STUDY ON AIR PARTICULATE MATTER FILTERS FOR BLACK CARBON, EMB-CAR

FINAL REPORT

Department of Environment and Natural Resources

Environmental Management Bureau

CORDILLERA AUTONOMOUS REGION

(DENR EMB-CAR)

Submitted by:

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Executive Summary

Black Carbon (BC), a known component of air particulate matter from incomplete combustion of solid and liquid fuels, is manifested by the blackness of the filter paper after it is exposed in the atmosphere with the aid of active sampling techniques.

The World Health Organization (WHO), in its most recent publication on air quality[1], acknowledges that measurement of black carbon is a good practice, specifically for the use in exposure assessments and source apportionment studies. Measurement of black carbon within the relevant jurisdiction may also be used in evaluating air quality improvements, and in setting-up appropriate targets towards its reduction.

The Cordillera Administrative Region (CAR) initiated the Study on Air Particulate Matter Filters for Black Carbon in response to the pressing concerns on the air quality in high altitude urban communities. Specifically, 126 unique PM10 filter samples from DENR-EMB-CAR monitoring sites in Baguio City (Forestry, Plaza Garden and PEZA) and La Trinidad, Benguet (Capitol/LTB) were submitted to the University of the Philippines Diliman College of Science Institute of Environmental Science and Meteorology for the determination of its BC concentration levels. These filter samples were sampled for 24 hours using US EPA reference equipment, and are sampled every six days from April 2019 to January 2022. The percentage of BC in PM10 in the monitoring sites was lowest in Forestry (5.9%BC in PM10), followed by PEZA (8.7% BC in PM10), Capitol/LTB (9.5% BC in PM10). The largest percentage of BC during the period covered is observed in Plaza Garden station at 12.7% BC in PM10.

The range of short term (24-hr) sampled BC in PM10 among all monitoring sites is from 0.4 μg/NCM to 14.3 μg/NCM. Around 25% of the BC in PM10 is below 1.4 μg/NCM, while another 25% of the PM10 filter samples have BC above 7.8 μg/NCM. Taking the 2019 and 2020 arithmetic mean marked an annual BC in PM10 concentration of 5.7 μg/NCM and 3.9 μg/NCM, respectively, approximately 10% of the annual PM10 concentration values.

Overall, a reduction of 17% to 41% in PM10 BC levels while in the pandemic were observed in the monitoring stations when compared to pre-pandemic situations, strengthening the evidence that BC levels in PM10 can be decreased when control measures to manage pollution from vehicle sources are in place.

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[1] World Health Organization. (2021). WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. https://apps.who.int/iris/handle/10665/345329. License: CC BY-NC-SA 3.0 IGO

Preface

The Study on Air Particulate Matter Filters for Black Carbon - EMB-CAR is an initiated study by the Environmental Management Bureau, Cordillera Administrative Region, funded under the Air Quality Management Fund (AQMF). The technical service provider has started working on the initially submitted set of filter samples for the HAZAP Phase 2 Project of the DENR EMB Central Office submitted in November 2021, composed of 60 filters from the 2020 monitoring of EMB-CAR. A second Batch of filters were received on February 9, 2022, composed of 70 additional air particulate matter filters. These filters are samples from KM0, PEZA, BSU and La Trinidad from April 2019 to January 2021. A chapter introducing the concepts of black carbon and its relevance in air quality and climate change are discussed in the Introduction. The Methods chapter details how the filter samples were collected, where the filters are sampled, how the filters were analyzed for black carbon, and how the data were validated. The analysis results and discussion are focused on the descriptive statistics of individual filter samples per sampling location, as well as the time-series of the black carbon levels from 2019-2021. The percentages of black carbon in the PM10 concentration are also visualized in pie charts and bar graphs. Appendices are provided detailing the numerical values of the black carbon levels of the individual filter samples.

List of Abbreviation

ANSTO	Australian Nuclear Science and Technology Organization
AQGV	Air Quality Guideline Values
AQMF	Air Quality Management Fund
BC	Black Carbon
BSU	Baguio State University
CAR	Cordillera Administrative Region
DENR	Department of Environment and Natural Resources
EMB	Environmental Management Bureau
EPSL	Environmental Pollution Studies Laboratory
ERLSD	Environmental Research and Laboratory Services Division
HAZAP	Hazardous Air Pollutants
IESM	Institute of Environmental Science and Meteorology
IQR	Interquartile Range
LTB	La Trinidad Benguet
MABI	Multi-wavelength Absorption Black Carbon Instrument
NAAQGV	National Ambient Air Quality Guideline Values
NCM	Normal Cubic Meter
OC/EC	Organic Carbon/Elemental Carbon
PCA	Partnership for Clean Air, Inc.
PEZA	Philippine Economic Zone Authority
PM10	Particulate Matter 10
SD	Standard Deviation
RSD	Relative Standard Deviation
TOT	Thermal Optical Transmission
UPD	University of the Philippines Diliman -
WHO	World Health Organization

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I. Introduction

The problem of air pollution due to black carbon has long been recognized as one of the man-made crises that require immediate attention (Fenger, J., 2009; Bach, W., 1976). Black Carbon (BC), often known as soot, is a prevalent air contaminant found in the environment. Black Carbon is a complex collection of highly absorbent particles released when fossil fuels, biomass, and biofuels are burned incompletely. Black carbon is a significant contaminant contributing to climate change and human health issues (Mishra, V. 2003). The incomplete combustion of fossil fuels, wood, coal, and biofuels (Goldberg E.D, 1985) produces it. The burning of agricultural fields releases a massive amount of black carbon into the atmosphere, while forest fires significantly impact pollution.

Determination of the baseline levels of BC are essential since insufficient data are unavailable globally to provide recommendations for air quality guideline values (AQGV) levels. Actions to enhance further baseline research on the risks of BC exposure and approaches for mitigation need to be underscored in the soonest time, as evidence on the health concerns related to these pollutants are becoming available.

The Department of Environment and Natural Resources (DENR), together with the Environmental Management Bureau (EMB) and Environmental Pollution Studies Laboratory (EPSL) under the University of the Philippines Institute of Environmental Science and Meteorology (UP IESM), has been taking extra steps and countermeasures in analyzing the BC in the different parts of the Philippines, for this instance the main focus of the study will be in CAR.

The primary objective of this research is to offer basic information on the state of BC in CAR. Furthermore, to estimate PM and BC concentrations, multi wavelength studies (mostly focused on 639 nm) were used. The findings of this research will assist the local government and other interested parties in developing and improving environmental laws and regulations to safeguard the public from the negative impacts of air pollution.

II. Method

2.1. Gathering of Filter Samples

The DENR-EMB-AQMS has started sending the PM filters sampled from the monitoring stations nationwide, since November 2020. The filters, after subjecting to DENR sampling procedures, are preserved in cold storage (4-- degrees Celsius) during delivery, and are delivered to University of the Philippines Institute of Environmental Science and Meteorology-Environmental Pollution Studies Laboratory (UP-IESM-EPSL) on a per-batch basis.

The second batch of filters were received in UP IESM-EPSL on February 9, 2022. As a protocol for the HAZAP Project, the filters were documented, checked for data sheets, analysed for Black Carbon and then sent to DENR-EMB-ERLSD for As, Cd, Hg, Pb (HAZAP Project) using XRF on March 11, 2022. The electronic data sheet containing the corresponding sampling data of the second batch of filters were received on April 16, 2022.

2.2 Sampling Location

The DENR-EMB CAR personnel collected the datasets from the air quality stations located in the region (Table 1 and Figure 1). For this study, the samples of PM10 fractions were collected from September to December of 2020 in the DENR-EMB CAR Stations (Table 1).

Table 1. The stations from CAR and their specific coordinates.

Station Name	Station Code	Latitude	Longitude
College of Forestry BSU Compound, La Trinidad, Benguet	Forestry	16.4562971	120.5942209
Plaza Garden Lower Session Road Baguio City	Plaza Garden	16.410921	120.5992743
Provincial Capitol Hall Ground, KM 6, La Trinidad, Benguet	Capitol(LTB)	16.462553	120.58771
Philippine Economic Zone Authority Baguio Ecozone (PEZA) Compound Loakan Road Baguio City	PEZA	16.3801	120.6182

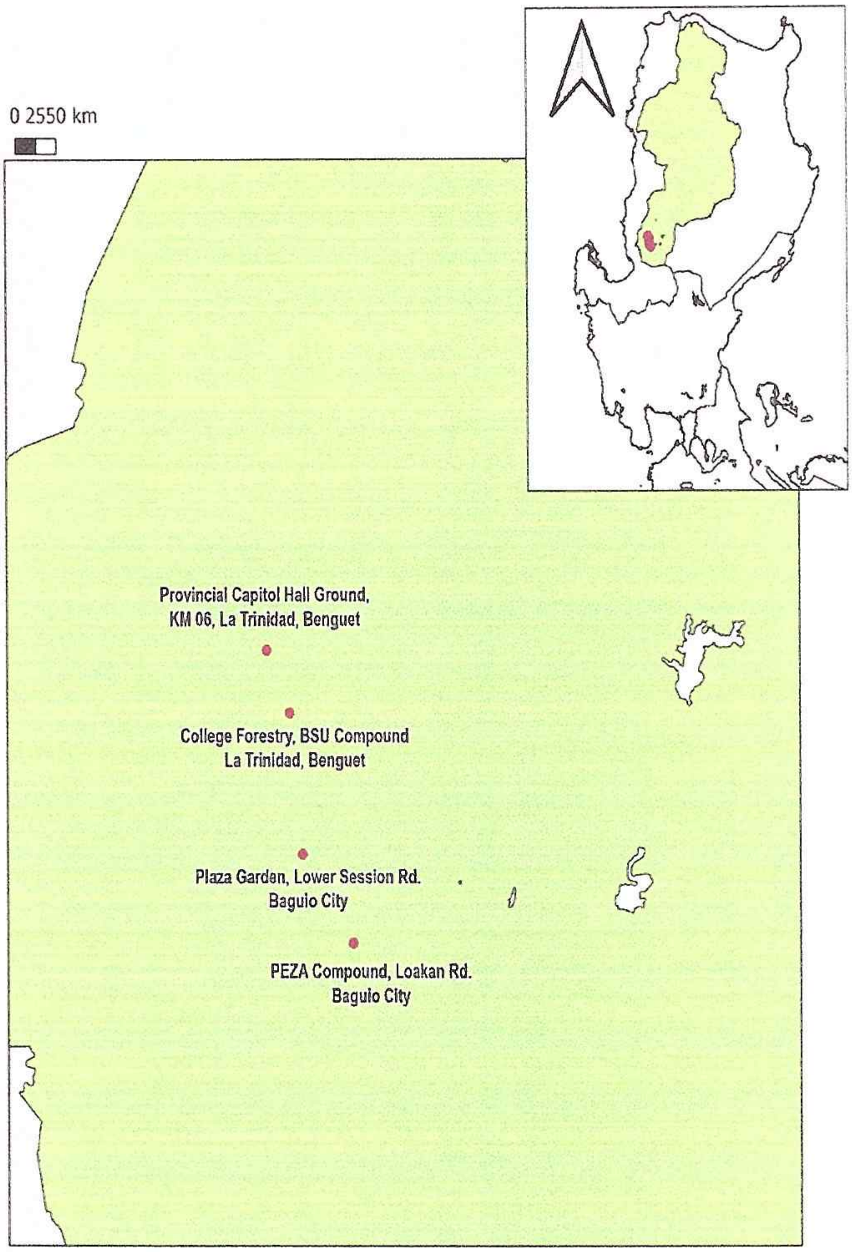


Figure 1. Plotted map of the CAR stations.

It is illustrated in Figure 1 the DENR-EMB air quality monitoring stations in CAR. The chosen sampling sites are located near the mountains and roadsides. For example, Mt. Kalugong is located near the BSU Compound AQMS. Meanwhile, Plaza Garden and Capitol Hall AQMS are situated near the urbanized roadsides. Lastly, PEZA station is located inside the Philippine Economic Zone Authority compound in CAR.

2.3 Sampling Method

The filter samples were gathered using the BGI PQ100 2890 and 2150. The samples were measured every 6th Day and lasted for 24 hours each sampling. Furthermore, the calculation and statistics of the data from the study were processed using Microsoft Office® Excel 2019, and Origin Lab, 2016.

2.4. ANSTO-MABI Instrument

Black carbon (BC), often known as light-absorbing carbon (LAC), is a crucial component of PM. Environmental management authorities and researchers can benefit significantly from a precise and accurate evaluation of BC's content and source contribution in air particle samples. Analysis of Black Carbon of the filter samples was performed using MABI -a Multi-wavelength Absorption Black Carbon Instrument developed by the Australian Nuclear Science and Technology Organization. MABI uses a seven (7) wavelengths: 405nm, 465nm, 525nm, 639nm, 870nm, 940nm, and 1050nm ("Multi-wavelength Absorption Black Carbon Instrument (MABI) Manual," n.d.). The goal is to use different wavelengths of light to discern better the various BC size fractions obtained in a sample. The distinct BC size fractions emanating from wood smoke or motor vehicles may subsequently be distinguished.

Following the recommendations from the ANSTO, the value of 639 nm will be used, which was the recommended wavelength for 47mm Teflon filters by ANSTO ("Multi-wavelength Absorption Black Carbon Instrument (MABI) Manual," n.d.; (Manohar, M. et al., 2021; Ryś & Samek, 2021). Additionally, an indicative presence of organic carbon may also be deduced from the wavelengths less than 500 nm, however, there is no published method yet to quantify the organic carbon as micrograms per normal cubic meter.

2.5. Validation of BC results from MABI using Thermal Optical Techniques.

The results of MABI analysis were validated using thermal optical Techniques. Selected filter samples were packed last June 16, 2022 for analysis of Organic Carbon and Elemental Carbon in Korea Institute of Standards and Science (KRISS), using Thermal Optical Techniques. The analysis was conducted from July 5, 2022 to July 15, 2022 by Dr. Mylene G. Cayetano, and the team of Dr. Jinsang Jung of KRISS.

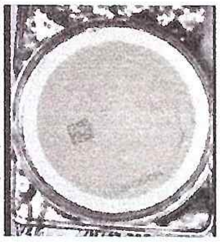
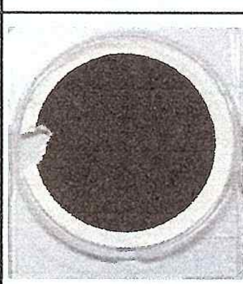
Selected filter samples were analyzed for organic carbon and elemental carbon (OC/EC) using thermal-optical techniques (Sunset Labs). The selection of the filters were done in such a way as to represent the high-level BC and the low-level BC. Ten filters were chosen from the first quartile to represent the low-level BC values, while 10 filters were chosen from the fourth quartile to represent the high-BC values.

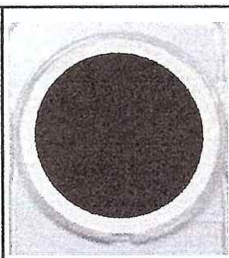
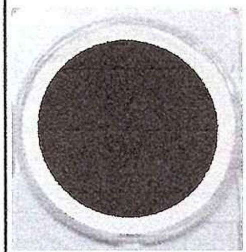
III. Results and Discussion

3.1. Descriptive Statistics of the Results

The raw data obtained using MABI were calculated accordingly using the Intensity values from the wavelength of 639 nm. A visual presentation of the notable descriptive statistics of the black carbon levels and PM10 levels per monitoring site are presented in Table 2. Included are the photos of the actual filters corresponding to the minimum levels of BC, maximum levels of BC and largest percentage of BC in PM10.

Table 2. Visual presentation and descriptive statistics of the BC levels in PM_{10} in the air filter samples from CAR in 2019-2021.

	MInimum BC in PM_{10}	**Maximum BC in PM_{10}**	**Max % of BC in PM_{10}**
Forestry No. of samples: 24 Mean BC: 1.0 ± 0.9			
	Oct 29, 2020 BC: 0.4 µg/NCM PM10: 10 µg/NCM % BC: 4 %	Dec 29, 2020 BC: 4.8 µg/NCM PM10: 54 µg/NCM %BC: 9 %	Aug 25, 2019 BC: 0.7 µg/NCM PM10: 2.5 µg/NCM %BC: 61 %
Plaza Garden No. of samples: 38 Mean BC: 6.7 ± 2.1			
	July 31, 2019 BC: 2.5 µg/NCM PM10: 23.1 µg/NCM %BC: 11 %	Aug 24, 2019 BC: 14.3 µg/NCM PM10: 63.7 µg/NCM % BC: 22 %	April 2, 2019 BC: 8.1 µg/NCM PM10: 20.9 µg/NCM % BC: 39 %

Capitol(LTB) No. of samples: 38 Mean BC: 6.9 ± 2.0			
	January 15, 2021 BC: 1.0 µg/NCM PM10: 9.9 µg/NCM %BC: 10 %	August 30, 2019 BC: 11.2 µg/NCM PM10: 28.8 µg/NCM %BC: 39 %	August 30, 2019 BC: 11.2 µg/NCM PM10: 28.8 µg/NCM %BC: 39 %
PEZA No. of samples: 27 Mean BC: 2.2 ± 2.3			
	August 14, 2019 BC: 0.8 µg/NCM PM10: 22.4 µg/NCM %BC: 4%	January 13, 2021 BC: 13.0 µg/NCM PM10: 156 µg/NCM % BC: 8%	Nov 28, 2019 BC: 2.4 µg/NCM PM10:5.4 µg/NCM %BC: 44%

The percentage of BC overall sampling per site during the sampling period from 2019-2021 is visualized in the pie chart in Figure 2. As hypothesized, the Forestry station marked the smallest percentage of BC in PM10, at 5.9%. On the other hand, the maximum percentage of BC in PM10 is observed from the Plaza Garden monitoring station, at 12.7%. The stations in Capitol (LTB) and PEZA both garnered a percentage of BC in PM10 at around 9%.

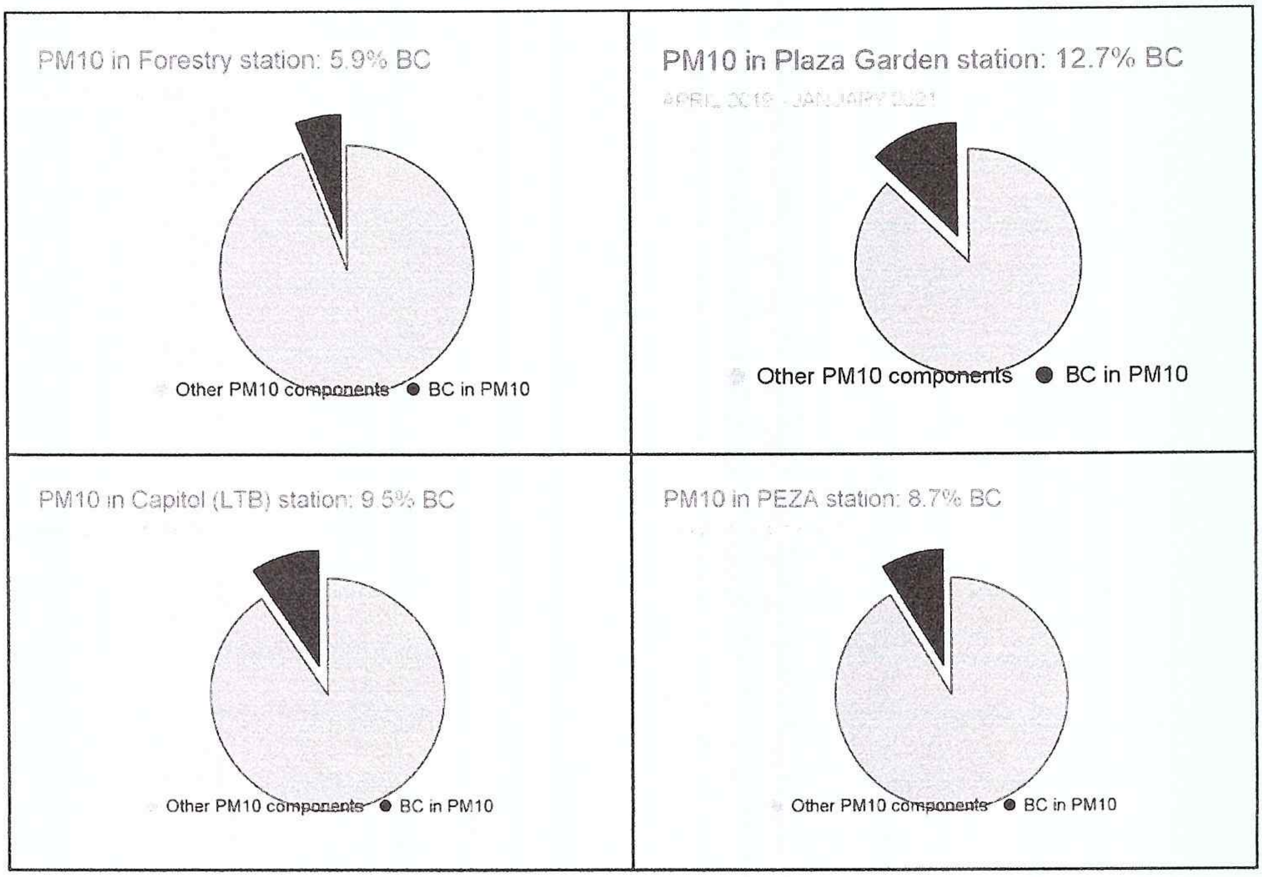


Figure 2. Percentage of BC in 24hr PM_{10} samples over all sampling days per monitoring site

Time-series representation of the BC levels at each site from 2019-2021 are presented in Figures 3- 6. showed a prominent peak during January 28, 2020 in Capitol (LTB). It also shows a high peak that occurred in PEZA on 13 January 2021. The sites corresponding to roadside sites exhibit a relatively higher range of BC levels, compared to those that are at certain distances away from the road, due to roadside emissions.

Moreover, the lowest value for 639 nm was recorded in Forestry station on October 29, 2020 with 0.4 ug/NCM as shown below.

