MULTI-INSTRUMENT PARTICULATE MATTER CHARACTERIZATION DURING THE 2004 NEW YEAR CELEBRATION IN MANILA (14°33.978’ N; 120°59.523’ E)

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ABSTRACT

Particulate matter from firecracker emission during the 2004 New Year Celebration in Manila (14°33.978’ N; 120°59.523’ E) were characterized using a horizontal LIDAR, low-volume air sampler, scanning electron microscopy (SEM) and x-ray microanalysis (EDX). Extinction coefficient measurements at 532 and 355nm were made using the LIDAR at an altitude 20m above sea level. 532nm depolarization ratio was also determined. SEM and EDX analysis of air samples collected, simultaneous to the LIDAR experiments, using a low volume impactor/sampler was done. SEM provides morphology and sizes of the particles. EDX analysis on New Year’s particles revealed elements used in manufacturing firecrackers such as Al, C, Ca, Cl, Cu, K, Na, O, Ba, Mg, S, Zn, and Fe.

1. INTRODUCTION

The advent of modernization has led to the deterioration of the environment in most developing countries. The air quality in Manila has become very bad and the situation becomes worse every New Year celebration because Filipinos always welcome it by using lots of firecrackers. The LIDAR technique has proven to be a most effective tool in characterizing air quality. Using LIDARs, aerosols or particulate matter evolution can be easily studied and characterized in detail with high temporal and spatial resolution. Extinction coefficients $[\sigma(r)]$ derived from LIDAR measurements yield optical properties of aerosols while depolarization (δ) measurements provide information on thermodynamic phase and sphericity. A new analysis aspect is provided by the morphology, size and composition data obtained from the SEM and EDX measurements as presented in [1].

In this paper, characterization of particulate matter during the 2004 New Year celebration in Manila using a horizontal LIDAR, low-volume air sampler, SEM, and EDX at De La Salle University (DLSU) will be presented. The horizontal LIDAR measurement was taken at 20 m above sea level assuming horizontal homogeneity of the atmosphere at this level. Dorado et al. [2] reported on vertical LIDAR, radiosonde, and air sampling measurements of PM_{10} for the 2000 New Year celebration from Ateneo De Manila University, Quezon City (ADMU). DLSU and ADMU are about 13 km apart. DLSU is located approximately 900 m from Manila Bay while ADMU is very close to the mountains. Aside from its proximity to Manila Bay, DLSU is flanked by Manila’s busiest avenues so the atmosphere is expected to be dominated by aerosols from vehicles and dust along with a possible sea-salt component brought about by land-sea interactions. Further, DLSU is surrounded by residential areas so firecracker aerosol concentration is expected to be high. Fig. 1 shows the location of the DLSU LIDAR. Main avenues are shown as long dashed lines while the short dashed line on the right of DLSU is a local elevated electric train route having a busy street running underneath it. Manila’s population is more than 15% of the 80 million Filipinos in the country. A 1992 study in Manila revealed that the concentration of suspended dust, nitrogen oxides, sulfur oxides and lead in sampled ambient air is much higher than the accepted levels set by the World Health Organization.

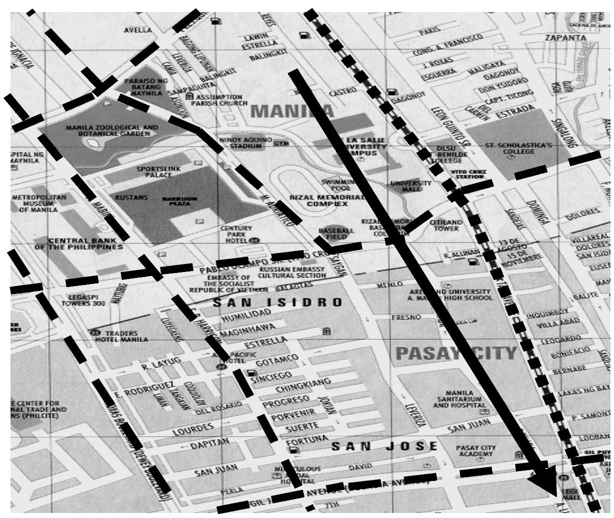

Fig. 1. The location of the DLSU LIDAR system and the major avenues surrounding it. The arrow shows the direction of the transmitted laser beam. Manila Bay is on the left side of the figure (not in the map).

