SOURCE APPORTIONMENT OF AMBIENT AIR TSP SAMPLES FROM INTERCITY STATION WAKAS, BOCAUE, BULACAN, REGION 3

Final Report Submitted To:

Department of Environment and Natural Resources
Environmental management Bureau - REGION 3

Through:
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PREFACE

In compliance with the upgrading the categorization of designated airshed, the Region 3 airshed is categorized as Level 2, pending the results of source apportionment studies. Hence, this report contains the results of the source apportionment studies for Intercity Wakas Station in Bocaue, Bulacan. The method employed is the same as that of in the first source apportionment studies conducted for the 2019 filter samples, and reported in 2020. This 2024 report, however, contains a comparison between the 2019 and the 2023 sources and contributions that may serve as evidence on the effectiveness or not of the interventions to mitigate air pollution in the past three years. The appendices contain the TSP filter sampling information, map of the sampling site, processed numerical data and the results of the laboratory analyses.

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EXECUTIVE SUMMARY

This source apportionment study provides crucial insights into the evolving pollution landscape of the Intercity Station Wakas, Bocaue, Bulacan airshed, informing ongoing efforts by regulatory agencies to improve air quality. The analysis reveals a significant decrease in vehicle emissions, likely reflecting the positive impact of control measures implemented since 2019. While this progress is commendable, the study also highlights a substantial increase in biomass burning as the dominant source of total suspended particulate matter in 2023, contributing 54.5%, up from 33% in 2019. Road dust remains a consistent contributor. These findings underscore the need for continued targeted interventions focusing on mitigating biomass burning and controlling road dust, crucial for achieving cleaner air and safeguarding public health in the specific station in Region 3. Public awareness and participation are essential to complement regulatory efforts and achieve cleaner air for all.

INTRODUCTION

Source apportionment studies are crucial in understanding the contributions of various sources to the overall air quality of a specific region. Source apportionment studies are also a requirement in order for an airshed to enter the higher category of airsheds, as a form of evaluating air quality improvements in a City. As a follow-up to the 2020 report on Source apportionment studies of Total Suspended Particulate (TSP) Matter Filters for Intercity Station, Wakas, Bocaue Bulacan (Site Location in Appendix 1), this source apportionment studies for the same site but three years later covers the month of January 2023 to December 2023.

Source Apportionment studies

Receptor models are valuable tools for understanding air pollution, specifically particulate matter. Unlike source-oriented models that track pollutants from their origin, receptor models focus on the ambient environment at the point of impact. A receptor model such as Positive Matrix Factorization (PMF) requires an analysis of the chemical composition of the collected samples, followed by identifying key tracer elements to pinpoint pollution sources and estimate the contributions of the identified sources to the total particulate matter concentration. This approach, based on the principle of aerosol mass balance, provides insights into how pollutants are distributed in the receiving monitoring site, as well as insights on physical or chemical changes during the transport.

Some studies also employ a variety of techniques to apportion the sources of air pollutants, particularly black carbon, in urban and rural areas (Mousavi et al., 2018). Innovations in statistical design also adds novelty to source apportionment studies by using gradient tree boosting regression, as described in a recent study (Du et al., 2019). This data-driven method leverages historical air pollution data and expert knowledge to estimate the contributions of different pollution sources automatically. Another emerging technique for source apportionment involves an integrated approach that combines atmospheric observations with bottom-up socioeconomic data. This method has been used to map emissions at fine scales, which can help link them to specific attribution information to facilitate mitigation actions (Mueller et al., 2021). The integrated approach offers a more comprehensive assessment of source-receptor relationships, as it ties the atmospheric observations to international standards and incorporates multiple overlapping socioeconomic data sources. (Mueller et al., 2021)

Essentially, receptor models offer a practical way to quantify pollution, identify sources, understand transport patterns and analyse transformations. The use of factor analysis methods in receptor modeling has allowed researchers to identify the major source types contributing to particulate matter in the R3 region (Hopke et al., 2005). Both the novelty in statistical methods (gradient tree boosting regression) and the factor-source-contribution output are exemplified by the recent version of US EPA PMF (Version 5). The output and outcomes of the source apportionment studies may eventually assist in providing evidence of air pollution from sources, and aiding in air quality management and mitigation strategies.

Problem Statement and Objectives of the Study

Three years after the initial source apportionment study in 2020 using the TSP filters from 2018-2019, it is important to know whether the air quality in Intercity Station, Wakas, Bocaue Bulacan has improved. This is to have a better understanding of the air pollution sources, and to evaluate if the mitigation strategies implemented in the past three years have been effective or otherwise.

The general objective of this study is to determine the factor sources and their contribution to ambient TSP in 2023 in Intercity Station in Wakas, Bocaue, Bulacan. Specifically:

- Using the eleven (11) trace elements composition, what is the fraction of mobile and fraction of area source emissions in Intercity Station, Waka, Bocaue Bulacan for 2023?
- How much are these emission sources contributing to the Total suspended particulate matter for the year 2023?
- Compared to 2019 source apportionment study, has the contribution of these sources improved after three years?