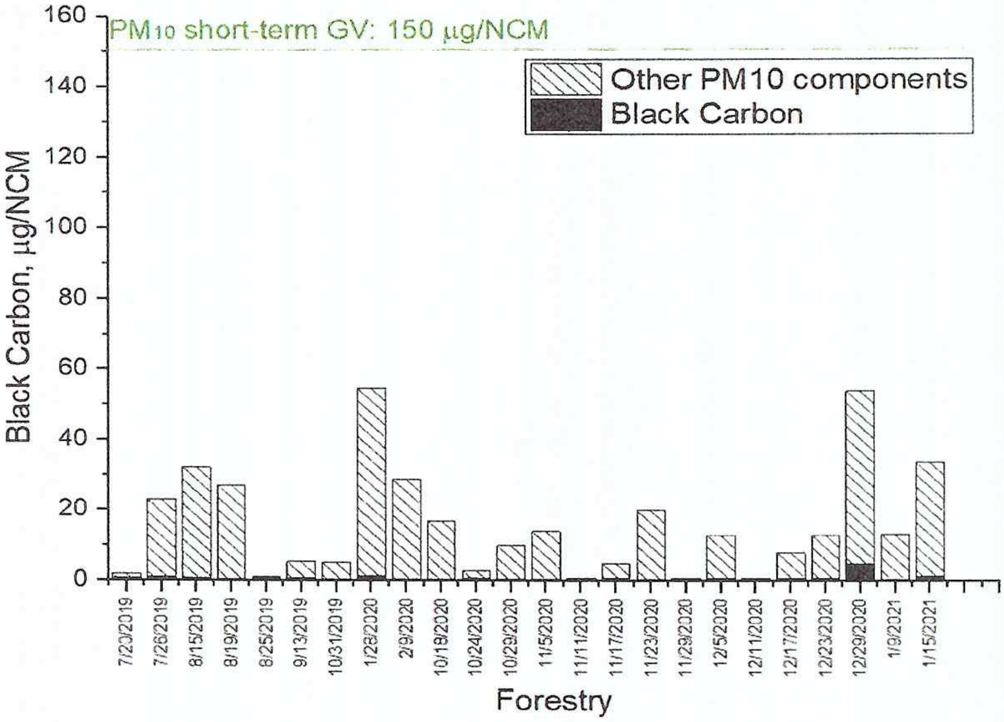


Figure 3. Time series of the fraction of BC in PM10 mass concentration (µg/Ncm) in BFAR/BSU Forestry station.

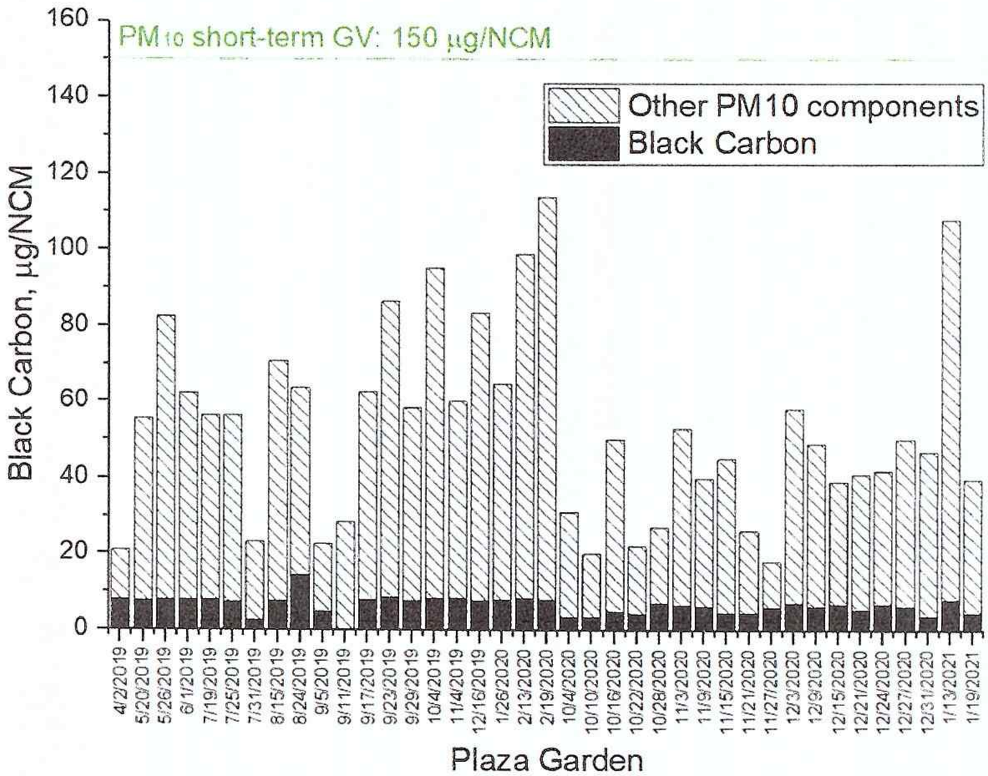


Figure 4. The PM Mass Concentration (µg/Ncm) in Plaza Garden station.

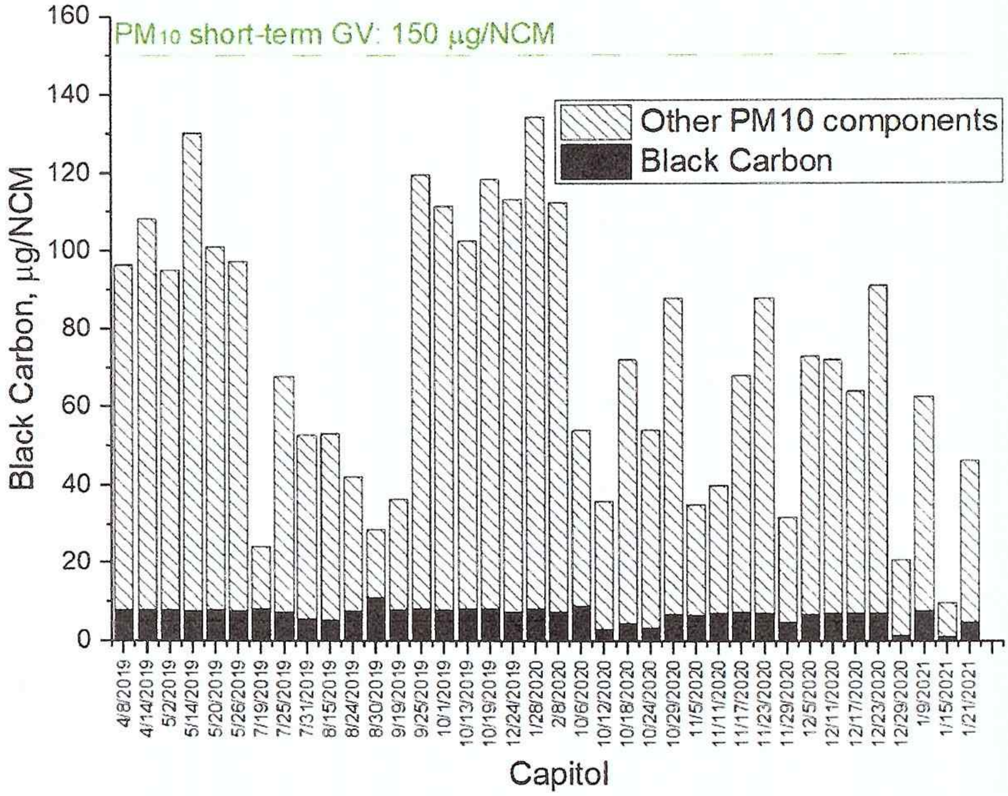


Figure 5. The PM Mass Concentration (µg/Ncm) in Capitol/LTB station.

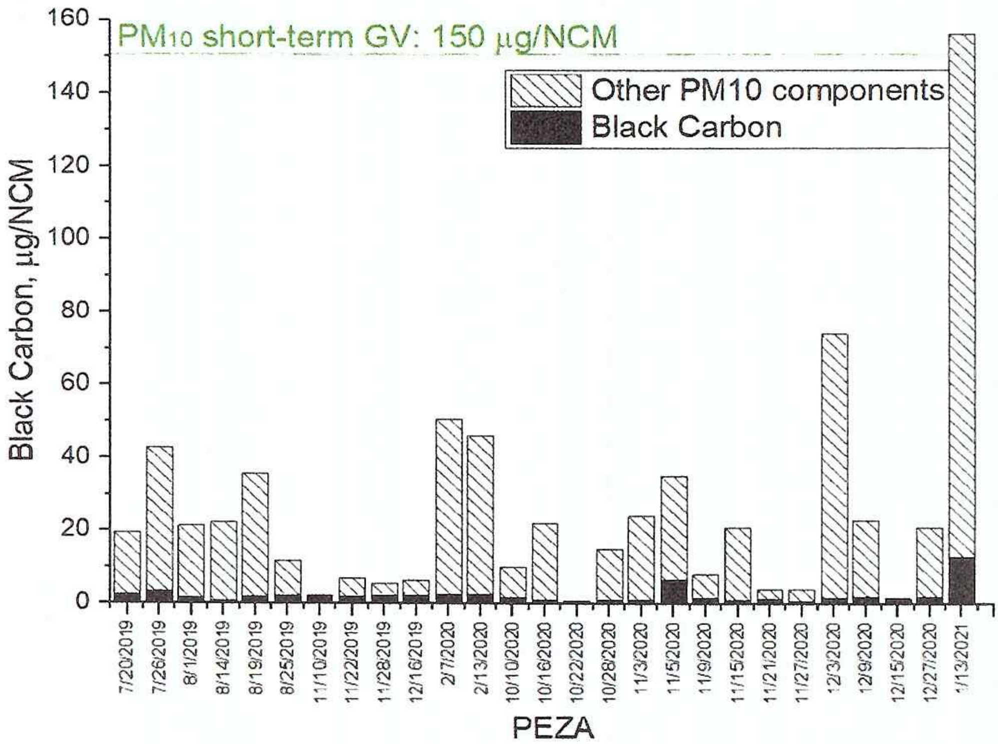


Figure 6. The PM Mass Concentration (µg/Ncm) in PEZA station.

Results showed that PM Mass concentrations for PM10 in CAR ranged from 1.0 μg/NCM (PEZA) to 156 μg/NcM (Capitol Hall), with an average of 45.4 μg/NCM (Figure 3). The average PM10 concentration in CAR complied with the NAAQGV of the Philippine Clean Air Act of 1999 which is (annual) 60 μg/NCM, however, it exceeded the guideline values set by the WHO which is 20 μg/m3 by 13%.

Table 3. Descriptive Statistics of the Black Carbon Levels and PM10 concentration, all sites and all samples from CAR (2019-2021)

Descriptive statistics	Overall Arithmetic Mean BC in PM10, ug/NCM	Overall Arithmetic Mean PM10, ug/NCM
Mean	4.7	45.5
SD	3.2	34.9
MIN	0.4	1.0
MAX	14.3	156.0
IQR1	1.4	20.0
IQR3	7.8	63.9
count	126	126

Annual Mean	Annual Arithmetic Mean BC in PM10, ug/NCM	Annual Arithmetic Mean PM10, ug/NCM	Count
2019	5.7	51.6	51
2020	3.9	39.4	67
2021	5.2	58.7	8

**Data are from April to December 2019*

*** There were no filter samples during the onset of the pandemic from March - September, 2020*

***Data are from January 2021 measurement only.*

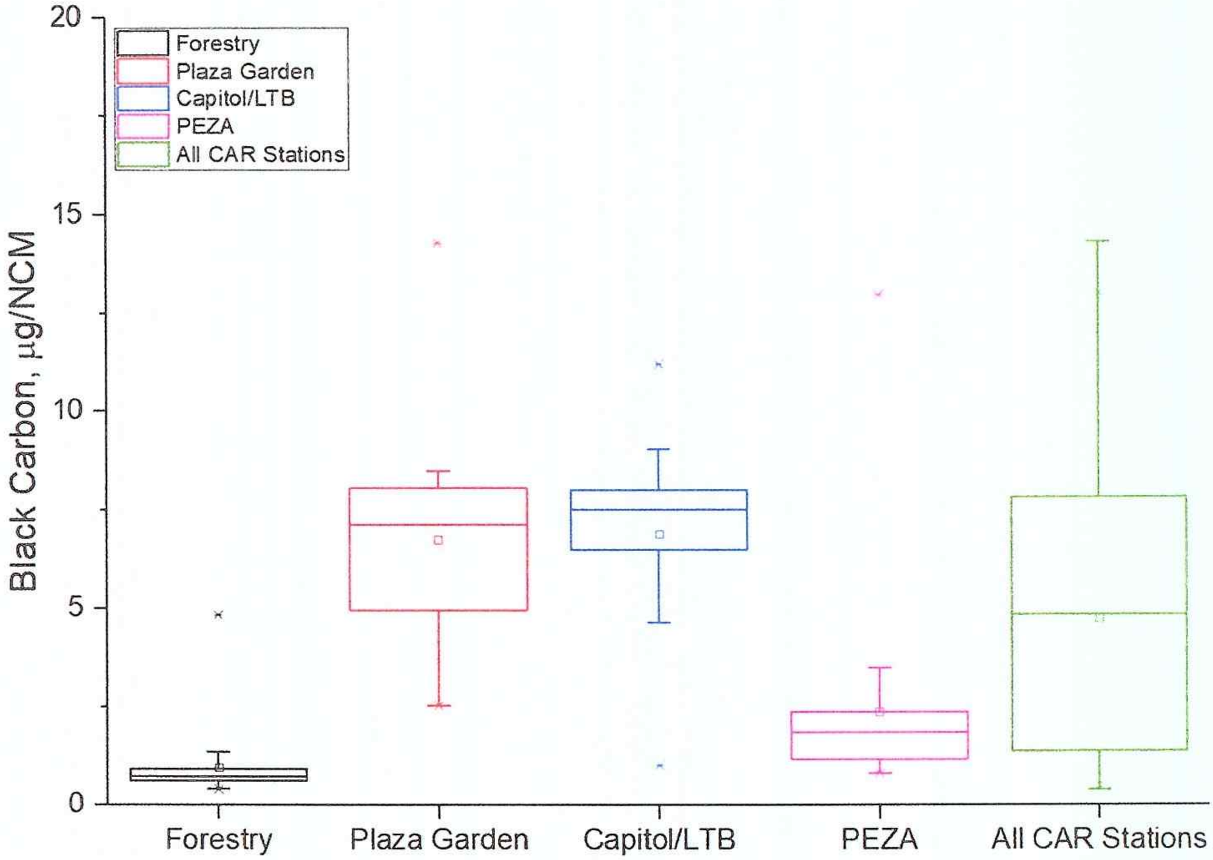


Figure 7. Box plot of Black Carbon Concentration in PM10 filters from CAR, 2019-2021

Using the boxplots of the BC concentrations per station, it can be seen that relatively higher mean, median and interquartile ranges occur in roadside stations of Plaza Garden and Captiol/LTB. PEZA and Forestry stations, on the other hand, have BC levels that are relatively lower in concentration.

3.2 Selected air particulate matter optical properties as indicator of organic carbon

According to the mass balance principle, the sum of the individual component masses cannot be greater than the mass of the whole. Hence, the values derived from the wavelength 400-500 nm can only indicate the presence of Organic carbon, but cannot at this point and with its current set of parameters indicate the actual mass of the organic carbon.

3.3 Discussion on the Validation Results

Specific to DENR-EMB-CAR filters, the coefficient used to calculate the Black carbon concentration (epsilon) was derived using the validation data from Thermal Optical Techniques. Details of which will be discussed in a technical report being prepared by Dr. Mylene G. Cayetano, in coordination with Partnership for Clean Air, Inc. (PCA) Technical & Research Team and will be submitted to a reputable scientific journal for possible publication.

Recalculation of the results after validation resulted in some percentage of BC in PM10 being greater than 100%, specifically those from the PEZA station. Note that the PM10 values used were from the DENR-EMB-CAR, while the BC values were from the MABI analysis used in this study. The best way to resolve this is to re-check the instruments used in each of the calculations. Since the MABI analysis results were validated using a Thermal Optical Technique, it is best to also validate the results of the PM10 analysis. Hence, since this is an inherent result due to calculations involving two unique instruments, the samples that resulted from this were not removed in the analysis.

3.4 Decrease in BC levels during the pandemic

From Appendix 6 to Appendix 8, aside from descriptive statistics, the percentage of reduction in PM10 BC concentration levels were illustrated in numbers. In the calculation, and also indicated, the pandemic period considered was only until Dec 2020. During the pandemic period, when the number of motor vehicles were lessened, there were observed 20% to 28% reduction in BC in the roadside stations (Plaza Garden and Capitol/LTB), and 17% reduction in BC in PM10 in background stations (Forestry). The industrial location marked the highest decrease in BC in PM10 at 41% when compared to pandemic levels of BC in PM10.

IV. Summary and Recommendations

4.1 Summary

In summary, this study provides baseline information black carbon concentrations in PM10 sampled from the Cordillera Administrative Region (CAR) in 2019-2021. Overall, from the 126 valid air particulate matter filters sampled for 24 hours, the mean levels of BC ranges from 0.4 to 14.3 µg/NCM. Roadside stations of Plaza Garden and Capitol/LTB exhibit higher ranges in BC, both at mean concentration of 6.7 µg/NCM , while those that are distances away from the roadside (Forestry and PEZA) have BC levels that have an average of 1.0 µg/NCM and 2.2µg/NCM, respectively. Reduction of 17% to 41% in PM10 BC levels while in the pandemic were observed in the monitoring stations when compared to pre-pandemic situations, strengthening the evidence that BC levels in PM10 can be managed when control measures to manage pollution from vehicle sources are in place.

4.2 Recommendation

The baseline levels of BC are determined in this study are essential in providing recommendations for air quality guideline values that are applicable in the Philippine setting.

The results from this study may also be used as input to source apportionment studies, in order to determine what are the other contributors to the PM10 . Note that it was found out from this study that BC contributes to around 10% of the PM10 mass concentration.

It is also suggested to utilize the results from this study in taking action in the management of air pollution from mobile sources. It is known that BC is mostly coming from incomplete combustion of vehicles.

Lastly, it is suggested to write the results and discussion in a format suitable for scientific publication, once the data processing of the additional information (organic carbon and elemental carbon using thermal optical techniques) and analysis are in satisfactory format. This may benefit the individuals from the DENR-EMB-CAR and from the Consultancy firm (Partnership for Clean Air, Inc.) as they may be invited as co-author, depending on their substantial contribution to the conceptualization, collection of data, conduct of the laboratory analysis, and construction of the paper, until its eventual publication.

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WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021. Licence: CC BYNCSA 3.0 IGO

VI. ANNEXES

ANNEX 1: Implementation Activities

1. The Technical service provider has started working on the initially submitted set of filter samples for the HAZAP Phase 2 Project of the DENR EMB Central Office submitted in November 2021, composed of 60 filters from the 2020 monitoring of EMB-CAR. A second Batch of filters were received on February 9, 2022, composed of 70 additional air particulate matter filters.

2. These filters are samples from KM0, PEZA, BSU and La Trinidad from April 2019 to January 2021. For context, the DENR-EMB-AQMS has started sending the PM filters sampled from the monitoring stations Nationwide, since November 2020. The filters, after subjecting to DENR sampling procedures, are preserved in cold storage (4-- degrees Celsius) during delivery, and are delivered to University of the Philippines Institute of Environmental Science and Meteorology-Environmental Pollution Studies Laboratory (UP-IESM-EPSL) on a per-batch basis.

3. The second batch of filters were received in UP IESM-EPSL on February 9, 2022. As a protocol for the HAZAP Project, the filters were documented, checked for data sheets, analysed for Black Carbon and then sent to DENR-EMB-ERLSD for As, Cd, Hg, Pb (HAZAP Project) using XRF on March 11, 2022. The electronic data sheet containing the corresponding sampling data of the second batch of filters were received on April 16, 2022.

4. The analysis of the filter samples were performed using a Multi-wavelength Absorption Black Carbon Instrument (MABI). The results of MABI analysis were validated using thermal optical Techniques. Selected filter samples were packed last June 16, 2022 for analysis of Organic Carbon and Elemental Carbon in Korea Institute of Standards and Science (KRISS), using Thermal Optical Techniques. The analysis was conducted from July 5, 2022 to July 15, 2022 by Dr. Mylene G. Cayetano, and the team of Dr. Jinsang Jung of KRISS.

ANNEX 2: Black Carbon Levels of the individual Filter Samples from CAR-Forestry Station in 2019-2021

Date	BC, ug/NCM	SD	RSD	% in PM 10
7/20/2019	1.0			49%
7/26/2019	1.1			5%
8/15/2019	0.7			2%
8/19/2019	0.6	0.001	0.12%	2%
8/25/2019	0.7			61%
9/13/2019	0.7			14%
10/31/2019	0.6	0.001	0.17%	12%
1/28/2020	1.4			3%
2/9/2020	0.6			2%
10/18/2020	0.5	0.004	0.70%	3%
10/24/2020	0.7			23%
10/29/2020	0.4			4%
11/5/2020	0.7			5%
11/11/2020	0.6			58%
11/17/2020	0.7			15%
11/23/2020	0.6			3%
11/29/2020	0.6			60%
12/5/2020	0.9			7%
12/11/2020	0.8	0.002	0.29%	83%
12/17/2020	1.0			12%
12/23/2020	0.8			6%
12/29/2020	4.8			9%
1/9/2021	0.7			5%
1/15/2021	1.4	0.001	0.04%	4%

ANNEX 3: Black Carbon Levels of the individual Filter Samples from CAR-Plaza Garden Station in 2019-2021

Date	BC, ug/NCM	SD	RSD	% in PM 10
4/2/2019	8.1			39%
5/20/2019	7.8			14%
5/26/2019	7.9			10%
6/1/2019	8.0			13%
7/19/2019	8.1			14%
7/25/2019	7.3			13%
7/31/2019	2.5			11%
8/15/2019	7.6			11%
8/24/2019	14.3	0.1	0.79%	22%
9/5/2019	4.9			22%
9/11/2019	5.5			19%
9/17/2019	8.1			13%
9/23/2019	8.5			10%
9/29/2019	7.8			13%
10/4/2019	8.5			9%
11/4/2019	8.3			14%
12/16/2019	7.8			9%
1/26/2020	8.0			12%
2/13/2020	8.3			8%
2/19/2020	8.0			7%
10/4/2020	3.3	0.01	0.43%	11%
10/10/2020	3.4	0.01	0.28%	17%
10/16/2020	5.0	0.1	2.52%	10%
10/22/2020	4.4	0.00	0.04%	20%
10/28/2020	7.1			26%
11/3/2020	6.5			12%

11/9/2020	6.2			16%
11/15/2020	4.5			10%
11/21/2020	4.6	0.01	0.24%	18%
11/27/2020	6.0			33%
12/3/2020	7.1			12%
12/9/2020	6.4	0.004	0.06%	13%
12/15/2020	6.9			18%
12/21/2020	5.5			13%
12/24/2020	6.8			16%
12/27/2020	6.4			13%
12/31/2020	3.6			8%
1/13/2021	7.9			7%
1/19/2021	4.5			11%

ANNEX 4: Black Carbon Levels of the individual Filter Samples from CAR-Capitol Station in 2019-2021

Date	BC, ug/NCM	SD	RSD	% in PM 10
4/8/2019	8.1			8%
4/14/2019	8.0			7%
5/2/2019	7.9			8%
5/14/2019	7.9			6%
5/20/2019	7.9			8%
5/26/2019	7.8			8%
7/19/2019	8.3			34%
7/25/2019	7.5			11%
7/31/2019	5.7			11%
8/15/2019	5.4			10%
8/24/2019	7.8			18%