2. DLSU MIE LIDAR SYSTEM

The DLSU scanning Mie LIDAR system is located at the STRC building (14°33.978' N; 120°59.523' E) and is about 20 meters above sea level. The LIDAR was oriented horizontally (12° East of South) for these experiments. The arrow in Fig. 1 indicates the direction of the transmitted laser beam. The 20 Hz prf Nd:YAG laser outputs at 532nm (160mJ) and 355nm (100mJ) were utilized. The backscattered signals were collected by a 200mm diameter, 800mm focal length Newtonian telescope and digitized by an 8-bit digital oscilloscope. LIDAR data up to 3km from DLSU was automatically acquired using a PC and processed using software developed by our group. Data was acquired every 40 seconds using an averaging of 512. Horizontal homogeneity of the atmosphere was assumed. The depolarization ratio (δ) was computed as the slope of the parallel backscatter vs. perpendicular backscatter signals. The extinction coefficient $[\sigma(r)]$ is retrieved using the slope method. Simultaneous measurements using a home-made low-volume air sampler were also performed.

3. RESULTS AND DISCUSSION

For the New Year observation, LIDAR measurements started Dec. 31, 2003 at 6:38 PM until 2:13 AM the following day Jan. 1, 2004. Background and noise signals were removed from each profile. To further minimize errors, the aerosol range for processing was determined from the range-squared corrected signal. The selected region was 350m to 1.5km from the LIDAR site. In our experiments, strong backscatter signals from firecracker explosions were expected since DLSU is surrounded by residential areas. Vehicular traffic from the avenues flanking the university was very light during the New Year celebrations especially as midnight approached. Fig. 2 shows the 532nm parallel backscatter signal for 11:48PM on Dec. 31, 2003. Figs. 3 and 4 shows the temporal variation of the 532nm and 355nm average extinction coefficient for the selected region, respectively. It can be seen from the two figures that σ started to increase around 10:00PM of Dec. 31 from an average value of 0.6km^{-1} for the 532nm and 0.7km^{-1} for the 355nm. It reached a maximum value of 3±0.05km^{-1} for 532nm and 2±0.07km^{-1} for 355nm at 12 midnight. At this time, the whole area was completely covered with smoke from firecracker emission. Visibility was very low. The extinction coefficient started to decrease at around 12:30AM. However, the average value obtained was higher compared to values obtained before midnight. This is very evident in Fig. 4, in which an average of 1km^{-1} for σ was obtained. This is indicative that the particulate matters from firecracker emission were still present several hours after midnight. The decrease after midnight can be partly explained by the fact that firecracker explosions decreased dramatically right after midnight.

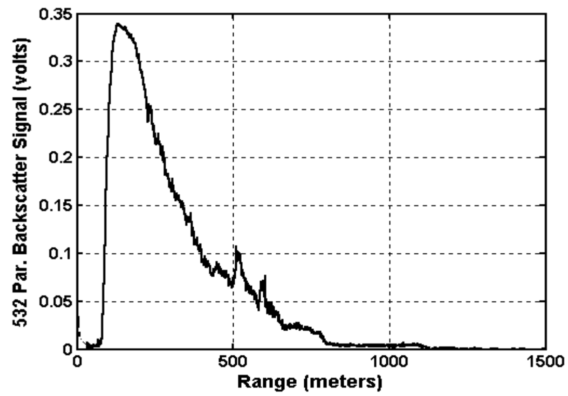

Fig. 2. 532nm parallel backscatter signal at 11:48PM on Dec. 31, 2003 showing firecracker aerosols.