METHOD

Digestion of Filter Samples

Fifty (50) TSP samples, received and labelled, were stored until analysis during the dates of January 1, 2023 to December 21, 2023. A 17.35 cm2 (47mm diameter circle) portion of the filter was cut, weighed, placed in digestion tubes, and preserved until analysis. To extract the trace elements from the TSP samples, microwave digestion was performed using ETHOS UP Microwave digested at a pre-set temperature program, which employed dilute nitric acid, unlike the usual protocol of using concentrated nitric acid digestion using a hot-plate digester. This method minimizes contamination risk and accelerates digestion. Despite using dilute acid, complete digestion was achieved, resulting in a clear solution. Digestates were filtered using 0.22 um pore-size nylon filter, and diluted to mark in 50mL volumetric flask, so that the final percentage of acid is not more than 2%. Trace elements quantification was conducted by CRL Labs using ICP-OES for the following elements: Ca, Na, K, Mg, Al, Cr, Cu, Mn, Ni, Pb and Zn.

PMF Analysis

The PMF modelling was conducted using US EPA PMF v5.0 GUI, utilising the TSP data set generated from the results of the trace elements analysis. In PMF analysis, the selection of chemical species is imperative, while accepting and rejecting variables (species and samples) are crucial. When optimizing the number of factors, it is necessary to look closely at the PMF run that apportions the TSP on all factors. A run is disqualified when it results in at least one factor having TSP equals zero. Results of PMF analysis are presented in Appendix 3.

RESULTS

PHASE 1: PMF ANALYSIS RESULTS

The Positive Matrix Factorization analysis used 12 input species including TSP mass concentration, with a modeled uncertainty of 10-20%, resulting in a moderate signal to noise ratio of 9 across all species. The PMF output, utilizing **six-factor profiles**, successfully resolved the average TSP mass concentration on the filter portion, ranging from 29µg/m3 to 621µg/m3, and a median of 185µg/m3. A comprehensive report detailing input and satisfactory (accepted) output data, including descriptive statistics, correlation coefficients, standard error, selected FPEAK runs and base model runs is provided in Appendix 3.

PHASE 2: PROFILES AND CONTRIBUTIONS

The six-factor profiles were then subjected to Phase 2 analysis (Diagnostics of Profiles and contributions), using the emission factors from a look-up table of emissions generated in-house (Cayetano 2020c EPSL-IESM-UPD), and are guaranteed emissions sourced from the Philippines. The ratio of the indicator elements were compared to the emission factors of the EPSL-IESM-UPD, with indications of 25%, 50% and 100% chances that the ratio of the TSP samples matches that of the EF. The resolved TSP factors were then assigned and presented in Table 1:

Table 1. US EPA PMF Version 5 resolved six-factor sources for EMB-Region 3 TSP sampled between January 2023 to December 2023 in Intercity Station, Wakas, Bocaue, Bulacan

Description of Emission	Biomass Burning Emissions	Road Dust Resuspension	Vehicle emissions	
Apportioned Factors			Diesel-fed Vehicles	Gasoline-fed Vehicles
Factor 1	59%	6%	3%	3%
Factor 2	53%	5%	12%	17%
Factor 3	50%	6%	17%	17%
Factor 4	64%	9%	11%	11%
Factor 5	45%	18%	9%	9%
Factor 6	18%	41%	2%	2%

All Factors have percentages of resolved biomass burning, road dust and vehicle emission sources. For Factors 1-4, it is apparent that biomass burning sources are resolved together with vehicle emissions, and with percentages of road dust that is not more than 10%. TSP samples are naturally expected to

carry road dust emissions, hence the percentage in Factors 1-4. On the other hand, Factors 5-6 are moderately influenced by road dust sources at 18% and 41%, respectively.

If classified according to DENR emission classification, Biomass burning and Road dust comprises the ‘area sources’, while vehicle emissions belong to ‘mobile sources'. Hence, this resolved factor has generated 15.1% from mobile sources (Diesel and gasoline-fed vehicles) and 84.9% from area sources, in this case, biomass burning and road dust (Figure 1).

