SIMULTANEOUS SCANNING LIDAR MEASUREMENT AND AIR SAMPLING USING A PERSONAL CASCADE IMPACTOR FOR TRAFFIC AEROSOL CHARACTERIZATION

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Abstract: Simultaneous vertical scanning lidar measurement and air sampling using a personal cascade impactor was presented in this paper. The fine particulate matters collected using the personal cascade impactor were characterized for their morphology and elemental composition using a scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM-EDX). The scanning Lidar provided a two-dimensional profile of the traffic aerosol showing the spatial distribution of the aerosol horizontally and vertically as indicated by the strong backscattering signal. SEM image showed that the particles collected from the sampling site were irregularly shaped particles. Elemental analysis showed the presence of C and O, in all particles are with traces of Ca, Si, Cu, V, Zn, Sb, Fe, Mg, K, Ba, Co, Cl, Sn, Ni, and Br. Most of these elements are typically associated with anthropogenic emissions such as traffic and combustion of fossil fuels. The study showed that a combined Lidar and air sampling with SEM-EDX analysis can give a better understanding of the characteristics of aerosols such as its spatial distribution, shape, morphology, and chemical composition, and possibly the source.

INTRODUCTION

Air quality continues to be at the forefront of concerns in the Philippines. Composed of 16 cities and municipalities, Metropolitan Manila is home to roughly 9.4 million Filipinos (MMDA, 2005). Its capital, Manila, is situated along the mouth of a natural harbor. It is one of the most industrialized cities in the country with numerous industrial sites scattered all over the area. Human activities, especially in urban areas, have an enormous impact on the amount of aerosols generated, as well as on the population's health. Among the main sources of urban aerosols come from industries such as steel and iron works, chemical manufacturing, and oil depots and the automotive fleet, over a million vehicles (Landulfo *et. al.*, 2003, Klima, 2005). In the area surrounding De La Salle University at Taft Avenue, Manila, the main source of urban aerosols are vehicular emissions as it is surrounded by four major thoroughfares where lots of private and public vehicles used these routes daily. Lidar technique has become a powerful tool to visualize, in real time: a) the atmospheric dynamical transport processes, using the aerosol particles as tracers, b) the vertical distribution of aerosol particles, either produced locally over the measuring site (car traffic, domestic heating, industrial activities etc.), or transported by the atmospheric circulation (land-sea breeze circulation, trans-boundary air pollution, desert dust events etc.) and c) the structure of the lower atmosphere (structure of the PBL, identification of several aerosol dust layers), and its correlation with ground air pollution levels (Vaughan, 2002).

Application of scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM-EDX) on the other hand can provide additional information concerning the shape, morphology, chemical composition, and source of atmospheric aerosols (Feng, *et. al.*, 2009). In this paper, characterization of traffic aerosols in the vicinity of De La Salle University, Manila is presented using simultaneous scanning Lidar measurement and air sampling with a personal cascade impactor during heavy traffic. The purpose of this work is to provide two-dimensional traffic aerosol profile and linear depolarization ratio of aerosol using a vertical scanning Lidar, and to understand the morphology and elemental compositions, and possibly the source of these traffic aerosols through a scanning electron microscopy-energy dispersive X-ray analysis (SEM-EDX). Air sampling was done using a personal cascade impactor.

METHODOLOGY

Scanning Lidar Measurement

The lidar system is situated at the De La Salle University (DLSU) Science and Technology Research Center (STRC) in Manila, and aimed along the direction of approximately 12° East of South of the lidar site, towards the Pasay City area. A map of the site's vicinity and the lidar path is shown in figure 1. The lidar site is surrounded by five main thoroughfares in Manila such as Taft Avenue, Mabini St, Vito Cruz St., Quirino Avenue, and Roxas Boulevard. No industrial plants are located near the vicinity and along the lidar path hence most of the aerosols detected by the lidar can be attributed to vehicular emission especially during peak traffic hours. The Mie scattering lidar system employs a Nd:YAG at 20 Hz pulse repetition frequency. It transmits three wavelengths simultaneously, 355-, 532, and 1064 nm. However, only the perpendicular and parallel backscattered signal at 532-nm collected by a 20 cm diameter Newtonian telescope was utilized in this study. The system is only capable of vertical scanning from 69^o to 87^o zenith angles because of several obstructions along the lidar path.

