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PARTNERSHIP FOR CLEAN AIR (PCA)

Philippine Nuclear Research Institute
Department of Science and Technology

# Assessment of respirable air particulate pollution sources in Metro Manila and receptor modeling (source apportionment)

## [Final Report]

| | | |
|---|---|---|
| Service Provider | : | Partnership for Clean Air, Inc. (PCA)<br>Contact Person: Rene Pineda / Juliet G. Manlapaz<br>U 3505, 35th Flr Robinsons Equitable Tower<br>ADB Ave., Pasig City Philippines<br>Tel no: +632-6311329 |
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| Technical Support | : | Philippine Nuclear Research Institute, Department of Science and Technology & Partnership for Clean Air, Inc. |
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| Period Covered | : | 14 July 2016 – 15 February 2017 |
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Partnership for Clean Air
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Service Summary Sheet

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| Title | : | **Assessment of respirable air particulate pollution sources in Metro Manila and receptor modeling (source apportionment)** |
| Service Provider | : | Partnership for Clean Air, Inc. (PCA)<br>Contact Person: Rene Pineda/Juliet G. Manlapaz<br>U 3505, 35th Flr Robinsons Equitable Tower<br>ADB Ave., Pasig City Philippines<br>Tel no: +632-6311329 |
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| Duration of the Project | : | 14 July 2016 – 15 February 2017 |
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## List of Acronyms/Abbreviations

CPF – Conditional Probability Function

PIXE – Photon-induced x-ray emission

APM – air particulate matter

PMF – Positive Matrix Factorization

PNRI – Philippine Nuclear Research Institute

DOST – Department of Science and Technology

US EPA – United States Environmental Protection Agency

WHO – World Health Organization

## Executive Summary

Air particulate matter ($PM_{10}$, fractionated into the coarse [$PM_{10-2.5}$] and fine [$PM_{2.5]}$])samples have been collected using Gent air samplers at three sampling sites (NAMRIA, MMDA and Valenzuela) for the period June to November 2016, making up to at least 100% of the total 75 samples collection requirement per site—76 samples from Valenzuela, 76 from NAMRIA and 79 from MMDA. Particulate mass was determined by gravimetry using a microbalance and black carbon by reflectometry, all done at PNRI. Multi-element levels were determined by PIXE done at ANSTO.

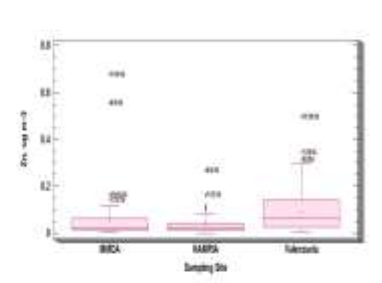
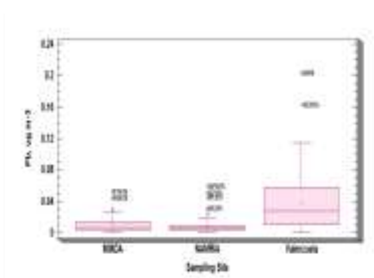
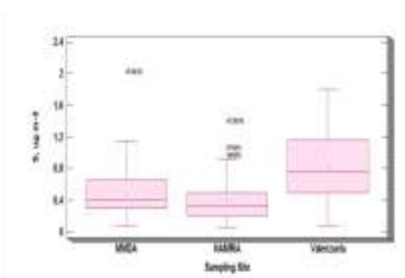
Focus of the study is on the respirable portion of APM and only filters in this fraction were analyzed for multi-element content and the resulting databases were processed using the PMF for source identification and apportionment studies. $PM_{10}$ levels across the three Metro Manila sites are in exceedance of the WHO 1-year guideline value of 20 $\mu$g $m^{-3}$ and even the Philippine 1-year guideline value of 60 $\mu$g $m^{-3}$. $PM_{2.5}$ levels are in exceedance of the WHO 1-year guideline value of 10 $\mu$g $m^{-3}$ which makes the ambient air quality in the Valenzuela, MMDA (EDSA) and NAMRIA sites considered as unhealthy for both $PM_{10}$ and $PM_{2.5}$ by the WHO standards. Comparison of APM concentration levels across all the sites is shown in the following table.

| Sampling Site | Site Description | No. samples | $PM_{10}$, ug $m^{-3}$ ave (range) | $PM_{2.5}$, ug $m^{-3}$ ave (range) | $PM_{10-2.5}$, ug $m^{-3}$ ave (range) | $\%PM_{2.5}$ |
|---|---|---|---|---|---|---|
| Valenzuela | General Ambient | 75 | 64.3 (25.0-160.7) | 25.9 (5.7-74.2) | 38.4 (10.8-89.5) | 40 (21 - 68) |
| MMDA (EDSA) | Roadside Ambient ($8^{th}$ Floor rooftop) | 79 | 62.1 (6.3-156.8) | 20.3 (4.0-45.2) | 41.8 (2.3-141.0) | 35 (9 - 82) |
| NAMRIA | General Ambient | 76 | 65.2 (23.6-146.9) | 19.0 (4.8-41.4) | 46.2 (13.2-126.2) | 31 (5- 51) |

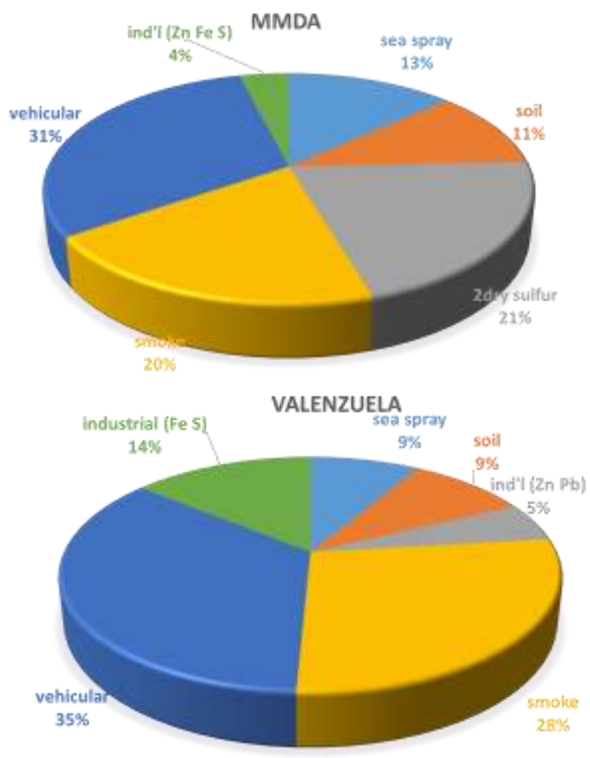
Black carbon levels are at an average of 8.7 $\mu$g $m^{-3}$ across all sites with % BC at an average of 31 – 46 % of the fine particulate mass. Comparable BC composition are seen in MMDA and NAMRIA (45 and 46%) while Valenzuela at 31%. BC is a fingerprint of incomplete combustion products. Comparison of $PM_{2.5}$ BC levels and %BC across all sites is shown in the following table.

| Sampling Site | Site Description | $PM_{2.5}$ BC, ug $m^{-3}$ ave (range) | %BC ($PM_{2.5}$) |
|---|---|---|---|
| Valenzuela | General Ambient | 8.3 (1.4 – 30.6) | 31 (13 - 49) |
| MMDA (EDSA) | Roadside Ambient (8th Floor rooftop) | 9.0 (0.6 – 18.0) | 45 (14 - 66) |
| NAMRIA | General Ambient | 8.7 (1.4 – 16.1) | 46 (6 - 66) |

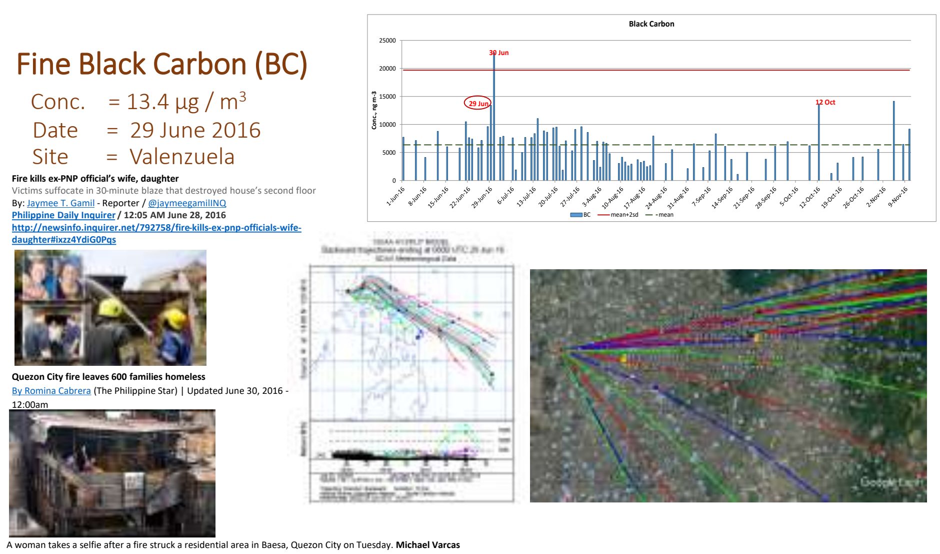
Based on the average values, MMDA profile can be shown, in decreasing order, as S>Na>Ca>F>Fe>Si>K>Cl>Zn>Al>Pb>Mn>P>Ti>Cu>Cr>Br>Ni>V>Co,Se,Sr; NAMRIA profile as S>Ca>Si>Na>F>Fe>Cl>K>Al>Zn>Pb>Mn>P>Ti>Cu>Br>Cr>Ni>V> Co,Se,Sr; Valenzuela profile as S>K>Na>Fe>Si>F>Ca>Zn>Cl>Pb>Al>Cu>P>Mn>Br> V>Ti>Cr>Ni>Co,Se,Sr. It can be observed that the highest elemental concentration across the three sites is coming from Sulfur (S). Multi-element profiles show Sulfur to have the highest contribution to the fine air particulate pollution across the three sites with the highest seen in Valenzuela. Valenzuela also exhibits Pb and Zn levels much higher than that of MMDA and NAMRIA which would point to a unique industrial source/sources in this area. A comparison of levels of these three anthropogenic elements across all the three sites is shown in the following graphs.

Source apportionment results show six (6) sources—seaspray, fine soil, vehicular emissions, biomass burning, industrial and secondary sulfur-- impacting the three sites. Vehicular emissions comprise 30-50% of the apportioned sources. An industrial source, predominantly Zn and Pb, is seen in Valenzuela. The following pie charts show the apportioned air pollution sources across the three sites.




Extremely high events (concentration levels exceeding the mean plus 2x the standard deviation) were analyzed if these were coming from transboundary sources. Some high BC events were attributed to reported fires in some places far from the receptor site.   An example of this is shown in the following analysis.



## 1. INTRODUCTION

Air pollution in Metro Manila and its adverse impacts to health continue to be a source of concern to various stakeholders. The provisions of the Clean Air Act of 1999 are meant to strengthen institutions responsible for air quality management. Supporting this mandate is the generation of air pollution data with which to evaluate the impact of air quality on health as well as the effectiveness of policies in place for improvement of air quality. Long-term sampling gives information on changes in air quality as influenced by particular events or policies. In addition to air particulate monitoring, studies to determine their principal sources and estimate their contribution are useful in formulating strategies for their management.

In dispersion modeling, pollutant concentrations are inferred based on the transport, dilution, and transformations that begin at the source and follow the pollutants to 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 pollutant sources in fine particulates. Receptor models are important air quality management tools for scientifically justifying priorities and observing trends (US EPA).

Particulate matter of most concern with regard to adverse effects on human health is generally <10 µm in size and 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 $PM_{10-2.5}$ and $PM_{2.5}$, respectively. $PM_{2.5}$ guideline values have been set, starting 2016, at 25 and 50 µg $Nm^{-3}$ for the long and short term guideline values, respectively. These fine particle sizes are correlated with health effects because these can penetrate into the lungs up to the alveoli which can then be readily taken up into the blood stream.

The Philippine Nuclear Research Institute, one of the research and development institutes of the Department of Science and Technology and the Partnership for Clean Air, Inc., has undertaken monitoring of particulate matter in the $PM_{10}$ range, fractionated to $PM_{10-2.5}$ (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 (Pabroa et al., 2013, Atanacio et al., 2016).

This study, which was undertaken with funding from the EU Switch Policy Support Component Philippines by the Partnership for Clean Air, Inc. (PCA) applies the methodology used in the PNRI air pollution project leading to the eventual identification of sources of air particulate matter collected at three Metro Manila sites:(1) Radyo ng Bayan Compound, Don Pedro Subdivision Road, Marulas, Valenzuela (General Ambient Station); (2) Namria Compound, Lawton Avenue, Fort Bonifacio, Taguig (General Ambient Station); and, (3) MMDA Compound or Makati Bureau of Fire Compound, Makati (Roadside Ambient Station). In particular, this study aims to make an assessment of the status of respirable air particulate pollution in these three Metro Manila sites, which are co-located with EMB air quality measuring stations, based on databases generated for $PM_{2.5}$ elemental concentrations and air pollutant sources.

The geographical focus for the study is the Metro Manila airshed which politically covers 17 cities and stretches from Pampanga and Bulacan in the north to Batangas in the south, and from Bataan and Cavite in the west to Rizal, Laguna and part of Quezon in the east. Due to limited resources for this project, only three sites were accommodated choosing two general ambient sites and one roadside ambient site. Valenzuela and NAMRIA are the two general ambient sites while MMDA is roadside ambient site. Valenzuela site was included as a reference site since PNRI has a long-running sample collection at this area and has been found to have high Pb levels. NAMRIA is co-located with an existing EUGFA sampling station which provided comparative data to derive the correction factor for the Gent sampler results. MMDA is along a major highway (EDSA) which makes it a good reference roadside site. Further considerations in the site selection were ease of access and logistics, availability of electricity and security of the area.

## 2. METHODOLOGY

Air particulate samples were collected from three Metro Manila sites-- (1) Radyo ng Bayan Compound, Don Pedro Subdivision Road, Marulas, Valenzuela (General Ambient Station); (2) Namria Compound, Lawton Avenue, Fort Bonifacio, Taguig (General Ambient Station); and, (3) MMDA Compound or Makati Bureau of Fire Compound, Makati (Roadside Ambient Station). Location of the sampling site is shown in Figure 1. These chosen sites are co-located with EMB sampling stations.