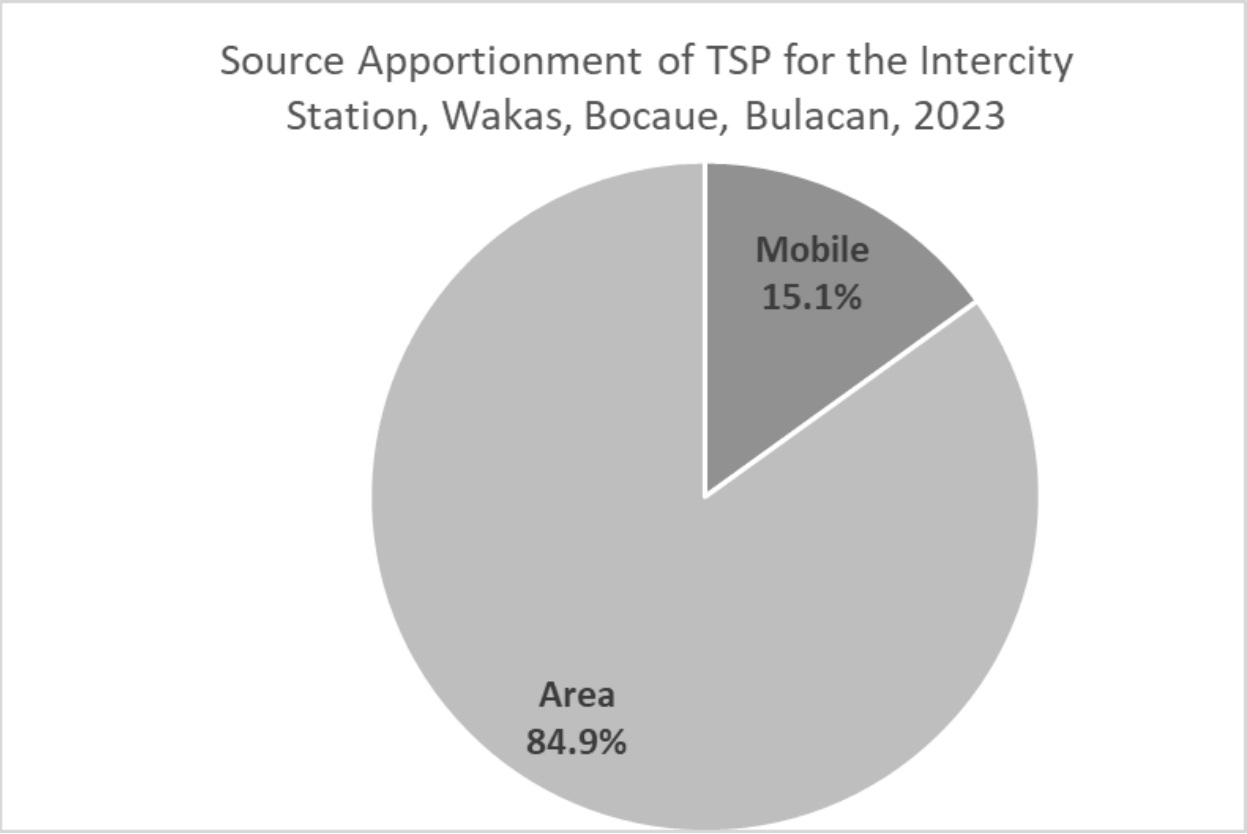

Figure 1. Apportioned sources of TSP from Intercity station in 2023

Phase 2 analysis also employs grouping the resolved factors into common factors, and were further resolved to a total of three (3) major source factors for TSP, presented in Table 2, and visualized in Figure 2. The percentages are also provided, with Biomass emission sources (at 54.5%) comprising the largest among all resolved factors, and vehicle emissions the lowest.

Table 2. Grouped Factor sources for EMB-Region 3 TSP sampled From January 2023 to December 2023 in Intercity Station, Wakas, Bocaue, Bulacan

Description of grouped factor sources	Percentage in the resolved TSP
Biomass emission	54.5%
Road dust	30.4%
Vehicle emissions	15.1%

Even though resolved across all factors, the source apportionment analysis is able to quantify the percentage of emissions coming from diesel-fed vehicles (in this case, 8%) and from gasoline-fed vehicles (in this case, 9%), as seen in Figure 3.

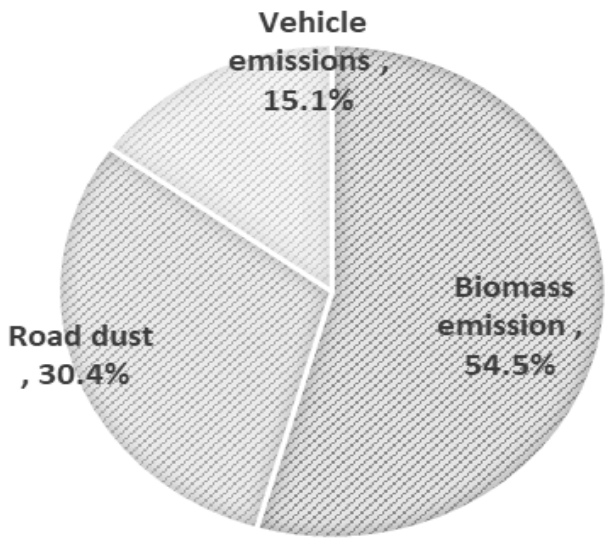

Figure 2. Grouped factor sources for EMB-Region 3 TSP sampled from January 2023 to December 2023 in Intercity Station, Wakas, Bocaue, Bulacan

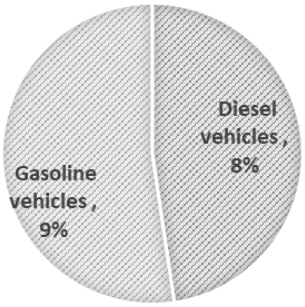

Figure 3. Grouped factor sources representing mobile sources for EMB-Region 3 TSP sampled from January 2023 to December 2023 in Intercity Station, Wakas, Bocaue, Bulacan

Overall, the 2024 source apportionment study using the 50 TSP filter samples from 2023 at the Intercity Station, Wakas, Bocaue, Bulacan was able to identify "vehicle emissions" as mobile sources, further categorized into diesel and gasoline-fed vehicles. Area sources are represented by "biomass emissions" and "road dust." In 2023, vehicle emissions (diesel + gasoline) contributed 15.1% (8% + 7%), while area sources (biomass + road dust) contributed 85% (54.5% + 30.5%). The combined contribution of the specified mobile and area sources to TSP in 2023 is approximately 100%.

2019 AND 2023 SOURCE APPORTIONMENT RESULTS

In Table 2, a comparison of the descriptive statistics shows the apparent decrease in the average concentration of Total Suspended Particulate Matter in Intercity Station Wakas, Bocaue Bulacan, in consideration of the years 2019-2023. A remarkable decrease in TSP levels is observed over the three-year period. The median TSP concentration dropped by 45%, from 337 μg/m³ to 185 μg/m³. The average TSP also decreased by 38%, from 326 μg/m³ to 201 μg/m³. This indicates an overall improvement in air quality regarding particulate matter pollution at the monitoring station.