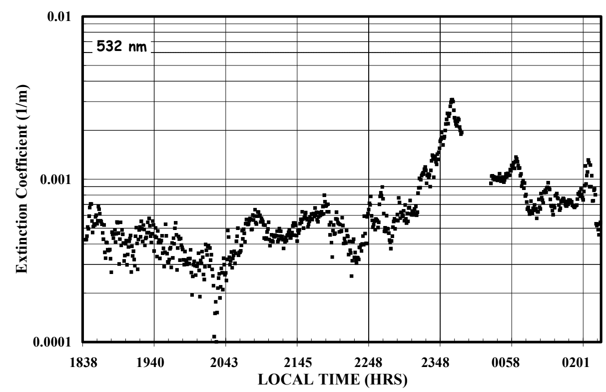

Fig. 3. Variation of 532nm extinction coefficient from 6:38PM, Dec. 31, 2003 to 2:13AM, Jan. 1, 2004.

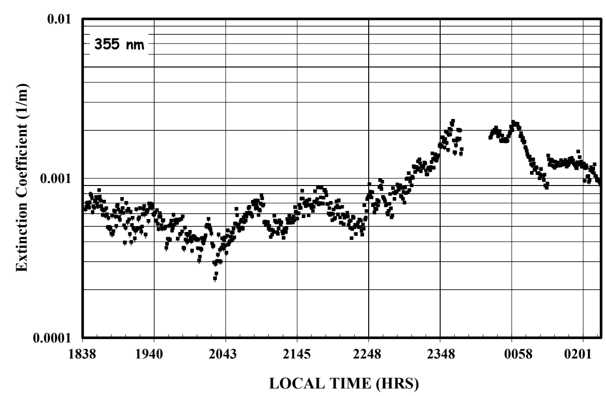

Fig. 4. Variation of 355nm extinction coefficient from 6:38PM, Dec. 31, 2003 to 2:13AM, Jan. 1, 2004.

Fig. 5 gives the plot of the 532nm parallel backscatter signal against the 532nm perpendicular backscatter signal for 11:48PM, Dec. 31, 2003 showing an average depolarization ratio of 14.5% for the processing range chosen. Numerous processing trials performed indicate that an error in the selection of the processing range results in a 10-20% change in the average δ indicated here. The dispersion of the data around the slope also indicates that δ can be taken as constant for the processing region.

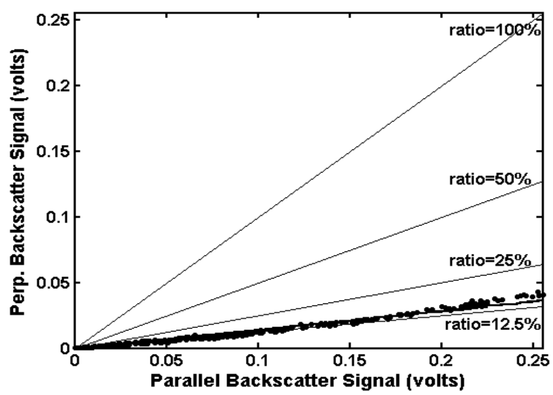

Fig. 5. Plot of the 532nm parallel backscatter signal against the 532nm perpendicular backscatter signal at 11:48PM on Dec. 31, 2003.

The temporal evolution of δ from 6:38PM, Dec. 31, 2003 to 2:13AM, Jan. 1, 2004 is plotted in Fig. 6. The increase in the average δ as midnight approaches is due to the fireworks used during the New Year's Eve celebration. Filipinos welcome each New Year this way and the series of firecracker explosions become more intense as midnight approaches. Further, very few cars are on the road during these times.

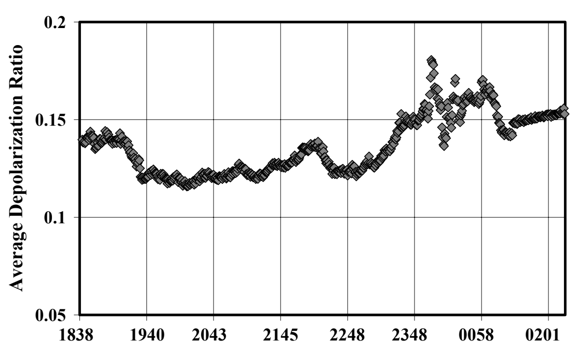

Fig. 6. Variation of the 532nm average δ from 6:38PM, Dec. 31, 2003 to 2:13AM, Jan. 1, 2004.

