4	8	± 3.8	95.6

Note. the average of each data point was based on 5–6 and 3 represented samples, respectively, for the online PPWD and impinger technique.

Test results show that the acetic acid gaseous concentrations determined by the online PPWD wetted by 0.5 mM H_2O_2 are higher than those of the impinger, as shown in Fig. 8. Linear regression indicates that the acetic overestimation is associated with the intrinsic nature of 0.5 mM H_2O_2 that exhibits extra signals on the chromatogram, overlapping the retention time of the acetate and resulting in extra acetate count on the chromatogram (Fig. 9).

PPWD Response Time

Rosman *et al.* (2001) stated that interactions between the target gas and substances that have accumulated on tubing lines during sampling, and denuder material may affect response time. Therefore, it is important to quantify the response time of the current online PPWD system. Fig. 10 shows the results of the response time measurement of the online PPWD which used the eluent concentration of 3.2 mM Na_2CO_3 and 1.0 mM $NaHCO_3$. It indicates that when introducing acetic acid gas into the PPWD with a mean concentrations of 11.1, 49.1 or 543.6 ppbv, the concentration of the denuder effluent collected within the
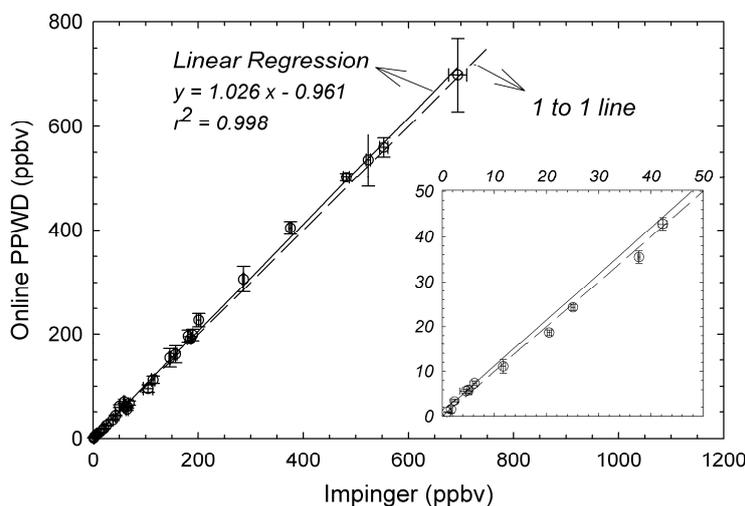
Fig. 7. Comparison of acetic acid gas concentration determined by the impinger with that determined by the online PPWD. Ultrapure water was the denuder liquid. The error bar represents one standard deviation.
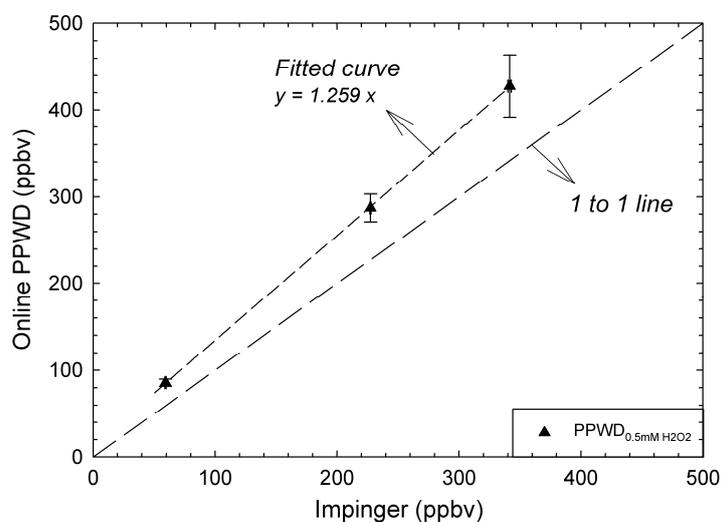
Fig. 8. Comparison of acetic acid gas concentrations determined by the impinger and by the online PPWD. The denuder liquid was 0.5 mM H_2O_2. The error bar represents one standard deviation.
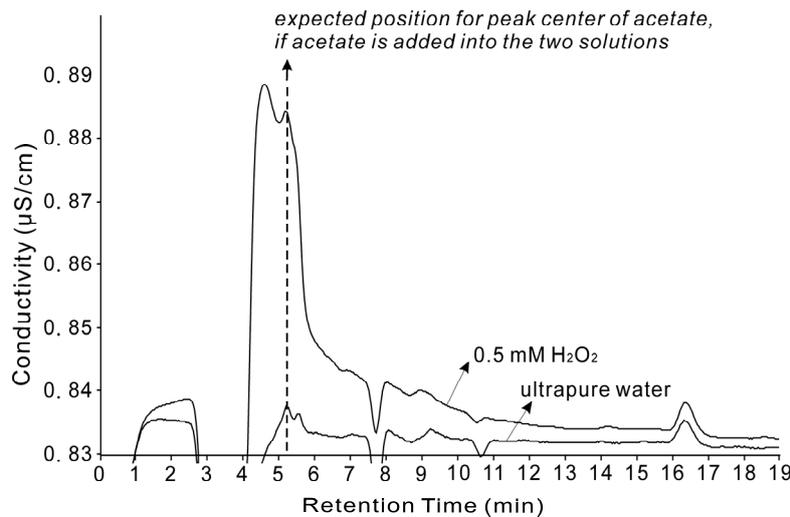
Fig. 9. Chromatograms of the two liquids: 0.5 mM H_2O_2 and ultrapure water.
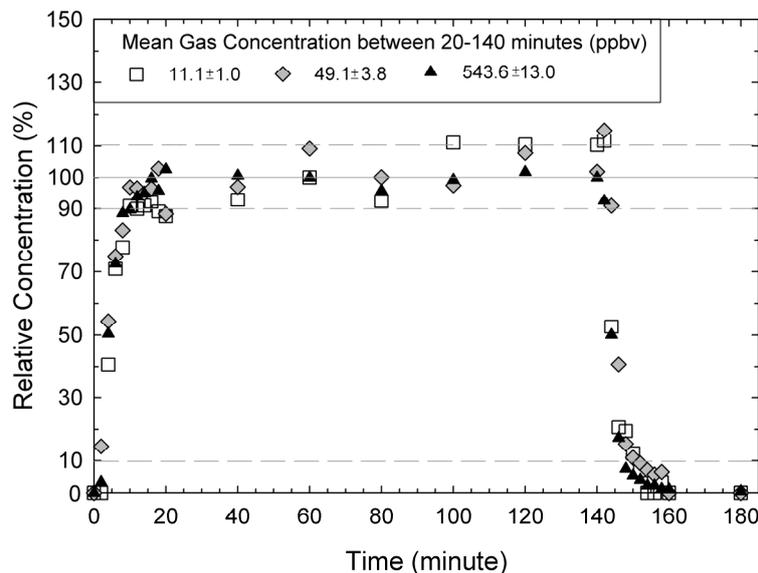
Fig. 10. Test results of response time for acetic acid gases of different concentrations. The x-axis represents the time of sampling.