Table 3: Descriptive statistics of the TSP concentration in Intercity Station Wakas, Bocaue Bulacan

Description of parameter	2019 (Reported in 2020) N = 51	2023 (reported in 2024) N = 50	% decrease
Minimum, μg/m3	15	29	
25th percentile, μg/m3	174	143	
Median, μg/m3	337	185	45%
75th percentile, μg/m3	456	239	
Maximum, μg/m3	784	621	
Average, μg/m3	326	201	38%
Standard deviation	182	104	

Table 4 presents a comparative analysis of source apportionment contributions to Total Suspended Particulates between 2019 and 2023 at the Intercity Wakas Station in Bocaue, Bulacan. A notable shift occurred with biomass emissions increasing significantly from 33% to 54.5%, potentially indicating increased agricultural activities or waste burning in the area. Road dust, another major contributor, saw a slight decrease from 26% to 30.4%. Conversely, vehicle emissions, encompassing both diesel and gasoline sources, decreased considerably from 41% to 15.1%, suggesting improved vehicle emission controls or a shift in transportation patterns. These changes highlight the evolving nature of air pollution sources over time.

Table 4. Comparison of contribution of apportioned sources from 2019-2023, Intercity Wakas Station Bocaue, Bulacan.

Description of grouped factor sources	Percentage in the resolved TSP (2019)	Percentage in the resolved TSP (2023)
Biomass emission	33%	54.5%

Road dust	26%	30.4%
Vehicle emissions Diesel-fed vehicles Gasoline-fed vehicles	41% 28% 13%	15.1% 8% 9%

Whether this change represents an improvement depends on the specific pollutants associated with each source and their respective health and environmental impacts. While overall vehicle emissions decreased, the substantial increase in biomass burning could be a cause for concern.

CONCLUSION

This study aimed to identify and quantify the sources contributing to total suspended particulate matter in the Intercity Station Wakas, Bocaue, Bulacan air, and to assess changes in source contributions compared to a 2019 baseline study. Using Positive Matrix Factorization applied to eleven trace elements, four major sources were identified: biomass burning, road dust, gasoline vehicle emissions, and diesel vehicle emissions. Results reveal a significant shift in source contributions over the three-year period. Biomass burning emerged as the dominant source in 2023, contributing 54.5% of TSP, a substantial increase from 33% in 2019. Road dust remained a significant contributor at 30.4%, slightly decreased from 26% in 2019. Vehicle emissions, both gasoline and diesel combined, decreased markedly from 41% in 2019 to 15.1% in 2023. While the decrease in vehicle emissions suggests improvements in transportation-related air quality, the substantial increase in biomass burning necessitates further investigation and targeted mitigation strategies. These findings provide crucial information for developing effective air quality management plans in the region.

RECOMMENDATION

The studies have employed receptor modeling techniques, such as positive matrix factorization, to apportion the contribution of different sources to the observed air pollution levels from a two separate years of study, covering the year 2019 and 2023. While the studies have provided valuable insights into the sources of air pollution in the R3 region, there is still a need for further research to refine the methodologies and address any remaining uncertainties. It is important to note that these apportioned sources and their contributions are site specific and period specific. The results of this source apportionment study is applicable only for TSP sampled in 2023 at Intercity Station, Wakas, Bocaue, Bulacan.

If sources and contribution for the rest of the air quality monitoring stations are needed, source apportionment studies need to be conducted separately. This is because sources may vary with sites and period of interest. Nevertheless, these results may provide guidance on further control measures that may be implemented in order to better manage the air quality of Region 3.

ACKNOWLEDGEMENT

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APPENDICES

APPENDIX 1: Site Location and TSP Filters

Appendix Figure 1: Pinned location is the Intercity Wakas Station in Bocaue, Bulacan.

EPSL Code	Sample ID	Date Sampled	Sample Type	Sampling Location
EPSL-Echem-2400001	9267715	1-Jan-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400002	9267716	1-Jan-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400003	9267707	7-Jan-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400004	9267708	7-Jan-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400005	9267722	13-Jan-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400006	9267721	13-Jan-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400007	9267724	19-Jan-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400008	9267723	19-Jan-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400009	9267713	25-Jan-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400010	9267714	25-Jan-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400011	9390400	31-Jan-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400012	9390399	31-Jan-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400013	9390322	6-Feb-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400014	9390323	6-Feb-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400015	9390326	12-Feb-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400016	9390327	12-Feb-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400017	9390332	18-Feb-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400018	9390333	18-Feb-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400019	9390308	24-Feb-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400020	9390309	24-Feb-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan

EPSL-Echem-2400021	9390307	2-Mar-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
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EPSL-Echem-2400028	9390368	26-Mar-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
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EPSL-Echem-2400042	9390023	13-May-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan

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EPSL-Echem-2400060	9379655	6-Jul-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400061	9379658	12-Jul-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400062	9379659	12-Jul-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400063	9379662	18-Jul-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400064	9379663	18-Jul-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan

EPSL-Echem-2400065	9379641	24-Jul-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400066	9379640	24-Jul-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400067	9380439	5-Aug-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400068	9380438	5-Aug-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400069	9380433	11-Aug-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400070	9380432	11-Aug-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400071	9380465	23-Aug-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400072	9380464	23-Aug-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400073	9380463	29-Aug-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400074	9380462	29-Aug-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400075	9380431	4-Sep-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400076	9380430	4-Sep-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400077	9380483	10-Sep-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400078	9380482	10-Sep-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400079	9380493	16-Sep-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400080	9380492	16-Sep-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400081	9380497	22-Sep-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400082	9380496	22-Sep-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400083	9379612	28-Sep-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400084	9379613	28-Sep-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400085	9379609	4-Oct-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400086	9379608	4-Oct-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan

EPSL-Echem-2400087	2023T-039	10-Oct-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400088	2023T-040	10-Oct-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400089	2023T-045	16-Oct-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400090	2023T-046	16-Oct-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400091	2023T-033	22-Oct-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400092	2023T-034	22-Oct-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400093	2023T-017	28-Oct-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400094	2023T-018	28-Oct-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400095	2023T-049	3-Nov-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400096	2023T-050	3-Nov-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400097	2023T-015	9-Nov-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400098	2023T-016	9-Nov-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400099	2023T-002	15-Nov-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400100	2023T-003	15-Nov-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400101	9379674	21-Nov-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400102	9379675	21-Nov-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400103	9800398	27-Nov-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400104	9800397	27-Nov-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400105	9800393	3-Dec-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400106	9800394	3-Dec-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400107	9800374	9-Dec-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400108	9800373	9-Dec-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan

EPSL-Echem-2400109	9800380	15-Dec-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400110	9800379	15-Dec-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400111	9800356	21-Dec-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400112	9800355	21-Dec-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400113	9800348	27-Dec-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400114	9800347	27-Dec-2023	Air Quality Filter	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan
EPSL-Echem-2400115	9380425			
EPSL-Echem-2400116	9839119			
EPSL-Echem-2400117	9839140			
EPSL-Echem-2400118	9839144			
EPSL-Echem-2400119	9839143			

APPENDIX 2: RESULTS OF ANALYSIS - ELEMENTAL COMPOSITION OF TSP

CODE	Date	PM	Cu, ug/m3	Ca, ug/m3	Pb, ug/m3	Mn, ug/m3	Ni, ug/m3	Zn, ug/m3	Mg, ug/m3	K, ug/m3	Na, ug/m3	Al, ug/m3	Cr, ug/m3
EPSL-Echem-2400001	1-Jan-2023	49.95	0.071376	0.502873	0.000173	0.001151	0.000268	0.000766	0.183791	0.250160	2.620724	0.094448	0.000447
EPSL-Echem-2400003	7-Jan-2023	237.51	0.010418	0.843715	0.000438	0.006386	0.000248	0.002504	0.302936	0.245353	3.621881	0.180260	0.000525
EPSL-Echem-2400005	13-Jan-2023	215.08	0.018390	1.075197	0.000462	0.004890	0.000020	0.004491	0.412115	0.295877	4.561440	0.208699	0.000345
EPSL-Echem-2400007	19-Jan-2023	205.54	0.015564	0.837717	0.000435	0.002861	0.000138	0.002486	0.352985	0.261010	4.118153	0.178978	0.000436
EPSL-Echem-2400009	25-Jan-2023	161.58	0.014062	0.852096	0.000519	0.002910	0.000051	0.000759	0.323645	0.265490	4.011846	0.146651	0.000330
EPSL-Echem-2400011	31-Jan-2023	177.71	0.015677	0.317975	0.000408	0.001129	0.000263	0.009514	0.127691	0.140210	2.219985	0.075112	0.000332
EPSL-Echem-2400013	6-Feb-2023	203.72	0.015553	0.283743	0.000034	0.002571	0.000235	0.005362	0.082665	0.109476	0.417050	0.082665	0.000295
EPSL-Echem-2400015	12-Feb-2023	155.32	0.017758	0.681113	0.000446	0.004722	0.000185	0.009694	0.165814	0.196426	1.011891	0.147957	0.000410
EPSL-Echem-2400017	18-Feb-2023	185.75	0.032936	0.299609	0.000492	0.002715	0.000292	0.007313	0.037746	0.082569	0.110092	0.054260	0.000413
EPSL-Echem-2400019	24-Feb-2023	188.97	0.010517	0.497890	0.000442	0.004678	0.000155	0.006066	0.128895	0.141532	0.825605	0.128895	0.000029
EPSL-Echem-2400021	2-Mar-2023	193.58	0.006988	0.285228	0.000402	0.001799	0.000011	0.004604	0.075237	0.094327	0.406132	0.067377	0.000393
EPSL-Echem-2400027	26-Mar-2023	230.42	0.017675	0.322465	0.001697	0.002922	0.000229	0.007871	0.076173	0.106642	0.296228	0.058399	0.000147
EPSL-Echem-2400029	1-Apr-2023	171.06	0.012199	0.432118	0.003002	0.002524	0.000053	0.008335	0.081159	0.076772	0.102363	0.081159	0.000415
EPSL-Echem-2400031	7-Apr-2023	153.83	0.015772	0.604934	0.000270	0.002608	0.000244	0.005438	0.163128	0.142737	0.898717	0.083830	0.000383
EPSL-Echem-2400033	13-Apr-2023	176.3	0.016398	0.793827	0.000412	0.002711	0.000247	0.010600	0.186090	0.148401	1.264155	0.087156	0.000304