Simultaneous with the LIDAR experiments, air samples were collected every hour using an aluminum, low-cost, low-volume impactor/sampler with nozzle diameter of 0.4 mm. Air particles were collected continuously for three minutes at a flow rate of 1liter per minute and an average vacuum pump pressure of 4cm Hg. Average ambient temperature on the evening of Dec. 31, 2003 was 26.3°C while the relative humidity was 59.4%. EDX analysis of particles collected during the 2004 New Year celebration showed traces of aluminum(Al), carbon(C), calcium(Ca), chlorine(Cl), copper(Cu), potassium (K), sodium(Na), oxygen(O), barium(Ba), Magnesium(Mg), sulfur(S), zinc(Zn), iron(Fe), silicon(Si), gold(Au), nickel(Ni), and niobium(Nb). All of these elements are used in the manufacturing of fireworks except for the last four. Si may be from the soil, Au is from the gold coating for good SEM resolution, Ni and Nb were from the mesh that was used as the substrate. Fig. 7 shows the EDX spectra of a particle having 0.75μm diameter.

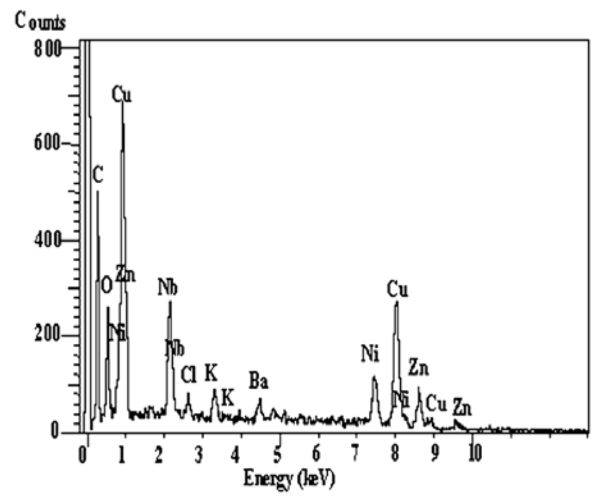

Fig. 7. EDX spectra of a particle having 0.75μm diameter collected on Dec. 31, 2003.

The carbon content found on the particle may also be attributed to vehicular emission since the sampling site is surrounded by main thoroughfares although very few cars are expected to be on the road close to midnight of Dec. 31.

4. CONCLUSION

A characterization of firecracker aerosols/particles during the 2004 New Year celebration in Manila has been presented. The particles were characterized using a combined horizontal LIDAR measurement, low-volume air sampling, scanning electron microscopy (SEM), and x-ray microanalysis (EDX). Horizontal LIDAR measurements provided the temporal variation from 350m to 1.5km away from the LIDAR site of the average extinction coefficient and average depolarization ratio for particles present at an altitude of about 20m above sea level assuming horizontal homogeneity of the atmosphere at this level. LIDAR measurements also revealed that these firecracker aerosols stayed in the atmosphere for several hours after midnight. Additional information about the morphological features and particle size was obtained from SEM images while EDX analysis yielded the composition of the particles collected by the low-volume air sampler. Sizes of EDX analyzed particles range between 0.25μm to 2.25μm for the 2004 New Year celebration. EDX analysis revealed elements used in manufacturing firecrackers such as Al, C, Ca, Cl, Cu, K, Na, O, Ba, Mg, S, Zn, and Fe. More experiments are being conducted using these instruments to fully characterize urban aerosols in Manila. A possible dependence of these aerosol properties with vehicular activity and meteorological parameters is also being investigated.

REFERENCES

1. Frejapon E. et al. Three-dimensional analysis of urban aerosols by use of a combined LIDAR, scanning electron microscopy, and x-ray microanalysis, *Applied Physics*, Vol. 37, 2231-2237, 1998.

2. Dorado S.V., et. al. Characterization of Urban Atmosphere of Manila with LIDAR, filter sampling, and radiosonde, *Proc. of SPIE*, Vol. 4153,591-598,2001.