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Receptor modeling studies for the characterization of air particulate lead pollution sources in Valenzuela sampling site (Philippines)

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ABSTRACT

Valenzuela, an industrial district in the northwestern part of Metro Manila, Philippines, was found to have higher particulate and lead levels than in the other Metro Manila air sampling stations of the Philippine Nuclear Research Institute. Results in 2004–2009 show that while PM_{10} annual mean levels are in compliance with the long and short–term Philippine standards for PM_{10}, $PM_{2.5}$, annual mean levels are in exceedance of the long–term standard of the US EPA (15 µg m^{-3}). Energy–dispersive x–ray fluorescence spectrometry, a non–destructive multi–element nuclear related analytical technique, was used to analyze the elemental components of the air particulates. Positive matrix factorization, a receptor modeling tool, was used to identify and apportion air pollution sources. This study has identified Pb sources in both the coarse ($PM_{2.5-10}$) and the fine ($PM_{2.5}$) fractions. The conditional probability function analysis plots of 2008 Pb levels in both the coarse and the fine fractions show patterns for probable sources in the 2008 data similar to that in the 2005 data indicating that Pb sources in 2005 were the same Pb sources in 2008. Further studies to locate possible sources of lead are needed to validate the results of this finding.

Keywords:
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1. Introduction

Valenzuela, is an industrial district in the northwestern part of Metro Manila, Philippines. In a 2005 study of the Philippine Nuclear Research Institute (PNRI), this site was found to have particulate and lead (Pb) levels to be higher than those in the other PNRI air sampling stations in Metro Manila.

Air pollution in Metro Manila and its adverse impacts to health is a source of concern to various stakeholders. To address the problem, the government needs scientific data on which to base policies to improve the air quality. Setting up air monitoring stations and accounting for air pollutant emissions are not enough. So, research on the actual pollutants that the general public is exposed to (at receptor sites) is equally important.

In receptor modeling, chemical measurements are done at monitoring sites (or receptor sites) from which estimation is made of pollutant source contributions. This is opposed to dispersion modeling where pollutant concentrations are inferred from transport, dilution, and transformations that begin at the source and follow the pollutants to the sampling or receptor site. In receptor modeling, the relative contributions from major sources to the pollution at receptor sites are calculated from speciated chemical data of the sampled particulate matter so that receptor–based modeling is also referred to as source apportionment. More advanced techniques that incorporate wind trajectory data can be applied to the gaseous pollutants or pollutants in fine particles. Receptor models are important air quality management tools for scientifically justifying priorities and observing trends (USEPA, 2010).

Particulate matter of most concern with regard to adverse effects on human health are generally <10 µm in size and are referred to as PM_{10}. Under the Philippine Clean Air Act of 1999, PM_{10} is included as one of the five primary criteria pollutants with Philippine National Ambient Air Quality Guideline Values set at 150 µg Nm^{-3} and 60 µg Nm^{-3} for the short–term and long–term guideline values, respectively. PM_{10} can be further subdivided into coarse and fine particles referring to $PM_{2.5-10}$ and $PM_{2.5}$, respectively. These particle sizes are correlated with health effects because these can penetrate into the lungs up to the alveoli which the pollutants they contain can then be taken up into the blood stream.

Lead is a significant environmental toxin being an integral part of many industrial processes. If found in the PM_{10} fraction, Pb may pose hazard to a person's health. Pb has been shown to be a potent toxin to the CNS and low levels of Pb (below the CDC established toxic blood level of 10 µg dL^{-1}) have been correlated with decreases in the IQ of children (Canfield et al., 2003).