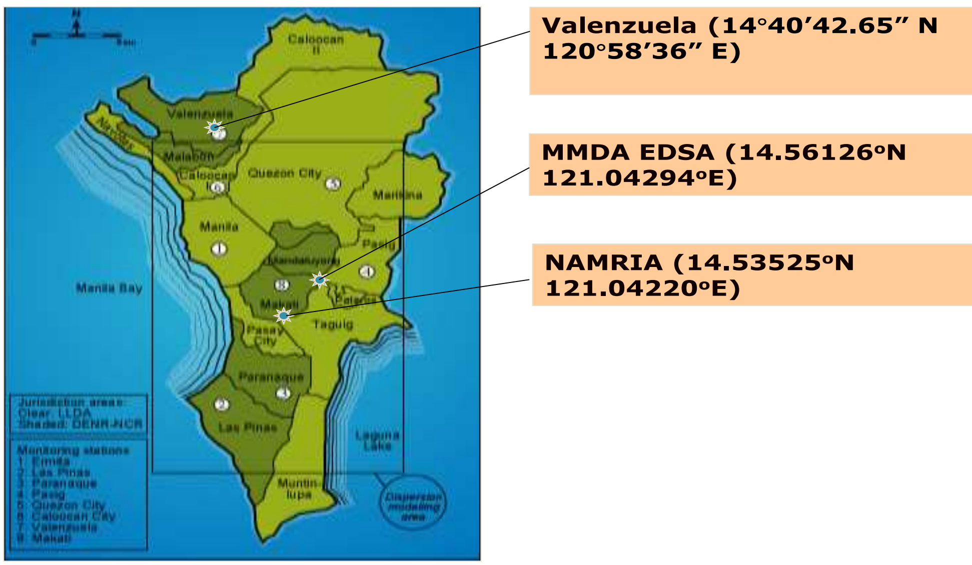



**Figure 1. Metro Manila Sampling Sites.** Location of the three Metro Manila sampling sites is shown in the map of the Metro Manila air shed (http://www.hangin.org, accessed January 1999).

Sampling has been done as per protocol of the PNRI and PCA, in particular collection by dichotomous sampling (coarse and fine) using the Gent sampler. Collection period was June to November 2016, collecting at least 75 samples per site.

Particulate mass was determined by gravimetry using the microbalance (Mettler Toledo AG245). 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 coefficient). Data analysis was done using EXCEL and STATGRAPHICS programs.

Elemental levels (F Na Al Si P S Cl K Ca Ti V Mn Fe Ni Cu Zn Se Br Pb Sr) in air particulate samples were determined using non-destructive nuclear related multi-element analytical technique by Photon-induced X-ray emission at the Australian Nuclear Science and Technology Organization (ANSTO).

Multi-element raw data provided by ANSTO were processed by PNRI. Receptor modeling was done using the positive matrix factorization ANSTO macro-assisted PMF2 DOS version (Atanacio et al., 2016). Probable geographical location of sources were determined by HYSPLIT for possible transboundary contribution.

## 3. RESULTS AND DISCUSSIONS

### 3.1 Particulate Matter Levels

$PM_{10}$ Levels--- fractionated into (fine) $PM_{2.5}$ and (coarse) $PM_{10-2.5}$, at the three Metro Manila sampling sites are shown in Figures 2, 3 and 4. As per protocol of the PNRI, sampling is supposed to be done at least twice a week—one weekday (Wednesday) and one weekend (Sunday)—and covering at least a one year period. Due to the time constraint imposed by this project and at the same time aiming to still provide statistically robust results, more samplers had to be deployed at the sampling sites. Samplers had to be shuffled from one site to another, thus frequency of samples is different across the months across the three (3) stations.

$PM_{10}$ levels (taken as the sum of $PM_{2.5}$ and $PM_{10-2.5}$) are compared to the Philippine long and short-term guideline values while $PM_{2.5}$ levels are compared to the WHO long and short-term guideline values. There are no available $PM_{10-2.5}$ guideline values. Table 1 shows the comparison of APM concentration levels across all the sites. A correction factor of 1.447 was applied to the databases of the three sampling sites. This factor was estimated from the comparison of results using the Gent sampler vs that of the co-located sampler of EU-GFA at NAMRIA and was found to be in agreement with that estimated from previous studies at the Ateneo de Manila University (ADMU) sampling site comparing Gent sampler results with that of the ASP sampler of the Australian Nuclear Science and Technology Organization (ANSTO).

$PM_{2.5}$ is referred to as the respirable fraction. Across all sites, $PM_{2.5}$ comprises about 5 to 82% of the total $PM_{10}$. All of the sampling sites have average levels in exceedance of the WHO 1-year guideline value with Valenzuela having the highest among the three sites. MMDA and NAMRIA have comparable $PM_{2.5}$ levels, considering both averages and ranges. It can be concluded from the $PM_{2.5}$ concentration levels, exceeding the WHO long-term guideline value, that the three sampling sites in this study have unhealthy levels of the fine particulate matter. The same conclusion can also be gleaned from the $PM_{10}$ average levels which are in exceedance of the Philippine 1-year guideline value.

Guideline values have been established primarily to protect the public from health effects of air pollution. Daily variations are assessed against the 24-hr guideline values. In Valenzuela, $PM_{10}$ has one daily value exceeding the Philippine 24-hr guideline value while $PM_{2.5}$ has fifteen daily values (or 20% of dataset) exceeding the WHO 24-hr guideline value (Figure 2). In MMDA, $PM_{10}$ has two daily values exceeding the

Philippine 24-hr guideline value while $PM_{2.5}$ has seventeen daily values (or about 22% of dataset) exceeding the WHO 24-hr guideline value (Figure 3). In NAMRIA $PM_{10}$ has no daily value exceeding the Philippine 24-hr guideline value while $PM_{2.5}$ has two daily values exceeding the WHO 24-hr guideline value (Figure 4). In terms of daily exceedances, Valenzuela and MMDA have comparable numbers and NAMRIA has the least with only two exceedances for $PM_{2.5}$. Pollution levels can be affected primarily by the pollution source itself and also by the prevailing weather and meteorological conditions which will reflect on daily levels and/or monthly averages. It is expected that during raining season, particulate pollution would be lower. Build up of traffic during a rainy day/flooded day, however, can also cause an increase in air particulate pollution since vehicles caught in the traffic would be in idling mode or always on first gear while waiting for traffic to let up.

**Table 1. Comparison of APM concentration levels across all the sites.**

| Sampling Site | Site Description | No. samples | $PM_{10}$, ug $m^{-3}$ ave (range) | $PM_{2.5}$, ug $m^{-3}$ ave (range) | $PM_{10-2.5}$, ug $m^{-3}$ ave (range) | $\%PM_{2.5}$ |
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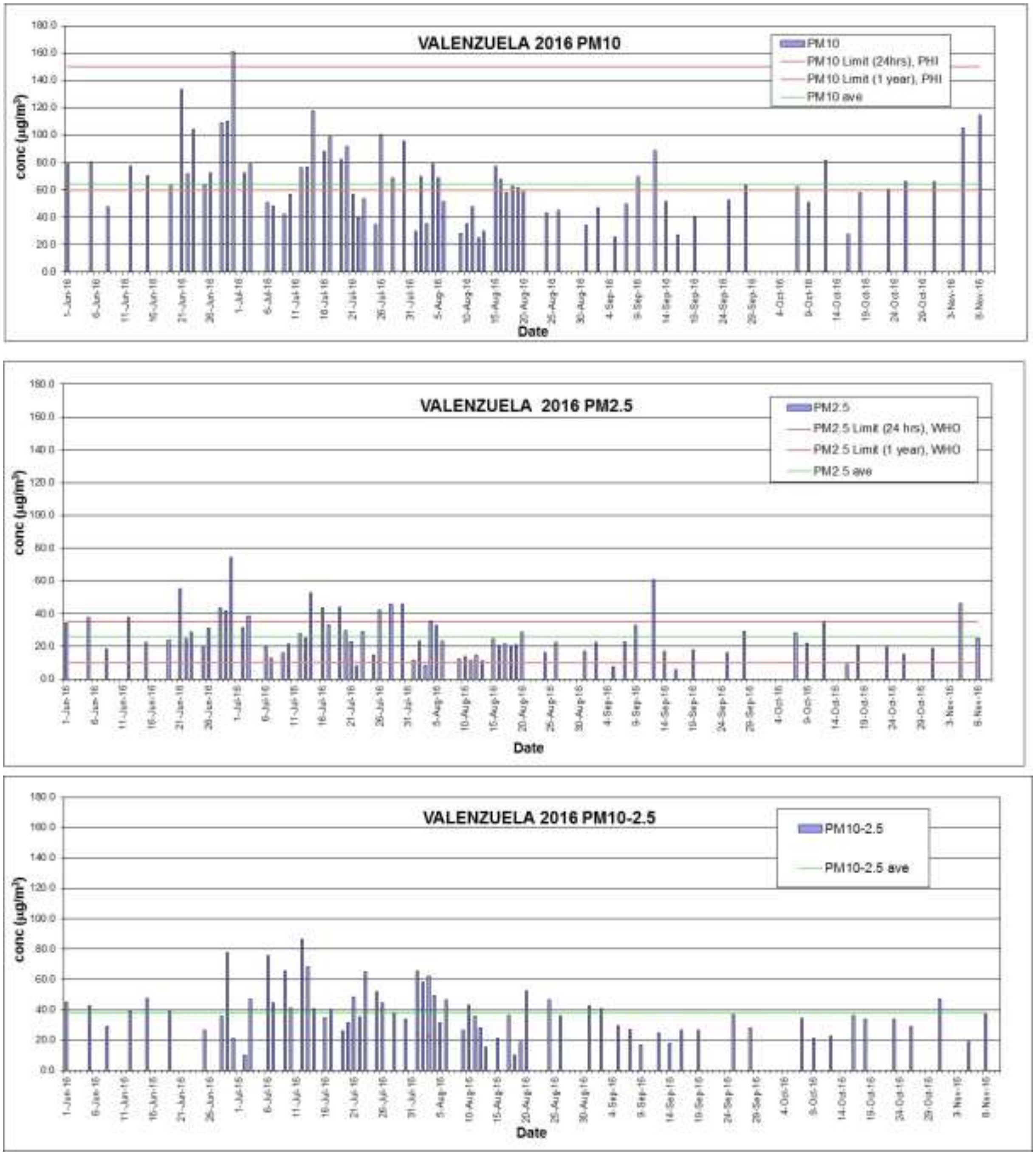


**Figure 2. $PM_{10}$ Levels at Valenzuela Sampling Sites**. Both $PM_{10}$ and $PM_{2.5}$ averages for the period are in exceedance of the Philippine and WHO guideline values, respectively. $PM_{10}$ has one daily value exceeding the Philippine 24-hr guideline value while $PM_{2.5}$ has fifteen daily values (or 20% of dataset) exceeding the WHO 24-hr guideline value.

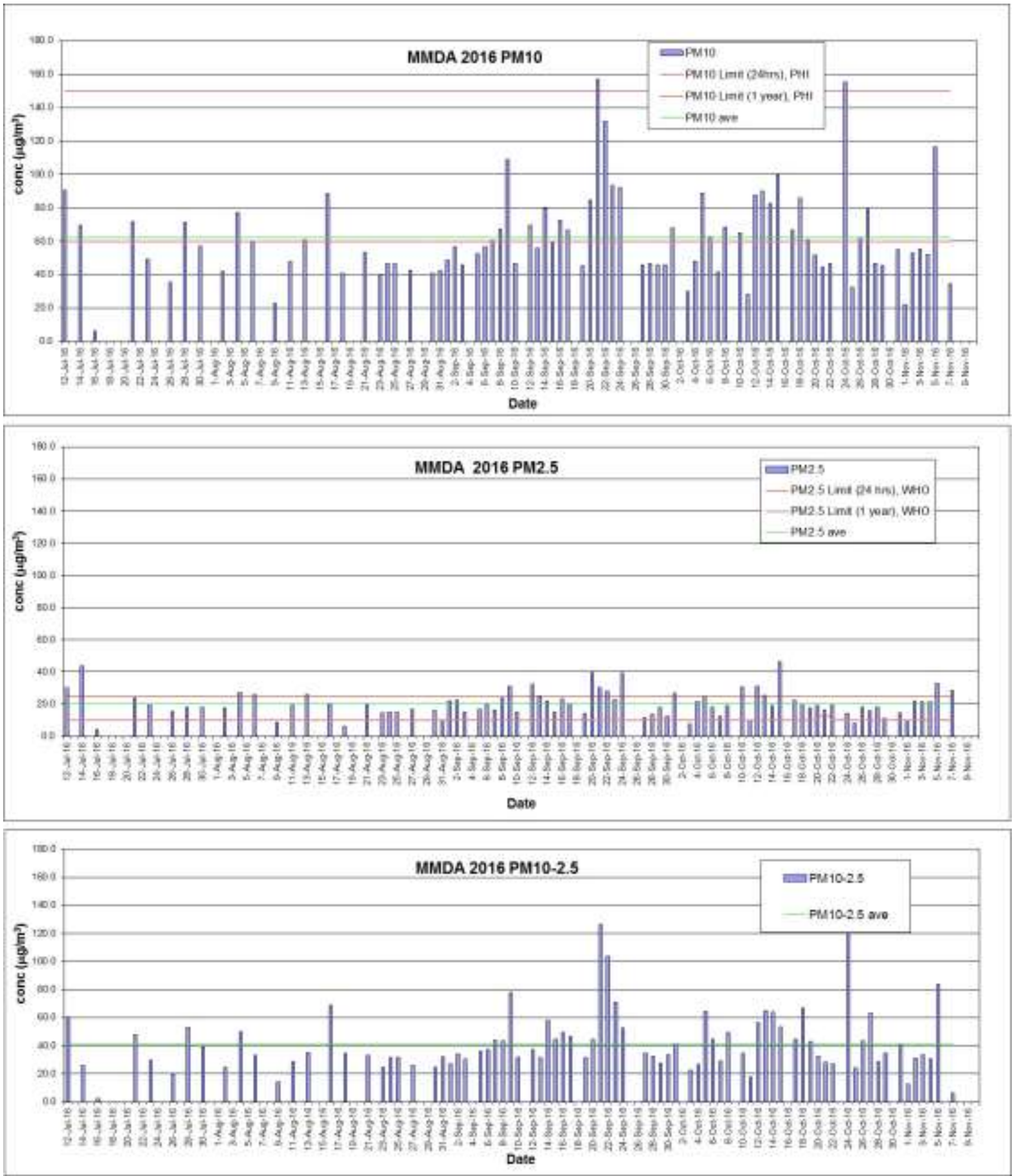


**Figure 3. $PM_{10}$ Levels at MMDA (EDSA) Sampling Site**. Both $PM_{10}$ and $PM_{2.5}$ averages for the period are in exceedance of the Philippine and WHO guideline values, respectively. $PM_{10}$ has two daily values exceeding the Philippine 24-hr guideline value while $PM_{2.5}$ has seventeen daily values (or about 22% of dataset) exceeding the WHO 24-hr guideline value.