8/30/2019	11.2			39%
9/19/2019	8.1			22%
9/25/2019	8.2			7%
10/1/2019	7.9			7%
10/13/2019	8.2			8%
10/19/2019	8.3			7%
12/24/2019	7.6			7%
1/28/2020	8.2			6%
2/8/2020	7.4			7%
10/6/2020	9.0	0.02	0.31%	17%
10/12/2020	3.1			9%
10/18/2020	4.7	0.01	0.21%	6%
10/24/2020	3.3	0.04	0.85%	6%
10/29/2020	6.9			8%
11/5/2020	6.5			18%
11/11/2020	7.2			18%
11/17/2020	7.3			11%
11/23/2020	7.1			8%
11/29/2020	4.8			15%
12/5/2020	7.0			10%
12/11/2020	7.0	0.04	0.51%	10%
12/17/2020	7.1			11%
12/23/2020	7.0			8%
12/29/2020	1.5			7%
1/9/2021	7.8			13%
1/15/2021	1.0			10%
1/21/2021	4.9			10%

ANNEX 5: Black Carbon Levels of the individual Filter Samples from CAR-PEZA Station in 2019-2021

Date	BC, ug/NCM	SD	RSD	% in PM 10
7/20/2019	2.6			14%
7/26/2019	3.5			8%
8/1/2019	1.6			8%
8/14/2019	0.8	0.001	0.07%	4%
8/19/2019	2.1			6%
8/25/2019	2.4			20%
11/10/2019	2.2			102%
11/22/2019	2.1			30%
11/28/2019	2.4			44%
12/16/2019	2.3			37%
2/7/2020	2.6			5%
2/13/2020	2.4			5%
10/10/2020	1.7	0.005	0.28%	17%
10/16/2020	1.2	0.002	0.18%	5%
10/22/2020	1.0			97%
10/28/2020	1.0			7%
11/3/2020	1.0			4%
11/9/2020	1.7			21%
11/15/2020	1.2			6%
11/21/2020	1.4			35%
11/27/2020	0.9			23%
12/3/2020	1.7			2%
12/9/2020	1.9			8%
12/15/2020	1.6			160%
12/27/2020	1.9			9%
1/13/2021	13.0			8%

ANNEX 6. Descriptive statistics of Black Carbon levels in PM10 filter samples from Forestry Station, 2019-2021

	Descriptive Statistics	
Overall	Count	24
	Average BC, ug/NCM	1.0
	Min	0.4
	Max	4.8
	SD	0.9
	iqr25	0.6
	iqr75	0.9
PRE-PANDEMIC	Count	9
	Average	0.8
	Min	0.6
	Max	1.4
	SD	0.3
AMID PANDEMIC	Count	12
until Dec 23, 2021 only	Average	0.7
	Min	0.4
	Max	1.0
	SD	0.2
% decrease		-17%

ANNEX 8. Descriptive statistics of Black Carbon levels in PM10 filter samples from Capitol/LTB Station, 2019-2021

	Descriptive Statistics	
Overall	Count	38
	Average	6.9
	Min	1.0
	Max	11.2
	SD	2.0
	iqr25	6.6
	iqr75	8.0
PRE-PANDEMIC	Count	20
	Average	7.9
	Min	5.4
	Max	11.2
	SD	1.1
AMID PANDEMIC	Count	14
until Dec 23, 2021 only	Average	6.3
	Min	3.1
	Max	9.0
	SD	1.7
% decrease		-20%

ANNEX 9. Descriptive statistics of Black Carbon levels in PM10 filter samples from PEZA Station, 2019-2021

	Descriptive Statistics	
Overall	Count	26
	Average	2.23
	Min	0.8
	Max	13.0
	SD	2.3
	iqr25	1.24
	iqr75	2.36
PRE-PANDEMIC	Count	12
	Average	2.2535
	Min	0.8
	Max	3.5
	SD	0.6
AMID PANDEMIC	Count	10
	Average	1.3377
	Min	0.9
	Max	1.9
	SD	0.4
% decrease		-41%

Prepared by:

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Consolidated by:

Partnership for Clean Air, Inc. (PCA)
Technical and Management Team

November 25, 2022

Ms. Maria Victoria V. Abrera
Regional Director-Cordillera Administrative Region
Environmental Management Bureau
DENR Compound, Gibraltar Road
Baguio City

SUBJECT: Submission of Final Report: Source Apportionment Studies for EMB-CAR

Dear RD Abrera:

Respectfully submitting the FINAL REPORT as part of the deliverable of the commissioned work, "Consultancy Services for the Source Apportionment Studies of Air Particulate Matter Filters for EMB-CAR" of the Department of Environment and Natural Resources (DENR), Environmental Management Bureau - Cordillera Administrative Region (EMB-CAR).

Remarkable finding was that of the PM10 sampled between April 2019 to January 2021, the largest source of PM10 was from BIOMASS BURNING (Open burning): 49.5% in Plaza Garden station, 43% in Provincial Capitol Station and 31% in PEZA Loakan station. Vehicle emission sources range from 30-31% of PM10 in the three stations.

We sincerely hope that this study may help in the better management of open burning sources in the Cordillera Administrative Region. Please feel free to schedule the consultation meeting with the EMB-CAR officers and stakeholders in relation to the results of the findings.

For feedback, please feel free to contact us through email (mcayetano@iesm.upd.edu.ph); pcasec2014@gmail.com. or phone (+639171147808)

Looking forward to your favorable response.

Truly,

JULIETA G. MANLAPAZ
NC/OIC-ED, PCA

MYLENE G. CAYETANO RCh PhD
Technical Service Provider (Consultant)/ Vice President, PCA

RENATO D. PINEDA, JR.
President, PCA

SOURCE APPORTIONMENT STUDIES OF AIR PARTICULATE MATTER FILTERS FOR EMB-CAR

FINAL REPORT

Department of Environment and Natural Resources

Environmental Management Bureau

CORDILLERA ADMINISTRATIVE REGION

(DENR EMB-CAR)

Submitted by:

PARTNERSHIP FOR CLEAN AIR, INC. (PCA)

Mylene G. Cayetano RCh PhD
Technical Service Provider (Consultant)
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November 2022

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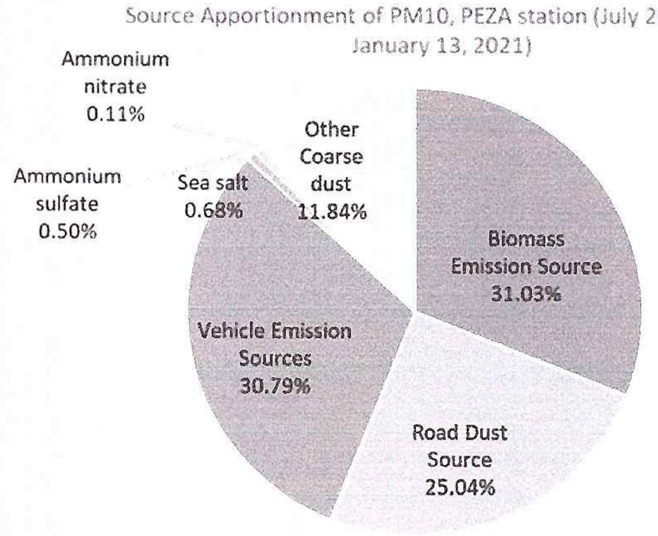
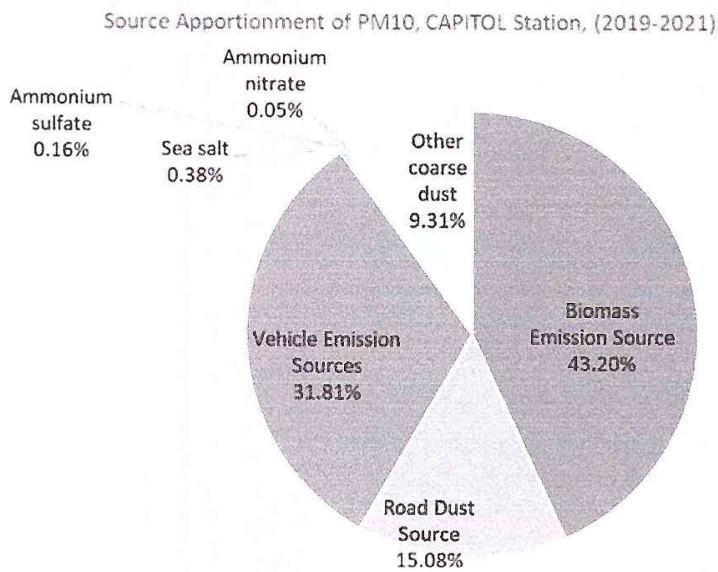
Executive Summary

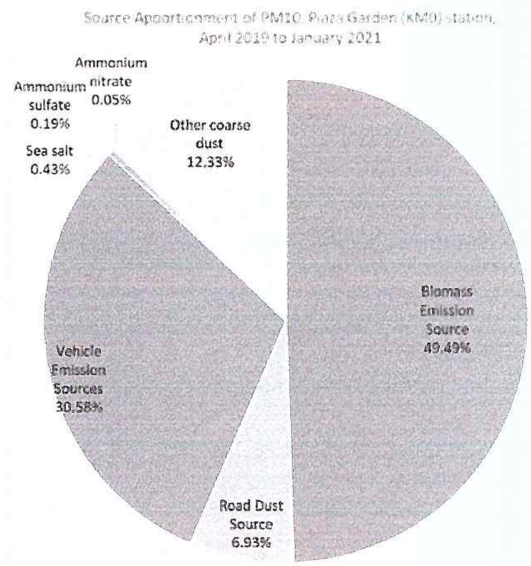
Air particulate matter filters collected between April 2019 to January 2021 collected from the four monitoring stations of EMB-CAR were submitted by the EMB-Central Office to the Environmental Pollution Studies Laboratory of the Institute of Environmental Science and Meteorology, University of the Philippines- Diliman (EPSL-IESM-UPD) . The one hundred twenty six (126) air particulate matter filter samples (PM10) underwent a series of laboratory analysis for twenty two (22) chemical species, (Black Carbon [BC], Arsenic [As], Cadmium [Cd], Mercury [Hg], Lead [Pb], Aluminum [Al], Chromium [Cr], Copper [Cu], Manganese [Mn], Nickel [Ni], Zinc [Zn], Chlorine [Cl^-], Sulfate [SO_4^{-2}], Nitrate [NO_3^{-1}], Phosphate [PO_4^{-3}], Lithium [Li^+], Ammonium [NH_4^+], Potassium [K^+], Magnesium [Mg^{+2}], Fluoride [F^-], Calcium [Ca^{+2}] and Sodium [Na^+]). Twenty-one (21) of the chemical species were included as input parameters in the source apportionment analysis using a positive matrix factorization (PMF) modeling. Six factor sources were resolved using the in-house emission factors from the EPSL-IESM-UP Diliman, which are applicable to the PM10 sampled between April 2019 to January 2021 in Provincial Capitol, Plaza Garden (KM0) and PEZA, Loakan Baguio City. It was not possible to analyse the PM10 samples from the Forestry station, nevertheless, this site was considered as background station.

The six factor sources were further resolved into three sources, with the vehicle sources resolved into gasoline-fed and diesel-fed vehicle sources. For the duration and site (CAPITOL, KM0 and PEZA) of the submitted PM10 samples, biomass emissions sources comprise the highest fraction of PM10, ranging from 31% to 49.5% of the emission source, while road dust contributes 7% to 25%. Vehicle sources, ranging from 30% to 31%, is made-up of 9.5% to 13%% emissions from diesel-fed engines, while 18% to 21.4% are emissions from gasoline-fed engines. When classified according to DENR emission classification where the biomass emissions and road dust comprises the 'area sources', while vehicle emissions 'mobile sources, the resolved factor sources has generated 30% to 31% from mobile sources (diesel and gasoline-fed vehicles) and 56% to 58% from area sources (biomass emissions, road dust and others).

These apportioned sources and their contributions are site specific and period specific. Hence, the results from this study are applicable to PM10 sampled between 2019-2021 in Provincial Capitol (LTB), Plaza Garden (KM0) and PEZA Loakan Baguio City.


Source Apportionment of PM10, PEZA station (July 20, 2019 to January 13, 2021)
Ammonium nitrate 0.11%
Ammonium sulfate 0.50%
Sea salt 0.68%
Other Coarse dust 11.84%
Biomass Emission Source 31.03%
Vehicle Emission Sources 30.79%
Road Dust Source 25.04%


Source Apportionment of PM10, CAPITOL Station, (2019-2021)
Ammonium sulfate 0.16%
Ammonium nitrate 0.05%
Sea salt 0.38%
Other coarse dust 9.31%
Biomass Emission Source 43.20%
Vehicle Emission Sources 31.81%
Road Dust Source 15.08%


Source Apportionment of PM10, Plaza Garden (KM0) station, April 2019 to January 2021
Ammonium nitrate 0.05%
Ammonium sulfate 0.19%
Sea salt 0.43%
Other coarse dust 12.33%
Biomass Emission Source 49.49%
Vehicle Emission Sources 30.58%
Road Dust Source 6.93%

Preface

The DENR-EMB-Cordillera Administrative Region (DENR-EMB-CAR), through its air quality monitoring network, has collected the PM10 samples from KM0, PEZA, BSU and La Trinidad from April 2019 to January 2021 for source apportionment analysis. The PM10 filter samples were submitted to the Environmental Pollution Studies Laboratory of the Institute of Environmental Science and Meteorology, University of the Philippines, Diliman. This report contains the report on the analysis performed on the filters, from receiving, cutting into portions, digestion, data analysis and diagnostics.

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List of Abbreviation

ANSTO	Australian Nuclear Science and Technology Organization
AQGV	Air Quality Guideline Values
AQMF	Air Quality Management Fund
BC	Black Carbon
BSU	Baguio State University
CAR	Cordillera Administrative Region
DENR	Department of Environment and Natural Resources
EMB	Environmental Management Bureau
EPSL	Environmental Pollution Studies Laboratory
ERLSD	Environmental Research and Laboratory Services Division
HAZAP	Hazardous Air Pollutants
IESM	Institute of Environmental Science and Meteorology
IQR	Interquartile Range
LTB	La Trinidad Benguet
MABI	Multi-wavelength Absorption Black Carbon Instrument
NAAQGV	National Ambient Air Quality Guideline Values
NCM	Normal Cubic Meter
OC/EC	Organic Carbon/Elemental Carbon
PEZA	Philippine Economic Zone Authority
PM10	Particulate Matter 10
SD	Standard Deviation
RSD	Relative Standard Deviation
TOT	Thermal Optical Transmission
UPD	University of the Philippines Diliman -
WHO	World Health Organization

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ANNEXES

I. Introduction

1.1. Source Apportionment Studies as a tool for Air Quality Management

To better understand the emissions and transport of particulate matter in an area, receptor models are efficient tools that can give better estimate of the pollutant sources, based on relative abundant fractions of tracer elements that facilitate profile identification (Cayetano MG, 2012). Receptor models can facilitate the identification of pollution sources and give a quantitative estimation of the emission rates of the pollutants. More so, receptor models gives a better understanding of the transport of the substances from the source to the downwind locations and can give insight on the physical and chemical transformation process that can occur during transport, wherein the overall key is the aerosol mass balance.

1.2. Positive Matrix Factorization

In brief, receptor models are management tools for air quality studies that involve the quantitative estimation of the emission rates of the pollutants, identification of the pollution source, understanding of the transport of substances from sources to downwind locations and the knowledge of the physical and chemical transformation process that occur during that transport (Hopke 2009). In one of his presentations, Philip Hopke stressed out that "receptor models focus on the behavior of the ambient environment at the point of impact", compared to "source oriented models that focus on the transport, dilution, and transformations that begin at the source and follow the pollutants to the sampling or receptor site" (Hopke 2011). The key in receptor modeling is conservation of mass. Details of which are presented in technical papers elsewhere (Malinowski 1991), the most common software is the one that uses Positive Matrix Factorization, PMF (Paatero 1997; Paatero 1999) is a weighted least squares model, weighted based on known uncertainty (error) of the elements of the data matrix (Paatero 1997), (Ramadan *et al.* 2003).

II. Method

2.1. Gathering of Filter Samples

The DENR-EMB-AQMS has started sending the PM filters sampled from the monitoring stations nationwide, since November 2020. The filters, after subjecting to DENR sampling procedures, are preserved in cold storage (4 degrees Celsius) during delivery, and are delivered to University of the Philippines Institute of Environmental Science and Meteorology-Environmental Pollution Studies Laboratory (UP-IESM-EPSL) on a per-batch basis.

The second batch of filters were received in UP IESM-EPSL on February 9, 2022. As a protocol for the HAZAP Project, the filters were documented, checked for data sheets, analysed for Black Carbon and then sent to DENR-EMB-ERLSD for As, Cd, Hg, Pb (HAZAP Project) using XRF on March 11, 2022. The electronic data sheet containing the corresponding sampling data of the second batch of filters were received on April 16, 2022.

2.2 Sampling Location

The DENR-EMB CAR personnel collected the datasets from the air quality stations located in the region (Table 1 and Figure 1). For this study, the samples of PM10 fractions were collected from September to December of 2020 in the DENR-EMB CAR Stations (Table 1).

Table 1. The stations from CAR and their specific coordinates.

Station Name	Station Code	Latitude	Longitude
College of Forestry BSU Compound, La Trinidad, Benguet	Forestry	16.4562971	120.5942209
Plaza Garden Lower Session Road Baguio City	Plaza Garden	16.410921	120.5992743
Provincial Capitol Hall Ground, KM 6, La Trinidad, Benguet	Capitol(LTB)	16.462553	120.58771
Philippine Economic Zone Authority Baguio Ecozone (PEZA) Compound Loakan Road Baguio City	PEZA	16.3801	120.6182

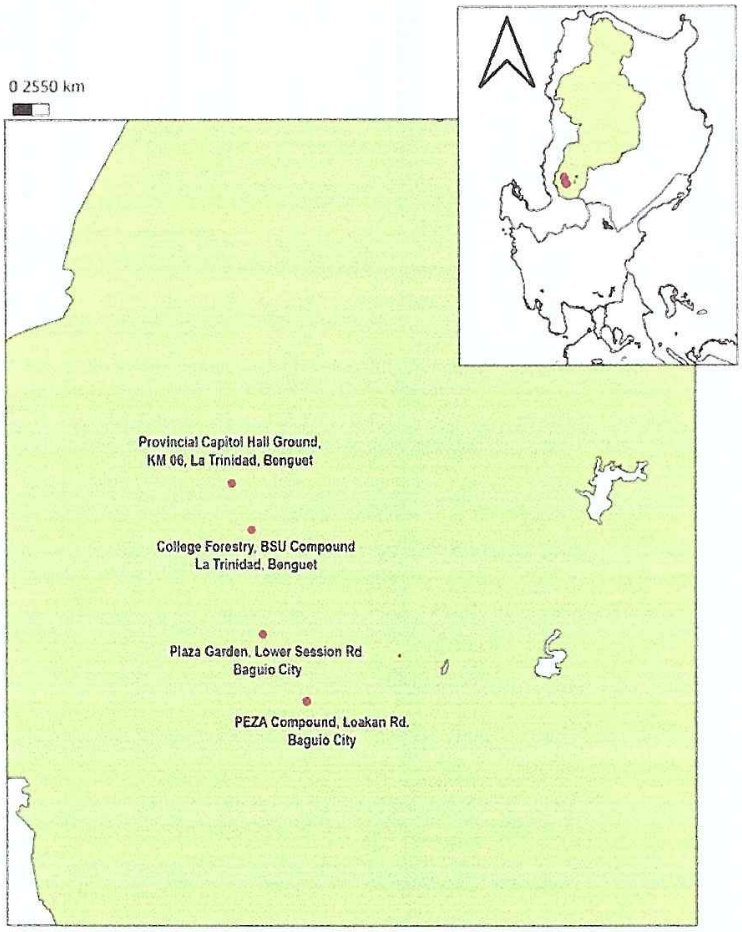

Figure 1. Map of the CAR sampling stations.

Figure 1 plots the DENR-EMB air quality monitoring stations that are considered in this source apportionment study for the EMB-CAR. The chosen sampling sites are located near the mountains and roadsides. For example, Mt. Kalugong is located near the BSU Compound AQMS. Meanwhile, Plaza Garden and Capitol Hall AQMS are situated near the urbanized roadsides. Lastly, PEZA station is located inside the Philippine Economic Zone Authority compound in CAR.

2.3 Sampling Method

The filter samples were gathered using the BGI PQ100 2890 and 2150. The samples were measured every 6th Day and lasted for 24 hours each sampling. Furthermore, the calculation and statistics of the data from the study were processed using Microsoft Office® Excel 2019, and Origin Lab, 2016.

2.4. Characterizing the chemical components of the PM10 samples

The PM10 filter samples received by the DENR-EMB Central office were sent to the University of the Philippines Diliman Institute of Environmental Science and Meteorology for the analysis of its components.

Black carbon (**BC**) of the filter samples was performed using MABI - a Multi-wavelength Absorption Black Carbon Instrument developed by the Australian Nuclear Science and Technology Organization, following the recommendations from the ANSTO to use the value of 639 nm, and with values calculated using the algorithm from the user's manual that leads to a final concentration as micrograms per normal cubic meter. After BC analysis, the filters were brought to the EMB-ERLSD for the determination of **As, Cd, Hg and Pb** using X-ray Fluorescence spectrophotometry.

The filters were then returned back to UP-IESM for partitioning into four parts. The first quarter was digested in order to extract the total metals that are within the PM10 filter samples. The ETHOS UP microwave digester of the EPSL-IESM-UPD was used. This process lowers the risk of contamination, and speeds up digestion. The ETHOS UP has a database which lists different matrices to be analyzed and the corresponding reagents that must be used before proceeding to the actual process of microwave-assisted digestion. In the methodology developed (Cayetano, 2020a), dilute nitric acid was used instead of concentrated nitric acid which was a modification in the instrument protocol. Although dilute nitric acid was used in the method, no traces of solids were separated since the final solution after digestion was a clear solution. The solution was then submitted to CRL labs for quantification of the trace elements using either inductively-coupled plasma – optical emission spectrometry (ICP-OES) which detected presence of trace elements due to its very low detection limit, or Flame Atomic Absorption Spectrophotometry (FAAS). The trace elements analysed were **Al, Cr, Cu, Mn, Ni and Zn**.

The second quarter portions of the PM10 filters were packed and sent to Korea Research Institute for Standards and Science for the determination of eleven (11) ion components namely: **Chlorine [Cl^-], Sulfate [SO_4^{-2}], Nitrate [NO_3^{-1}], Phosphate [PO_4^{-3}], Lithium [Li^+], Ammonium [NH_4^+], Potassium [K^+], Magnesium [Mg^{+2}], Fluoride [F^-], Calcium [Ca^{+2}] and Sodium [Na^+]**. The second portion was placed in pre-cleaned nutrient-free extraction bottle and was extracted with 15 mL organic-free ultrapure water under ultrasonication (Power Sonic 410) for 30 minutes. Extracted samples were then filtered through a 0.45 µm syringe filter (Pall Gelman Acrodisc®) to remove water-insoluble suspended materials. Filtered water extracts were placed in test tubes with lid, labeled and stored in refrigerator at 4°C until further analysis. An aliquot (1.2 mL) of the water extract was used in the analysis of the cations: [Na^+], [K^+], [NH_4^+], [Ca^{2+}] and [Mg^{2+}]. These were measured using ion chromatography (IC), Thermo Fisher Scientific, Dionex ICS-5000, employing similar analytical conditions used by Jung J. *et al.* (2014) which are summarized in Table 2. Analysis for anions, on the other hand, was carried out using Dionex, DX 120 ion chromatography. About 1 mL of each of the water extracts was used in the analysis. Analytical conditions employed are also shown in Table 2.