The Philippine Nuclear Research Institute, one of the research and development institutes of the Department of Science and

Technology, has undertaken monitoring of particulate matter in the PM_{10} range, fractionated to $PM_{2.5\text{-}10}$ (coarse fraction) and $PM_{2.5}$ (fine fraction) size ranges. The primary objective of the project is the identification of the major sources of air pollution and the estimation of their contribution at sampling sites in Metro Manila. Nuclear analytical techniques such as photon–induced X–ray emission (PIXE) and energy–dispersive X–ray fluorescence (EDXRF) were the main tools used for multi–element analysis of the air filters. The project generated the first long–term data on $PM_{2.5}$ and PM_{10} for Metro Manila. In this study, receptor modeling is applied to air particulate matter collected at the Valenzuela sampling site to characterize air particulate lead pollution sources in the area.

2. Methodology

Air particulate samples were collected from Valenzuela City (VB), an industrial area in the north–eastern part of Metro Manila. Location of the sampling site is shown in Figure 1. Location of the other current PNRI sampling sites such as the Ateneo de Manila University (ADMU) and the POVEDA Learning Center (PO) and NAMRIA (NM) are also indicated on the map.

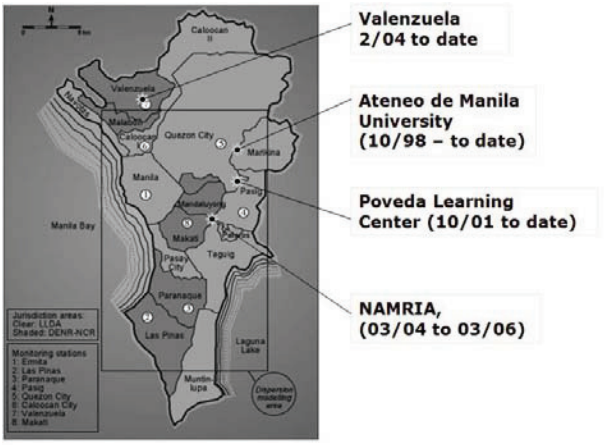

Figure 1. *Current PNRI Air Monitoring stations in Metro Manila. Location of the Valenzuela City sampling station is shown in the map of the Metro Manila air shed relative to the location of the other current PNRI sampling stations—Ateneo de Manila University (ADMU), the POVEDA Learning Center (PO) and NAMRIA (NM).*

Sampling was done twice a week on Wednesdays and Sundays, using the Gent dichotomous sampler (Hopke et al., 1997) which collects particulate matter in the PM_{10} range and fractionated to fine ($PM_{2.5}$) and coarse ($PM_{2.5\text{-}10}$). Air particulate samples were collected on Nuclepore filters (8 µm pore size for the coarse fraction and 0.4 µm for the fine fraction). Particulate mass was determined by gravimetry using a micro analytical balance (Mettler MT5) with 1 µg sensitivity. Black carbon analysis was done by reflectometry using the M34D Smokestain Reflectometer with $\varepsilon = 7\ m^2\ g^{-1}$ (ε: the average fine particle mass absorption co-efficient).

Elemental levels (Na, Mg, Al, Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, Br, and Pb) in air particulate samples were determined using non–destructive nuclear related multi–element analytical technique at the PNRI using Kevex ED–771 and then the Panalytical Epsilon 5 Energy Dispersive X–ray Fluorescence spectrometer (E5 EDXRF). Spectra were fitted and results were calculated using a software package QXAS (Quantitative X–ray Analysis System developed by the IAEA) which is an integrated system for the quantitative evaluation of spectra measured with dispersive X–ray spectrometers. Quality assurance for the XRF results was observed with the use of NIST SRM2783, a multi–element standard on filter medium. Data analysis was done using EXCEL and STATGRAPHICS programs. Receptor modeling was done using the positive matrix factorization, EPA PMF v.3 (Paatero, 1997). Probable geographical location of sources was determined using Conditional Probability Function (Kim and Hopke, 2004).