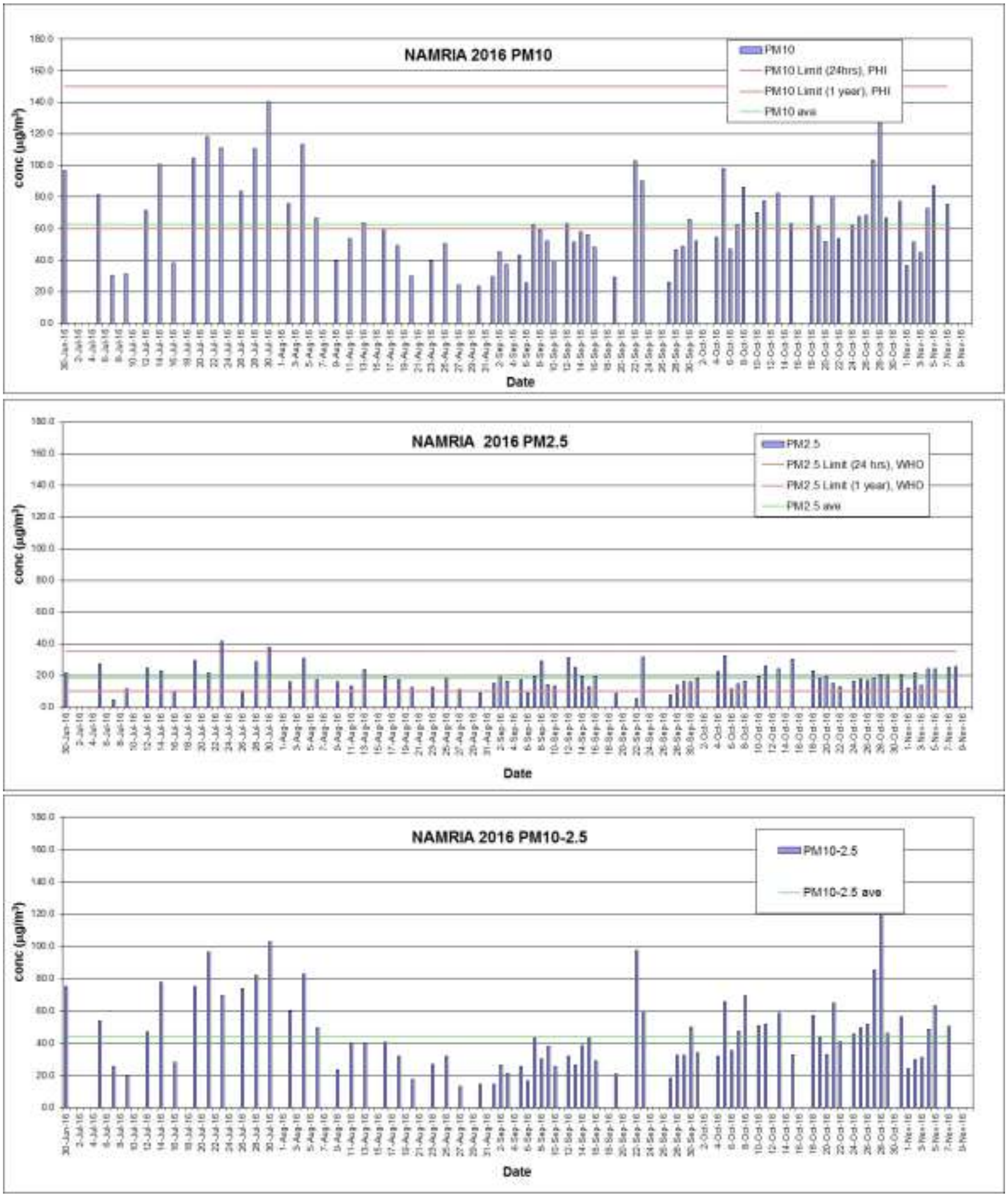


**Figure 4. $PM_{10}$ Levels at NAMRIA Sampling Site**. Both $PM_{10}$ and $PM_{2.5}$ averages for the period are in exceedance of the Philippine and WHO guideline values, respectively. $PM_{10}$ has no daily value exceeding the Philippine 24-hr guideline value while $PM_{2.5}$ has two daily values exceeding the WHO 24-hr guideline value.

### 3.2. Elemental Levels

Information on elemental composition of particulate matter can yield useful information for air quality management. The use of nuclear and related analytical techniques such as the Photon-induced x-ray emissions (PIXE) spectrometry makes possible the non-destructive multi-element analysis of air filters. No sample digestion is required so that analysis can be shortened to less than 5 min per filter, thereby, increasing throughput. In addition to generating a multi-element database for use in pollution source apportionment, the concentration of the criteria pollutant, Pb, will also be obtained. Information on indicator elements for various pollutants i.e. Zn / Mn as fingerprint for tire wear will also be obtained.

Multi-element analyses were done at ANSTO. Profiles of the elemental concentrations at the different sampling sites are shown in Figures 5 (MMDA), 6 (NAMRIA) and 7 (Valenzuela). Based on the average values, MMDA profile can be shown, in decreasing order, as S>Na>Ca>F>Fe>Si>K>Cl> Zn>Al>Pb>Mn>P>Ti>Cu> Cr>Br>Ni>V>Co,Se,Sr; NAMRIA profile as S>Ca>Si>Na>F>Fe>Cl>K>Al>Zn>Pb>Mn> P>Ti>Cu>Br>Cr>Ni>V>Co,Se,Sr; Valenzuela profile as S>K>Na>Fe>Si>F>Ca>Zn>Cl> Pb>Al>Cu>P>Mn>Br>V>Ti>Cr>Ni>Co,Se,Sr. It can be observed that the highest elemental concentration across the three sites is coming from Sulfur (S). The second highest is different at the three sites—Na for MMDA, Ca for NAMRIA and K for Valenzuela. The last three elements—Co,Se,Sr—have very small signal to noise ratio (<0.2) and more than 50% of the data are less than the limit of detection, thus these elements will be excluded from further treatment in PMF runs.

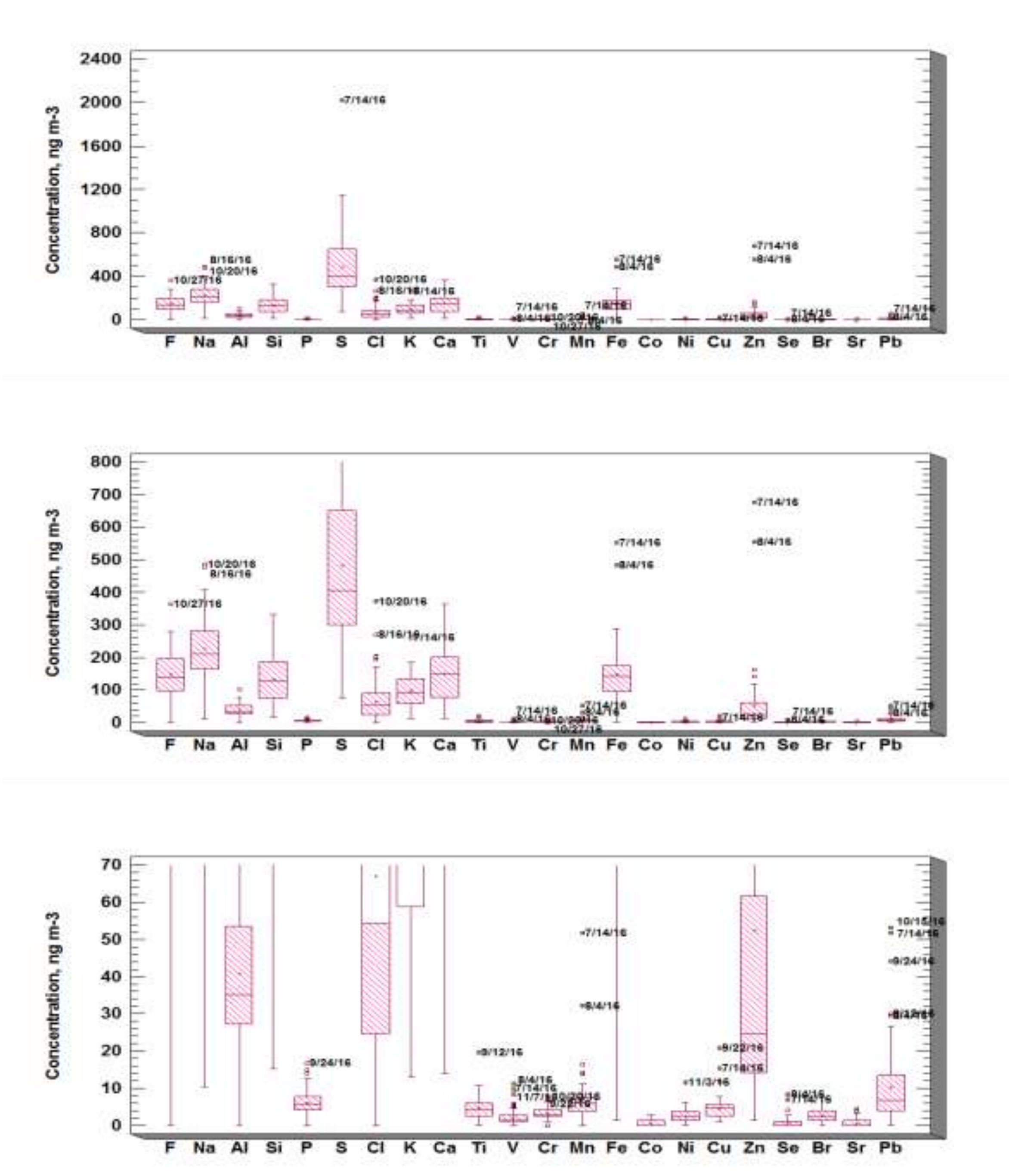


**Figure 5. Multi-element profile at the MMDA sampling site** (Graphs shown with varying y-axis range to highlight (a) high-, (b) mid- and (c) low-range concentration levels). The highest contribution comes from Sulfur (S). *The annual mean is represented by the (+) sign; the median by the horizontal 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.*

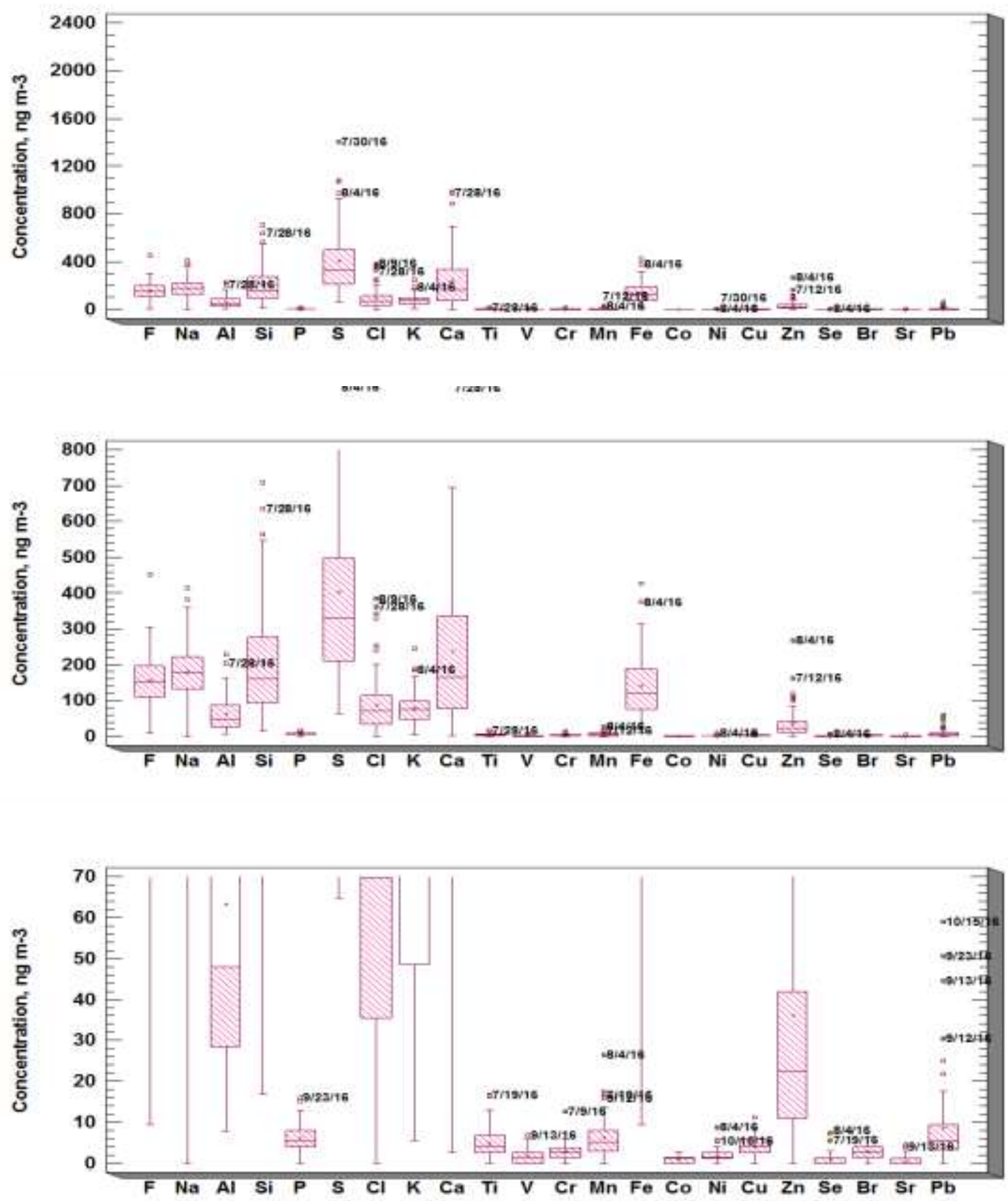


**Figure 6. Multi-element profile for NAMRIA sampling site** (Graphs shown with varying y-axis range to highlight (a) high-, (b) mid- and (c) low-range concentration levels). The highest contribution comes from Sulfur (S). *The annual mean is represented by the (+) sign; the median by the horizontal 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.*