CODE	Date	PM	Cu, ug/m3	Ca, ug/m3	Pb, ug/m3	Mn, ug/m3	Ni, ug/m3	Zn, ug/m3	Mg, ug/m3	K, ug/m3	Na, ug/m3	Al, ug/m3	Cr, ug/m3
EPSL-Echem-2400035	19-Apr-2023	272.45	0.012225	0.279170	0.000385	0.004069	0.000136	0.006814	0.050558	0.092324	0.102582	0.065946	0.000458
EPSL-Echem-2400037	25-Apr-2023	256.52	0.016436	0.795689	0.000588	0.004370	0.000138	0.012278	0.186527	0.165277	1.432398	0.103888	0.000522
EPSL-Echem-2400039	7-May-2023	267.85	0.030843	0.280567	0.000629	0.002543	0.000281	0.005302	0.097204	0.108250	0.721669	0.050811	0.000067
EPSL-Echem-2400041	13-May-2023	116.51	0.017231	0.141086	0.000218	0.001116	0.000249	0.011138	0.056930	0.086632	0.462038	0.022277	0.000230
EPSL-Echem-2400043	19-May-2023	63.16	0.009135	0.704641	0.000554	0.001190	0.000112	0.013723	0.226963	0.147790	1.785794	0.097647	0.000462
EPSL-Echem-2400045	25-May-2023	143.37	0.016790	0.306304	0.000559	0.002776	0.000364	0.011697	0.139887	0.903235	0.703454	0.030148	0.000300
EPSL-Echem-2400049	6-Jun-2023		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
EPSL-Echem-2400051	12-Jun-2023	106.47	0.016852	0.137990	0.000710	0.001092	0.000196	0.010894	0.055680	0.152515	0.621357	0.021788	0.000184
EPSL-Echem-2400053	18-Jun-2023	163.74	0.032581	0.459737	0.000515	0.004319	0.000078	0.028471	0.151690	0.147023	1.089056	0.102682	0.000401
EPSL-Echem-2400055	24-Jun-2023	166.61	0.010291	0.487165	0.003384	0.006308	0.000283	0.009397	0.143429	0.173104	0.807820	0.143429	0.000261
EPSL-Echem-2400057	30-Jun-2023	148.25	0.016235	0.296184	0.000588	0.002684	0.001134	0.010495	0.118940	0.097951	0.761839	0.053640	0.000019
EPSL-Echem-2400059	6-Jul-2023	127.69	0.015942	0.290848	0.001210	0.002636	0.000059	0.011909	0.100766	0.080155	0.587803	0.052673	0.000041
EPSL-Echem-2400061	12-Jul-2023	165.88	0.016137	0.456673	0.000208	0.002668	0.000102	0.005564	0.150679	0.113589	0.919527	0.085771	0.000489
EPSL-Echem-2400063	18-Jul-2023	28.91	0.035896	0.506504	0.000450	0.000619	0.000057	0.004371	0.185118	0.107986	1.199840	0.077133	0.000224
EPSL-Echem-2400065	24-Jul-2023	64.33	0.047201	0.078813	0.000394	0.001015	0.000198	0.005404	0.020266	0.031525	0.078813	0.000394	0.000394
EPSL-Echem-2400067	5-Aug-2023	114.9	0.052325	0.317027	0.000269	0.001126	0.000136	0.012981	0.162258	0.104843	0.990188	0.074888	0.000148
EPSL-Echem-2400069	11-Aug-2023	98.6	0.047765	0.209643	0.000881	0.001027	0.000128	0.010254	0.108239	0.071780	0.983649	0.044435	0.000326