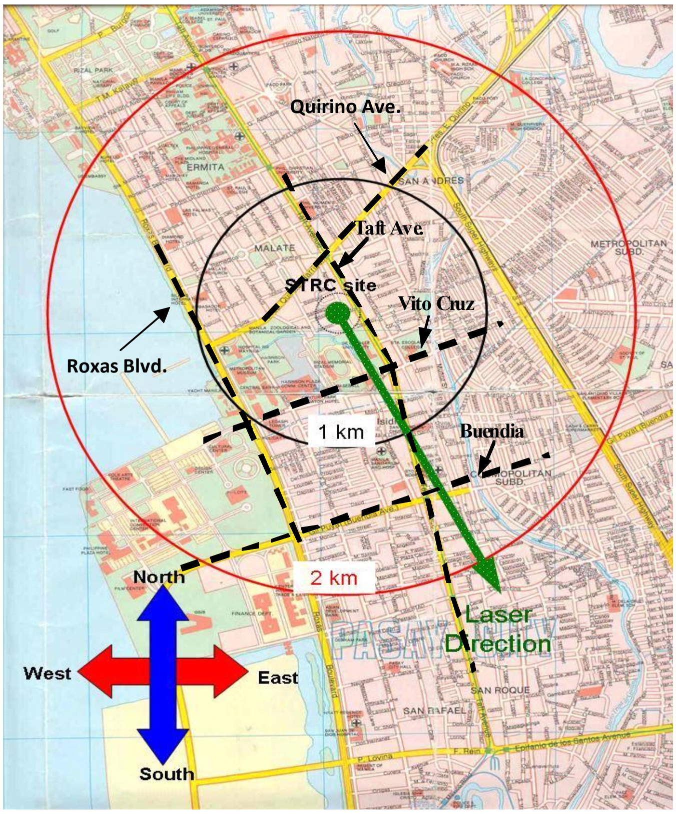

Figure 1: The location of the DLSU LIDAR system and the major avenues surrounding it. The arrow shows the direction of the transmitted laser beam. Manila Bay is on the left side of the figure (not in the map).

Air Sampling Using a Personal Cascade Impactor and Scanning Electron Microscopy

The personal 2-stage low-volume cascade impactor, shown in figure 2, was made from aluminum and had a nozzle diameter of 0.4 mm. It operates using a 9-V battery. Particles were impacted on an 8-mm diameter cellulose filter. Morphological features and elemental composition of individual particles were analyzed with a SEM (JSM 5310 JEOL) equipped with an EDX (Oxford) Analyser. Particle size was estimated from the direct appearance of individual particles in the scanning electron micrograph. SEM/EDX was done according to the standard operating procedure for sample preparation and analysis of particulate matter samples by scanning electron microscopy. Scanning Electron Microscope was operated at an acceleration voltage of 15 kV during the analysis. The SEM images and analytical data of trace elements concentration were recorded with a Link Isis 3.0 software system with a SemAfore 5.0 SA20 Scan Digitizer for digital imaging. EDX analysis was performed with 5000x magnification on individual particles.

Figure 2: The two-stage personal cascade impactor**.** beam.

RESULTS/ANALYSIS

Simultaneous Lidar experiment and air sampling was conducted last Feb 9, 2012 during peak traffic hours. Heavy traffic usually starts at 4:30 PM up to 7:30 PM. Air sampling was conducted at the intersection of Vito Cruz and Taft Avenue from 5:45 to 5:50 PM. Lidar experiment was conducted from 5:30 PM to 6:00 PM. One Lidar scan takes three and half minutes to complete. At this period of time, heavy traffic is always expected along the busy thoroughfares surrounding the Lidar site. Figure 3 shows a two-dimensional traffic aerosol profile obtained from the scanning lidar measurement and it represents the range-squared corrected signal scanning plot for the 532-nm