Table 2. Analytical conditions used in the analysis of water-soluble components.

Parameters	Conditions	
	Anion	Cation
Column	IonPac AS15 (3x150mm)	IonPac CS-12A (4x250 mm)
Detector	Thermal Conductivity Detection	Thermal Conductivity Detection
Eluent	KOH	Methanesulfonic acid (MSA)
Eluent flow rate (mL/min)	0.5	1.0

Measurement calibrations for cation were performed using Dionex Six Cation-II Standards. Cation standard concentrations used in the analysis were 0.2, 0.5, 1.0, 2.0 ug/mL (ppm). Standards were measured before and after each analytical sequence of analysis. Filter and water blanks were employed for every batch of analysis, while spiked filter samples were also analyzed in every batch of 25 samples. The same protocol was employed for the analysis of anion using Dionex Seven Anion Standard II as standard reference material.

A third portion of selected PM10 filter samples are also packed and sent to KRISS for the validation study of black carbon results MABI analysis. Details of which are discussed in the Final Report of the Black Carbon Study of EMB-CAR Filters.

2.5 Preliminary data analysis

The resulting chemical species data underwent data screening and mass balance calculation. The data screening includes calculation of the detection limit, descriptive statistics, interquartile ranges and finally grouping according to sites. The final output of the preliminary data analysis is the set of concentration files and the uncertainty files of the PM10 samples, grouped according to the monitoring site: Forestry, PEZA, KM0 and Capitol.

2.6 Phase I data analysis

Phase 1 data analysis involves plugging-in the prepared concentration files and the uncertainty files of the PM10 samples in the PMF Model The PMF modeling was conducted using US EPA PMF v5.0 GUI. In the 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 PM10 on all factors. A run is disqualified when it results in at least one factor having PM10 equals zero. The resulting output of phase 1 data analysis are the spreadsheets of the chemical profiles of the factor sources, Time series of contribution per factor and the diagnostic files. Results of the Phase 1 data analysis are presented in ANNEXES 5-7.

2.7 Phase II data analysis

The output of Phase 1 data analysis, chemical profiles of the factor sources are then plugged-in the in-house spreadsheet of Environmental Pollution Studies laboratory (EPSL) that contains the indicative chemical fingerprints of emissions (emission factors) such as vehicles emissions, VE (gasoline and diesel fuels), biomass burning, BB (fuel wood, rice straw, charcoal, saw dust, cooking) and road dust, RD. The combination of chemical fingerprints of the emission sources are categorized as weak, probable and strong emission factors. The resulting report of the Phase 2 data analysis are the identified factor sources with corresponding percentages in the PM 10, as well as the calculated percentages of the identified sources in the overall PM10 per monitoring site.

II. Results and Discussion

3.1 Preliminary Data Analysis Results

The results of preliminary data analyses for Forestry, PEZA, Capitol and KM0 are presented in ANNEXES 1-4. The tables also showed the percentages of the components in PM10 (mass balance) in which when combined as an accumulated sum of components, some sampling days exceed the measured PM10 (last column, green cells). These may be due to sampling uncertainties among all parameters which is an expected source of error because of the varying analytical techniques involved. The preliminary data analysis resulted in the elimination of the ions **Fluoride [F^-]** and **Lithium [Ca^{+2}]** in the Phase 1 data analysis.

The method detection limits (MDLs) are also presented in the tables in ANNEXES 1-4 the MDLs are determined using the concentrations obtained from the filter blanks. When the sample concentrations are below the Method detection limit, these are substituted with ½ MDL.

The number of sampling dates considered for the Source apportionment modeling are 26 dates for PEZA, 37 dates for Capitol and 39 dates for Plaza Garden. Seventy-five (75) percent of the PM10 for Forestry is below 1.3ug/m3, which makes it a background station. Unfortunately, the number of sampling dates (25) for Forestry station is not enough to be accepted by the PMF modeling software. Hence, the three stations (PEZA, Capitol and Plaza Garden) proceeded in the Phase I and Phase II data analyses.

To get an idea on how high the results of the Phase I analysis are, the 75th percentile of the concentration of PM10, as well as the concentrations of the major chemical species considered are also presented in Table 3. The 75th percentile tells about the level at which 75% of the data points of the said chemical components may be found.

Table 3. 75th percentile of the PM10 and major chemical species for Forestry, PEZA, Capitol and Plaza Garden

	Forestry	**PEZA**	**Capitol**	**Plaza Garden**
Number of filter samples	25	26	37	39
Selected Chemical Species	**75th percentile**			
PM10	1.3	26.8	99.3	63.7
BC	1.00	2.4	8.1	8.0
$[SO_4^{-2}]$	0.06	0.1	0.1	0.1
$[NO_3^{-1}]$	0.02	0.02	0.04	0.03
$[PO_4^{-3}]$	0.03	0.03	0.03	0.03
$[NH_4^{+}]$	0.05	0.1	0.1	0.2
$[K^{+}]$	0.14	0.2	0.3	0.2
Chemical species with $P < 0.05$		As, Pb	$[Cl^{-}]$, As, Pb	$[Cl^{-}]$, As, Hg, Ni, Pb

3.2 Phase 1 Data analysis

The PMF input data consisted of **21** species (including PM10 mass), with species input set to a modeling uncertainty of 10-20%, and resulting in a signal to noise ratio of 0.1-8.6. The PMF run output passed the diagnostic statistics, at six factor profiles, which resolved the average PM10 in the filter portion from 0.83 ug/m3 to 8.95 ug/m3 for PEZA, 0.38 ug/m3 to 27.37 ug/m3 for CAPITOL, AND 2.92 ug/m3 to 16.63 ug/m3 for Plaza Garden (KM0) . The residuals did not exceed +/- 5, except for a few, but are still within acceptable results. Report on the input data, and the satisfactory output data, including descriptive statistics, correlation coefficients, standard error, FPEAK runs selected and base model runs are presented in ANNEXES 5-7 (Results of Analysis, EPSL).

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3.3 Phase 2 Data Analysis

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 (EF) of the EPSL-IESM-UPD, with indications of 25%, 50% and 100% chances that the ratio of the PM10 samples matches that of the EF. The indicator elements are those that are coming from the vehicle emissions (VE), which can be resolved into either diesel or gasoline source. Also included are indicator elements for biomass burning (BB) and road dust (RD). It is important to note that RD and coarse dust will be mentioned as emission source in the succeeding discussion, in which the major difference is that RD are the emission source that are identified using the elemental indicators from the EF, while **'coarse dust'** are the fraction of PM10 **resolved** during the PMF run after the all the 20 species are diminished from the Total PM10. The resolved coarse dust are then apportioned with the amount ofVE, BB and RD that are resolved in the PM10.The resolved coarse dust are presumed to be those portions of PM10 that are insoluble in water, but formed a part of the chemical signatures that are considered in the Phase 1 data analysis. There will also be a mentioned "other coarse dust" in which are assigned to those remaining unresolved fraction of the PM 10. The resolved PM10 factors were then assigned and presented in Tables 3-5.

Source Apportionment Results for PEZA Compound Loakan Road Baguio City (2019-2021)

The PM10 concentration from PEZA ranges from 1.0 ug/m3 to 74.0 ug/m3 out of 26 unique sampling data from July 20, 2019 to January 30, 2021. Source apportionment modeling resolved 24% in slight correlation with observed data (r2 = 0.57, Figure 2) of the observed PM 10. This fraction of PM10 is then resolved into six (6) factors sources (Table 4). The contribution of the resolved factors in the PM10 samples are plotted in a time series in Figure 3.

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The highest PM 10 was resolved in Factor 1, which comprises 93% of coarse dust that are made up from biomass burning and vehicle emissions sources, two percent (2%) of which are black carbon. The rest of the components of Factor 1 (5%) are made-up of biomass burning and vehicle emissions. The sample from December 9, 2020 gained the highest contribution of coarse dust, while the filter sample from Nov 27, 2020 marked the lowest coarse dust fraction. Factors 2 and 6 gained the second and third highest resolved PM10 from PEZA, at 16% and 15%, respectively, and both had the highest percentage of biomass burning and vehicle emissions. Factors 3 and 4 comprise the rest of the PM10, and are also dominated by biomass burning and vehicle emission sources. Although all the resolved factors are mixed with road dust, RD was evident in factors 2, 3 and 5 in PEZA station.

The highest BC fraction was resolved in Factor 5 at 60% of the resolved PM10. The sampling date from Jan 13, 2021 marked the highest resolved BC. One can also notice that the emission factor markers indicate that Factor 5 mainly comes from biomass burning and vehicle emission sources. In the time series for PEZA (Figure 3), the biomass burning and vehicle emissions are also apparent in Factor 6 during the pre-pandemic period, and then were reduced during the pandemic period. Only the Factor 1, mostly from coarse dust fractions from biomass burning and the amount of PM 10 increased starting October 2020 onwards, which is the period when the work activities are starting to slowly resume after long months of being on lock-down due to COVID-19 restrictions. Illustration of the filter samples are presented in Table 5.

Table 4. The USEPA PMF V.5 resolved six-factor sources for EMB-CAR PM10 sampled between July 2019 to January 2021 in PEZA station.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Percentage of PM10, out of all factors resolved	45%	16%	13%	4%	6%	15%
Percentage of BC out of each of the factor PM10	2%	5%	6%	13%	60%	25%
Percentage of Coarse dust out of each of the factor PM10	93%	73%	43%	16%	0%	14%
Highest percentage of emission from	BB	BB, VE	VE	BB	BB, VE	VE
Mixed with:	VE	RD	BB, RD	VE	RD	BB

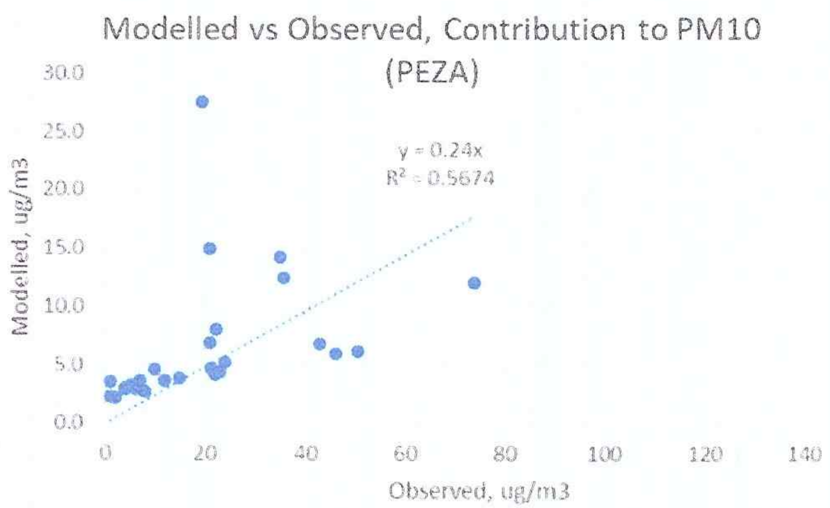


Figure 2. Correlation between modelled and observed values, forced to zero intercept for PEZA, showing the percentage of the resolved PM10 values on each sampling date by the source apportionment model.

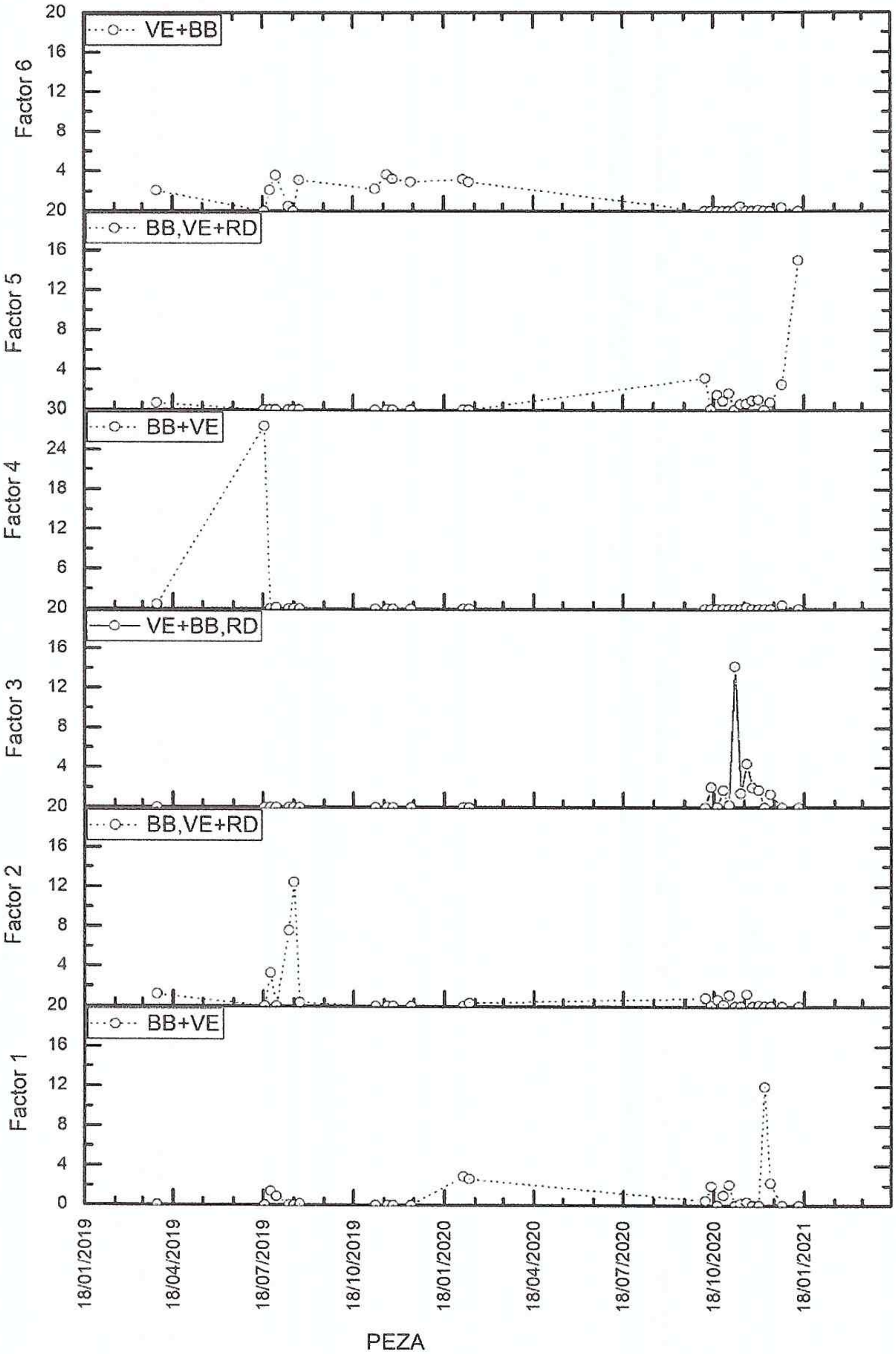
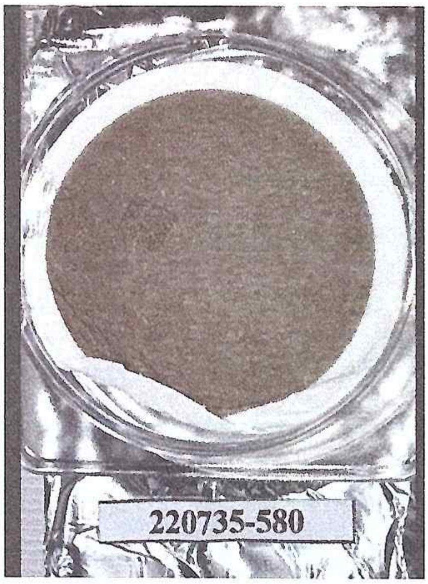
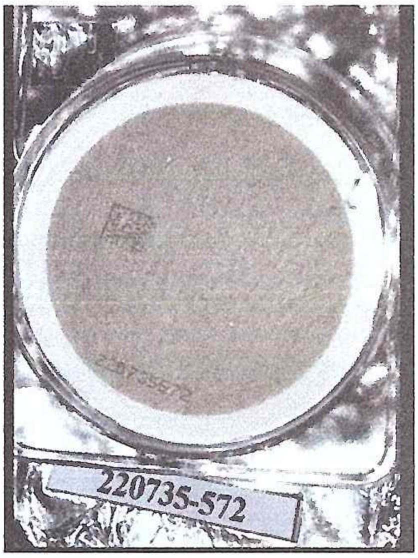
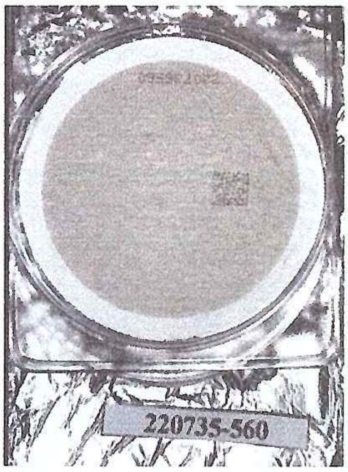


Figure 3. Time series of the contribution of resolved factor sources in the PM10 samples from PEZA

Table 5: Photo of filter samples that have the highest and lowest percentages of Coarse dust and Black carbon (BC).

 Highest apportioned Coarse dust, Factor 1 from PEZA on Dec 9, 2020	 Lowest apportioned Coarse dust, Factor 1, from PEZA on Nov 27, 2020
 220929-437 Highest apportioned BC, Factor 5, from PEZA on January 13, 2021.	 Lowest apportioned BC from Factor 5 Nov 9, 2020

The VE, RD, and BB apportioned are plotted in a pie chart in Figure 4, in which shown side-by-side are the apportioned fraction of the factor sources attributed to diesel-fed (9.4%) and gasoline-fed (21.4%) vehicles plying the area of PEZA. The fraction of ammonium sulfate, ammonium nitrate and seasalt were all less than 1%. Overall in PEZA, biomass burning and vehicle emission sources dominate the PM10 fractions from 2019 to 2021, marking both at 31%. The component of PM10 was followed by road dust at 25% and other coarse dust at 12%.

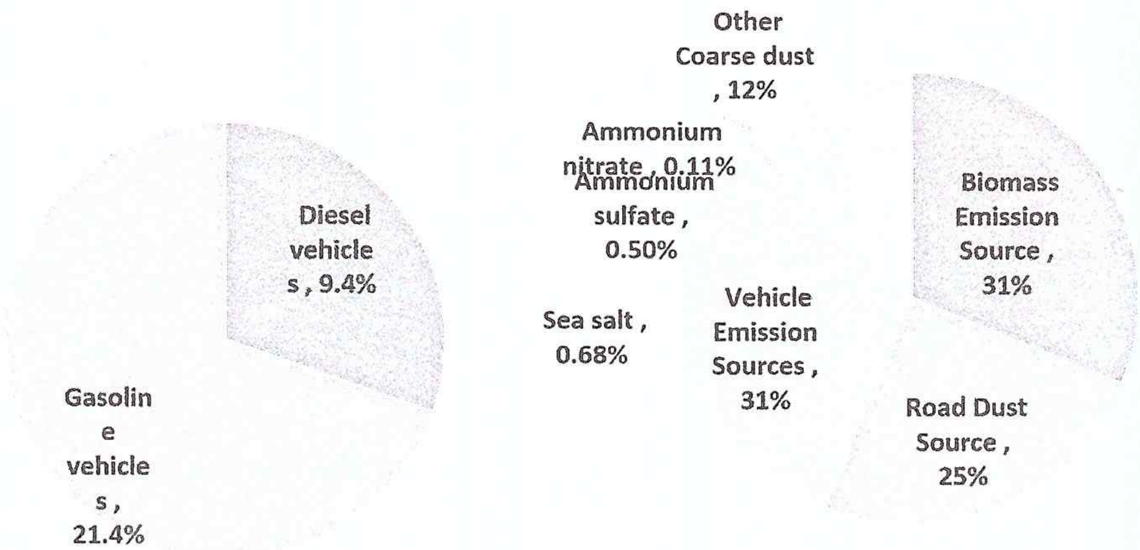


Figure 4. Pie charts for source apportionment of PM10 in PEZA Station, 2019-2021. (left) Fraction of apportioned PM10 attributed to diesel-fed and gasoline-fed vehicles. (Right) The apportioned PM10 attributed to all the identified sources.

Source Apportionment Results for Provincial Capitol Hall Ground, La Trinidad, Benguet (KM 6, 2019-2021)

The PM10 concentration from the Provincial Capitol Hall Ground, La Trinidad, Benguet (KM 6) ranges from 9.9 ug/m3 to 134.3 ug/m3 out of 37 unique sampling data from April 8, 2019 to January 21, 2021. Source apportionment modeling resolved from 5% to 91% (Average = 12%) in moderate correlation with observed data (r2 = 0.65, Figure 5) of the observed PM 10. This fraction of PM10 is then resolved into six (6) factors sources (Table 5). The contribution of the resolved factors in the PM10 samples are plotted in a time series in Figure 6.

The highest PM 10 was resolved in Factor 6, which comprises 89% of coarse dust that are made up from vehicle emission sources mixed with biomass burning and road dust sources, nine percent (9%) of which are black carbon. The sample from September 15, 2019 gained the highest contribution of coarse dust, while the filter sample from January 21, 2021 marked the lowest coarse dust fraction. Factors 1 and 5 gained the second and third highest resolved PM10 from Provincial Capitol Compound, at 29% and 22%, respectively, and both had dominant fractions of biomass burning and vehicle emissions. Factors 2, 3 and 4 comprise the rest of the PM10, and are also dominated by biomass burning and vehicle emission sources.

The highest BC fraction was resolved in Factor 3 at 68% of the resolved PM10. The sampling date from Feb 8, 2020 marked the highest resolved BC, and it was during the onset of the COVID-19 pandemic. One can also notice that the emission factor markers indicate that Factors 1-6 mainly come from biomass burning and vehicle emission sources. In the time series for Provincial Capitol Compounds (Figure 6), the biomass burning emissions sources are apparent in Factors 1-4, and differentiated according to the occurrences of biomass burning episodes. For example, Factor 1 are emissions from biomass burning before the pandemic, and are mixed with sulfate. Two thirds of the black carbon from factor 1 may be attributed to biomass burning sources, as 69% of this factor is from BB, while 23% are from Vehicle emission sources. Factor 2 biomass burning, on the other hand, are those emissions amid the pandemic, as most of its contributions occurs from Oct 2020 to January 2021.