CODE	Date	PM	Cu, ug/m3	Ca, ug/m3	Pb, ug/m3	Mn, ug/m3	Ni, ug/m3	Zn, ug/m3	Mg, ug/m3	K, ug/m3	Na, ug/m3	Al, ug/m3	Cr, ug/m3
EPSL-Echem-2400073	29-Aug-2023	90.57	0.084412	0.084505	0.000423	0.000244	0.000192	0.004105	0.008451	0.016901	0.619705	0.000423	0.000155
EPSL-Echem-2400075	4-Sep-2023	621.25	0.069755	0.840710	0.012145	0.016841	0.000672	0.047898	0.266932	0.209554	0.814931	0.266932	0.000469
EPSL-Echem-2400077	10-Sep-2023	259.54	0.066535	0.635333	0.001591	0.006070	0.000259	0.012374	0.154669	0.083283	0.777311	0.171326	0.000401
EPSL-Echem-2400079	16-Sep-2023	188.19	0.015324	0.433671	0.000599	0.002534	0.000215	0.009906	0.066041	0.061639	0.256827	0.081451	0.000308
EPSL-Echem-2400081	22-Sep-2023	306.35	0.032418	0.457430	0.000302	0.005923	0.000625	0.012074	0.118421	0.097523	0.433436	0.102167	0.000391
EPSL-Echem-2400083	28-Sep-2023	184.89	0.032348	0.294258	0.000443	0.002667	0.000079	0.028267	0.037072	0.048657	0.108126	0.037072	0.000136
EPSL-Echem-2400085	4-Oct-2023	221.56	0.051819	0.660064	0.000448	0.002845	0.000191	0.012855	0.160690	0.138440	0.980619	0.108775	0.000048
EPSL-Echem-2400087	10-Oct-2023	328.69	0.033841	0.084837	0.000531	0.006183	0.000032	1.624509	0.008484	1.085915	0.084837	0.802317	0.000424
EPSL-Echem-2400089	16-Oct-2023	436.43	0.056700	0.094674	0.007489	0.012581	0.000240	1.888620	0.009467	1.287572	0.094674	1.027894	0.000473
EPSL-Echem-2400091	22-Oct-2023	219.2	0.050753	0.084745	0.000188	0.004482	0.000162	1.656640	0.008474	1.101682	0.084745	0.801444	0.000424
EPSL-Echem-2400093	28-Oct-2023	140.4	0.050844	0.084896	0.000296	0.001094	0.000026	1.642624	0.008490	1.052716	0.084896	0.785898	0.000424
EPSL-Echem-2400097	9-Nov-2023	380.47	0.010430	0.075094	0.000305	0.002469	0.000199	1.407909	0.007509	0.931168	0.075094	0.635082	0.000375
EPSL-Echem-2400099	15-Nov-2023	244.64	0.015616	0.078512	0.000393	0.002582	0.000065	1.393479	0.007851	0.895039	0.078512	0.663989	0.000393
EPSL-Echem-2400101	21-Nov-2023	280.04	0.006109	0.435830	0.000139	0.002546	0.000233	0.008407	0.097343	0.108404	0.567833	0.097343	0.000387
EPSL-Echem-2400103	27-Nov-2023	236.43	0.017118	0.484419	0.000609	0.002830	0.000137	0.030000	0.142621	0.137703	0.803267	0.073769	0.000388
EPSL-Echem-2400105	3-Dec-2023	167.2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
EPSL-Echem-2400107	9-Dec-2023	403.43	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

CODE	Date	PM	Cu, ug/m3	Ca, ug/m3	Pb, ug/m3	Mn, ug/m3	Ni, ug/m3	Zn, ug/m3	Mg, ug/m3	K, ug/m3	Na, ug/m3	Al, ug/m3	Cr, ug/m3
EPSL-Echem-2400109	15-Dec-2023	222.12	0.016746	0.810678	0.000421	0.002769	0.000220	0.009141	0.206879	0.168390	1.290991	0.139523	0.000185
EPSL-Echem-2400111	21-Dec-2023	114.84	0.023799	0.527779	0.000210	0.001822	0.000175	0.010237	0.163794	0.119433	0.982003	0.108058	0.000237

APPENDIX 3: SOURCE APPORTIONMENT OF AIR PARTICULATE MATTER (EPSL-SAAPM)

ENVIRONMENTAL POLLUTION STUDIES LABORATORY

SOURCE APPORTIONMENT OF AIR PARTICULATE MATTER (EPSL-SAAPM)

US EPA PMF v5	**TEST #:EPSL-SAAPM-2024-001**	Date of Model Run	Nov 11, 2024 to Nov 28, 2024
NAME	EMB-R3		
Location	Intercity Industrial Subdivision, Brgy. Wakas, Bocaue, Bulacan		
Period Covered	01/01/2023 to 21/12/2023		
Sample type	TSP sampled in Filter paper		
Number of Filters used for PMF	50		

Phase 1: PMF Model Run results — **Descriptive statistics**

**** Input Data Statistics ****

Species	**Category**	**S/N**	ug/m3 **Min**	ug/m3 **25th**	ug/m3 **Median**	ug/m3 **75th**	ug/m3 **Max**
PM, ug/m3	Strong	9	29	143	185	239	621
Cu, ug/m3	Strong	9	0.00611	0.016	0.0172	0.0352	0.084
Ca, ug/m3	Strong	9	0.07509	0.280	0.4348	0.6653	1.075
Pb, ug/m3	Strong	9	0.00003	0.000	0.0004	0.0006	0.012
Mn, ug/m3	Strong	9	0.00024	0.002	0.0027	0.0044	0.017
Ni, ug/m3	Strong	9	0.00001	0.0001	0.0002	0.0002	0.001
Zn, ug/m3	Strong	9	0.00076	0.006	0.0102	0.0131	1.889
Mg, ug/m3	Strong	9	0.00751	0.057	0.1283	0.1841	0.412
K, ug/m3	Strong	9	0.01690	0.097	0.1393	0.2189	1.288
Na, ug/m3	Strong	9	0.07509	0.286	0.7903	1.2001	4.561
Al, ug/m3	Strong	9	0.00039	0.064	0.0908	0.1538	1.028
Cr, ug/m3	Strong	9	0.00002	0.0002	0.0004	0.0004	0.001

**** Base Run Summary ****

Species	Intercept	Slope	SE	r^2	Stat	P Value	**Remarks**
PM, ug/m3	4.36	0.92	42.45	0.84	0.07	0.98	ACCEPTED
Cu, ug/m3	0.00	0.97	0.00	0.98	0.17	0.12	ACCEPTED
Ca, ug/m3	0.02	0.90	0.09	0.88	0.12	0.46	ACCEPTED
Pb, ug/m3	0.00	1.06	0.00	0.99	0.22	0.01	ACCEPTED
Mn, ug/m3	0.00	0.73	0.00	0.88	0.10	0.66	ACCEPTED
Ni, ug/m3	0.00	0.30	0.00	0.23	0.17	0.11	ACCEPTED
Zn, ug/m3	0.00	1.02	0.06	0.99	0.25	0.004	ACCEPTED
Mg, ug/m3	-0.01	1.04	0.02	0.96	0.08	0.89	ACCEPTED
K, ug/m3	0.01	0.89	0.12	0.86	0.11	0.62	ACCEPTED
Na, ug/m3	0.13	0.78	0.21	0.94	0.17	0.09	ACCEPTED
Al, ug/m3	0.00	0.96	0.03	0.98	0.06	1.00	ACCEPTED
Cr, ug/m3	0.00	0.63	0.00	0.38	0.15	0.21	ACCEPTED