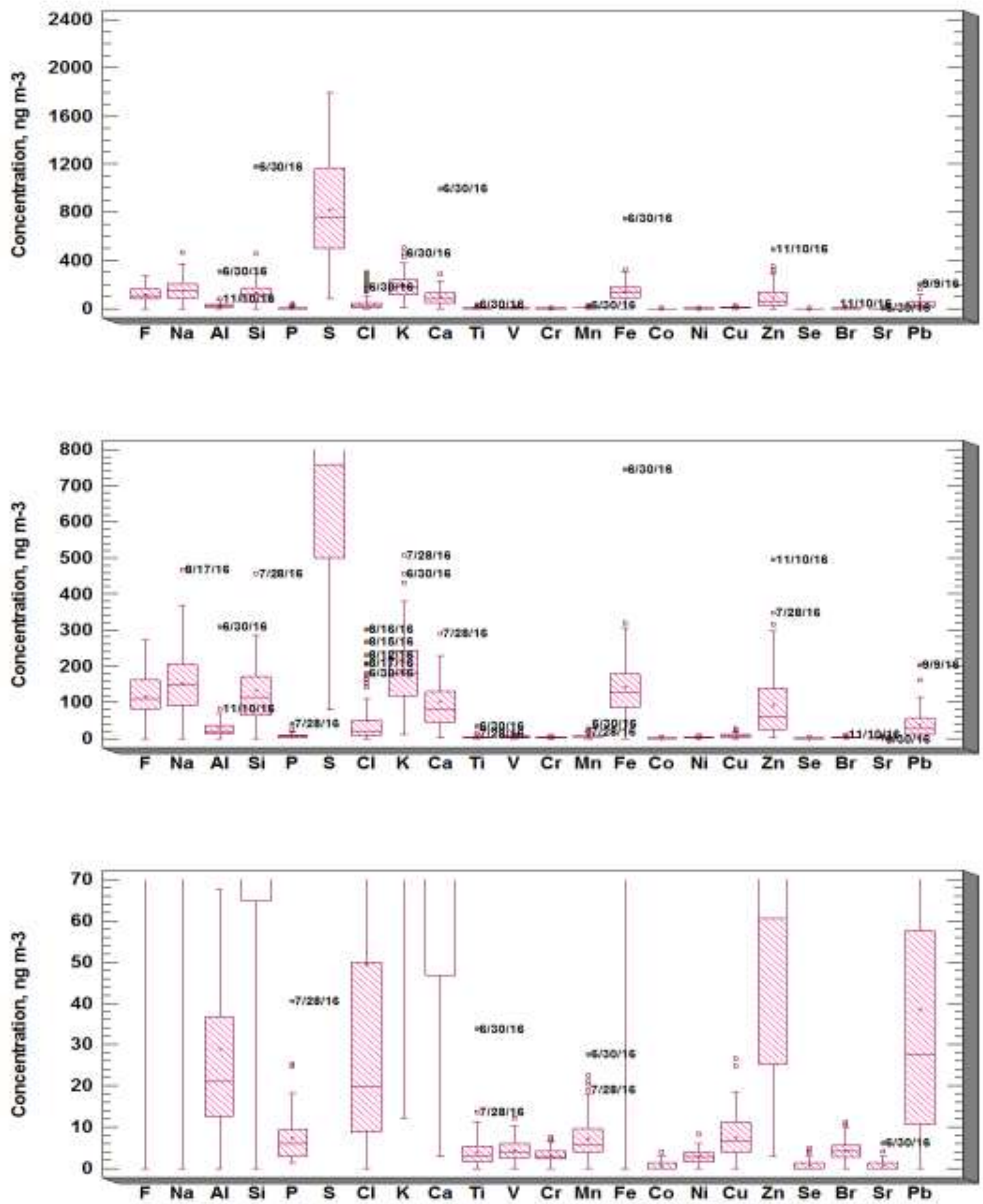


**Figure 7. Multi-element profile for Valenzuela sampling site** (Graphs shown with varying y-axis range to highlight (a) high-, (b) mid- and (c) low-range concentration levels). The highest contribution comes from Sulfur (S). *The annual mean is represented by the (+) sign; the median by the horizontal 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.*

All the three sampling sites have the highest elemental contribution coming from Sulfur. Sulfur in airborne particulate matter is generally present because of the atmospheric conversion of $SO_2$ to sulfate through homogeneous processes (Hopke, P.K. et al. 2008). This conversion can take place comparatively rapidly in urban areas. Effects of sulfate exposure at levels above the standard (ARB USEPA sulfates standard at 25 µg/m$^3$ for a 24-hour averaging period) include a decrease in ventilatory function, aggravation of asthmatic symptoms, and an increased risk of cardio-pulmonary disease. Sulfates are particularly effective in degrading visibility, and, due to fact that they are usually acidic, can harm ecosystems and damage materials and property. A comparison of the S levels at the three sites (Figure 8) show that the highest is in Valenzuela, then MMDA and followed by NAMRIA.

Pb levels (Figure 9) are comparable at MMDA and NAMRIA sites, but Valenzuela exhibits much higher levels which would indicate that there is a Pb source in the area which are not found in the other two sites. This warrants further investigation. Zn levels (Figure 10) are also highest in Valenzuela with the other two sites having comparable levels. Zn may come from industrial inputs.

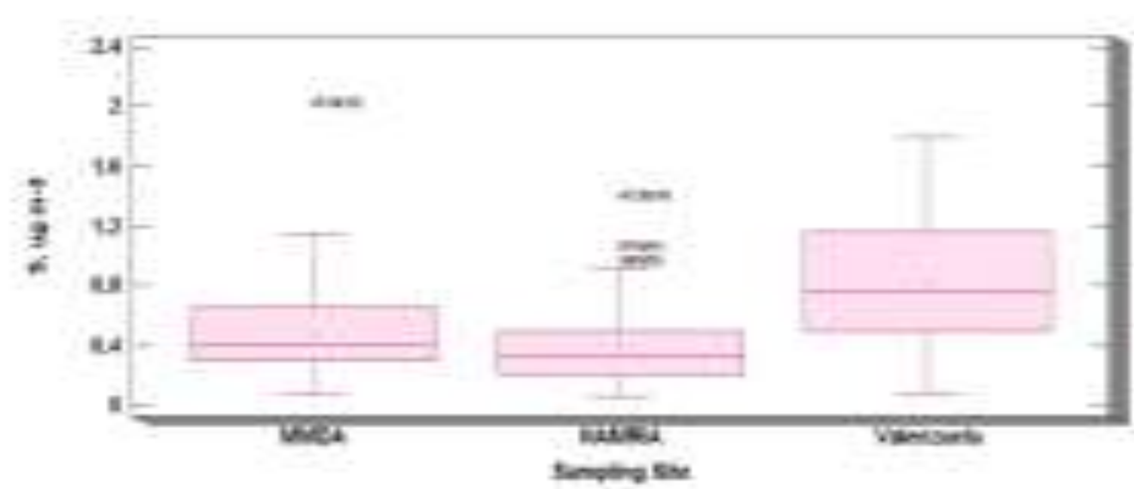


**Figure 8. Comparative profile of Sulfur (S) concentration levels across the three sampling sites.** Sulfur concentration levels are highest at Valenzuela, followed by MMDA. Sulfur mean level at Valenzuela is significantly different from that of NAMRIA and MMDA at 95% confidence level using the Multiple Range Test. *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.*

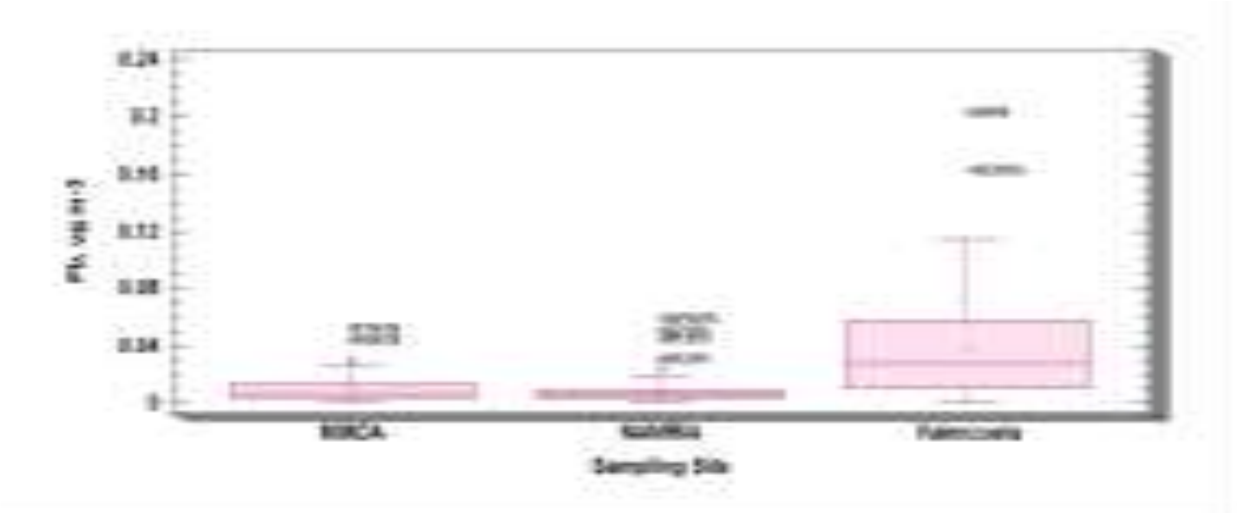

**Figure 9. Comparative profile of Lead (Pb) concentration levels across the three sampling sites.** Pb concentration levels are highest at Valenzuela. MMDA and NAMRIA have comparable levels of Pb. Pb mean level at Valenzuela is significantly different from that of NAMRIA and MMDA at 95% confidence level using the Multiple Range Test. *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.*

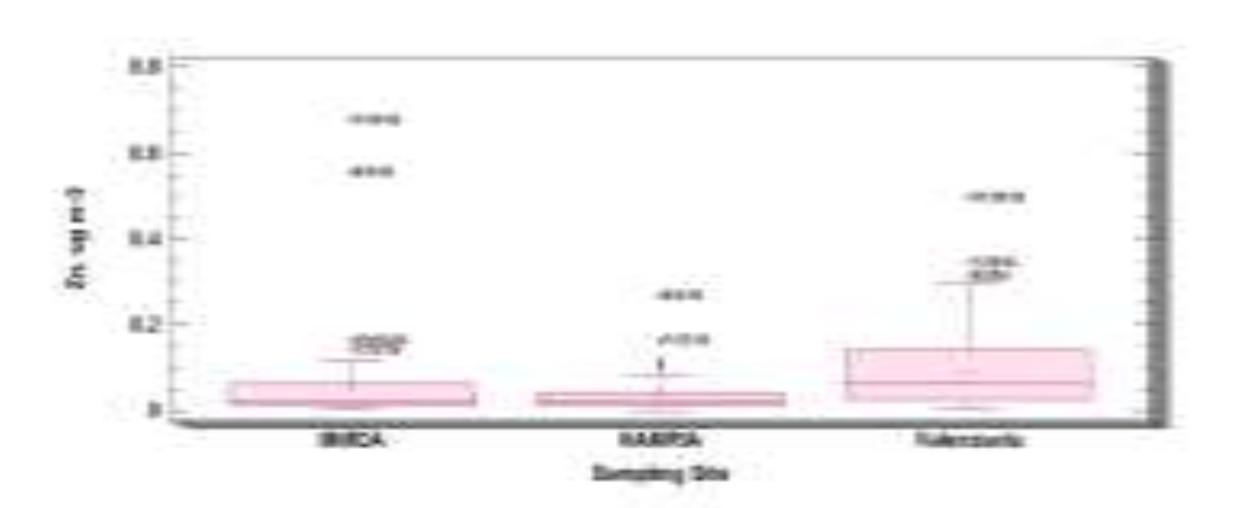

**Figure 10. Comparative profile of Zinc (Zn) concentration levels across the three sampling sites.** Zn levels are highest at Valenzuela. MMDA and NAMRIA have comparable levels of Zn. Zn mean level at Valenzuela is significantly different from that of NAMRIA and MMDA at 95% confidence level using the Multiple Range Test. *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.*

The databases were completed for each sampling site containing the multi-element composition, black carbon data and the gravimetric mass of the air particulate matter. The complete databases were treated for use in Positive Matrix Factorization to generate source identification and apportionment results for the three sites (refer to Section 3.4).

### 3.3 Black Carbon Levels

Another component of the air particulate matter is black carbon (BC). Black carbon is composed of small, soot-like particles formed through the incomplete combustion of fossil fuels, biofuel and biomass. In a modelling experiment by Shindell and colleagues (NASA 2010) black carbon was shown to absorb incoming solar radiation and have a strong warming influence on the atmosphere. Black carbon, compared to the primary greenhouse gas $CO_2$ with an atmospheric lifetime of more than 100 years, stays in the atmosphere for only several days to weeks (Wikipedia 2010). It is for this reason that many scientists such as Ramanathan, Bond and others (Wikipedia 2010) believe that reduction of black carbon emissions can be the fastest means of slowing down climate change in a near-term.

A summary of the black carbon (BC) levels found in the respirable fraction is shown in Table 2. NAMRIA and MMDA sites show the higher percentage of BC in the fine fraction than that in Valenzuela. The daily black carbon profile of the $PM_{2.5}$ fractions from the three study sites are shown in Figures 11 to 13.

**Table 2. Summary of $PM_{2.5}$ Black Carbon at the Metro Manila Sampling Sites.**

| Sampling Site | Site Description | $PM_{2.5}$ BC, ug $m^{-3}$ ave (range) | %BC ($PM_{2.5}$) |
|---|---|---|---|
| Valenzuela | General Ambient | 8.3 (1.4 – 30.6) | 31 (13 - 49) |
| MMDA (EDSA) | Roadside Ambient (8th Floor rooftop) | 9.0 (0.6 – 18.0) | 45 (14 - 66) |
| NAMRIA | General Ambient | 8.7 (1.4 – 16.1) | 46 (6 - 66) |

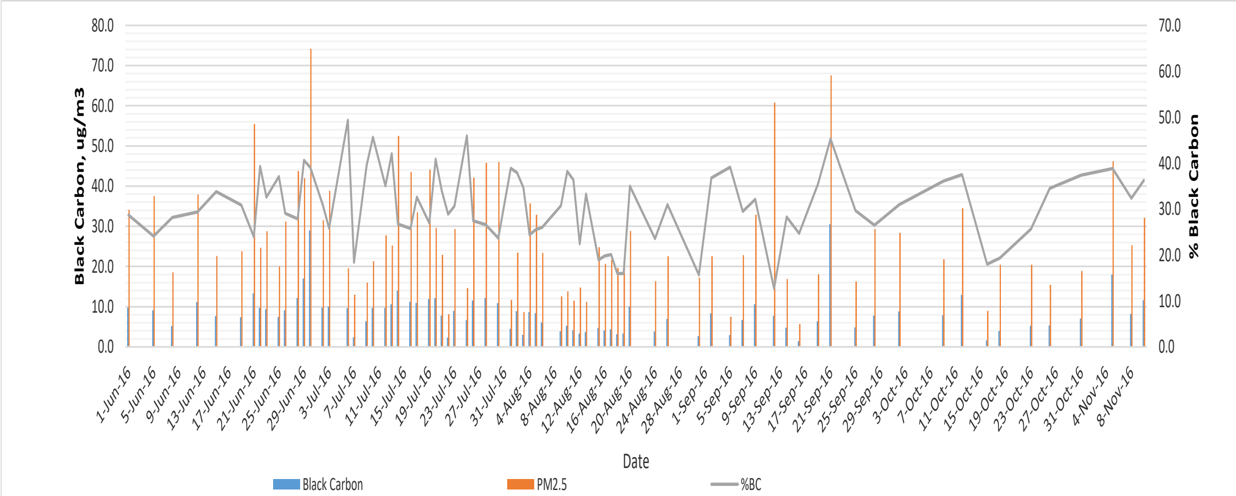


**Figure 11. Black carbon (BC) profile for $PM_{2.5}$ Valenzuela City.** BC concentration levels range for the indicated sampling period is 1.4 to 30.6 μg $m^{-3}$, averaging at 8.3 μg $m^{-3}$. % BC of the $PM_{2.5}$ is at an average of 31 % (ranges at 13 to 49%).