Around 63% of the black carbon in Factor 2 are attributed to biomass burning, while 31% to vehicle emission sources. Although Factor 3 marked the smallest fraction of resolved PM10, it is in this factor when the highest fraction of black carbon from the pre-pandemic period occurred. The resolved Factor 3 is also mixed with the largest fraction of phosphate, an indicator of smoke from biomass burning. Factor 4 are those emissions that happened before the pandemic period as well, and are also attributed to biomass burning, vehicle emissions with a mix of coarse dust. In addition, a practical portion of seasalt components are apportioned in Factor 4, and is apparent by the high level of Chlorine ion component on August 30, 2019. On the other hand, majority of Factor 5 are attributed to vehicle emissions, then secondarily to biomass burning emissions, while factor 6, largest resolved PM 10, is attributed almost equally to BB, VE and RD. Illustration of the filter samples are presented in Table 5.

Table 5. The US EPA PMF V.5 resolved six-factor sources for EMB-CAR PM10 sampled between January 2019 to January 2021 station between January 2019 to January 2021 in Capitol Compound, LTB station.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Percentage of PM10, out of all factors resolved	29%	6%	1%	2%	22%	41%
Percentage of BC out of each of the factor PM10	9%	9%	68%	31%	8%	9%
Percentage of Coarse dust out of each of the factor PM10	84%	42%	0%	48%	86%	89%
Highest percentage of emission from	BB	BB	BB	BB	VE	VE
Mixed with:	VE	VE	VE	VE	BB	BB, RD

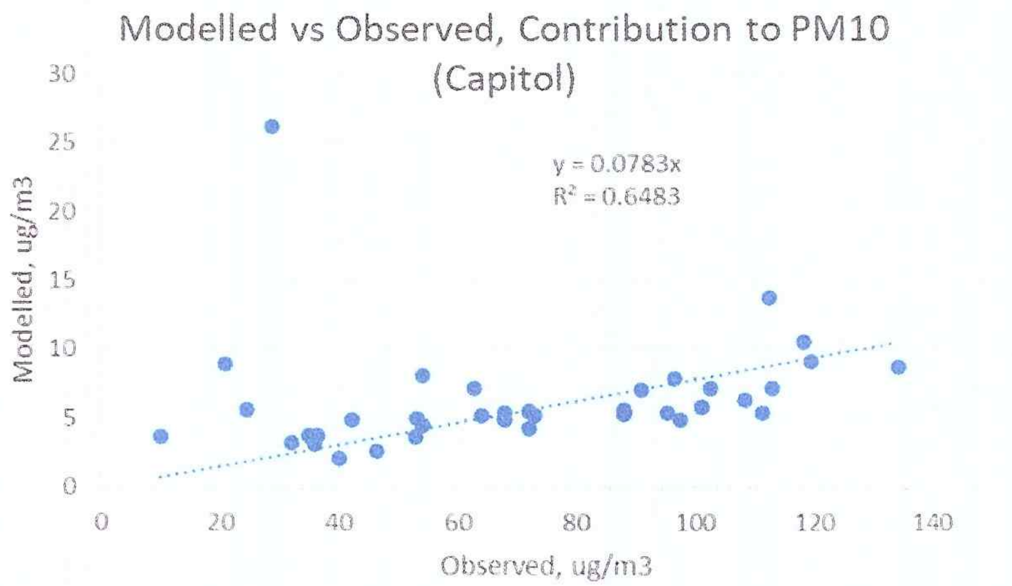


Figure 5. Correlation between modelled and observed values, forced to zero intercept for Capitol Compound LTB station, showing the percentage of the resolved PM10 values on each sampling date by the source apportionment model.

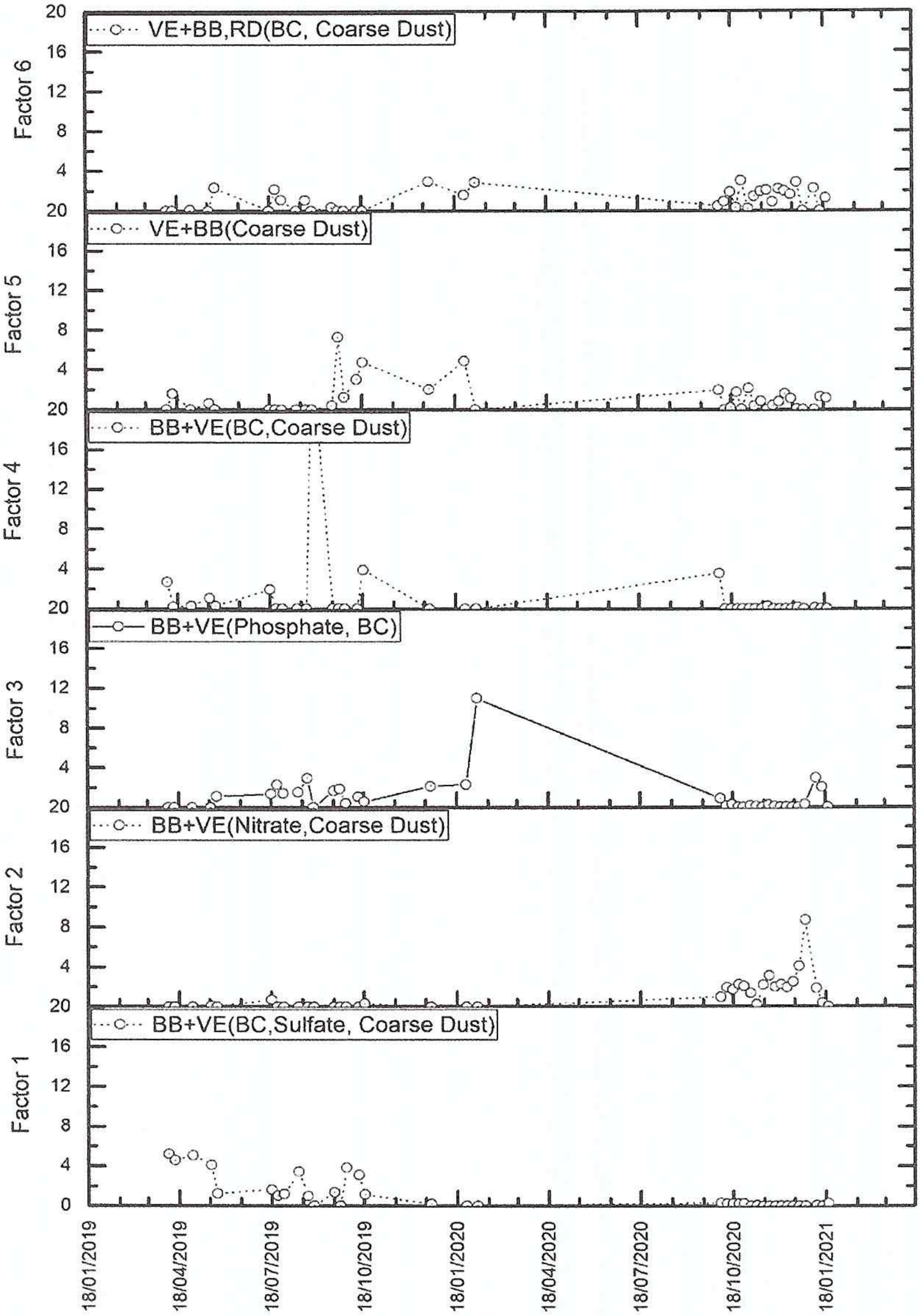
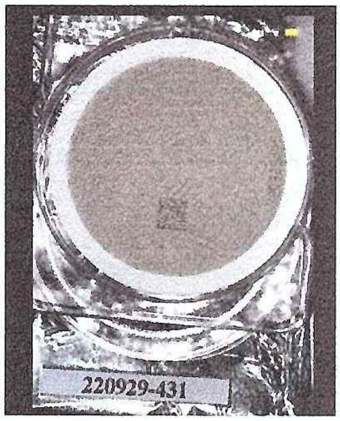


Figure 6. Time series of the contribution of resolved factor sources in the PM10 samples from Capitol Compound LTB station.

Table 6: Photo of filter samples that have the highest and lowest percentages of Coarse dust and Black carbon (BC).

<table>
<tr>
<td>
Highest apportioned Coarse dust, Factor 1 from Capitol Compound, LTB station on Sep 25, 2019</td>
<td>
Lowest apportioned Coarse dust, Factor 1, from Capitol Compound, LTB station on January 21, 2021</td>
</tr>
<tr>
<td>
Highest apportioned BC, Factor 3, from Capitol Compound, LTB station on February 8, 2020.</td>
<td>

Lowest apportioned BC, Factor 6 from Capitol Compound, LTB station Dec 29, 2020</td>
</tr>
<tr>
<td colspan="2">

Recorded high concentration of [Cl-] at 2.6ug/m3 on August 30, 2019 in Capitol Compound, LTB station.</td>
</tr>
</table>

The VE, RD, and BB apportioned are plotted in a pie chart in Figure 7, in which shown side-by-side are the apportioned fraction of the factor sources attributed to diesel-fed (13%) and gasoline-fed (18%) vehicles plying the area of Capitol Compound, LTB station. The fraction of ammonium sulfate, ammonium nitrate and seasalt were all less than 1%, while the unresolved other coarse dust is about 9.3%. Overall in Capitol Compound, LTB station, the biomass burning (43.2%) and vehicle emission (31.8%) sources dominate the PM10 fractions from 2019 to 2021. The component of PM10 was followed by road dust at 15.1% and other unresolved coarse dust at 9.3%.

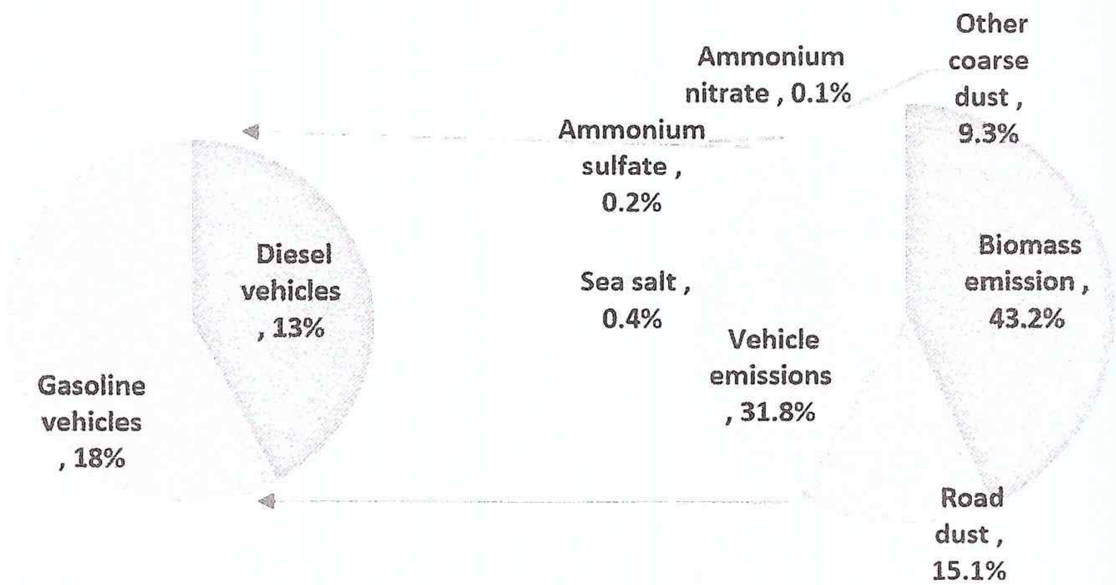


Figure 7 Pie charts for source apportionment of PM10 in Capitol Compound, LTB station, 2019-2021. (left) Fraction of apportioned PM10 attributed to diesel-fed and gasoline-fed vehicles. (Right) The apportioned PM10 attributed to all the identified sources.

Source Apportionment Results for Plaza Garden Lower Session Road Baguio City (KM0, 2019-2021)

The PM10 concentration from the Plaza Garden Lower Session Road Baguio City (KM 0) ranges from 18 ug/m3 to 113.9 ug/m3 out of 39 unique sampling data from April 2, 2019 to January 19, 2021. Source apportionment modeling resolved from 5% to 40% (Average = 13%) in good correlation with observed data ($r2 = 0.73$, Figure 8) of the observed PM 10. This fraction of PM10 is then resolved into six (6) factors sources (Table 7). The contribution of the resolved factors in the PM10 samples are plotted in a time series in Figure 9.

The highest PM 10 was resolved in Factor 2, which comprises 77% of coarse dust that are made up from vehicle emission sources mixed with biomass burning and vehicle emission sources, thirteen percent (13%) of which are black carbon. The sample from February 19, 2020 gained the highest contribution of coarse dust, while the filter sample from Oct 16, 2022 marked the lowest coarse dust fraction. Factors 3 and 1 gained the second and third highest resolved PM10 from Plaza Garden Lower Session Road Baguio City , at 24% and 21%, respectively, and both had dominant fractions of biomass burning and vehicle emissions. Factors 4 and 5 have PM10 resolved at the following percentages, 6% (BC: 14%) and 10% (BC: 15%), respectively, and are also dominated by biomass burning and vehicle emission sources. Lastly, Factor 6 resolved 7% of the PM10, in which 11% is BC, 1% seasalt component and 1% ammonium sulfate component.

The highest BC fraction was resolved in Factor 3 at 16% of the resolved PM10. The sampling date from December 24, 2020 marked the highest resolved BC in Factor 3 which was a high-tourism event during the 2020. But the highest resolved contribution of PM10 was recorded on Nov 4, 2019 in Factor 4 (at 23.9 ug/m3), during a cold season and a few months before the onset of the COVID-19 pandemic. Notice the intense blackness of the filter sample on Nov 4, 2019. On the other hand, the source apportionment model was also able to point at the sampling date with the highest fraction contributed by black carbon (from Factor 3), which happened on

Dec 24, 2020; also the sampling date with the lowest apportioned BC that happened on Oct 22, 2020 (pandemic period). Factor 3 are the PM10 attributed to biomass burning and vehicle emissions amid the pandemic period (shown in Figure 9, contribution plot Factor 3), while Factor 2 is the PM10 attributed to biomass burning and vehicle emissions before the onset of the COVID-19 pandemic (shown in Figure 9, contribution plot Factor 2). The resolved Factors 1, 4, 5, 6 are influenced by coarse dust episodes of various occasions, but majorly a mixture of biomass burning and vehicle emissions. Illustration of the filter samples are presented in Table 8.

Table 7. The US EPA PMF V.5 resolved six-factor sources for EMB-CAR PM10 sampled between April 2019 to January 2021 in Plaza Garden Lower Session Road Baguio City

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Percentage of PM10, out of all factors resolved	21%	33%	24%	6%	10%	7%
Percentage of BC out of each of the factor PM10	8%	13%	16%	14%	15%	11%
Percentage of Coarse dust out of each of the factor PM10	85%	77%	68%	63%	61%	58%
Highest percentage of emission from	BB	BB	BB	BB	BB	VE
Mixed with:	VE	VE	VE	VE	VE	BB

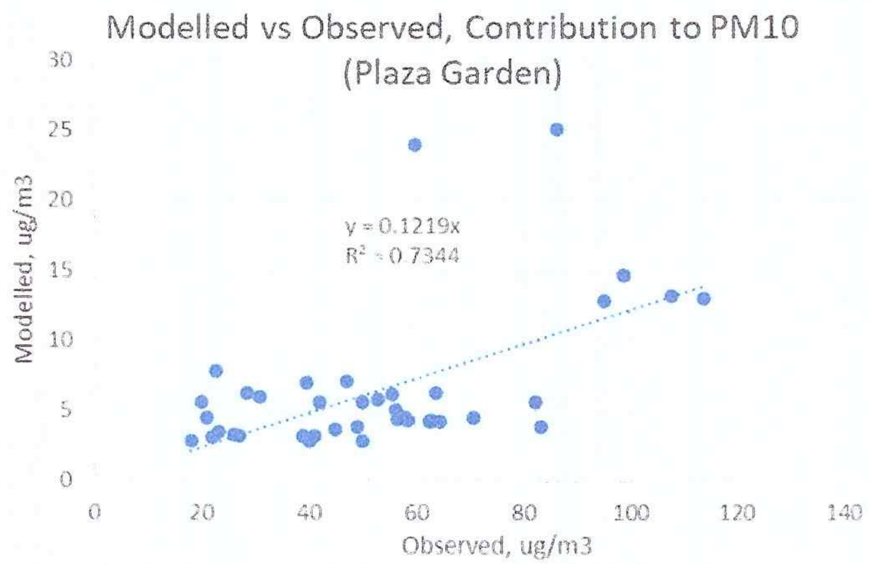
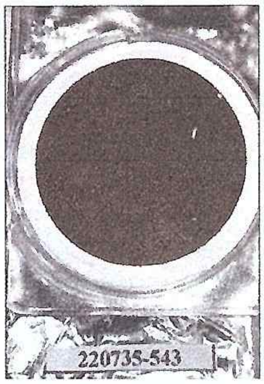
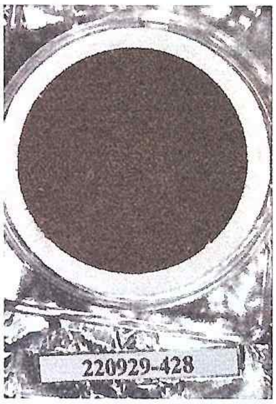
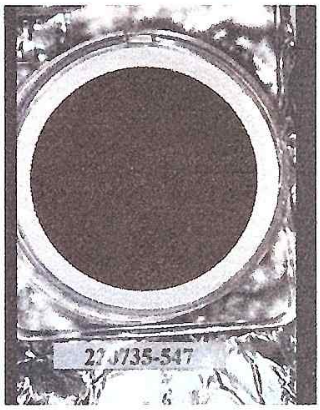


Figure 8. Correlation between modelled and observed values, forced to zero intercept for Plaza Garden (KM0), showing the percentage of the resolved PM10 values on each sampling date by the source apportionment model.

Table 8: Photo of filter samples that have the highest and lowest percentages of Coarse dust and Black carbon (BC).

 Highest apportioned Coarse dust, Factor 3 from Plaza Garden Lower Session Road Baguio City station on February 19, 2020	 Lowest apportioned Coarse dust, Factor 1, from Plaza Garden Lower Session Road Baguio City station on Oct 16, 2022
 Highest apportioned BC, Factor 3, from Plaza Garden Lower Session Road Baguio City station on December 24, 2020.	 Lowest apportioned BC, Factor 1 from Plaza Garden Lower Session Road Baguio City station Oct 22, 2020
 Recorded high percentage of resolved BC (14%) and seasalt (6%) on Nov 4, 2019 in Plaza Garden Lower Session Road Baguio City station for Factor 4 that comprises mainly of BB and VE sources.	

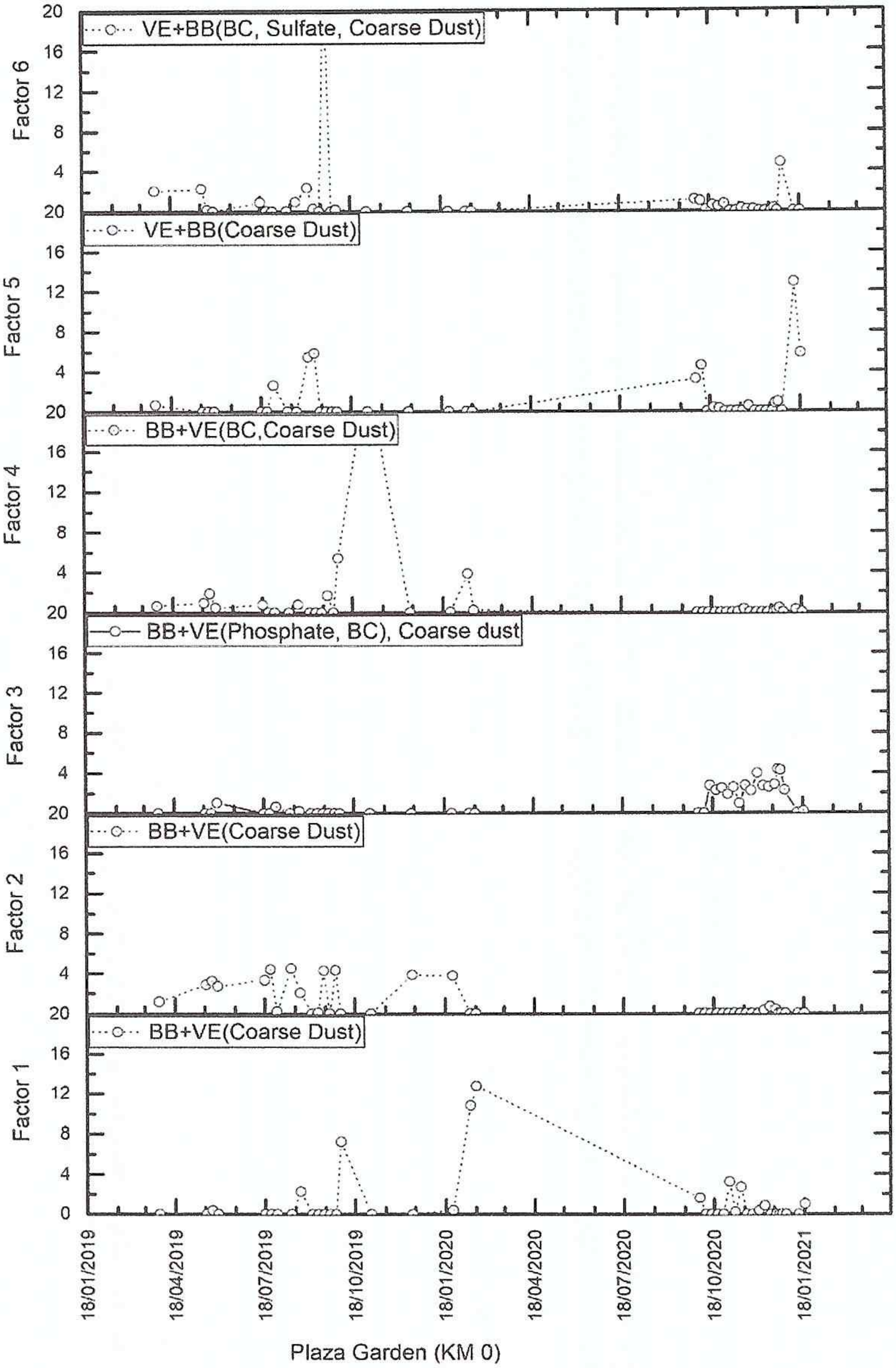


Figure 9 Time series of the contribution of resolved factor sources in the PM10 samples from Plaza Garden Lower Session Road Baguio City station

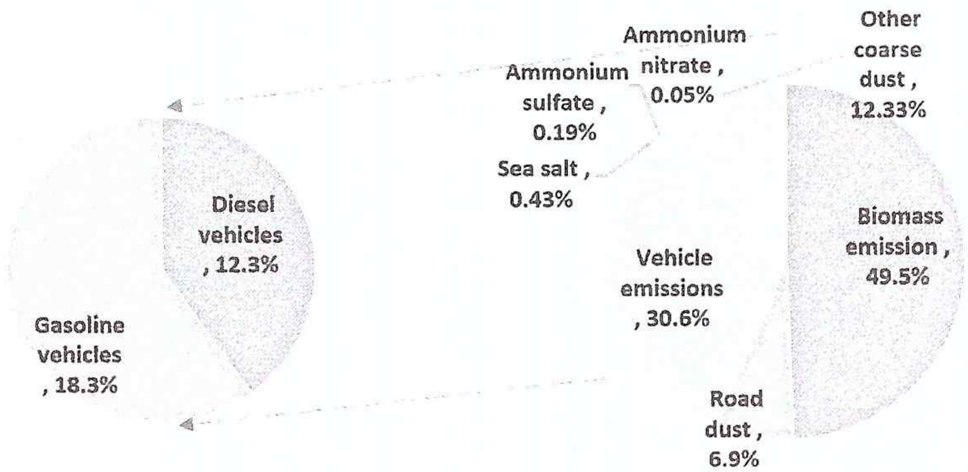


Figure 10 Pie charts for source apportionment of PM10 in Plaza Garden Lower Session Road Baguio City station, 2019-2021. (left) Fraction of apportioned PM10 attributed to diesel-fed and gasoline-fed vehicles. (Right) The apportioned PM10 attributed to all the identified sources.

