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Elemental distribution and source analysis of atmospheric aerosols from Meycauayan, Bulacan, Philippines

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ABSTRACT

One of the industrialized cities in the Philippines is Meycauayan, Bulacan. This study reports the elemental distribution and source apportionment in eight varying land cover-land use type sampling points located along the Marilao-Meycauayan- Obando Rivers System. Elemental analysis was conducted using a scanning electron microscope coupled with energy dispersive x-ray. Cu, Pb, Zn, Cr, Mn, As, Cd, Co, Fe, Ni, Ti, and V concentrations were determined using Inductively Coupled Plasma Mass Spectrometry, and Hg concentrations by Mercury analyzer. Principal component analysis (PCA), hierarchical cluster analysis (HCA), and Pearson's r correlation were used to analyze different sources of heavy metals and its corresponding land use-land cover type. The aerosol samples showed the presence of heavy metals Pb and Hg, elements that were also detected in trace amounts in the water measurements. Concentrations of heavy metals such as Cu, Fe, Pb, Zn, V, Ni, and As found in the atmospheric aerosols and urban dusts were attributed to anthropogenic sources such as residential, commercial and industrial wastes. Other source of aerosols in the area were traffic and crustal emissions in Meycauayan. Using HCA, there are 3 clusters observed based on the similar sets of heavy metals: (1) AQS1 (Caingin), AQS2 (Banga), and AQS8 (Malhacan); (2) AQS3(Calvario), AQS4 (Camalig), and AQS5(Langka); (3) AQS1(Sto Nino-Perez), and (AQS7) (Sterling). These groups are related based on different land use setting such as residential/commercial, agricultural, and commercial/industrial areas. Our study recommends the need to address heavy metal pollution in Meycauayan in support to the ongoing implementation of laws and regulations by the local and private sectors.

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1. Introduction

Rapid urbanization and industrialization may pose serious problems in the environment and the society. Major sources of contamination in urban dusts and atmospheric aerosols are heavy metals that are possibly harmful to human health and the environment. These potentially harmful heavy metals come from different sources caused by anthropogenic and natural factors. Major anthropogenic and natural sources of heavy metals in atmospheric aerosols and urban dusts include industrial emissions, household and traffic effluents, weathering, and erosion [1,2]. The increasing population growth in urbanized cities leads to higher values of heavy metals as observed in different urban areas in Asia and the World [3–6].

In the Philippines, limited data have been published on heavy metals present in atmospheric aerosols and urban dusts [7]. As urban dust acts as source of heavy metals, it is necessary to measure heavy metal concentration as an indicator of environmental quality in the area. Elemental pollution and source analyses of urban dusts of different land uses were studied in urban areas [8]. An emerging city in the Philippines is Meycauayan, Bulacan with population density of 199, 154 and over a land area of 3210 ha [9]. The different land uses present in Meycauayan, Bulacan may have different effects on heavy metal pollution.

In this study, the pollution risk of heavy metals under specific land-use types has been explored. This study aims to determine elemental analysis and sources of heavy metals in the urban dusts in Meycauayan, Bulacan, Philippines. The specific objectives of the study are as follows: (1) investigate the concentrations and spatial distribution characteristics of heavy metals such as Copper (Cu), Lead (Pb), Zinc (Zn), Chromium (Cr), Manganese (Mn), Arsenic (As), Cadmium (Cd), Cobalt (Co), Iron (Fe), Nickel (Ni), Titanium (Ti), Mercury (Hg), and Vanadium (V) in the atmospheric aerosols and urban dusts, and (2) differentiate pollution sources under different land-use settings. The pollution risk in urban areas studied in this report serves as a good reference for policy making bodies on environmental laws and protection. It also gives a better understanding on preventing and controlling heavy metal pollution from the different sources.

2. Materials and methods

2.1. Study area

Meycauayan city, Bulacan is about nineteen (19) kilometers north of Manila and about 22 km south of Malolos city, the capital city of the province of Bulacan (between 14.738° and 14.755° north and between 120.943° and 120.995° east) [10]. It is bounded by the town of Marilao to the north, Valenzuela City to the south, Caloocan City to the east and the town of Obando to the west. Major industries include fine jewelry making, leather products manufacturing and commercial establishments [11]. The province of Bulacan is also considered the biggest producer of used lead acid battery (ULAB) [10]. The neighboring town, Marilao, houses a lead smelting plant owned by the largest lead battery recycler in the country as well as numerous unregulated ULAB plants [10,12].

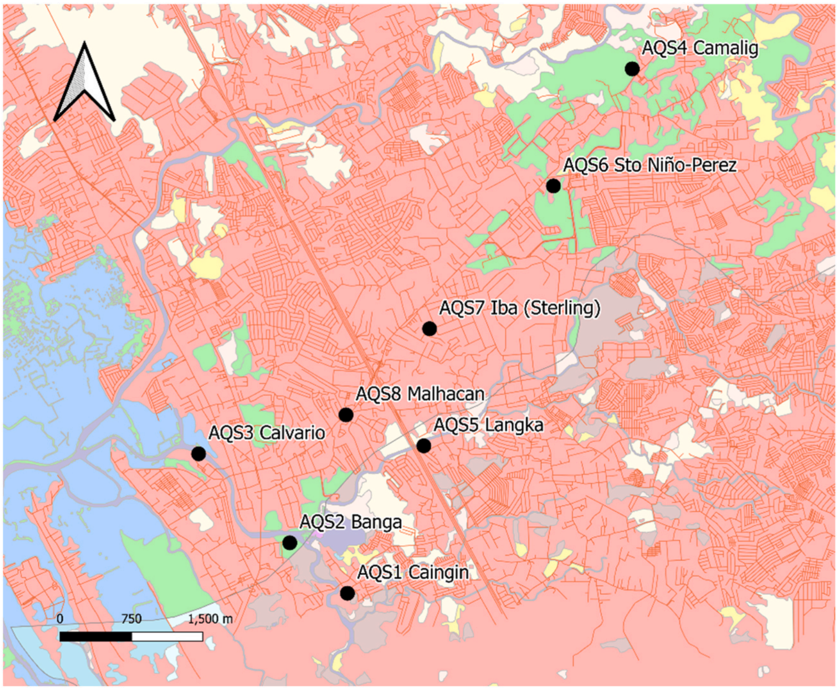

Fig. 1. Locations of aerosol sampling (AQS) stations. Land cover measurements of Bulacan were collected from Geoportal [17] and were mapped out using QGIS 3.22.16 [18].