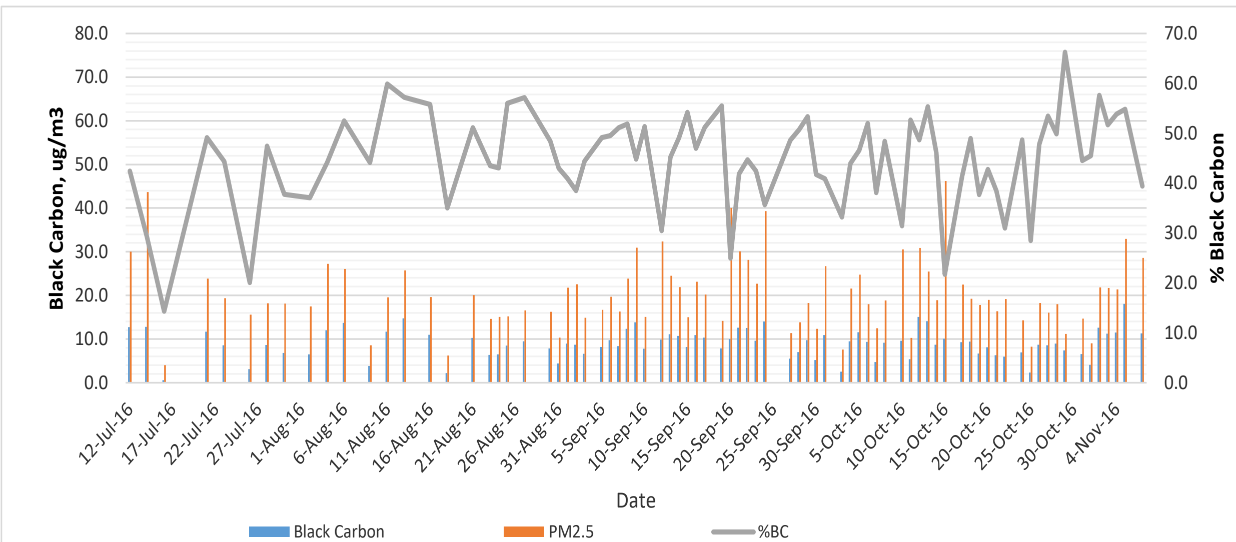


**Figure 12. Black carbon (BC) profile for $PM_{2.5}$ MMDA (EDSA).** BC concentration levels range for the indicated sampling period is 0.6 to 18 μg $m^{-3}$, averaging at 9.0 μg $m^{-3}$. % BC of the $PM_{2.5}$ is at an average of 45% (ranges at 14 to 66%).

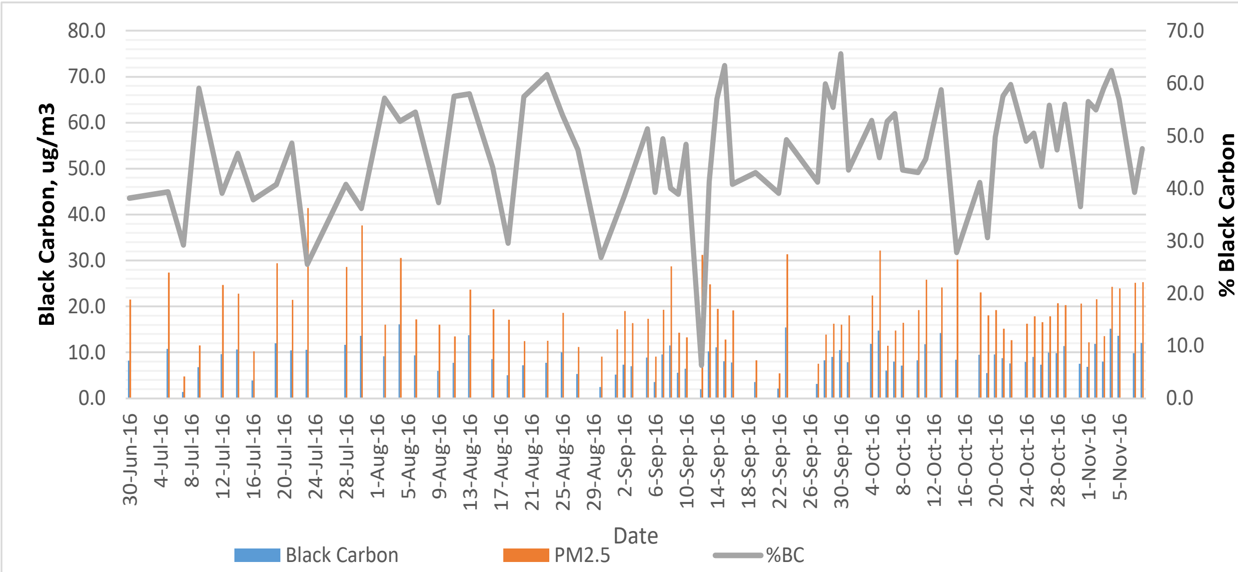


**Figure 13.  Black carbon (BC) profile for $PM_{2.5}$ NAMRIA.** BC concentration levels range for the indicated sampling period is 1.4 to 16.1µg $m^{-3}$, averaging at 8.7 µg $m^{-3}$.  % BC of the $PM_{2.5}$ is at an average of 46% (ranges at 6 to 66%).

Black carbon profile in the study sites were compared with regional data (2001-2009) results from the IAEA/RCA regional project involving 14 Member States in the Asia-Pacific region (refer to Figure 14).  The study sites have BC levels which are comparable to that of Bangladesh (BAN), but outlying points in the study sites are not as high as those of Bangladesh.  The Philippine (PHI) BC data were taken from the sampling site at the Ateneo de Manila University, Quezon City.  PHI BC data are much higher than that in the study sites.

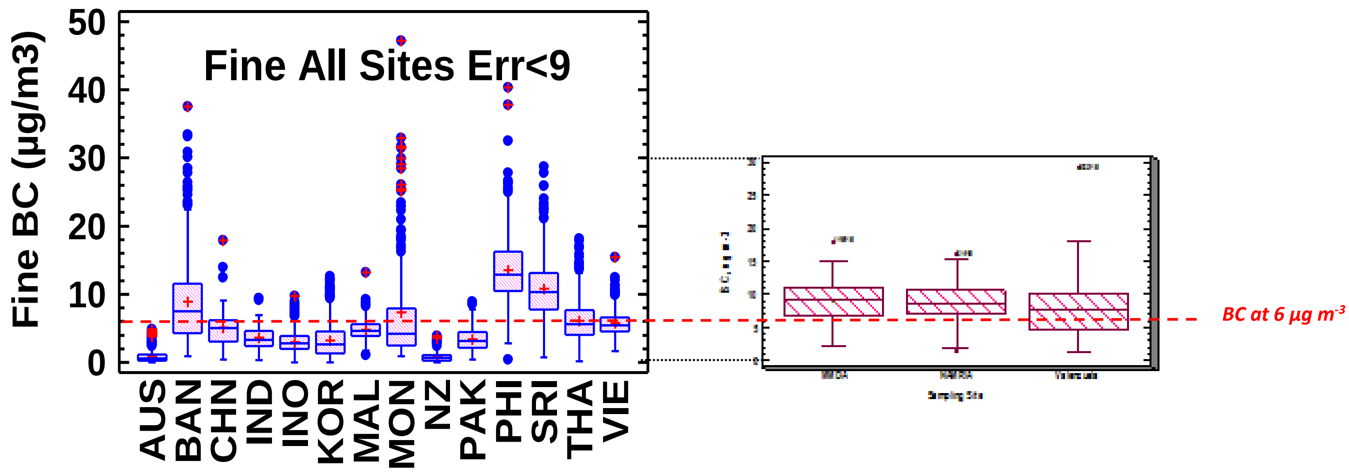


**Figure 14. Comparison of black carbon (BC) levels in the study sites (MMDA, NAMRIA and Valenzuela) with that of the regional data (2001-2009) (Atanacio et al. 2016).** The study sites have average levels above 6 µg $m^{-3}$, comparable to average levels in Bangladesh (BAN), but lower than that of Sri Lanka (SRI) and Philippines (PHI, ADMU station). *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.*

### 3.4 Source Apportionment

Air quality management is best implemented when information on the identification and apportionment of pollutants to their sources is available. In this regard, the use of receptor modeling is advantageous. In receptor modeling pollutant concentrations are measured at the sampling site and processed by some modeling tools such as the positive matrix factorization (PMF). PMF is a factor analytic technique where the left and right factor matrices (corresponding to scores and loadings) are constrained to nonnegative values (Paatero 1997, Hopke 1991). The PMF model is able to statistically correlate multiple elemental concentrations into a reduced number of source factors representing key pollution source fingerprints and their contributions to the total measured mass.

Source apportionment results were obtained using the ANSTO macro file-assisted PMF2 DOS version. In general, six (6) sources are impacting the three sampling sites in this study (Figures 15, 17 and 19 show the PMF-derived air pollution sources for MMDA, NAMRIA and Valenzuela, respectively). The corresponding time series plots of the apportioned air pollution sources are shown in Figures 16, 18 and 20 for the three sites.

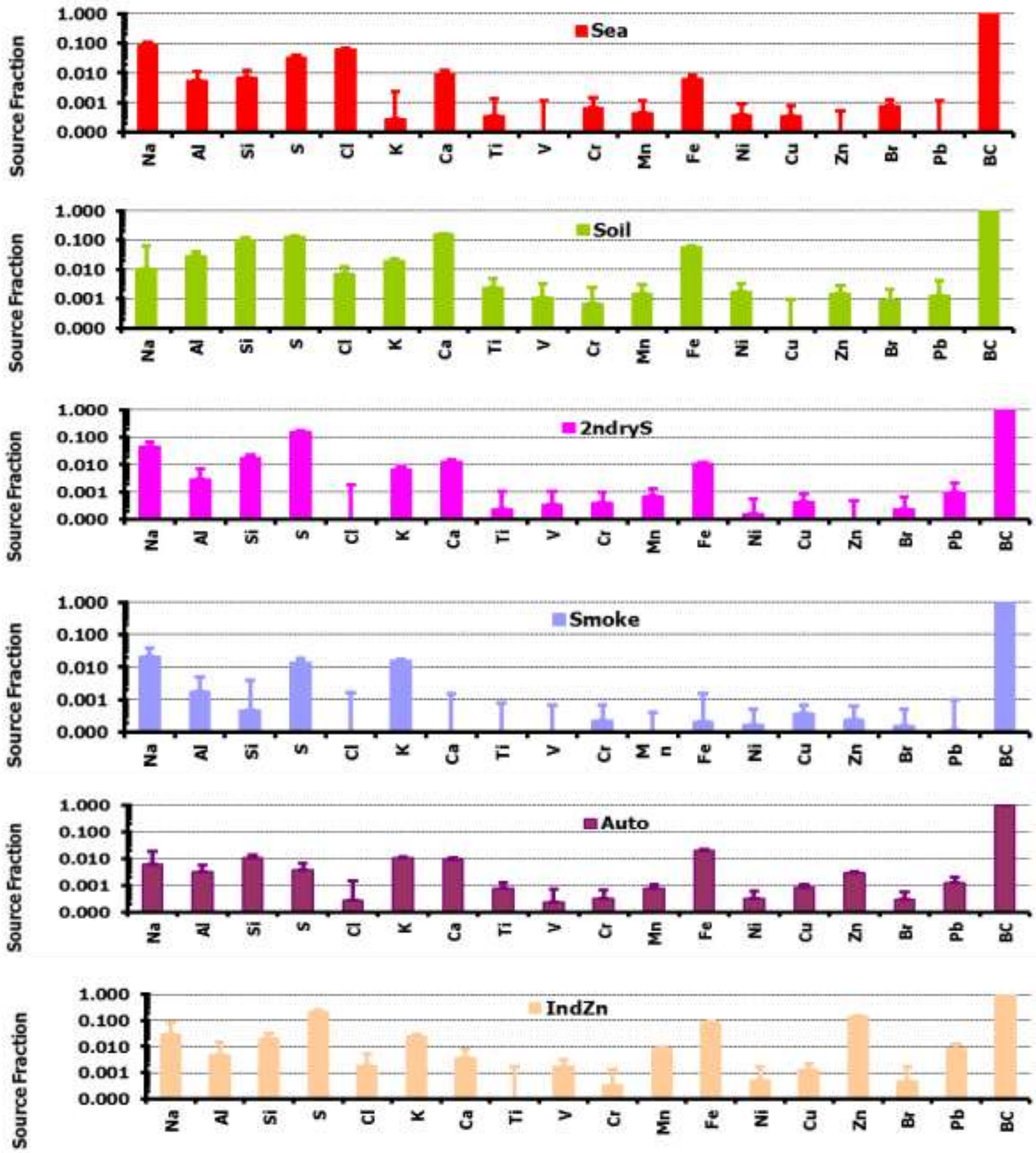


**Figure 15.  Source apportionment results at the MMDA sampling site for the period June to November 2016.**  Six (6) pollutant sources were found for the fine fraction:  1) sea spray =13.3%; 2) soil = 11.0 %; 3) Secondary sulfur = 21.1%; 4) smoke = 20.0%  ; 5) Auto (or vehicular) = 30.7% ; and, 6) industrial = 3.9%.  Source apportionment done with the ANSTO macro file-aided PMF2 DOS version, using error value of 0.05 and fpeak = 0.01.