		% of Resolved PM factor sources	
Base model run number:	9	Factor 1	13%
Number of Fpeak runs:	5	Factor 2	28%
Number of factors:	6	Factor 3	9%
Extra modeling uncertainty (	0	Factor 4	9%
Fpeak #	-10	Factor 5	2%
Converged	Yes	Factor 6	40%

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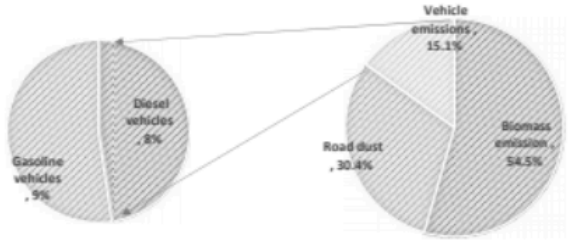
Phase 2: Profiles and Contributions		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Indicator for	Ratio	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
vehicles only	Cu/Cr	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
vehicles only	Cu/Mg	Not applicable	50% chance vehicle	100% chance vehicle	25% chance vehicle	Not applicable	100% chance vehicle
vehicles only	Cu/Ni	Not applicable	25% chance Diesel vehicles	Not applicable	Not applicable	Not applicable	Not applicable
BB, RD only	Mg/Al	25% chance Road dust	Not applicable	50% chance Biomass emissions	Not applicable	50% chance Biomass emissions	50% chance Biomass emissions
ALL	Mg/Cr	50% chance Biomass emissions	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Gas(4W), BB, RD only	Mn/Cr	100% chance Road dust	100% chance Road dust	100% chance Road dust	100% chance Road dust	25% chance Biomass	100% chance Road dust
Gas(4W), BB, RD only	Mn/Mg	25% chance Biomass	25% chance Biomass	25% chance Biomass	25% chance Biomass	25% chance Biomass	25% chance Biomass
BB, RD only	Mn/Na	50% chance biomass emissions	50% chance biomass emissions	50% chance biomass emissions	25% chance Biomass emissions	25% chance Biomass emissions	50% chance biomass emissions
BB, RD only	Na/Al	100% chance road dust	50% chance Biomass emissions	Not applicable	Not applicable	Not applicable	Not applicable
ALL except Gas (4W)	Na/Cr	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
vehicles only	Ni/Cr	25% chance vehicle	50% chance vehicle	50% chance vehicle	25% chance vehicle	50% chance vehicle	Not applicable
Diesel, Gasoline (4W) only	Pb/Mg	Not applicable	25% chance Gasoline vehicles (4W)	Not applicable	25% chance Gasoline vehicles (4W)	Not applicable	50% chance gasoline vehicle (4W)
BB only	Pb/Zn	25% chance Biomass	25% chance Biomass	50% chance Biomass emissions	25% chance Biomass	25% chance Biomass	25% chance Biomass

DIAGNOSTICS		Contribution to PM			Percentage of the resolved PM		
Percentage	PM	Biomass Emission Source	Road Dust Source	Vehicle Emission Sources	Biomass emission Source	Road Dust Source	Vehicle Emission Sources
Factor 1	24.61	14.5	1.4	1.4	59%	6%	6%
Factor 2	50.78	26.7	2.7	13.4	53%	5%	26%
Factor 3	15.87	0.0	0.0	0.0	50%	6%	33%
Factor 4	15.68	10.0	1.4	2.9	64%	9%	18%
Factor 5	2.96	1.3	0.5	0.5	45%	18%	18%
Factor 6	74.35	13.1	30.6	-	18%	41%	0%

Description		Highest percentage	Mixed with	Strong Indicator for		Diesel vehicles	Gasoline vehicles
Factor 1		BB	VE	Biomass emissions mixed with Vehicle emissions		3%	3%
Factor 2		BB	VE	Biomass emissions mixed with Vehicle emissions		12%	17%
Factor 3		BB	VE	Biomass emissions mixed with Vehicle emissions	Fraction of Vehicles Resolved	17%	17%
Factor 4		BB	VE	Biomass emissions mixed with Vehicle emissions		11%	11%
Factor 5		VE	BB	Vehicle emissions mixed with Road dust		9%	9%
Factor 6		VE	BB, RD	Road dust mixed with Vehicle emissions and BB		2%	2%

		Percentage in the resolved PM	Sub-percentage
OVERALL	Biomass emission	54.5%	
	Road dust	30.4%	
	Vehicle emissions	15.1%	
	Diesel vehicles		8%
	Gasoline vehicles		9%



PM: Total Suspended Particulate Matter; S/N: Signal to Noise Ratio; SE: Sta dard Error; BB: Biomass Burning; RD: Road Dust; 4W: Four-Wheeler vehicles; VES: Vehicle Emission Source

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