3. Results and Discussions

Results of PM_{10} for the 6–year period (2004 – 2009) are shown in Figure 2. PM_{10} annual mean levels (Figure 2) are in compliance to the long and short–term Philippine standards for PM_{10} (60 µg m^{-3} and 150 µg m^{-3}, respectively). $PM_{2.5}$ annual mean levels (Figure 3) have always been in exceedance of the long–term standard of the US EPA (15 µg m^{-3}). This is true for other PNRI monitoring stations in Metro Manila. $PM_{2.5}$ data from 2004 to 2009 indicated increasing levels up to 2006 followed by a sharp drop in 2007. This decreasing trend is maintained up to 2009, indicating some improvement in $PM_{2.5}$ levels. However, these values are still higher than the US EPA long–term standard for $PM_{2.5}$. $PM_{2.5\text{-}10}$ levels increase slightly from 2004 levels from 2005 to 2006. No drastic change in $PM_{2.5\text{-}10}$ is observed though the significant drop observed in 2009.

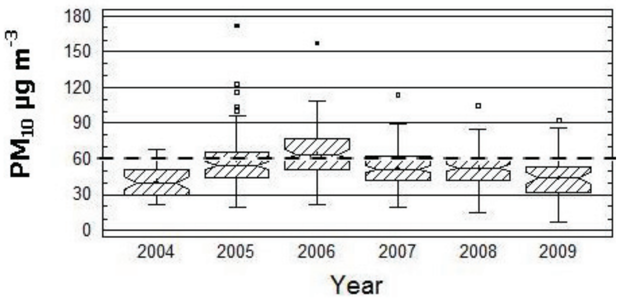

Figure 2. *Summary data for PM_{10} in Valenzuela, 2004 to August 2009. PM_{10} annual mean values for 2004 and 2009 are in compliance with the Philippine 1-year guideline value (represented by the dashed line) except for PM_{10} annual mean value for 2006. The annual mean is represented by the (+) sign; the median by the horizontal bar; middle 50% of the data by the hatched boxes; largest and smallest observations by the whiskers; outliers, 1.5 times or 3 times the interquartile range above or below the limits of the box, by square symbol and square symbol with plus sign, respectively.*

Comparison of coarse and fine particulate levels in 2008 for the PNRI three monitoring stations is shown in Figure 4. It is seen that $PM_{2.5\text{-}10}$ or coarse fraction is higher in Valenzuela than in ADMU and Poveda. Examination of the site conditions provides an explanation for this observation. Valenzuela, aside from being a highly industrialized area, is also a highly traffic impacted area. Vehicles may contribute to the dispersion of dust particles. The Poveda station is close to EDSA, a major highway in Metro Manila and would be expected to have higher concentrations of the coarse fraction than the ADMU sampling site. $PM_{2.5}$ levels are almost the same for ADMU and Valenzuela and are much lower in Poveda. The sampling station in Poveda is located on top of a four–storey school building which may account for the much lower $PM_{2.5}$ levels in this site.

Comparison of PM_{10} Pb levels for the four sampling stations in 2005 indicated higher levels in Valenzuela than in other PNRI monitoring stations (Figure 5). Pb has long been recognized as a harmful environmental pollutant and is now a global health problem whatever its source may be (Gavaghan, 2002). It is a poisonous metal and has been shown to cause damage to the nervous connections especially in young children thus resulting in blood and brain disorders. Its varied application in industry has made this element ubiquitous in soil, water and even in the air.

Summary data of Pb levels in $PM_{2.5}$ and $PM_{2.5\text{-}10}$ for 2004 to 2008 are shown in Figure 6. Pb levels in PM_{10}, obtained by adding levels in $PM_{2.5}$ and $PM_{2.5\text{-}10}$, show that Pb levels are below the Philippine Guideline value of 1.5 µg m^{-3} for 3 months averaging and 1 µg m^{-3} for 1 year averaging and are also below the WHO annual guideline value of 0.5 µg m^{-3} (WHO, 2000). A downward trend in PM_{10} Pb levels is also indicated from 2006 to 2009.