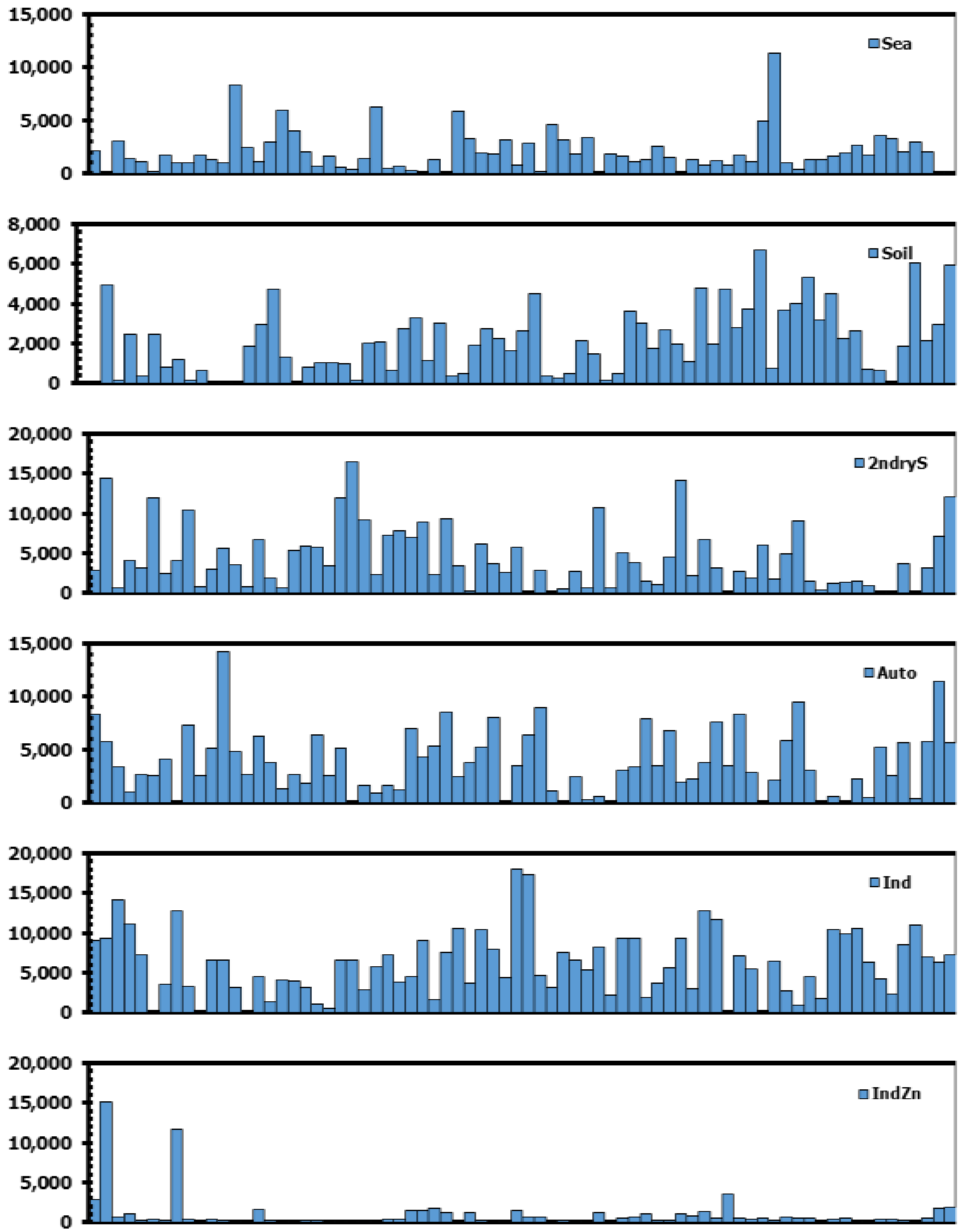


**Figure 16. Time series plots of the concentration (ng m$^{-3}$) of PMF-derived air pollution sources from MMDA.**

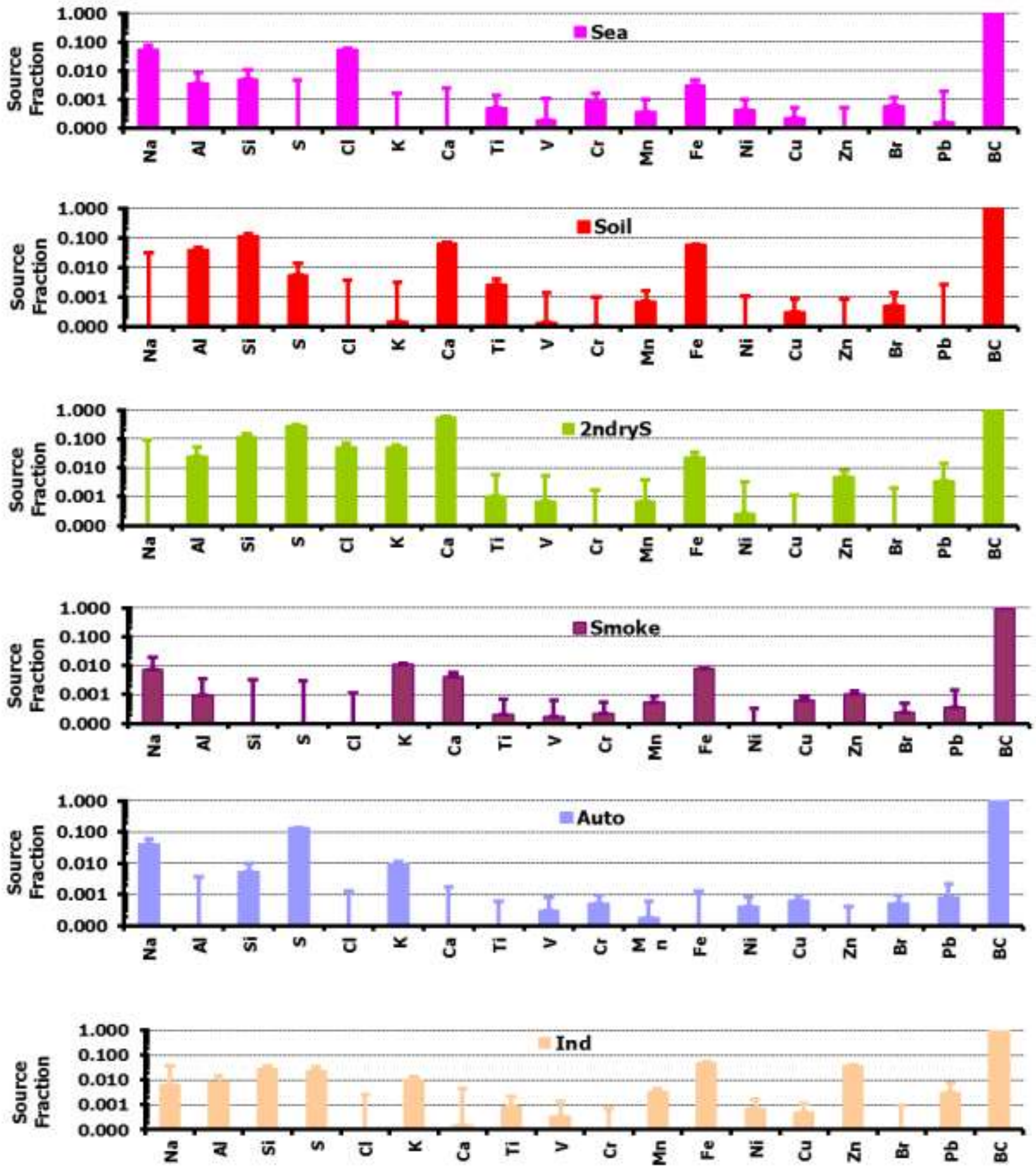


**Figure 17. Source apportionment results at the NAMRIA sampling site for the period June to November 2016.** Six (6) pollutant sources were found for the fine fraction: 1) sea spray =14.5%; 2) soil = 13.5 %; 3) Secondary sulfur = 7.9%; 4) smoke = 24.9%; 5) Auto (or vehicular) = 32.5%; and, 6) industrial (Zn Fe) = 6.7%. Source apportionment done with the ANSTO macro file-aided PMF2 DOS version, using error value of 0.05 and fpeak = 0.01.

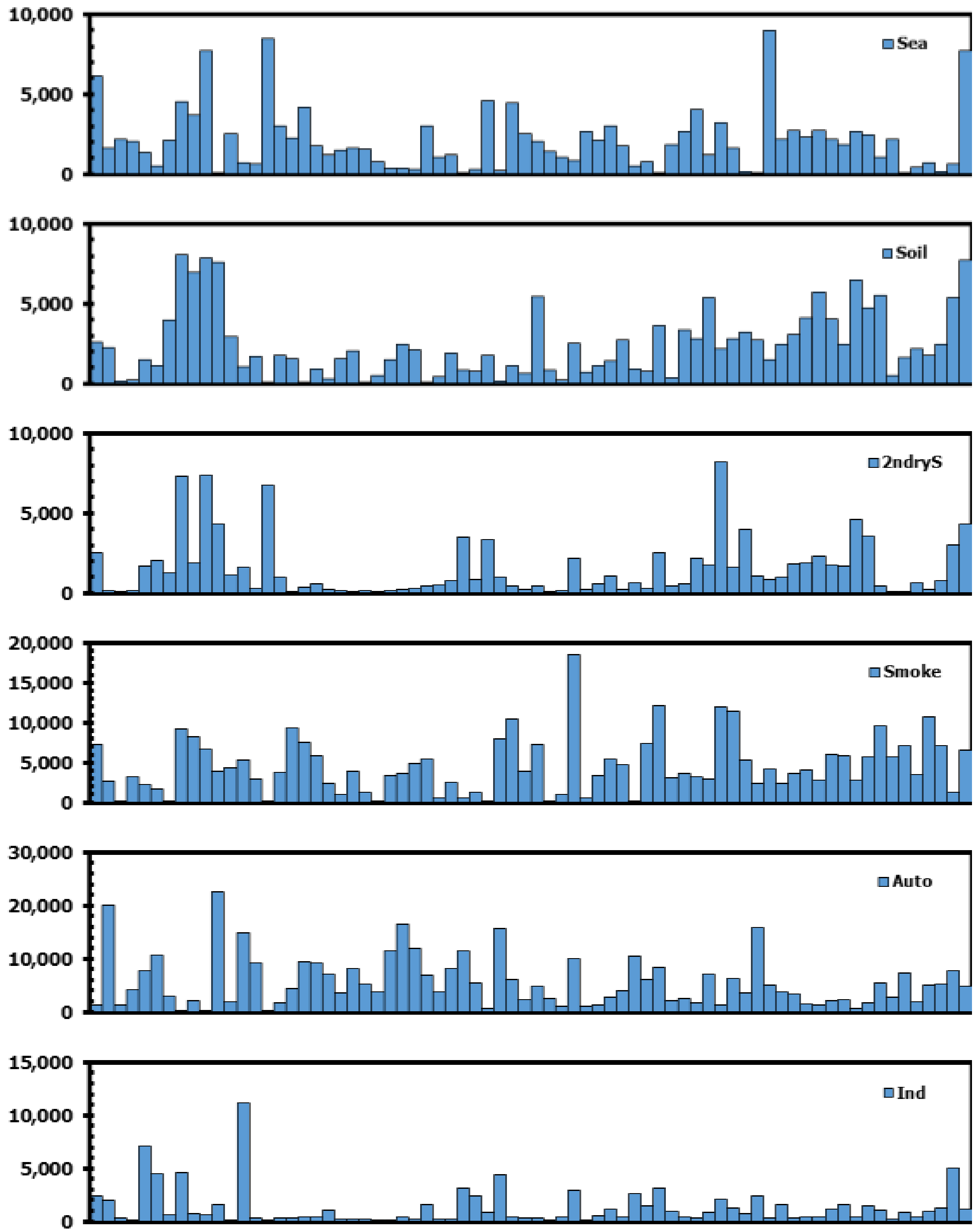


**Figure 18.  Time series plots of the concentration (ng m$^{-3}$) of PMF-derived air pollution sources from NAMRIA.**

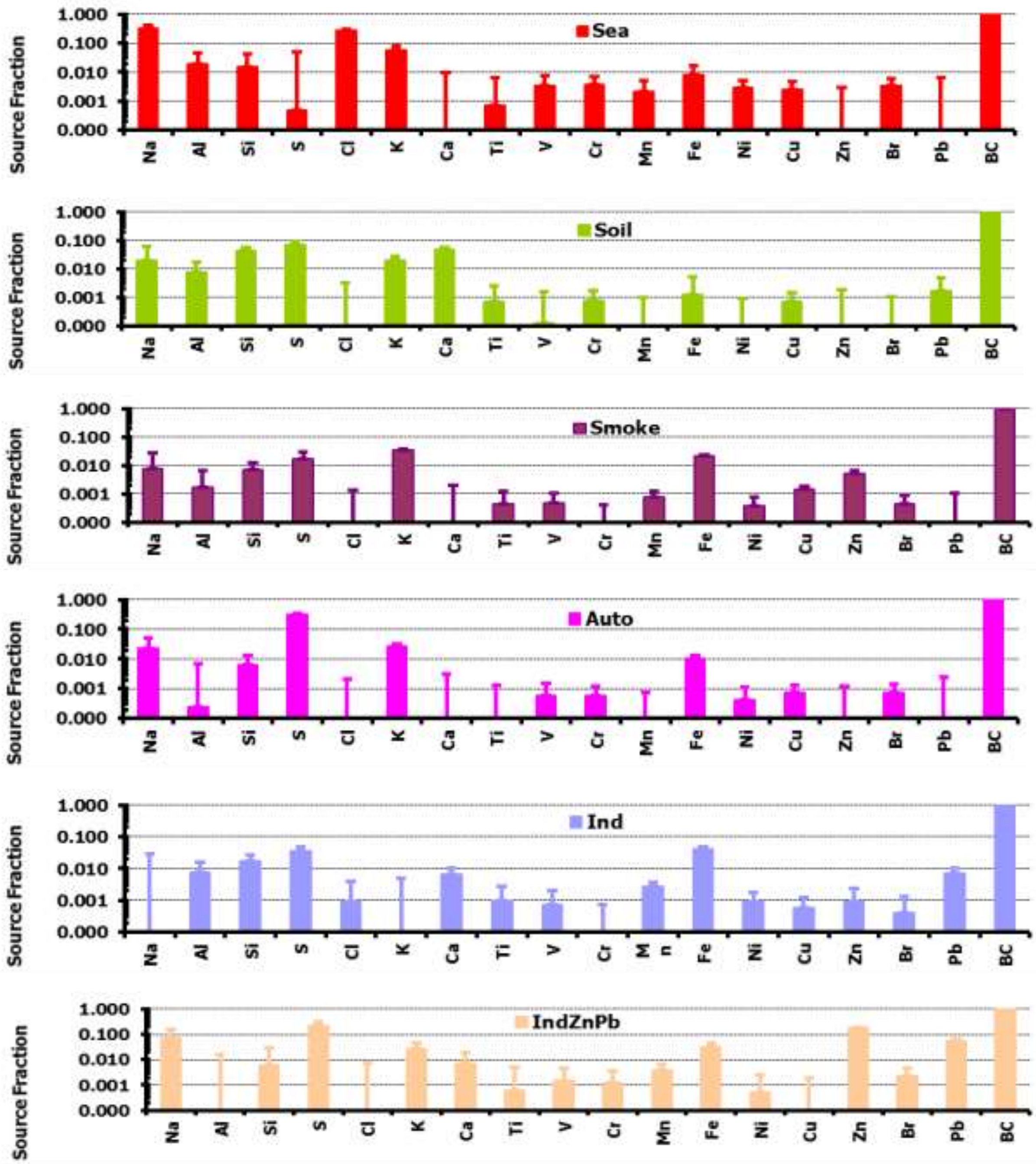


**Figure 19. Source apportionment results at the Valenzuela sampling site for the period June to November 2016.** Six (6) pollutant sources were found for the fine fraction: 1) sea spray =8.5%; 2) soil = 9.2 %; 3) smoke = 27.6%; 4) Auto (or vehicular) = 35.2%; 5) industrial (S Fe) = 14.0 %; and (6) industrial (Zn Pb) = 5.4%. Source apportionment done with the ANSTO macro file-aided PMF2 DOS version, using error value of 0.10 and fpeak = 0.