The BB and VE apportioned are plotted in a pie chart in Figure 10, in which shown side-by-side are the apportioned fraction of the factor sources attributed to diesel-fed (12.3%) and gasoline-fed (18.3%) vehicles plying the area of Plaza Garden Lower Session Road Baguio City station from 2019-2021. The fraction of ammonium sulfate, ammonium nitrate and seasalt were all less than 1%, while the unresolved other coarse dust is about 12.33%. Overall in Plaza Garden Lower Session Road Baguio City station, the biomass burning (49.5%) and vehicle emission (30.6%) sources dominate the PM10 fractions from 2019 to 2021. The component of PM10 was followed by road dust at 6.9% and other unresolved coarse dust at 12.33%.

III. Summary and Recommendations

4.1 Summary

In summary, this study provides Source apportionment study results for PM_{10} sampled from the Cordillera Administrative Region (CAR) in 2019-2021. Overall, from the 126 valid air particulate matter filters sampled for 24 hours, the main factor source is from biomass burning that ranges from 31% to 49.5% of the PM10. Roadside stations of Plaza Garden and Capitol/LTB exhibit almost the same percentages of resolved PM10 due to vehicle emissions, at 30.6% and 31.8% respectively, while the percentage of road dust is highest in PEZA (Loakan) station, at 25%.

4.2 Recommendations

Since the highest source of PM10 has been attributed to biomass burning, it is suggested to strictly implement the 'no open burning' policy in open spaces of Cordillera Administrative Region.

Cooking using inefficient solid fuels such as firewood and charcoal is also suggested to be regulated.

Awareness campaigns to mainstream the prohibition of open burning may also be conducted at all levels of education. Moreover, public information campaigns on the harmful effects of biomass burning in the environment and the health are also highly encouraged to be conducted.

Implementation of a traffic scheme that will avoid further emissions from vehicle sources are highly recommended. Regulating the traffic and managing when the vehicles begin to congest in one place is also one suggested solution.

Environmental users fee for all vehicles entering the CAR is recommended as well. The fund that will be generated may be used in managing the mobile sources.

Studies relating the health and economical benefits when the air pollution is managed are also recommended.

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Cayetano, MG, (2020c) Look-up Table of Emission Factors – Philippines. Environmental Pollution Studies Laboratory Lab notebook No. 2, Appendix 1, pp 1-2

ANNEXES

V. ANNEXES

ANNEX 1: Preliminary Data Analysis Results in PM10 filter samples from FORESTRY Station, 2019-2021

Count	EPSL Code	Volume of a	Sample Code	Date	PM 10 conc	BC, ug/NC	Cl	SO4-2, ug/	NO3-, ug/m3	PO4-3, ug	Li+, ug/	Na+, ug/	NH4+, ug	K+ ug/m	Mg2+, ug	Ca2+, ug/m	Al, ug/m3	As, ug/m3	Cd, ug/m3	Cr, ug/m3	Cu, ug/m3	Hg, ug/m3	Mn, ug/m3	Ni, ug/m3	Pb, ug/m3	Zn, ug/m3	% in PM10
305	2200501 F	21.4	UPD-ESM-DENR2100425B	October 29, 2020	10	0.4	0.3172	0.0246	0.0072	0.0127	*****	2.3670		0.0510	0.0780	0.2280	0.0005	0.0003	0.0070	0.0088	0.0005	0.0034	0.0002	0.0053738	0.0008	0.0234	38.62%
306	2200502 F	21.8	UPD-ESM-DENR2100417B	October 18, 2020	17	0.5	0.3197	0.0299	0.0057	0.0144	*****	2.6190		0.0440	0.0730	0.2330	0.0013	0.0024		0.0072	0.0019	0.0103	0.0003	0.0004930	0.0018	0.0463	24.67%
307	2200503 F	21.5	UPD-ESM-DENR2100433B	November 11, 2020	1	0.6	0.2968	0.0063	0.0129	0.0144	*****	2.9670		0.0590	0.0700	0.2400						0.0057					475.00%
308	2200504 F	21.4	UPD-ESM-DENR2100445B	November 29, 2020	1	0.6	0.2281	0.0196	0.0098	0.0166	*****	2.6640		0.0473	0.0640	0.3180						0.0077					447.27%
309	2200505 F	20.6	220735-282BFAR	August 19, 2019	27.1	0.6	0.3915	0.2315	0.0187	0.0563	*****	3.5880		0.1440	0.2500	0.8150	0.0034	0.0077	0.3063	0.0083	0.0034	0.0049	0.0005		0.0031	0.0485	24.30%
310	2200506 F	20	UPD-ESM-DENR2100441B	November 23, 2020	20	0.6	0.3858	0.0323	0.0195	0.0125	*****	3.1160	0.0000	0.0940	0.1020	0.3440	0.0030	0.0020	0.0059		0.0030	0.0101			0.0034	0.0500	24.41%
311	2200507 F	21	220735-385BFAR	February 9, 2020	26.8	0.6	1.8257	0.0188	0.0137	0.0157	*****	3.0070		0.0440	0.2130	0.4280	0.0021	0.0051	0.2397	0.0054	0.0021	0.0127	0.0005			0.0714	21.52%
312	2200508 F	20.3	220735-312BFAR	October 31, 2019	5.1	0.8	0.5067	0.0348	0.0079	0.0217	0.0360	3.1760		0.0710	0.1710	0.3850	0.0017	0.0071	0.2855	0.0084	0.0017	0.0043	0.0015		0.0016	0.1232	107.76%
313	2200509 F	20.8	220929-435BFAR	January 9, 2021	13.2	0.7	2.8431	0.0189	0.0194	0.0368	*****	6.4040		0.0810	0.4270	0.8280	0.0159	0.0105	0.3381	0.0171	0.0159	0.0093	0.0058	0.0036058	0.0058	0.0431	90.61%
314	2200510 F	21.5	UPD-ESM-DENR2100429B	November 5, 2020	14	0.7	2.6758	0.0850	0.0400	0.0359	*****	#######		0.1540	0.0000	0.1150	0.0014		0.0253		0.0014	0.0063			0.0006	0.0455	395.73%
330	2200532 F	20.8	220735-262BFAR	July 20, 2019	2	1		0.0581	0.0123	0.0293	*****	3.7530	0.0020	0.0920	0.2910	0.6310	0.0012	0.0057	0.7100	0.0123	0.0012	0.0090	0.0154	0.0024030	0.0000	0.4008	359.55%
340	2200536 F	20.8	220735-266BFAR	July 26, 2019	22.9	1.1		0.0839	0.0118	0.0324	*****	4.2020	0.0100	0.0910	0.1120	0.4630	0.0034	0.5766	0.2568	0.0079	0.0034	0.1115	0.0005		0.6329	0.0481	35.44%
345	2200541 F	20.9	220735-276BFAR	August 15, 2019	32.1	0.7		0.2333	0.0140	0.0271	*****	3.9500	0.0040	0.1450	0.2570	0.5390	0.0043	0.0077	0.3043	0.0098	0.0043	0.0059	0.0024		0.0033	0.0478	19.74%
351	2200547 F	20.5	220735-280BFAR	August 25, 2019	1.2	0.7		0.0586	0.0202	0.0292	*****	3.1760		0.0650	0.1590	0.4110	0.0027	0.0070	0.2924	0.0100	0.0027	0.0076			0.0025	0.0409	427.64%
353	2200549 F	11.6	220735-290BFAR	September 13, 2019	5.3	0.7		0.2386	0.0291	0.0549	0.0130	5.7710	0.1130	0.2460	0.4230	1.3690	0.0241	0.0135	0.4893	0.0220	0.0241	0.0153	0.0086	0.0030172	0.0056	0.0652	182.11%
369	2200565 F	20.9	220735-377BFAR	January 26, 2020	54.6	1.4	0.0146	0.1096	0.0516	0.0969	*****	4.0070	0.0300	0.2450	0.2380	1.0440	0.0007	0.0102	0.3139	0.0087	0.0007	0.0117	0.0014		0.0071	0.0239	14.03%
370	2200566 F	20.8	220735-303PE2A	February 7, 2020	50.6	2.6	0.0128	0.0613	0.0305	0.0320	*****	3.5990	0.0040	0.2280	0.2020	0.9860	0.0153	0.0148	0.3000	0.0072	0.0159	0.0209	0.0100	0.0040065	0.0134	0.0461	16.49%
377	2200573 F	21	220929-439BFAR	January 15, 2021	33.6	1.4		0.0393	0.0272	0.0442	*****	3.6300		0.0800	0.1280	0.5150	0.0181	0.0096	0.4016	0.0121	0.0181	0.0084	0.0105	0.0030952	0.0053	0.0476	19.41%
390	2200586 F	21.1	UPD-ESM-DENR2100421B	October 24, 2020	3	0.7	0.0046	0.0517	0.0133		0.0004	2.9990		0.0870	0.0880	0.3860	0.0052	0.0022	0.0048	0.0121	0.0052	0.0117	0.0017		0.0042	0.0711	149.34%
403	2200599 F	20	UPD-ESM-DENR2100437B	November 17, 2020	5	0.7		0.0236	0.0171	0.0097	0.0004	3.3130		0.0640	0.1010	0.4640	0.0013		0.0265		0.0013	0.0065				0.0500	57.21%
413	2200609 F	21	UPD-ESM-DENR2100449B	December 5, 2020	13	0.9		0.0184	0.0169	0.0022	0.0003	3.3920		0.1440	0.0900	0.5390	0.0021			0.0040	0.0021	0.0091	0.0002	0.0004762		0.0476	41.92%
417	2200613 F	21.1	UPD-ESM-DENR2100453B	December 11, 2020	1	0.8		0.0357	0.0205		0.0004	3.7480		0.1120	0.1220	0.5080	0.0005	0.0026		0.0078	0.0005	0.0118			0.0044	0.0474	570.70%
421	2200617 F	21.3	UPD-ESM-DENR2100457B	December 17, 2020	8	1	0.0025	0.0228	0.0161		0.0005	2.9360		0.0850	0.0920	0.5080	0.0012	0.0029		0.0040	0.0012	0.0035	0.0014	0.0050685	0.0050	0.1174	63.43%
424	2200620 F	21.1	UPD-ESM-DENR2100460B	December 23, 2020	13	0.8	0.0511	0.0146	0.0137		0.0004	6.5840		0.0920	0.4350	0.9390	0.0023	0.0030	0.0111	0.0066	0.0029	0.0100	0.0629		0.0055	0.0474	69.86%
423	2200625 F	21.1	UPD-ESM-DENR2100465B	December 29, 2020	54	4.8	0.0605	0.0184	0.0188	0.0045	*****	6.0480	0.0100	0.0480	0.5440	1.6100	0.0023	0.0079	0.0063	0.0059	0.0028	0.0105	0.0043	0.0016588	0.0141	0.0474	24.71%
MDL					**1.1**	**1.2**	0.0007	0.0017	0.0013	0.0009	0.1510	0.0520	0.0930	0.0790	0.0900	0.3400	**0.0227**	**0.0100**	**0.4432**	**0.0135**	**0.0227**	**0.0136**	**0.0263**	**0.0066**	**0.0142**	**0.1527**	
average (lower limit)					0.8																						
SD(N=30, 2.821)					0.1																						
Median	**missing**				10	4.05	0.00624	0.050003	0.01300	0.02055	0.076	3.451	0.0465	0.1095	0.1035	0.013	0.00506039	0.00790647	0.27419377	0.00380661	0.00506039	0.01031335	0.00703333	0.00327257	0.00734340	0.07211530	
Minimum					1	0.4	0.00035	0.0063	0.00543	0.00045	2E-04	0.026	0	0.003	0	0.115	0.00046729	0.0003328	0.00075387	0.00024038	0.00046729	0.00353415	0.00023364	0.00011261	2.2835E-05	0.02336449	
1/2 MDL	**values are**				0.55597581	0.6	0.00035	0.00085	0.00065	0.00045	0.076	0.028	0.0465	0.0395	0.015	0.174	0.01133001	0.00501722	0.22159899	0.0067627	0.01133001	0.00676719	0.01338127	0.00327857	0.0070938	0.07635728	
75th percentile					27.1	1.00		0.0613	0.02049	0.032			0.0465	0.144													
max					54.6	4.8		0.2385	0.0516	0.0569			0.1130	0.2480													
98th percentile																											

ANNEX 2: Preliminary Data Analysis Results in PM10 filter samples from PEZA Station, 2019-2021

Count	EPSL Code		Volume of a	Sample Code	Date	PM 10 conc	BC, ug/NCM	Cl
335	2200531	P	20.8	220735-261PEZA	July 20, 2019	19.5	2.6	1.5353
339	2200535	P	20.8	220735-265PEZA	July 26, 2019	42.5	3.5	0.0118
343	2200539	P	24	220735-269PEZA	August 1, 2019	21.4	1.6	0.0260
344	2200540	P	24	220735-275PEZA	August 14, 2019	22.4	0.8	#####
348	2200544	P	20.8	220735-281PEZA	August 19, 2019	35.7	2.1	#####
350	2200546	P	20.8	220735-285PEZA	August 25, 2019	11.9	2.4	#####
361	2200557	P	21	220735-313PEZA	##############	2.1	2.2	#####
362	2200558	P	20.8	220735-326PEZA	##############	7	2.1	#####
363	2200559	P	21	220735-330PEZA	##############	5.4	2.4	#####
365	2200561	P	20.8	220735-342PEZA	##############	6.3	2.3	0.0114
370	2200566	F	20.8	220735-383PEZA	February 7, 2020	50.6	2.6	0.0128
373	2200563	P	20.9	220735-367PEZA	February 13, 2020	45.1	2.4	0.0120
382	2200573	P	20.4	UPD-IESM-DENR2100411PE	October 10, 2020	10	1.7	0.0073
385	2200581	P	21.1	UPD-IESM-DENR2100415PI	October 16, 2020	22	1.2	#####
388	2200584	P	22.2	UPD-IESM-DENR2100419PI	October 22, 2020	1	1	0.0095
392	2200588	P	20.8	UPD-IESM-DENR2100423P	October 28, 2020	15	1	0.0035
395	2200591	P	21.8	UPD-IESM-DENR2100427P	November 3, 2020	24	1	#####
398	2200594	P	7.6	UPD-IESM-DENR2100431PI	November 9, 2020	35	1.7	#####
401	2200597	P	21.4	UPD-IESM-DENR2100435P	##############	8	1.2	#####
405	2200601	P	21.7	UPD-IESM-DENR2100439P	##############	21	1.4	0.0261
408	2200604	P	21.2	UPD-IESM-DENR2100443P	##############	4	0.9	#####
411	2200607	P	21	UPD-IESM-DENR2100447P	##############	4	1.7	#####
415	2200611	P	21.3	UPD-IESM-DENR2100451PI	##############	74	1.9	0.0025
419	2200615	P	22	UPD-IESM-DENR2100455P	##############	23	1.6	0.0004
427	2200623	P	21.1	UPD-IESM-DENR2100463P	##############	1	1.9	0.0541
323	2200519	P	7.7	220929-437PEZA	January 13, 2021	21	13	3.3158
MDL						1.1	1.2	0.0007
average (lower lmt)						0.8		
SD N=10, 2.021						0.1		
Median	missing						4.65	0.00624
Minimum							0.4	0.00035
1/2 MDL	values are					0.55587581	0.6	0.00035

Count	SO4-2, ug/m3	NO3-, ug/m3	PO4-3, ug/m3	Li+, ug/m3	Na+, ug/m3	NH4+, ug/m3	K+ ug/m3	Mg2+, ug/m3	Ca2+, ug/m3
335	0.1152	0.0261	0.0177	#####	######	0.2260	0.1870	0.0700	0.1450
339	0.1739	0.0125	0.0381	#####	3.7590	0.2660	0.1690	0.2500	1.0460
343	0.0611	0.0253	0.0337	0.0140	6.4930	0.2170	0.1700	0.2050	0.6540
344	0.2450	0.0074	0.0411	#####	4.0290	0.0310	0.1370	0.2700	0.6370
348	0.3576	0.0083	0.0413	#####	4.7280	0.1960	0.2660	0.3210	0.8230
350	0.0811	0.0194	0.0285	#####	3.5950	0.0010	0.0570	0.2050	0.6630
361	0.0262	0.0088	0.0254	0.0130	2.6030	0.0760	0.0360	0.1640	0.6510
362	0.0515	0.0240	0.0605	0.0150	3.2130	0.1040	0.0390	0.1990	0.9060
363	0.0445	0.0186	0.0563	#####	2.5090		0.0340	0.1530	0.5210
365	0.0424	0.0111	0.0305	0.0130	3.2850		0.0170	0.2100	0.7780
370	0.0613	0.0305	0.0320	#####	3.5990	0.0040	0.2280	0.2020	0.9860
373	0.0681	0.0252	0.0315	0.0140	3.7090	0.0370	0.1730	0.2480	0.7730
382	0.0697	0.0208		#####	3.4030	0.1990	0.4160	0.3160	2.0230
385	0.0129	0.0055	0.0009	0.0004	2.9370	0.0500	0.0230	0.0530	0.2880
388	0.0371	0.0073	0.0010	0.0008	3.7810		0.1600	0.0870	0.3120
392	0.0190	0.0038		0.0003	3.3890			0.0960	0.3560
395	0.0644	0.0196	0.0019	0.0004	3.8090		0.0300	0.1570	0.4350
398	0.0266	0.0192	0.0086	0.0005	######			0.1490	0.7710
401	0.0178	0.0098	0.0059	0.0005	2.9720		0.0190	0.0810	0.4010
405	0.0647	0.0484	0.0059	0.0004	6.3060		0.1990		1.1680
408	0.0092	0.0093		0.0004	3.3370		0.0070	0.0820	0.3640
411	0.0160	0.0118	0.0023	#####	3.2890		0.0090	0.0540	0.3310
415	0.0229	0.0114		#####	3.0350		0.0260	0.0930	0.5790
419	0.0106	0.0097		0.0003	3.2210		0.0280	0.0820	0.4380
427	0.0146	0.0175	0.0049	0.0003	6.2900		0.0570	0.4540	1.1570
323	0.1016	0.0778	0.0468	#####	######	0.0700	0.6540	1.3820	3.3670
MDL	0.0017	0.0013	0.0009	0.1510	0.0520	0.0930	0.0790	0.0900	0.3400
Median	0.050065	0.01888	0.02035	0.076	3.451	0.0465	0.1095	0.1865	0.819
Minimum	0.0053	0.00543	0.00045	2E-04	0.026	0	0.003	0	0.115
1/2 MDL	0.00065	0.00065	0.00045	0.076	0.026	0.0465	0.0395	0.045	0.174

Count	Al, ug/m3	As, ug/m3	Cd, ug/m3	Cr, ug/m3	Cu, ug/m3	Hg, ug/m3	Mn, ug/m3	Ni, ug/m3	Pb, ug/m3	Zn, ug/m3	% in PM10
335	0.0010	0.0039	0.2913	0.0039	0.0010	0.0031	0.0010		0.0065	0.0481	68.64%
339	0.0060	0.1153	0.2290	0.0123	0.0060	0.0355	0.0053	0.0013231	0.1538	0.0962	23.35%
343	0.0021	0.0072	0.2915	0.0077	0.0021	0.0107	0.0033	0.0018750	0.0030	0.0417	55.52%
344	0.0021	0.0112	0.2688	0.0127	0.0021	0.0070	0.0071	0.0104187	0.0095	0.0825	30.03%
348	0.0159	0.0104	0.3120	0.0055	0.0159	0.0130	0.0202	0.0188269	0.0072	0.0962	23.41%
350	0.0135	0.0104	0.2707	0.0084	0.0135	0.0184	0.0048	0.0001202	0.0072	0.0481	63.12%
361	0.0181	0.0060	0.3100	0.0060	0.0181	0.0103	0.0057		0.0034	0.0476	286.67%
362	0.0183	0.0169	0.2876	0.0123	0.0183	0.0076	0.0082		0.0195	0.0481	102.20%
363	0.0157	0.0107	0.2825	0.0098	0.0157	0.0156	0.0057		0.0078	0.0476	123.76%
365	0.0153	0.0117	0.2893	0.0147	0.0153	0.0225	0.0082		0.0104	0.0721	114.43%
370	0.0158	0.0148	0.3608	0.0072	0.0158	0.0208	0.0105	0.0040855	0.0134	0.0481	16.43%
373	0.0158	0.0061	0.2572	0.0084	0.0158	0.0110	0.0031	0.0004785	0.0013	0.0476	17.10%
382	0.0059		0.0123	0.0125	0.0059	0.0110	0.0027	0.0036765		0.0980	83.55%
385	0.0035	0.0005	0.0135	0.0216	0.0085	0.0085	0.0036		0.0012	0.0948	21.53%
388	0.0059	0.0013	0.0008	0.0137	0.0059	0.0047	0.0018	0.0001126	0.0027	0.0676	557.59%
392	0.0055	0.0023		0.0099	0.0055	0.0114	0.0029	0.0001442	0.0029	0.1202	35.62%
395	0.0039		0.0131	0.0089	0.0039	0.0092	0.0023			0.0688	24.21%
398	0.0053	0.0054		0.0263	0.0059	0.0341	0.0079		0.0094	0.1316	61.16%
401	0.0042	0.0007		0.0098	0.0042	0.0107	0.0012		0.0017	0.0497	63.22%
405	0.0083	0.0011		0.0394	0.0083	0.0063	0.0030		0.0025	0.0891	46.02%
408	0.0028	0.0017		0.0120	0.0028	0.0073	0.0014	0.0002123	0.0032	0.0472	125.41%
411	0.0019	0.0032		0.0217	0.0019	0.0168	0.0036	0.0014286	0.0060	0.0714	146.97%
415	0.0040			0.0143	0.0040	0.0087	0.0042			0.1174	8.35%
419	0.0050	0.0008	0.0008	0.0116	0.0050	0.0063	0.0023	0.0030303	0.0020	0.0455	24.02%
427	0.0021	0.0038		0.0121	0.0021	0.0125	0.0017		0.0073	0.0711	1033.38%
323		0.0324	1.2048			0.0368			0.0259		191.20%
MDL	0.0227	0.0180	0.4432	0.0135	0.0227	0.0136	0.0268	0.0066	0.0142	0.1527	
Median	0.00506099	0.00790547	0.27419377	0.00380861	0.00506099	0.01031935	0.00708333	0.00327857	0.00731548	0.07211539	
Minimum	0.00046723	0.0003328	0.00075287	0.00024038	0.00046729	0.00352415	0.00023364	0.0001261	2.2855E-05	0.02336449	
1/2 MDL	0.01133001	0.00501722	0.22159639	0.0067827	0.01133001	0.0067878	0.01338127	0.00327857	0.0070938	0.07635728	