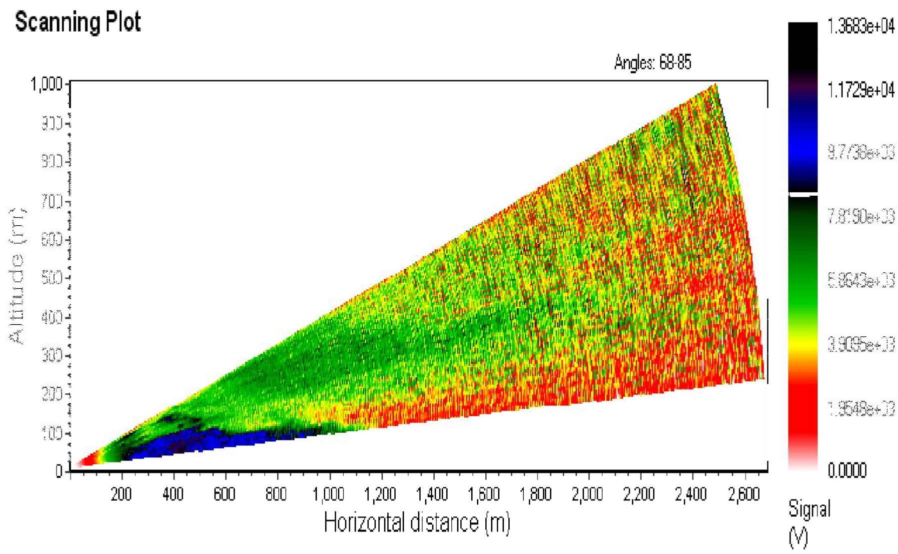

Figure 3: Two-dimensional range-squared corrected signal scanning plot for 532 nm laser wavelength.

The region of interest in figure 3 was the horizontal distance from 200 m to 1200 m. As seen from figure 1 this horizontal distance range is between the Lidar site and Vito Cruz. The intersection of Vito Cruz and Taft Ave. is roughly 500 m from the Lidar site. A strong backscattering signal was observed between 200 to 1200 m horizontally, and 50 to 100 m vertically. The depolarization ratio of this region was between 5 - 25 %, as shown in figure 4. The depolarization ratio is an indicator of the non-sphericity of the particle. Furthermore, since the sampling site is near Manila Bay, sea salt particles could have contributed to the high value of the depolarization ratio. The depolarization ratio of sea salt is about 8-22% (Murayama, *et. al.*, 1999).

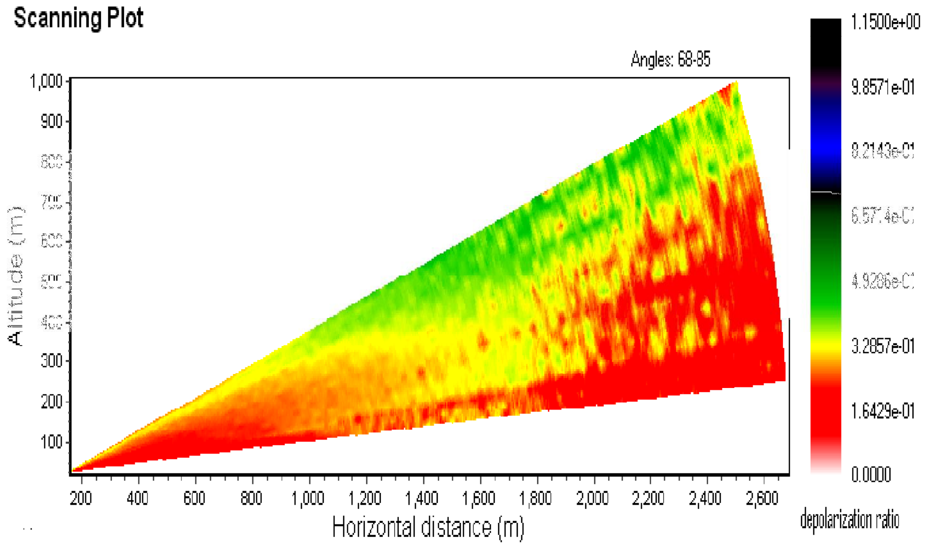

Figure4: The linear depolarization ratio of the lidar backscattered signal shown in figure 3.