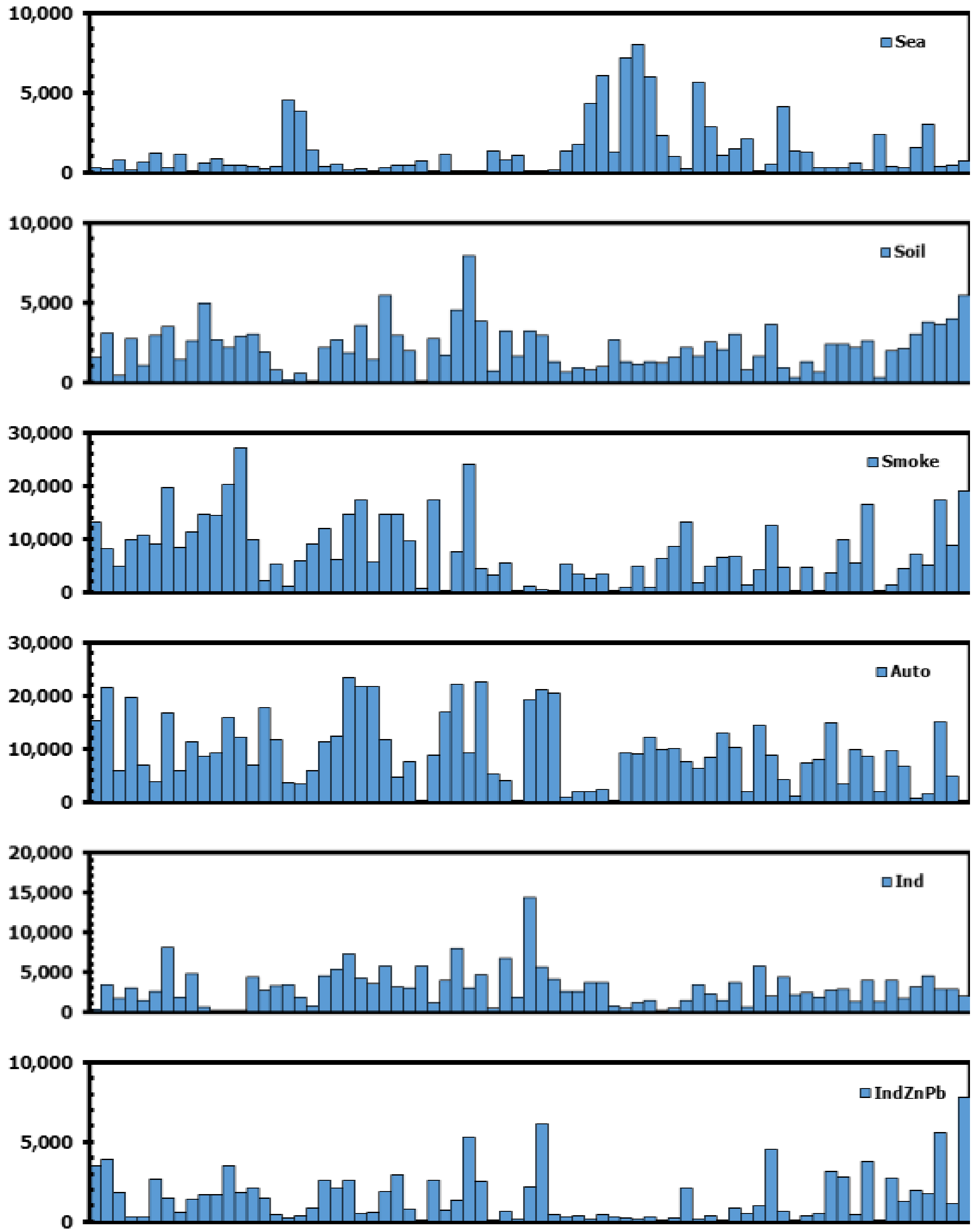


**Figure 20. Time series plots of the concentration (ng m$^{-3}$) of PMF-derived air pollution sources from Valenzuela.**

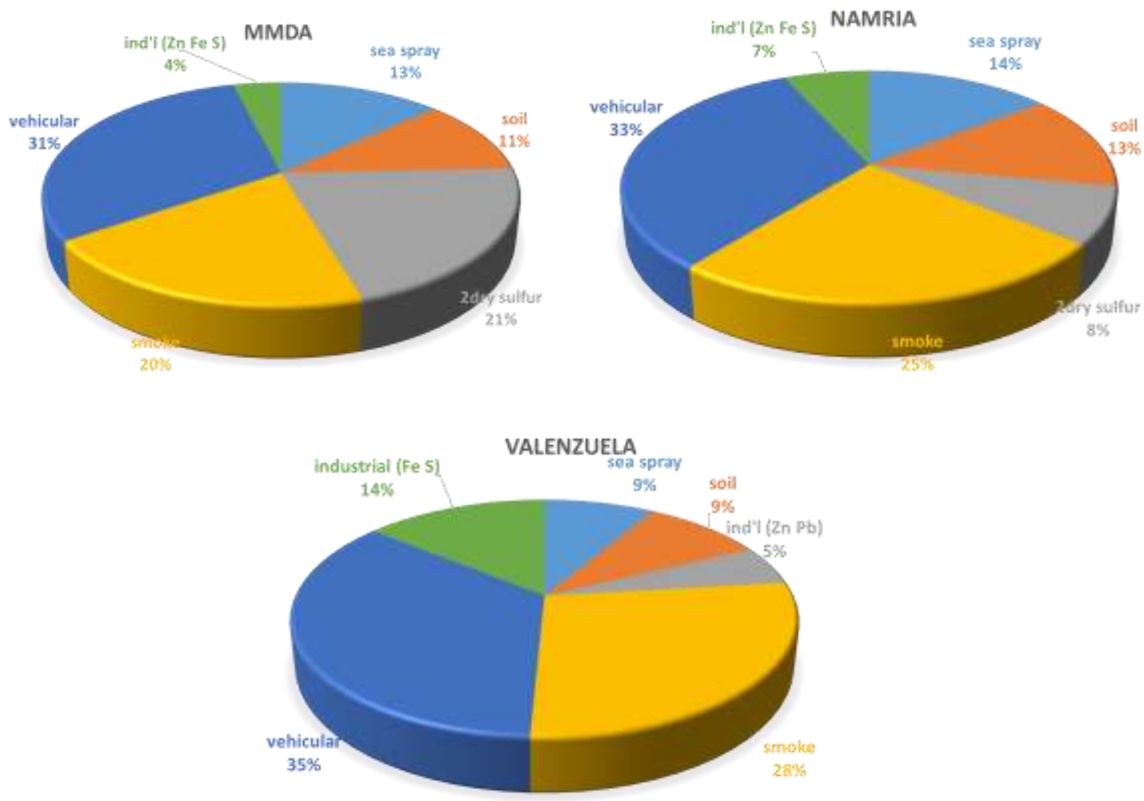


**Figure 21. Comparison of apportioned air pollutant sources across the three sampling sites.** Six (6) sources have been identified --- seaspray, fine soil, vehicular emissions, biomass burning (smoke), industrial and secondary sulfur-- impacting the sites. Vehicular emissions comprise 30-50% (vehicular and secondary sulfur) of the apportioned sources. Industrial source, predominantly Zn and Pb, is seen in Valenzuela.

The sources indicated 30-50% coming from vehicular emissions corroborating previous studies coming up with similar findings (Pabroa et al., 2013). Sea spray source is generally not a pollutant, but in this study BC contributes also to this factor. This would mean that BC being a major component of the total APM mass, affects also other sources, even with the sea spray. BC is a component of all the other sources, too. A distinct industrial source is seen at the Valenzuela sampling site with Pb and Zn as major components.

### 3.5 Locating Air Pollution Sources

Air pollution sources can be located either by HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) or by CPF (Conditional Probability Function). HYSPLIT is a trajectory model (Draxler and Hess, 1997), which uses the meteorological data produced by the National Weather Service ETA model to compute advection and dispersion of air parcels. This is used for back trajectory analysis to obtain possible location of air pollution, especially for transboundary air pollution studies. The conditional probability function (CPF) is used to give an indication of the general direction from which a particular source had the greatest contribution. CPF analyzes point source impacts from varying wind directions using the source contribution estimates from PMF coupled with the wind direction values measured on site (Kim et al. 2003). It estimates the probability that a given source contribution from a given wind direction will exceed a predetermined threshold criterion and is defined as $CPF_{\Delta\theta} = m_{\Delta\theta} / n_{\Delta\theta}$ , where $m_{\Delta\theta}$ is the number of occurrence from wind sector $\Delta\theta$ that exceeded the threshold criterion and $n_{\Delta\theta}$ is the total number of data from the same wind sector. The sources are likely to be located to the directions that have high conditional probability values. However, this statistical analysis would need local meteorological data. EU-SWITCH was supposed to provide local meteorological data from NAMRIA while EMB was supposed to provide for the MMDA and Valenzuela sites. Since local meteorological data are not available, CPF cannot be done for now. Instead, only the estimation of the transboundary contribution to pollution at the three sampling sites were analyzed using the HYSPLIT.

Extremely high events (concentration levels exceeding the mean plus 2x the standard deviation) were analyzed if these were coming from transboundary sources. Table 3 lists extreme events with possible transboundary component.

**Table 3. List of extreme events with possible transboundary source.**

**3a. Report for the Valenzuela site:**

| Date (2016) | Elements (high events) | Concentration (ng $m^{-3}$) | Date (2016) | Elements (high events) | Concentration (ng $m^{-3}$) |
|---|---|---|---|---|---|
| June 29 | *Black Carbon* | *13422* | August 15 | Sodium | 281 |
| | | | | Chlorine | 211 |
| June 30 | *Black Carbon* | *22840* | | | |
| July 14 | Manganese | 16.0 | | | |
| | Sulfur | 1388 | | | |
| July 26 | Vanadium | 7.8 | August 16 | Sodium | 289 |
| | | | | Chlorine | 238 |

| | | | | | |
|---|---|---|---|---|---|
| July 28 | Silicon | 359 | August 17 | Sodium | 369 |
| | Phosphorus | 32 | | Chlorine | 164 |
| | Manganese | 14.9 | | | |
| | Potassium | 398 | | | |
| | Zinc | 273 | | | |
| August 4 | Manganese | 17.8 | August 24 | Copper | 20.9 |
| | | | | Chlorine | 162 |
| August 5 | Zinc | 248 | | | |
| | Chromium | 5.97 | | | |
| | Manganese | 16.7 | | | |
| | Sulfur | 1414 | | | |

High Black Carbon Concentration was observed with the following dates: June 29 & 30, October 12 and November 5 for the year 2016. High BC events on 29 and 30 June can be attributed to the fire incidents reported last June 28, 2016 at the Batasan Hills and at Barangay Baesa, Quezon City (refer to Figure 21).  There was no proof of fires for October 12 and November 5 which can indicate that the source may have come from increased vehicular emissions in proximity to the area.

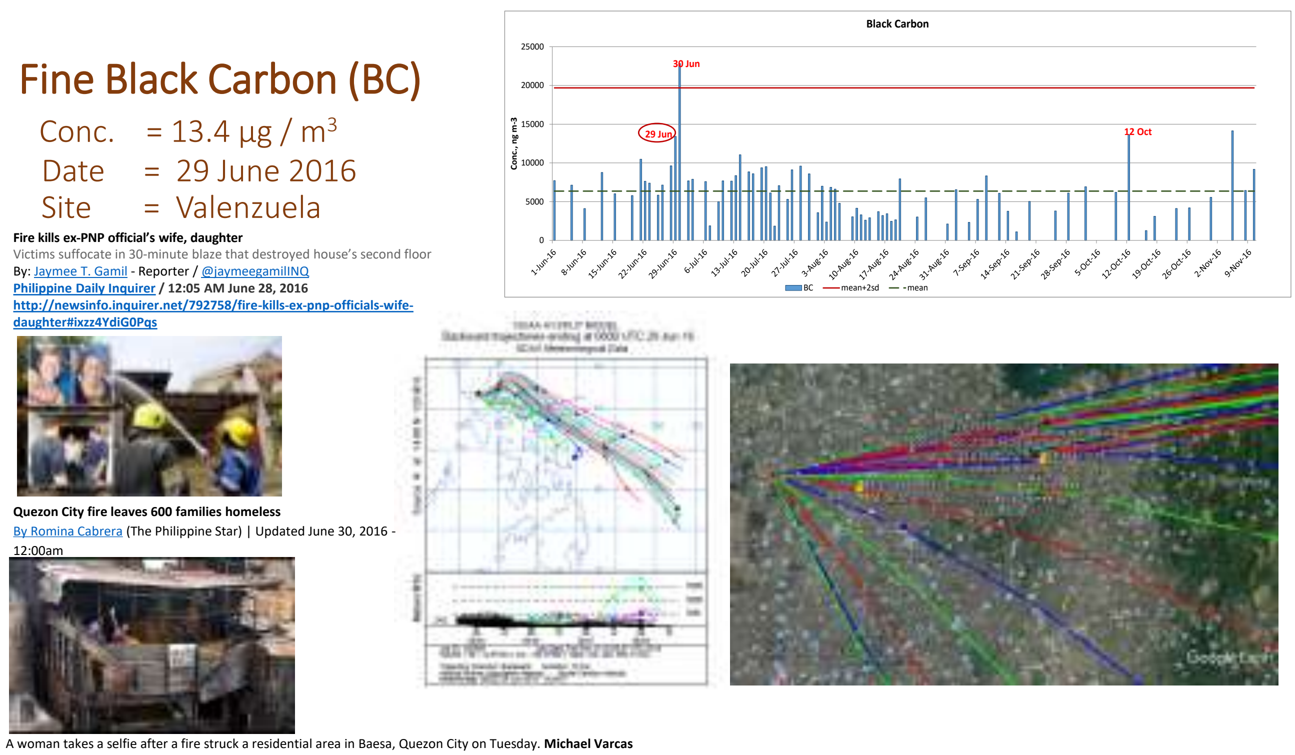


**Figure 22.  Back trajectory analysis of fine black carbon at the Valenzuela sampling site on 29 June 2016.**

**3b. Report for the MMDA site:**

| Date (2016) | Elements (high events) | Concentration(ng $m^{-3}$) |
|---|---|---|
| July 14 | Sulfur | 1592 |
| | Potassium | 205 |
| | Vanadium | 7.72 |
| | Manganese | 40.9 |
| | Iron | 435 |
| | Copper | 12.1 |
| | Zinc | 534 |
| | Lead | 40.8 |
| July 26 | Lead | 3.07 |
| July 28 | Chromium | 5.51 |
| August 4 | Sulfur | 880 |
| | Vanadium | 8.82 |
| | Manganese | 25.4 |
| | Iron | 381 |
| | Zinc | 438 |
| August 14 | Chlorine | 33.1 |
| September 21 | Copper | 4.41 |
| October 12 | *Black Carbon* | *11845* |
| October 15 | Lead | 23.1 |
| October 19 | Calcium | 105 |
| October 20 | Sodium | 259 |
| | Chlorine | 33.1 |
| | Chromium | 4.42 |
| November 3 | Calcium | 263 |
| | Nickel | 9.21 |

High concentration of Black Carbon at MMDA sampling site was observed last October 12, 2016 but no fire incidents were reported to have occurred at that time.   This high BC event may have been due to some burning of combustible wastes which was sighted in the area.