ANNEX 4: Preliminary Data Analysis Results in PM10 filter samples from KM0 Station, 2019-2021

Count	EPSL Code	Volume of a	Sample Code	Date	PM 10 conc	BC, ug/NCM	Cl	SO_4^{2-}, ug/	NO_3^-, ug/m3	PO_4^{3-}, ug	Li^+, ug/	Na^+, ug/m	NH_4^+, ug	K^+ ug/m	Mg^{2+}, ug	Ca^{2+}, ug/m	Al, ug/m3	As, ug/m3	Cd, ug/m3	Cr, ug/m3	Cu, ug/m3	Hg, ug/m3	Mn, ug/m3	Ni, ug/m3	Pb, ug/m3	Zn, ug/m3	% in PM10
325	2200521 B	20.7	220735-215KM0	April 2, 2019	20.9	8.1	0.1108	0.0934	0.0086	0.0268	#####	3.2300	0.1260	0.1940	0.1660	0.4890	0.0012	0.0125	0.3042	0.0059	0.0072	0.0113	0.0043	#####	0.0109	0.0725	62.46%
323	2200525 B	20.9	220735-232KM0	May 20, 2019	55.5	7.8	0.1599	0.1888	0.0187	0.0251	#####	3.1400	0.6690	0.0910	0.1370	1.4930	0.0024	0.0167	0.4803	0.0081	0.0024	0.0146	0.0033	#####	0.0166	0.0478	24.03%
331	2200527 B	20.7	220735-234KM0	May 26, 2019	82.5	7.9	0.2254	0.0685	0.0234	0.0288	#####	2.8510	0.1890	0.1540	0.1160	0.3900	#####	0.0105	0.2777	0.0087	#####	0.0053	0.0010	#####	0.0084	0.0483	15.04%
333	2200529 B	20.4	220735-236KM0	June 1, 2019	62.5	8	0.0657	0.0815	0.0167	0.0263	#####	3.4380	0.0600	0.3230	0.1860	0.6160	0.0029	0.0102	0.2958	0.0223	0.0029	0.0142	0.0034	0.0014706	0.0083	0.0735	21.23%
334	2200530 B	20.7	220735-259KM0	July 19, 2019	50.9	8.1	0.1150	0.0850	0.0151	0.0253	#####	3.6660	0.0420	0.0810	0.2050	0.5180	0.0029	0.0119	0.3340	0.0093	0.0029	0.0100	0.0043	#####	0.0090	0.0725	22.79%
337	2200533 B	20	220735-262KM0	July 25, 2019	58.5	7.3	#####	0.0815	0.0213	0.0346	#####	3.0460	0.1750	0.1500	0.2070	1.0040	0.0057	0.0551	0.3425	0.0145	0.0057	0.0467	0.0087	#####	0.0714	0.0952	22.55%
341	2200537 B	20.8	220735-267KM0	July 31, 2019	23.1	2.5	#####	0.0164	0.0104	0.0221	#####	3.2130	0.0220	0.0080	0.1580	0.5060	0.0063	0.5398	0.2502	0.0089	0.0063	0.0938	0.0053	#####	0.8336	0.0962	36.32%
346	2200542 B	20.8	220735-277KM0	August 15, 2019	70.8	7.6	#####	0.2541	0.0139	0.0363	0.0170	3.9840	0.3220	0.2350	0.3250	0.8590	0.0027	0.0111	0.4095	0.0149	0.0027	0.0068	0.0053	#####	0.0082	0.0728	20.03%
324	2200520 B	20.7	220735-284KM0	August 24, 2019	63.7	14.3	0.1117	0.0960	0.0216	0.0199	#####	3.2320	0.2170	0.2690	0.2970	1.0750	0.0957	0.0101	0.3152	0.0065	0.0957	0.0171	0.0032	0.0001431	0.0061	0.0483	31.91%
352	2200548 B	19.2	220735-289KM0	September 5, 2019	22.7	4.9	0.0238	0.1659	0.0190	0.0514	#####	3.8780	0.1000	0.5450	0.4060	1.3100	0.0181	0.0112	0.3773	0.0051	0.0181	0.0031	0.0059	#####	0.0073	0.0549	52.02%
354	2200550 B	18	220735-291KM0	September 11, 2019	28.4	5.5	#####	0.0540	0.0240	0.0329	#####	3.4680	0.0200	0.0610	0.2360	0.6900	0.0156	0.0082	0.3607	0.0169	0.0156	0.0038	0.0094	0.0027778	0.0045	0.0833	37.64%
355	2200551 B	19.8	220735-293KM0	September 17, 2019	62.8	8.1	#####	0.0492	0.0248	0.0343	0.0410	3.0720	0.0920	0.1670	0.2270	0.7340	0.0192	0.0122	0.3359	0.0103	0.0192	0.0036	0.0056	0.0035354	0.0037	0.0758	20.77%
320	2200516 B	13.4	220735-295KM0	September 23, 2019	88.4	8.5	0.8093	0.3560	0.0714	0.0296	#####	18.0400	0.3460	0.2460	0.4140	1.8490	0.0196	0.0141	0.4682	0.0131	0.0196	0.0078	0.0133	0.0015484	0.0191	0.0773	38.33%
358	2200554 B	19	220735-297KM0	September 29, 2019	50.4	7.6	#####	0.0651	0.0206	0.0468	#####	3.4380	0.0500	0.0710	0.1910	0.9420	0.0174	0.0100	0.3567	0.0161	0.0174	0.0003	0.0033	0.0002032	0.0067	0.0526	22.50%
319	2200515 B	13.7	220735-299KM0	October 4, 2019	95.9	8.5	0.6457	0.1247	0.0339	0.0195	#####	2.4890	0.2000	0.1620	0.2530	1.3820	0.0168	0.0142	0.7344	0.0123	0.0168	0.0152	0.0090	#####	0.0122	0.0508	15.51%
318	2200514 B	13.4	220735-313KM0	November 4, 2019	60	8.3	1.4868	0.0646	0.0280	0.0376	#####	4.4030	0.1870	0.2760	0.3530	1.9700	0.0222	0.0126	0.7810	0.0131	0.0222	0.0147	0.0139	0.0023136	0.0102	0.1031	30.14%
364	2200560 B	20	220735-341KM0	December 16, 2019	63.3	7.0	0.0135	0.0563	0.0109	0.0279	#####	2.9730	0.0540	0.0860	0.2130	0.9590	0.0190	0.0121	0.3399	0.0103	0.0190	0.0124	0.0110	0.0030000	0.0089	0.0750	15.41%
367	2200563 B	20.8	220735-374KM0	January 26, 2020	84.6	8	0.0163	0.0481	0.0243	0.0256	#####	2.7510	0.1680	0.0990	0.1970	0.9530	0.0207	0.0136	0.3553	0.0147	0.0207	0.0035	0.0108	0.0001523	0.0123	0.0721	19.96%
316	2200512 B	19.8	220735-302KM0	February 13, 2020	98.6	8.3	0.4361	0.0781	0.0715	0.0261	#####	4.5920	0.1720	0.5980	0.3390	1.7980	0.0242	0.0129	0.5072	0.0129	0.0242	0.0031	0.0111	0.0005051	0.0105	0.0758	17.33%
372	2200568 B	20.3	220735-309KM0	February 19, 2020	113.9	8	0.0196	0.1092	0.0474	0.0387	0.0110	3.9010	0.2940	0.2090	0.3080	1.5990	0.0212	0.0110	0.4278	0.0062	0.0212	0.0118	0.0084	0.0013704	0.0080	0.0433	13.25%
380	2200576 B	20.4	UPD-ESM-DENR2100406K	October 4, 2020	31	3.3	#####	0.0322	0.0201	0.0210	0.0100	2.0160	0.0020	0.0760	0.0830	0.6100	0.0049	0.0031	#####	0.0150	0.0049	0.0117	0.0032	0.0012255	0.0056	0.0735	23.76%
381	2200577 B	20.5	UPD-ESM-DENR2100410K	October 10, 2020	20	3.4	#####	0.0696	0.0275	0.0238	0.0030	2.8860	0.0350	0.1440	0.1350	0.5370	0.0022	0.0038	#####	0.0080	0.0022	0.0067	0.0017	#####	0.0074	0.0732	37.36%
384	2200580 B	20.5	UPD-ESM-DENR2100414K	October 16, 2020	50	5	0.0004	0.0156	0.0054	#####	0.0150	3.2810	0.0290	0.0540	0.1330	0.5430	0.0044	0.0030	#####	0.0173	0.0044	0.0123	0.0130	#####	0.0083	0.0483	18.83%
387	2200583 B	20.5	UPD-ESM-DENR2100418K	October 22, 2020	22	4.4	#####	0.0286	0.0091	0.0020	0.0003	3.0510	0.0150	#####	#####	0.9790	0.0051	0.0016	0.0008	0.0173	0.0051	0.0109	0.0020	#####	0.0029	0.0732	33.51%
391	2200587 B	20.5	UPD-ESM-DENR2100422K	October 28, 2020	27	7.1	0.0045	0.0263	0.0123	0.0031	0.0002	3.3090	0.0020	0.0030	#####	0.5810	0.0005	0.0029	0.0400	0.0034	0.0005	0.0034	0.0027	0.0021951	0.0056	0.0488	41.48%
394	2200590 B	20.5	UPD-ESM-DENR2100426K	November 3, 2020	53	6.5	#####	0.0782	0.0263	0.0047	0.0004	3.4460	0.1390	0.0170	0.2040	0.7640	0.0054	0.0003	0.0073	0.0138	0.0054	0.0038	0.0003	0.0243902	0.0003	0.1463	21.52%
397	2200593 B	20.4	UPD-ESM-DENR2100430K	November 9, 2020	40	6.2	#####	0.0130	0.0095	0.0013	0.0002	2.7390	0.0330	#####	0.1050	0.5110	0.0049	0.0027	0.0139	0.0049	0.0049	0.0088	0.0027	#####	0.0050	0.0490	24.37%
400	2200596 B	20.5	UPD-ESM-DENR2100434K	November 15, 2020	45	4.5	0.0096	0.0187	0.0150	0.0022	#####	1.3600	0.0110	0.0290	0.1300	0.7840	0.0049	0.0040	#####	0.0124	0.0049	0.0084	0.0037	#####	0.0081	0.0480	16.11%
404	2200600 B	20.5	UPD-ESM-DENR2100438K	November 21, 2020	26	4.6	0.0518	0.0193	0.0072	#####	0.0003	6.9830	#####	0.0280	0.4930	0.6870	0.0037	0.0042	#####	0.0124	0.0037	0.0113	0.0059	0.0014634	0.0083	0.1220	51.20%
407	2200603 B	20.5	UPD-ESM-DENR2100442K	November 27, 2020	18	6	#####	0.0147	0.0109	0.0023	0.0003	3.4240	#####	#####	0.1370	0.6510	0.0041	0.0037	0.0065	0.0059	0.0041	0.0075	0.0058	#####	0.0077	0.1707	58.53%
410	2200606 B	20.4	UPD-ESM-DENR2100446K	December 3, 2020	58	7.1	0.0068	0.0264	0.0209	#####	#####	3.8580	#####	0.1280	#####	1.0260	0.0051	0.0044	#####	0.0150	0.0051	0.0116	0.0047	#####	0.0034	0.0735	21.66%
414	2200610 B	20.5	UPD-ESM-DENR2100450K	December 9, 2020	49	6.4	0.0048	0.0173	0.0183	0.0050	0.0003	3.2290	0.0060	0.0660	0.1820	0.7070	0.0027	0.0012	#####	0.0093	0.0027	0.0033	0.0048	0.0014634	0.0019	0.0976	22.42%
418	2200614 B	20.5	UPD-ESM-DENR2100454K	December 15, 2020	39	6.9	0.0056	0.0139	0.0108	0.0060	0.0003	3.0670	#####	0.0310	#####	1.0040	0.0046	0.0023	#####	0.0143	0.0046	0.0099	0.0059	0.0019512	0.0045	0.0732	29.42%
422	2200618 B	20.5	UPD-ESM-DENR2100458K	December 21, 2020	41	5.5	0.0040	0.0097	0.0091	0.0040	0.0005	3.4800	#####	#####	0.1680	0.6850	0.0037	#####	#####	0.0173	0.0037	0.0105	0.0029	0.0029512	#####	0.0732	25.18%
425	2200621 B	20.5	UPD-ESM-DENR2100461K	December 24, 2020	42	6.8	0.0461	0.0343	0.0341	0.0062	0.0005	6.3480	#####	0.2590	0.4880	1.2710	0.0034	0.0078	#####	0.0149	0.0034	0.0129	0.0034	0.0029823	0.0148	0.1220	37.43%
426	2200622 B	20.5	UPD-ESM-DENR2100462K	December 27, 2020	50	6.4	0.0667	0.0191	0.0245	0.0079	0.0004	7.2090	0.0050	0.0880	#####	1.5930	0.0063	0.0033	0.0057	0.0088	0.0063	0.0053	0.0054	0.0012195	0.0074	0.1220	31.28%
430	2200626 B	20.7	UPD-ESM-DENR2100466K	December 31, 2020	47	3.6	0.0691	0.1068	0.0160	0.0067	0.0003	6.9550	0.0465	4.6060	#####	1.3550	0.0473	0.0084	#####	0.0147	0.0473	0.0103	0.0130	#####	0.0185	0.0725	38.31%
375	2200571 B	20.0	220929-436Plaza Garden	January 13, 2021	107.7	7.9	0.0402	0.0756	0.0626	0.0576	0.0100	6.8980	0.1080	0.3130	0.6120	2.6980	0.0209	0.0170	0.5431	0.0124	0.0209	0.0104	0.0155	0.0021045	0.0193	0.0720	10.11%
378	2200574 B	20.5	220929-440Plaza Garden	January 19, 2021	33.7	4.5	#####	0.0480	0.0314	0.0261	0.0120	3.6180	0.0760	0.1400	0.2510	1.5240	0.0210	0.0121	0.3780	0.0149	0.0210	0.0091	0.0187	0.0056098	0.0100	0.0976	27.23%
MDL					1.1	1.2	0.0007	0.0017	0.0013	0.0009	0.1510	0.0520	0.0930	0.0790	0.0900	0.3480	0.0227	0.0100	0.4432	0.0135	0.0227	0.0138	0.0268	0.0086	0.0142	0.1527	
average (lower limit)					0.8																						
SD Nr.10.2.821					0.1																						
Median	missing					4.65	0.00624	0.050065	0.01888	0.02095	0.076	3.4505	0.0465	0.1095	0.1685	0.619	0.00506098	0.00730647	0.27413377	0.00980851	0.00506098	0.01031935	0.00708333	0.00327657	0.00734546	0.07211530	
Minimum						0.4	0.00035	0.0063	0.00543	0.00045	2E-04	0.026	0	0.003	0	0.115	0.00046729	0.0003323	0.00075307	0.00024039	0.00046729	0.00353415	0.00023364	0.00011261	2.2895E-05	0.02308443	
1/2 MDL	values are				0.55567681	0.6	0.00035	0.00085	0.00065	0.00045	0.076	0.026	0.0465	0.0395	0.045	0.174	0.01133001	0.00501722	0.22153659	0.0067627	0.01133001	0.00578718	0.01338127	0.00327857	0.0070938	0.07635728	

ANNEX 5: Phase I and Phase II data analysis results of PM10 filter samples from PEZA Station for source apportionment, 2019-2021

SOURCE APPORTIONMENT OF AIR PARTICULATE MATTER
(EPSL-SAAPM)

US EPA PMF v5	**TEST #:EPSL-SAAPM-2022-005**	Date of Model Run	Sep 27, 2022 to Nov 14, 2022
NAME	EMB-CAR		
Location	PEZA		
Period Covered	20/07/2019 to 13/01/2021		
Sample type	PM10 sampled in Quartz filter		
Number of Filters submit	26		

Phase 1: PMF Model Run results

**** Input Data Statistics ****

			Descriptive statistics				
			ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Species	**Category**	**S/N**	**Min**	**25th**	**Median**	**75th**	**Max**
PM 10 concentration	Strong	6.3	1.0	6.1	20.3	26.8	74.0
BC, ug/NCM	Strong	2.2	0.8	1.2	1.8	2.4	13.0
Cl	Strong	3.8	0.0004	0.0004	0.001	0.01	3.3
SO4-2, ug/m3	Strong	7.6	0.01	0.02	0.05	0.1	0.4
NO3-, ug/m3	Strong	6.6	0.01	0.01	0.02	0.02	0.1
PO4-3, ug/m3	Strong	5.4	0.0005	0.001	0.01	0.03	0.1
Na+, ug/m3	Strong	8.6	2.6	3.2	3.6	5.1	18.2
NH4+, ug/m3	Strong	0.9	0.001	0.05	0.05	0.1	0.3
K+ ug/m3	Strong	1.6	0.01	0.03	0.05	0.2	0.7
Mg2+, ug/m3	Strong	2.5	0.05	0.1	0.2	0.2	1.4
Ca2+, ug/m3	Strong	2.7	0.1	0.4	0.7	0.9	3.4
Al, ug/m3	Strong	0.2	0.001	0.004	0.01	0.02	0.02
As, ug/m3	Strong	1.1	0.0005	0.002	0.01	0.01	0.1
Cd, ug/m3	Strong	0.5	0.001	0.2	0.2	0.3	1.2
Cr, ug/m3	Strong	1.0	0.01	0.01	0.01	0.01	0.03
Cu, ug/m3	Strong	0.2	0.001	0.004	0.01	0.02	0.02
Hg, ug/m3	Strong	1.3	0.005	0.01	0.01	0.02	0.1
Mn, ug/m3	Strong	0.1	0.001	0.002	0.004	0.01	0.02
Ni, ug/m3	Strong	0.5	0.0001	0.002	0.003	0.003	0.02
Pb, ug/m3	Strong	0.7	0.001	0.003	0.01	0.01	0.2
Zn, ug/m3	Strong	0.3	0.04	0.05	0.1	0.1	0.1

**** Base Run Summary ****

Species	**Intercept**	**Slope**	**SE**	**r^2**	**Stat**	**P Value**	**Remarks**
PM 10 concentration	0.14	1.0	0.39	1.00	0.15	0.56	ACCEPTED
BC, ug/NCM	0.08	0.9	0.52	0.94	0.10	0.97	ACCEPTED
Cl	0.0001	1.0	0.001	1.00	0.26	0.06	ACCEPTED
SO4-2, ug/m3	-0.002	1.0	0.004	1.00	0.20	0.26	ACCEPTED
NO3-, ug/m3	-0.0004	0.9	0.01	0.78	0.15	0.61	ACCEPTED
PO4-3, ug/m3	-0.00001	1.0	0.001	1.00	0.25	0.07	ACCEPTED
Na+, ug/m3	0.55	0.9	0.61	0.97	0.20	0.27	ACCEPTED
NH4+, ug/m3	0.04	0.2	0.03	0.25	0.16	0.50	ACCEPTED
K+ ug/m3	0.01	0.8	0.06	0.80	0.20	0.26	ACCEPTED
Mg2+, ug/m3	0.04	0.7	0.05	0.93	0.12	0.87	ACCEPTED
Ca2+, ug/m3	0.06	0.9	0.19	0.91	0.09	0.99	ACCEPTED
Al, ug/m3	0.003	0.6	0.004	0.47	0.15	0.61	ACCEPTED
As, ug/m3	0.01	0.1	0.01	0.18	0.34	0.005	ACCEPTED
Cd, ug/m3	0.03	0.8	0.08	0.84	0.12	0.86	ACCEPTED
Cr, ug/m3	0.01	0.4	0.004	0.17	0.08	0.99	ACCEPTED
Cu, ug/m3	0.003	0.6	0.004	0.47	0.15	0.61	ACCEPTED
Hg, ug/m3	0.01	0.1	0.01	0.15	0.23	0.14	ACCEPTED
Mn, ug/m3	0.002	0.6	0.002	0.69	0.11	0.88	ACCEPTED
Ni, ug/m3	0.001	0.5	0.002	0.52	0.13	0.75	ACCEPTED
Pb, ug/m3	0.01	0.04	0.005	0.06	0.33	0.01	ACCEPTED
Zn, ug/m3	0.03	0.5	0.02	0.26	0.12	0.82	ACCEPTED

		% of Resolved PM10 factor sources	
Base model run number:	7	Factor 1	45%
Number of Fpeak runs:	5	Factor 2	30%
Number of factors:	6	Factor 3	33%
Extra modeling uncertaint	0	Factor 4	15%
Fpeak #	-5	Factor 5	24%
Converged	Yes	Factor 6	70%

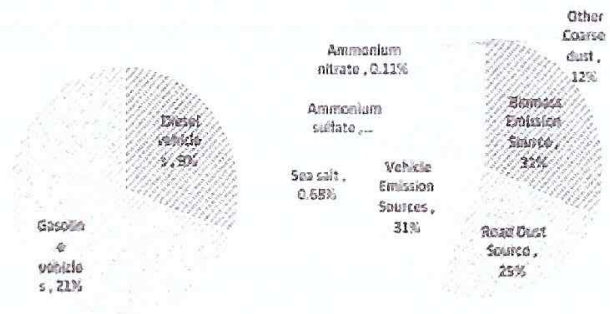
page 2 of 2

Phase 2: Profiles and Contributi		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	25% chance Gasoline vehicles	Not applicable	Not applicable	25% chance Gasoline vehicles	50% chance Gasoline vehicles
vehicles only	Cu/Mg	Not applicable	Not applicable	100% chance vehicle	100% chance vehicle	Not applicable	Not applicable
vehicles only	Cu/Ni	25% chance Gasoline vehicle	25% chance Gasoline vehicle	50% chance Gasoline vehicle	25% chance Gasoline vehicle (4W)	100% chance Gasoline vehicle	25% chance Diesel vehicles
BB, RD only	Mg/Al	Not applicable	100% chance Biomass emissions	Not applicable	Not applicable	Not applicable	100% chance Biomass emissions
ALL	Mg/Cr	25% chance vehicles, RD	25% chance vehicles, RD	25% chance vehicles, RD	25% chance vehicles, RD	25% chance vehicles, RD	25% chance vehicles, RD
Gas(4W), BB, RD only	Mn/Cr	25% chance Biomass	50% chance Biomass	25% chance Biomass	25% chance Biomass	50% chance Biomass	25% chance Biomass
Gas(4W), BB, RD only	Mn/Mg	25% chance Biomass	50% chance Biomass	25% chance Biomass	25% chance Biomass	25% chance Biomass	25% chance Biomass
BB, RD only	Mn/Na	25% chance Biomass emissions	25% chance Biomass emissions	25% chance Biomass	25% chance Biomass emissions	25% chance Biomass emissions	25% chance Biomass emissions
BB, RD only	Na/Al	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
ALL except Gas (4W)	Na/Cr	50% chance Biomass emissions	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
vehicles only	Ni/Cr	25% chance vehicle	50% chance vehicle	25% chance vehicle	25% chance vehicle	25% chance vehicle	25% chance vehicle
Diesel, Gasoline (4W) on	Pb/Mg	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
BB only	Pb/Zn	50% chance Biomass emissions	50% chance Biomass emissions	50% chance Biomass	50% chance Biomass emissions	50% chance Biomass emissions	50% chance Biomass emissions