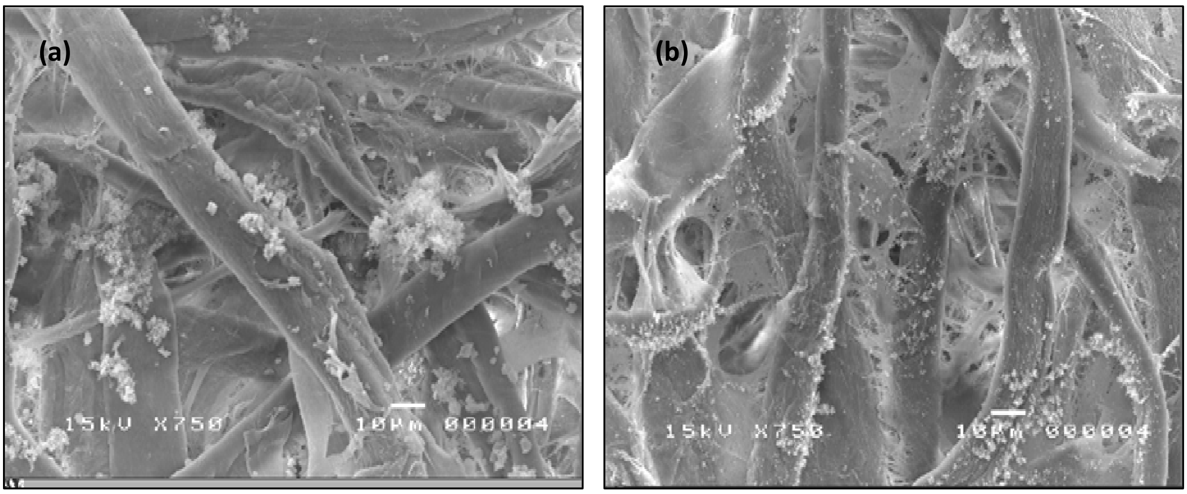

Figure5: SEM images of the particles collected using a personal cascade impactor which were taken at 750x magnification and at an acceleration voltage of 15kV.

SEM images of the particles collected using a personal cascade impactor are shown in figures 5a and 5b. These images were taken at 750x magnification. As can be seen from both figures the particles are irregularly shaped typical for a fly ash particles agglomerate from fossil fuel combustion process. Figure 6 shows some of the individual particles at 5000x magnification where EDX analysis was performed. EDX analysis was done on 22 particles, 12 from stage 1 and 10 from stage 2, to determine the percent mean elemental concentration on each particle. The size of the particles ranged from 1.3 µm to 2.4 µm. Table 1 shows the result of the EDX analysis. Elemental composition analysis of several particles collected from the site revealed the presence of Na and Cl in some of the particles, which could come from sea salt. The EDX spectra of all analyzed particles indicated elemental compositions consisting of C and O with trace amounts of Ca, Si, Cu, V, Zn, and Sb. More than 50% of the particles on stage 1 were found to have traces of Fe, Zn, Mg, K, Ba, Co, Cl, Sn, Ni, Br, and Al whereas Sc, Sn, Co, and Cl were found on 50% of the particles on stage 2. Some particles had traces of Cd, Mn, Cr, Na, As, and Ti. C-rich particles are mainly resulting from the vehicular traffic (Tasic, 2007). Trace metals such as Cr, Ni, Co, Cu, and V are typically associated with anthropogenic emissions (traffic, combustion of fossil fuels, various industries) (Gebre, 2010). Irregular/crustal particles composed of K, Mg, or Ca are components of sea salt and may be aerosols of maritime origin and Si, Ca, (Al, Fe) particles are soil derived (Mogo, 2005). Mn, Zn, Fe, Al, and Ni, can be attributed to road dust.