**3c. Report for the NAMRIA site:**

| Date (2016) | Elements (high events) | Concentration (ng $m^{-3}$) | Date (2016) | Elements (high events) | Concentration (ng $m^{-3}$) |
|---|---|---|---|---|---|
| July 9 | Chromium | 9.99 | September 12 | Manganese | 12.5 |
| July 12 | Manganese | 13.4 | September 13 | Vanadium | 5.34 |
| | Zinc | 128 | | | |
| July 19 | Aluminum | 180 | September 23 | Phosphorus | 12.5 |
| | Silicon | 558 | | Potassium | 193 |
| | Potassium | 132 | | Vanadium | 4.56 |
| | Calcium | 771 | | *Black Carbon* | *12160* |
| | Titanium | 13.1 | | | |
| | Manganese | 13.1 | | | |
| | Iron | 336.4 | | | |
| July 21 | Aluminum | 128 | October 5 | Manganese | 13.764 |
| | Silicon | 380 | | | |
| July 28 | Aluminum | 160 | October 11 | Potassium | 148.501 |
| | Silicon | 500 | | Calcium | 696.758 |
| | Chlorine | 284 | | | |
| | Calcium | 765 | | | |
| | Titanium | 13.0 | | | |
| July 30 | Silicon | 433 | October 15 | Vanadium | 4.226 |
| | Sulfur | 1106 | | Nickel | 4.226 |
| | Nickel | 4.46 | | | |
| August 4 | Sodium | 275 | October 20 | Sodium | 325.242 |
| | Potassium | 147 | | Chlorine | 270.868 |
| | Manganese | 20.8 | | | |
| | Iron | 296 | | | |
| | Nickel | 6.93 | | | |
| | Copper | 6.93 | | | |
| | Zinc | 211 | | | |
| | *Black Carbon* | *12705* | | | |
| August 9 | Chlorine | 302.785 | October 22 | Phosphorus | 11.963 |
| August 16 | Sodium | 301.349 | October 31 | Copper | 8.762 |
| | Bromine | 5.073 | | | |
| August 18 | Sodium | 282.679 | November 8 | Silicon | 445.615 |
| | | | | Chlorine | 260.131 |
| | | | | Titanium | 10.179 |

High levels of Black Carbon were observed during August 4 and September 23. Investigation showed no fire incidents occurring within the concerned area so it can be deduced that this high BC event can rather be due to increase vehicular emissions impacting the area.

## 4. CONCLUSIONS AND RECOMMENDATIONS

Results show $PM_{10}$ levels across the three Metro Manila sites to be non-compliant to the Philippine1-year guideline value of 60 $\mu$g m$^{-3}$. Although not presented in the graphs, these levels are way above the WHO 1-year guideline value of 20 $\mu$g m$^{-3}$. $PM_{2.5}$ levels are in exceedance of the WHO 1-year guideline value of 10 $\mu$g m$^{-3}$. The ambient air quality in the Valenzuela, MMDA (EDSA) and NAMRIA sites can be considered as unhealthy for both $PM_{10}$ and $PM_{2.5}$ by the WHO standards.

Black carbon levels (average at 8.7 $\mu$g m$^{-3}$) across the three sampling sites are at an average of 31–46 % of the fine particulate mass. Comparable BC composition are seen in MMDA and NAMRIA (45 and 46%) while Valenzuela at 31%. BC is a fingerprint of incomplete combustion products, indicative of vehicular emissions at roads in proximity to the sampling sites.

Multi-element profiles show Sulfur to have the highest contribution to the fine air particulate pollution across the three sites with Valenzuela exhibiting the highest. Valenzuela also exhibits Pb and Zn levels much higher than that of MMDA and NAMRIA which would point to a unique industrial source/sources in this area.

Source apportionment results show six (6) sources—seaspray, fine soil, vehicular emissions, biomass burning, industrial and secondary sulfur-- impacting the three sites. Vehicular emissions comprise 30-50% of the apportioned sources (auto and secondary sulfate). An industrial source, predominantly Zn and Pb, is seen in Valenzuela.

Extremely high events (concentration levels exceeding the mean plus 2x the standard deviation) were analyzed if these were coming from transboundary sources. Some high BC events were attributed to reported fires in some places far from the receptor site.

The project resulted in a better understanding of the sources of particulate pollution in Metro Manila, in addition to generating basic data for air quality management.

Source apportionment studies can show unique air pollution sources such as in Valenzuela City which indicate the need to do a more comprehensive evaluation of the area to determine the sources of Pb and formulate measures to bring down its ambient levels.

Addressing problems regarding traffic-related activities can greatly reduce our fine particulate pollution problems including the black carbon which can bring about better air quality in the area resulting to a healthier air to breath by the general public and contributing to the mitigation of climate change.

**Table 4.  Project Timeline.**

| Activities | 2016 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | M1 | M2 | M3 | M4 | M5 | M6 | | | | |
| | | | | | | | | | | | | |
| 1. Sample Collection | | | x | x | x | x | x | | | | | |
| 2. Particulate mass determination | | | x | x | x | x | x | | | | | |
| 3. Black carbon (elemental carbon determination) | | | x | x | x | x | x | | | | | |
| 4. Elemental analysis | | | x | x | x | x | | x | | | | |
| 5. Data analysis | | | | | x | x | x | x | | | | |
| 6. Preparation and submission of mid-term progress report | | | | | x | | | | | | | |
| 7. Source apportionment studies | | | | | | | x | x | | | | |
| 8. Preparation of final report | | | | | | | x | x | | | | |
| 9. Submission of Final Report | | | | | | | | x | | | | |

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## 6. APPENDICES

A. Pictures at the sampling sites:

### A.1. NAMRIA

# A.2. MMDA








# A.1. VALENZUELA


B. Summary of statistical values of multi-element data from MMDA, NAMRIA and Valenzuela sampling sites.

| | MMDA (EDSA) | | | | NAMRIA | | | | Valenzuela | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ave | min | max | SD | ave | min | max | SD | ave | min | max | SD |
| F | 149.471 | 0.000 | 363.776 | 63.723 | 158.247 | 9.387 | 453.521 | 68.407 | 117.194 | 0.000 | 272.141 | 62.035 |
| Na | 227.094 | 10.394 | 486.900 | 89.687 | 181.609 | 0.000 | 412.830 | 79.983 | 153.524 | 0.000 | 468.361 | 94.391 |
| Al | 40.751 | 0.000 | 103.536 | 19.415 | 63.181 | 7.712 | 228.729 | 46.263 | 28.997 | 0.000 | 307.451 | 36.875 |
| Si | 134.572 | 15.266 | 332.295 | 66.327 | 202.443 | 16.709 | 709.059 | 147.905 | 135.805 | 0.000 | 1176.768 | 143.600 |
| P | 6.218 | 0.000 | 16.890 | 3.318 | 6.150 | 0.000 | 15.916 | 3.224 | 7.308 | 1.328 | 40.618 | 6.206 |
| S | 485.532 | 76.350 | 2021.054 | 313.971 | 403.054 | 64.802 | 1403.386 | 271.799 | 822.252 | 80.334 | 1794.627 | 458.266 |
| Cl | 67.097 | 0.000 | 373.570 | 62.270 | 88.812 | 0.000 | 384.325 | 83.569 | 49.314 | 0.000 | 302.584 | 67.446 |
| K | 98.763 | 12.996 | 260.240 | 48.303 | 78.054 | 5.624 | 244.524 | 44.690 | 190.195 | 12.126 | 506.372 | 104.607 |
| Ca | 151.483 | 13.991 | 363.664 | 80.049 | 238.116 | 2.812 | 978.682 | 222.138 | 102.357 | 3.031 | 991.529 | 118.939 |
| Ti | 4.750 | 0.000 | 19.613 | 3.152 | 4.789 | 0.000 | 16.635 | 3.709 | 4.069 | 0.000 | 33.820 | 4.381 |
| V | 2.265 | 0.000 | 11.193 | 2.157 | 1.713 | 0.000 | 6.772 | 1.543 | 4.355 | 0.000 | 12.126 | 2.682 |
| Cr | 3.256 | 0.000 | 7.579 | 1.724 | 2.809 | 0.000 | 12.677 | 1.749 | 3.256 | 0.000 | 7.579 | 1.669 |
| Mn | 6.919 | 0.000 | 51.768 | 6.635 | 6.223 | 0.000 | 26.375 | 4.537 | 7.275 | 0.000 | 27.671 | 5.229 |
| Fe | 147.839 | 1.399 | 552.659 | 86.335 | 141.166 | 9.304 | 426.960 | 89.216 | 144.140 | 0.000 | 745.568 | 100.517 |
| Co | 0.694 | 0.000 | 3.031 | 0.830 | 0.856 | 0.000 | 2.873 | 0.909 | 0.589 | 0.000 | 3.976 | 0.842 |
| Ni | 2.629 | 0.000 | 11.693 | 1.797 | 1.891 | 0.000 | 8.792 | 1.444 | 2.952 | 0.000 | 8.307 | 1.656 |
| Cu | 4.680 | 0.909 | 20.841 | 2.963 | 4.227 | 0.000 | 11.122 | 2.158 | 7.530 | 0.000 | 26.584 | 5.384 |
| Zn | 52.384 | 1.326 | 677.183 | 97.608 | 36.293 | 0.000 | 268.150 | 43.062 | 92.721 | 3.031 | 496.694 | 91.834 |
| Se | 0.759 | 0.000 | 8.395 | 1.659 | 0.709 | 0.000 | 7.327 | 1.271 | 0.775 | 0.000 | 4.961 | 1.204 |
| Br | 2.809 | 0.000 | 7.579 | 1.520 | 2.945 | 0.000 | 6.439 | 1.561 | 4.382 | 0.000 | 11.193 | 2.397 |
| Sr | 0.663 | 0.000 | 4.547 | 1.094 | 0.630 | 0.000 | 4.668 | 1.060 | 0.767 | 0.000 | 6.149 | 1.204 |
| Pb | 10.325 | 0.000 | 53.167 | 10.289 | 8.605 | 0.000 | 59.007 | 10.473 | 38.544 | 0.000 | 202.875 | 36.988 |

C. Report on the Public Forum held at the Great Eastern Hotel on 12 December 2017.

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**Report on Assessment of Respirable Air Particulate Pollution Sources in Metro Manila & Role of NCR Airshed Governing Board**


The Partnership for Clean Air, Inc. (PCA) in partnership with EU Switch Philippines together with Philippine Nuclear Research Institute (PNRI) of Department of Science and Technology (DOST) and the National Capital Region - Airshed Governing Board (NCR-AGB) with support from the NCR-Environmental Management Bureau (EMB) conducted a one day Public Forum dated December 12, 2016 to disseminate the information, awareness of the results and findings of the monitoring activities of the three (3) sampling stations in Metro Manila for the past six months period.

The program of the said Forum started around 9:00 am with Mr. Renato Pineda, Jr., PCA President welcomed warmly the participants stated that the event is very important to give them better understanding of the importance of air in the environment for them to contribute to the changes and improvement in the air quality. This was followed by the message of Dr. Channa Gunawerdena, Team Leader of EU Switch Philippines who pointed out that the project is funded by European Union which is a global advocate for sustainable development. He also discussed clearly the origin, role in the Philippines, objectives and components of the EU-Switch Project. After which, Dr. Carlos Primo David, Officer-In-Charge of PNRI-DOST exclaimed eagerly that whatever learnings got from this event will be a part of the improvement of air quality likewise he looks forward to the report of the researchers regarding this study.

In behalf of the EMB NCR Director Vizminda Osorio, Engr. Diosdado Doctor, Chief of Environmental Monitoring and Enforcement Division (EMED), EMB-NCR provided information that EMB is continuously monitoring the Total Suspended Particulates (TSP) in NCR and presented the initiatives of EMB-NCR in implementing the Clean Air Act and other environmental laws. Later on, the Vice Chairman of Airshed Governing Board, Mr. Renato Pineda, Jr. presented the definition of the Airshed. He discussed the NCR Airshed Governing Board including its composition, coverage and objectives. Likewise, he presented the NCR Airshed Action Plan.

Preciosa Corazon Pabroa, Ph.D., Supervising Research Specialist from PNRI-DOST presented and discussed the importance of air, effects of air pollution in the human body, the objectives of the project, Particulate Matter (PM) 10 and 2.5 results from June to November 2016 of the stations located at Radyo ng Bayan, Valenzuela City, Namria in Taguig City and MMDA in Makati City. Moreover, she explained the aspect of Receptor Modeling and the findings of the elements that were analyzed. She encouraged everyone to be concern of the air we breathe and her tag line " Malinis na hangin ay dahil sa akin".

When asked about the sampling time and average of the particulates, Dr. Pabroa answered that the particulate matter's sampling time average is 24 hour. She also clarified that the sampling for air monitoring is coordinated with the air monitoring section of EMB-NCR.

Ms. Everlyn Tamayo, lecturer from University of the Philippines provided information of the study she made regarding Atmospheric Particulate Matter but without Source Apportionment Study.

The Forum ended around 3:00 pm with Mr. Mike Alunan as Master of Ceremony. Attached are the program and pictures undertaken during the said Forum.

| | |
|---|---|
| Prepared by: | Noted by: |
| JULIETA G. MANLAPAZ | RENATO D. PINEDA, Jr. |
| Executive Director, PCA | President, PCA |

***Forum on Respirable Air Particulate Pollution Sources in Metro Manila and Role of NCR Airshed Governing Board***

PROGRAMME

December 12, 2016

| | | |
|---|---|---|
| AM | | |
| 8:30 – 9:30 | Registration | |
| 9:30 – 9:40 | Preliminaries | |
| 9:40 – 9:50 | Welcome Address | Mr. Renato D. Pineda, Jr.<br>President, PCA |
| 9:50 – 10:00 | Opening Remarks | Dr. Carlos Primo David<br>Officer-in-Charge, PNRI-DOST |
| 10:00 – 10:15 | - Snacks – | |
| 10:15 – 10:25 | M E S S A G E | Dr. Channa Gunawardena<br>Team Leader, EU Switch Philippines |
| 10:25 – 10:35 | M E S S A G E | Engr. Vizminda Osorio<br>Regional Director, EMB NCR |
| 10:35 – 11:00 | Presentation of NCR Airshed Governing Board Activities | Mr. Renato D. Pineda, Jr.<br>Chairman, Finance Committee<br>NCR Airshed Governing Board |
| 11:00 – 12:00 | Assessment of Respirable Air Particulate Pollution Sources in Metro Manila And Receptor Modelling (Source Apportionment) | Dr. Preciosa Corazon Pabroa<br>Supervising Research Specialist<br>Philippine Nuclear Research Institute<br>Department of Science and Technology |
| PM | | |
| 12:00 – 12:30 | Q & A | |
| 12:30 – 3:00 | - Lunch & Networking – | |
| 3:00 – 3:15 | - Snacks – | |
| 3:15 – 3:30 | Closing Remarks | |

**Assessment of Respirable Air Particulate Pollution Sources in Metro Manila and Role of NCR Airshed Governing Board**

Great Eastern Hotel, Quezon Avenue, Quezon City
December 12, 2016


**Photo Documented by Evita Fampulme and Catherine Cayabyab**

## 7. ACKNOWLEDGEMENTS

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