DIAGNOSTICS		Contribution to PM10			Percentage of PM10		
Percentage	PM10	Biomass Emission Source	Road Dust Source	Vehicle Emission Sources	Biomass emission Source	Road Dust Source	Vehicle Emission Sources
Factor 1	8.95	3.4	2.74	2.74	38%	31%	31%
Factor 2	3.19	1.1	0.9	1.1	36%	29%	36%
Factor 3	2.64	0.8	0.8	1.0	31%	31%	38%
Factor 4	0.63	0.3	0.1	0.2	43%	21%	36%
Factor 5	1.24	0.0	0.0	0.0	38%	25%	38%
Factor 6	2.90	0.6	0.49	1.1	29%	21%	50%

Description		Highest percentage	Mixed with	Strong indicator for		Diesel vehicles	Gasoline vehicles
Factor 1		BB	VE	Coarse Soil	Fraction of Vehicles Resolved	11.5%	19.2%
Factor 2		BB, VE	RD	Coarse Soil		10.7%	25.0%
Factor 3		VE	BB, RD	Coarse Soil		15%	23%
Factor 4		BB	VE	Coarse Soil		14%	21%
Factor 5		BB, VE	RD	BC		3%	34%
Factor 6		VE	BB	BC		14%	36%

		Percentage in PM10	Sub-percentage
OVERALL	Biomass Emission Source	31%	
	Road Dust Source	25%	
	Vehicle Emission Sources	31%	
	Diesel vehicles		9%
	Gasoline vehicles		21%
	Sea salt	0.68%	
	Ammonium sulfate	0.50%	
	Ammonium nitrate	0.11%	
	Other Coarse dust	12%	



PM10: Particulate Matter with diameter of 10 micrometer and below; S/N: Signal to Noise Ratio; SE: Sta dard Error; BB: Biomass Burning; RD: Road Dust; 4W: Four-Wheeler vehicles; VES: Vehicle Emission Source

NAME	EMB-CAR
Location	PEZA
Period Covered	20/07/2019 to 13/01/2021

ANNEX 6: Phase I and Phase II data analysis results of PM10 filter samples from CAPITOL Station for source apportionment, 2019-2021

SOURCE APPORTIONMENT OF AIR PARTICULATE MATTER (EPSL-SAAPM)

US EPA PMF v5	**TEST 8:EPSL-SAAPM-2022-003**	Date of Model Run	Sep 27, 2022 to Nov 14, 2022
NAME	EMB-CAR		
Location	CAPITOL (LTB)		
Period Covered	08/04/2019 to 21/01/2021		
Sample type	PM10 sampled in Quartz filter		
Number of Filters submitt	37		

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

**** Input Data Statistics ****

Species	Category	S/N	Min (ug/m3)	25th (ug/m3)	Median (ug/m3)	75th (ug/m3)	Max (ug/m3)
PM10 concentration	Strong	8.3	9.9	41.2	68.0	99.3	134.3
BC, ug/NCM	Strong	5.1	1.0	6.1	7.4	8.1	11.2
Cl	Strong	5.1	0.0004	0.0004	0.01	0.1	2.6
SO4-2, ug/m3	Strong	7.9	0.01	0.03	0.05	0.1	0.3
NO3-, ug/m3	Strong	7.4	0.01	0.02	0.03	0.04	0.1
PO4-3, ug/m3	Strong	6.3	0.0005	0.004	0.02	0.03	0.1
Na+, ug/m3	Strong	8.3	0.03	3.1	3.5	3.9	14.3
NH4+, ug/m3	Strong	1.5	0.003	0.05	0.1	0.1	0.6
K+ ug/m3	Strong	2.9	0.04	0.1	0.2	0.3	0.6
Mg2+, ug/m3	Strong	2.8	0.05	0.05	0.2	0.3	0.7
Ca2+, ug/m3	Strong	4.6	0.5	0.9	1.9	2.3	3.0
Al, ug/m3	Strong	0.4	0.001	0.003	0.01	0.02	0.04
As, ug/m3	Strong	1.6	0.002	0.01	0.01	0.02	0.3
Cd, ug/m3	Strong	1.0	0.003	0.2	0.3	0.5	1.6
Cr, ug/m3	Strong	0.6	0.0002	0.01	0.01	0.01	0.02
Cu, ug/m3	Strong	0.4	0.001	0.003	0.01	0.02	0.04
Hg, ug/m3	Strong	1.0	0.005	0.01	0.01	0.01	0.1
Mn, ug/m3	Strong	0.2	0.001	0.01	0.01	0.01	0.02
Ni, ug/m3	Strong	0.6	0.0002	0.002	0.003	0.004	0.03
Pb, ug/m3	Strong	1.2	0.004	0.01	0.01	0.02	0.4
Zn, ug/m3	Strong	0.2	0.05	0.05	0.1	0.1	0.2

**** Base Run Summary ****

Species	Intercept	Slope	SE	r^2	Stat	P Value	Remarks
PM10 concentration	10.7	0.81	7.2	0.93	0.13	0.56	ACCEPTED
BC, ug/NCM	0.1	0.93	1.7	0.58	0.15	0.39	ACCEPTED
Cl	-0.001	1.01	0.004	1.00	0.37	0.0001	ACCEPTED
SO4-2, ug/m3	-0.001	1.01	0.01	0.99	0.22	0.05	ACCEPTED
NO3-, ug/m3	0.001	0.97	0.002	0.99	0.11	0.76	ACCEPTED
PO4-3, ug/m3	0.003	0.85	0.003	0.97	0.20	0.10	ACCEPTED
Na+, ug/m3	0.02	0.99	0.1	1.00	0.08	0.95	ACCEPTED
NH4+, ug/m3	0.1	0.41	0.1	0.66	0.14	0.49	ACCEPTED
K+ ug/m3	0.1	0.49	0.1	0.54	0.09	0.94	ACCEPTED
Mg2+, ug/m3	0.1	0.59	0.1	0.50	0.13	0.60	ACCEPTED
Ca2+, ug/m3	0.2	0.86	0.3	0.82	0.08	0.96	ACCEPTED
Al, ug/m3	0.002	0.73	0.004	0.74	0.08	0.96	ACCEPTED
As, ug/m3	0.01	0.04	0.01	0.08	0.30	0.002	ACCEPTED
Cd, ug/m3	0.1	0.63	0.1	0.68	0.09	0.90	ACCEPTED
Cr, ug/m3	0.004	0.38	0.003	0.20	0.07	1.00	ACCEPTED
Cu, ug/m3	0.002	0.73	0.004	0.74	0.08	0.96	ACCEPTED
Hg, ug/m3	0.01	0.15	0.004	0.08	0.15	0.34	ACCEPTED
Mn, ug/m3	0.0033	0.66	0.003	0.61	0.09	0.95	ACCEPTED
Ni, ug/m3	0.0030	0.01	0.001	0.002	0.18	0.18	ACCEPTED
Pb, ug/m3	0.01	0.01	0.01	0.02	0.26	0.01	ACCEPTED
Zn, ug/m3	0.02	0.61	0.02	0.31	0.08	0.95	ACCEPTED

		% of Resolved PM10 factor sources	
Base model run number:	18	Factor 1	29%
Number of Fpeak runs:	5	Factor 2	6%
Number of factors:	6	Factor 3	1%
Extra modeling uncertaint	0	Factor 4	2%
Fpeak #	-3	Factor 5	22%
Converged	Yes	Factor 6	41%

Analysed by: Mylene G. Cayetano RCh, PhD
Head, Environmental Pollution Studies Laboratory

Date: November 24, 2022
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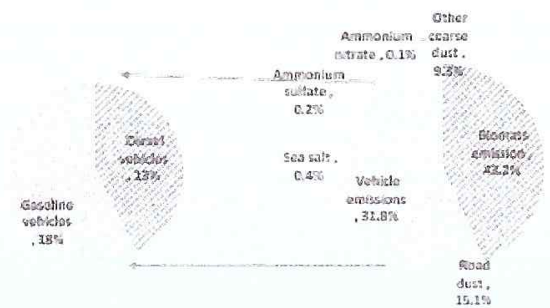
Phase 2: Profiles and Contribu		Test 1	Test 2	Test 3	Test 4	Test 5	Test 6
Indicator for	**Ratio**	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**
vehicles only	Cu/Cr	Not applicable	25% chance Diesel vehicle	Not applicable	100% chance Gasoline vehicles (MC)	100% chance Gasoline vehicles (MC)	50% chance Diesel vehicle
vehicles only	Cu/Mg	25% chance vehicle	25% chance vehicle	25% chance vehicle	50% chance vehicle	50% chance vehicle	
vehicles only	Cu/Ni	25% chance Gasoline vehicle (4W)	25% chance Gasoline vehicle (4W)	25% chance Diesel vehicles	25% chance Diesel vehicles	25% chance Diesel vehicles	50% chance Gasoline vehicle (4W)
BB, RD only	Mg/Al	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	25% chance Road dust
ALL	Mg/Cr	50% chance Biomass emissions	100% chance Biomass emissions	Not applicable	25% chance Biomass emissions	25% chance Biomass emissions	25% chance vehicles, RD
Gas(4W), BB, RD only	Mn/Cr	50% chance Biomass	25% chance Biomass	50% chance Biomass	50% chance Biomass	50% chance Road dust	25% 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	
BB, RD only	Mn/Na	25% chance Biomass emissions	25% chance Biomass emissions	25% chance Biomass emissions	50% chance biomass emissions	50% chance biomass emissions	50% chance biomass emissions
BB, RD only	Na/Al	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
ALL except Gas (4W)	Na/Cr	Not applicable	Not applicable	Not applicable	25% chance biomass emissions	Not applicable	Not applicable
vehicles only	Ni/Cr	25% chance vehicle	50% chance vehicle	25% chance vehicle	25% chance vehicle	25% chance vehicle	25% chance vehicle
Diesel, Gasoline (4W) onl	Pb/Mg	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	
BB only	Pb/Zn	50% chance Biomass emissions	50% chance Biomass emissions	50% chance Biomass emissions	50% chance Biomass emissions	50% chance Biomass emissions	50% chance Biomass emissions

DIAGNOSTICS		Contribution to PM10			Percentage of PM10		
Percentage	**PM10**	**Biomass Emission Source**	**Road Dust Source**	**Vehicle Emission Sources**	**Biomass emission Source**	**Road Dust Source**	**Vehicle Emission Sources**
Factor 1	19.21	13.1	1.5	4.4	69%	8%	23%
Factor 2	3.78	2.2	0.2	1.1	63%	6%	31%
Factor 3	0.38	0.4	0.1	0.2	58%	17%	25%
Factor 4	1.59	0.7	0.1	0.6	53%	5%	42%
Factor 5	14.98	5.7	2.5	6.6	39%	17%	44%
Factor 6	27.37	3.7	6.8	10.7	36%	25%	39%

Description		Highest percentage	Mixed with	Strong Indicator for		Diesel vehicles	Gasoline vehicles
Factor 1		BB	VE	BC, Sulfate, Coarse dust	Fraction of Vehicles Resolved	8%	15%
Factor 2		BB	VE	Nitrate, Coarse dust		16%	16%
Factor 3		BB	VE	Phoshate, BC		17%	8%
Factor 4		BB	VE	BC, Coarse dust		13%	29%
Factor 5		VE	BB	Coarse dust		14%	31%
Factor 6		VE	BB, RD	Coarse dust, BC		20%	20%

		Percentage in PM10	Sub-percentage
OVERALL	Biomass emission	43.2%	
	Road dust	15.1%	
	Vehicle emissions	31.8%	
	Diesel vehicles		13%
	Gasoline vehicles		18%
	Sea salt	0.4%	
	Ammonium sulfate	0.2%	
	Ammonium nitrate	0.1%	
	Other coarse dust	9.3%	

PM10: Particulate Matter with diameter of 10 micrometer and below; S/N: Signal to Noise Ratio; SE: Sta dard Err
RD: Road Dust; 4W: Four-Wheeler vehicles; VES: Vehicle Emission Source



Analysed by: Mylene G. Cayetano RCh, PhD
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Date: November 24, 2022
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SOURCE APPORTIONMENT OF AIR PARTICULATE MATTER
(EPSL-SAAPM)

US EPA PMF v5	**TEST 8:EPSL-SAAPM-2022-004**	Date of Model Run	Sep 27, 2022 to Nov 14, 2022
NAME	EMB-CAR		
Location	KMO (Plaza Garde, Baguio City)		
Period Covered	02/04/2019 to 13/01/2021		
Sample type	PM10 sampled in Quartz filter		
Number of Filters submitt	39		

Phase 1: PMF Model Run results

**** Input Data Statistics ****

			Descriptive statistics				
			ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Species	**Category**	**S/N**	**Min**	**25th**	**Median**	**75th**	**Max**
PM 10 concentration	Strong	8.2	18.0	31.0	50.0	63.7	113.9
BC, ug/NCM	Strong	5.1	2.5	5.0	7.1	8.0	14.3
Cl, ug/m3	Strong	5.2	0.0004	0.0004	0.01	0.1	1.4
SO4-2, ug/m3	Strong	7.7	0.01	0.02	0.1	0.1	0.4
NO3-, ug/m3	Strong	7.0	0.01	0.01	0.02	0.03	0.1
PO4-3, ug/m3	Strong	6.4	0.0005	0.005	0.03	0.03	0.1
Na+, ug/m3	Strong	8.5	1.4	3.1	3.4	3.9	18.0
NH4+, ug/m3	Strong	1.3	< MDL	0.03	0.1	0.2	0.6
K+ ug/m3	Strong	2.2	0.003	0.04	0.1	0.2	4.6
Mg2+, ug/m3	Strong	2.8	0.05	0.1	0.2	0.3	0.6
Ca2+, ug/m3	Strong	3.4	0.4	0.6	0.9	1.3	2.7
Al, ug/m3	Strong	0.6	0.0005	0.004	0.01	0.02	0.1
As, ug/m3	Strong	1.3	0.0003	0.004	0.01	0.01	0.5
Cd, ug/m3	Strong	0.7	0.001	0.2	0.3	0.4	0.8
Cr, ug/m3	Strong	1.1	0.003	0.01	0.01	0.01	0.02
Cu, ug/m3	Strong	0.6	0.0005	0.004	0.01	0.02	0.1
Hg, ug/m3	Strong	1.1	0.01	0.01	0.01	0.01	0.1
Mn, ug/m3	Strong	0.1	0.001	0.003	0.01	0.01	0.02
Ni, ug/m3	Strong	0.4	0.0002	0.002	0.003	0.00	0.02
Pb, ug/m3	Strong	0.9	0.001	0.01	0.01	0.01	0.8
Zn, ug/m3	Strong	0.3	0.05	0.1	0.1	0.1	0.2

**** Base Run Summary ****

Species	Intercept	Slope	SE	r^2	Stat	P Value	**Remarks**
PM 10 concentration	4.3	0.9	5.2	0.95	0.16	0.28	ACCEPTED
BC, ug/NCM	1.9	0.7	1.3	0.54	0.11	0.75	ACCEPTED
Cl, ug/m3	-0.0002	1.0	0.002	1.00	0.28	0.005	ACCEPTED
SO4-2, ug/m3	-0.002	1.0	0.005	1.00	0.17	0.20	ACCEPTED
NO3-, ug/m3	-0.001	1.1	0.002	0.98	0.11	0.70	ACCEPTED
PO4-3, ug/m3	-0.0001	1.0	0.002	0.99	0.17	0.21	ACCEPTED
Na+, ug/m3	1.0	0.7	0.3	0.97	0.17	0.24	ACCEPTED
NH4+, ug/m3	0.04	0.5	0.05	0.66	0.08	0.95	ACCEPTED
K+ ug/m3	0.12	0.003	0.1	0.001	0.20	0.10	ACCEPTED
Mg2+, ug/m3	0.09	0.5	0.1	0.47	0.10	0.80	ACCEPTED
Ca2+, ug/m3	0.23	0.7	0.2	0.71	0.09	0.89	ACCEPTED
Al, ug/m3	0.01	0.1	0.01	0.12	0.21	0.06	ACCEPTED
As, ug/m3	0.01	0.0005	0.004	0.0001	0.31	0.001	ACCEPTED
Cd, ug/m3	0.04	0.8	0.1	0.80	0.11	0.74	ACCEPTED
Cr, ug/m3	0.01	0.1	0.003	0.03	0.09	0.91	ACCEPTED
Cu, ug/m3	0.01	0.1	0.01	0.12	0.21	0.06	ACCEPTED
Hg, ug/m3	0.01	0.01	0.003	0.002	0.25	0.02	ACCEPTED
Mn, ug/m3	0.004	0.3	0.002	0.36	0.11	0.71	ACCEPTED
Ni, ug/m3	0.003	0.004	0.001	0.001	0.26	0.01	ACCEPTED
Pb, ug/m3	0.01	-0.002	0.003	0.01	0.29	0.003	ACCEPTED
Zn, ug/m3	0.05	0.3	0.02	0.14	0.10	0.86	ACCEPTED

Base model run number:	8		
Number of Fpeak runs:	5		
Number of factors:	6		
Extra modeling uncertaint	0		
Fpeak #	-4		
Converged	Yes		

% of Resolved PM10 factor sources

Factor 1	21%
Factor 2	33%
Factor 3	24%
Factor 4	6%
Factor 5	10%
Factor 6	7%

Analysed by: Mylene G. Cayetano RCh, PhD
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Date: November 24, 2022
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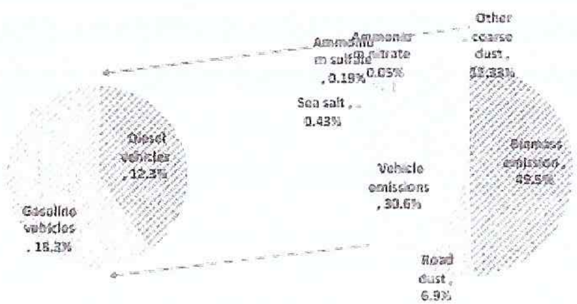
Phase 2: Profiles and Contribution

Indicator for	Ratio	Test 1 Factor 1	Test 2 Factor 2	Test 3 Factor 3	Test 4 Factor 4	Test 5 Factor 5	Test 6 Factor 6
vehicles only	Cu/Cr	% chance Gasoline vehicles (MC)	50% chance Diesel vehicle	Not applicable	50% chance Gasoline vehicles (MC)	0% chance Gasoline vehicles (4W)	% chance Gasoline vehicles (MC)
vehicles only	Cu/Mg	25% chance vehicle	25% chance vehicle	25% chance vehicle	25% chance vehicle	25% chance vehicle	25% chance vehicle
vehicles only	Cu/Ni	25% chance Diesel vehicles	25% chance Diesel vehicles	% chance Gasoline vehicle (MC)	25% chance Diesel vehicles	25% chance Diesel vehicles	25% chance Diesel vehicles
BB, RD only	Mg/Al	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
ALL	Mg/Cr	50% chance Biomass emissions	25% chance Biomass emissions	25% chance vehicles, RD	25% chance Biomass emissions	50% chance Biomass emissions	25% chance Biomass emissions
Gas(4W), BB, RD only	Mn/Cr	25% chance Biomass	25% chance Biomass	25% chance Biomass	50% chance Biomass	25% chance Biomass	50% chance Biomass
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	25% chance Biomass emissions	25% chance Biomass emissions	25% chance Biomass emissions	25% chance Biomass emissions	25% chance Biomass emissions	25% chance Biomass emissions
BB, RD only	Na/Al	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
ALL except Gas (4W)	Na/Cr	Not applicable	100% chance Biomass emissions	Not applicable	Not applicable	Not applicable	Not applicable
vehicles only	Ni/Cr	25% chance vehicle	25% chance vehicle	25% chance vehicle	25% chance vehicle	25% chance vehicle	25% chance vehicle
Diesel, Gasoline (4W) onl	Pb/Mg	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
BB only	Pb/Zn	50% chance Biomass emissions	50% chance Biomass emissions	50% chance Biomass emissions	50% chance Biomass emissions	50% chance Biomass emissions	50% chance Biomass emissions

DIAGNOSTICS		Contribution to PM10			Percentage of PM10		
Percentage	PM10	Biomass Emission Source	Road Dust Source	Vehicle Emission Sources	Biomass emission Source	Road Dust Source	Vehicle Emission Sources
Factor 1	10.37	5.0	0.6	4.4	50%	6%	44%
Factor 2	16.63	10.4	0.94	4.7	65%	6%	29%
Factor 3	11.79	6.1	1.52	3.5	55%	14%	32%
Factor 4	2.32	1.4	0.2	0.9	57%	7%	36%
Factor 5	5.02	2.3	0.3	2.0	50%	6%	44%
Factor 6	3.42	1.8	0.2	1.1	57%	7%	36%

Description		Highest percentage	Mixed with	>50% contribution to	Fraction of Vehicles sources Resolved	Diesel vehicles	Gasoline vehicles
Factor 1		BB	VE	BC, Coarse dust		13%	31%
Factor 2		BB	VE	BC, Coarse dust		24%	6%
Factor 3		BB	VE	BC, Phosphate, Coarse dust		11%	20%
Factor 4		BB	VE	BC, Coarse dust		14%	21%
Factor 5		BB	VE	BC, Coarse dust		13%	31%
Factor 6		VE	BB	BC, SulfateCoarse dust		14%	21%

		Percentage in PM10	Percentage in BC
OVERALL	Biomass emission	49.5%	
	Road dust	6.9%	
	Vehicle emissions	30.6%	
	Diesel vehicles		12.3%
	Gasoline vehicles		18.3%
	Sea salt	0.43%	
	Ammonium sulfate	0.19%	
	Ammonium nitrate	0.05%	
	Other coarse dust	12.33%	



PM10: Particulate Matter with diameter of 10 micrometer and below; S/N: Signal to Noise Ratio; SE: Sta dard Error; RD: Road Dust; 4W: Four-Wheeler vehicles; VES: Vehicle Emission Source

Analysed by: Mylene G. Cayetano RCh, PhD
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Date: November 24, 2022
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Submitted by: Partnership for Clean Air, Inc. (PCA) as Contracting Party and Dr. Mylene G. Cayetano as Service Provider/Consultant