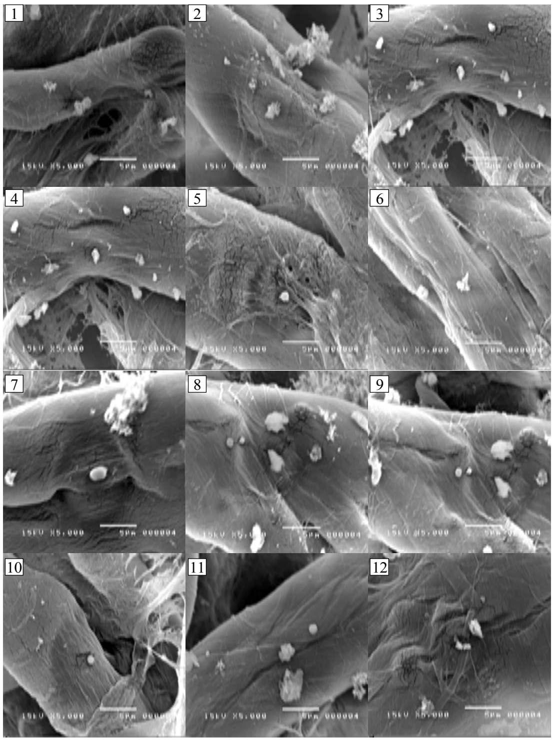

Figure6: SEM images of the particles collected using a personal cascade impactor which were taken at 750x magnification and at an acceleration voltage of 15kV.

Table 1. Percent mean elemental concentration of particles.

	Stage 1		Stage 2	
	%	Count	%	Count
C	55.31	12	75.21	10
O	34.35	12	21.64	10
F	16.18	1	0.00	0
Fe	2.79	9	0.14	4
S	1.52	2	0.00	0
Ca	1.44	12	0.06	4
Na	1.40	3	0.32	1
Zn	1.07	9	0.62	8
Br	0.90	5	2.24	1
Si	0.84	12	0.18	10
Al	0.77	5	0.00	0
Ba	0.67	8	0.15	4
Mg	0.60	9	0.09	4
Cu	0.46	11	0.72	9
Sb	0.39	5	0.41	7
Sn	0.31	6	0.38	6
Co	0.24	8	0.23	6
Cd	0.23	4	0.43	3
Cl	0.18	8	0.10	5
K	0.16	9	0.09	3
As	0.12	3	0.00	0
Ni	0.12	6	0.30	7
Mn	0.10	4	0.15	4
Cr	0.09	4	0.08	3
V	0.07	10	0.30	3
Sc	0.06	1	0.10	7
Ti	0.05	3	0.22	4
Se	0.02	2	0.00	0

CONCLUSIONS

Simultaneous vertical scanning lidar measurement and air sampling using a personal cascade impactor was presented in this paper. The scanning Lidar provided a two-dimensional profile of the traffice aerosol showing the spatial distribution of the aerosol horizontally and vertically as indicated by the strong backscattering signal. The high value of depolarization ratio obtained from Lidar measurement could be the result of the irregularly shaped particles as revealed by the SEM image of the individual particles using 5000x magnification. This could also be the effect of the location of the Lidar site which is near Manila Bay. Sea salt particles could result to a high depolarization ratio. Elemental analysis of several particles revealed the presence of Na and Cl which could come from sea salt. Furthermore, irregular/crustal particles composed of K, Mg, or Ca are components of sea salt and may be aerosols of maritime origin. Elemental analysis showed the presence of C and O, in all particles with traces of Ca, Si, Cu, V, Zn, Sb, Fe, Mg, K, Ba, Co, Cl, Sn, Ni, and Br. Most of these elements are typically associated with anthropogenic emissions such as traffic and combustion of fossil fuels. This study revealed that a combined Lidar and air sampling with SEM-EDX analysis can give a better understanding of the characteristics of aerosols such as its spatial distribution, shape, morphology, and chemical compositon, and possibly the source. However, further study is needed to be able to identify the major contributor of enhanced particulate scattering as well as its transport as seen from the Lidar profile.

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