10 to 11 minute period will rise to the relative concentration of 91, 97 or 90%, respectively. Moreover, when the incoming acetic acid gas concentration is reduced to zero at 140 minute, the concentration of the denuder effluent collected during the 150–151 minute time interval will drop to the relative concentrations of 12, 11 or 5% (average = 9%) to the mean acetic acid concentrations of 11.1, 49.1 or 543.6 ppbv, respectively. That is, both the rise and fall times for the present online PPWD system to detect the true concentration with 10% error is about 10 minutes (Fig. 10). The response time reported in this study is the first published experimental value for wet diffusion denuder monitoring acetic gas. The response time of 10 minutes indicates that the time resolution/cycle time of the present online PPWD, is either 10 or 20 minutes depending on the concentration of eluent used in the IC. Moreover, the online PPWD system with time resolution

of 10 minutes is better than previous researches in which the time resolution of 1 hour or 30 minutes was reported (Löflund *et al.*, 2001; Fisseha *et al.*, 2004, 2006).

Exposure Concentration of Acetic Acid Gas in Front of the Laboratory Fume Hood

Table 3 shows the measurement results of the air velocity and the exposure concentration of acetic acid gas in front of the laboratory fume hood. It is seen that the exposure concentration of acetic acid gas varies with different measurement positions with the middle position being the highest. The exposure concentration is the highest when the sash height is 60 cm, and it decreases dramatically when the sash height is reduced below 45 cm. For example, at the middle position, the concentration changed from 402.4 to 98.6, 9.6 and 13.1 ppbv as the sash height was changed from 60 cm to 45, 30 and 15 cm,

Table 3. Air velocity and exposure concentration of acetic acid gas in front of a laboratory fume hood.

Sash Height (cm)	Left				Middle				Right			
	Air Velocity (cm/s)		Gas Conc.[a] (ppbv)		Air Velocity (cm/s)		Gas Conc. (ppbv)		Air Velocity (cm/s)		Gas Conc. (ppbv)	
	Mean	1std	Mean	1std	Mean	1std	Mean	1std	Mean	1std	Mean	1std
60	25	3	56.7	4.2	18	2	402.4	42.9	21	3	45.6	4.9
45	30	2	5.0	0.9	31	3	98.6	8.5	25	4	3.1	0.3
30	31	3	2.0	0.3	32	2	9.6	2.3	36	3	3.6	0.4
15	51	3	9.4	1.1	50	4	13.1	2.1	52	4	10.9	1.2

[a] No. of samples = 3

respectively. Relatively uniform air velocity ranging from 18 to 36 cm/sec was observed when the sash height was kept between 30 and 60 cm. However, when the sash height was reduced further from 30 to 15 cm, the average suction air velocity was increased from 26–36 cm/sec to 50–52 cm/s (Table 3). This velocity increase led to a slightly increase in the exposure concentration from 9.6 to 13.1 ppbv, 2.0 to 9.4 ppbv, and 3.6 to 10.9 ppbv, at the left, middle and right measurement position, respectively. The reason for the increase is due to the enhanced flow turbulence inside the hood when the air velocity increases at the smallest sash height of 15 cm. This finding was also observed by Tsai *et al.* (2009), who found that the highest exposure during handing alumina nanoparticles in a conventional hood occurred at the lowest sash height due to very large vertical eddies that carried nanoparticles released by the handling tasks up the back of the hood, across the top and then downward toward the sash opening. The suction air velocity at the sash height of 15 cm in the current by-pass hood exceeded that at the optimum operating sash height of 30–45 cm as found in this study. As a result, the laboratory was filled with pungent odor.

CONCLUSIONS

The present PPWD coated with TiO_2 nanoparticles and wetted by ultrapure water is an efficient collector for gaseous acetic acid, achieving the collection efficiency of 93.8–96.4%. The online PPWD coupled with ion chromatography was validated by the impinger method and showed excellent agreement. This online system enables semi-continuous monitoring of acetic acid gas in ambient air with response time of 10 minutes, time resolution of 10–20 minutes and the detection limit of 1.2 ppbv. The system was used to measure the acetic acid gas exposure concentration near a laboratory flume hood system successfully. Test results demonstrate that the system is an excellent measurement system for acetic acid gas in indoor environment. In the future, the current online PPWD system will be used to monitor other water soluble gases in both indoor and ambient environments.

ACKNOWLEDGEMENTS

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