Leather tanning industries are known emitters of Volatile Organic Compounds (VOCs) and Hazardous Air Pollutants (HAPs). Heavy metal air emissions from tannery operations are chromium (Cr), chromium compounds, manganese (Mn), and Manganese compounds [13,14]. Chromium compounds, identified as one of the HAPs emitted by tanning industries, mainly come from chromium salts, which are the most widely used tanning substance. When emitted into the atmosphere, Cr species are present in the form of particles and droplet aerosols [15]. Occupational exposure to hexavalent chromium compounds has been associated with increased risk of respiratory system cancers [16].

Sampling sites were chosen from eight different barangays in Meycauayan city. The eight barangays are as follows: (AQS1) Barangay Caingin, (AQS2) Barangay Banga, (AQS3) Barangay Calvario, (AQS4) Barangay Camalig, (AQS5) Barangay Langka, (AQS6) Barangay Perez, (AQS7) Barangay Iba and (AQS8) Barangay Malhacan. The barangays were selected to represent the different land classifications according to use whether agricultural, industrial, residential, or just open space. The eight (8) air quality sampling (AQS) locations are shown in Fig. 1 and described in Table 1.

The location of AQS1 (Caingin) is a former dumpsite but people continue to throw garbage in the area. There were also people living around this dump site. AQS2 (Banga) is an open space area wherein trucks used for construction are being kept. There are no residences within this area. AQS3 (Calvario) has a public market and an open space wherein some people throw garbage and turn it into a dump site. There are about three to four families living in this area who are caretakers of the land. Flooding is also evident in this area even if the sampling was done during the summer season, which has minimal or no rain at all. AQS4 (Camalig) is identified as agricultural land and there are no industrial buildings in the area. In AQS5 (Langka), there are industries situated along the riverbanks and a residential area as well. AQS6 (Perez) is a purely residential area, the sampling here was done inside a subdivision. AQS7 (Iba) is a purely industrial land where there are factories and warehouses around the sampling site. Lastly, the sampling site AQS8 (Malhacan) is along the roadside. The mentioned barangays are situated along the riverbanks except for barangay Camalig, Iba and Malhacan.

2.2. Aerosol sampling and characterization

Collection was carried out during the summer season (May 2016). On the first day, samples were taken from Barangays Caingin, Banga, and Calvario at around 1500H–1800H. On the second day, samples were taken from the rest of the barangays at around 0800H–1200H. An air pump was used to suction surrounding air with a sampling flow rate of about 83.5 standard cubic feet per hour (SCFH) or 2.35 m^3/h [19,20]. Aerosols were deposited on glass-fiber filters at 15 min per location, and 1 m above the ground. The filters were changed every barangay and labeled according to sampling site.

During the analysis, a quadrant is taken from each filter and coated with gold using a JEOL JFC-1200 Fine Coater. The prepared filter is then studied using the JEOL JSM-5310 Scanning Electron Microscope (SEM) with an accelerating voltage of 15–20 kV and spot size of 7. For elemental analysis, the attached Energy Dispersion X-ray (EDX) feature of the SEM was used with a spot size of 12. Randomly selected particles from each filter were studied for morphology and elemental composition. The imaging software used was SemAfore version 5.2.1.

2.3. Heavy metal data and analysis

All samples were dried at 40 °C for 2 days and kept in a dehumidifier chamber ready for testing. The dried samples were ground and sieved through a 200-mesh sieve. In this method, small portion of each collected sample (1–2 g) was prepared and 20 mL mixture ratios of 10:10:10:1 HF, H_2SO_4, HNO and $HClO_4$ was added and heated for 4 h. Residue were redissolved using the 10 mL HCl and 50 mL Deionized water at 1:1 mixing ratio. Inductively Coupled Plasma Mass Spectrometry (ICP-OES 5100, Thermo Fisher Scientific, MA, USA) were used for Cu, Pb, Zn, Cr, Mn, As, Cd, Co, Fe, Ni, Ti, and V metal concentrations. Total Hg was analyzed using Mercury analyzer (ATS Scientific Inc., Mercury Analyzer-Direct DMA 80 evo, Burlington, Canada).

Table 1
Aerosol sampling point location in Meycauayan city.

Sampling Point	Location	Coordinates	Typical Land Use
AQS1	Caingin	14. 725092° N 120.96978° E	Reclaimed Dumpsite
AQS2	Banga	14.73000° N 120.96417° E	Residential/Commercial
AQS3	Calvario	14.73866° N 120.9553° E	Residential/Commercial
AQS4	Camalig	14.77612° N 120.99750° E	Agricultural
AQS5	Langka	14.73944° N 120.97722° E	Agricultural
AQS6	Sto Nino-Perez	14.76472° N 120.99833° E	Commercial/Industrial
AQS7	Iba (Sterling)	14.75083° N 120.97778° E	Commercial/Industrial
AQS8	Malhacan	14.74245° N 120.96964° E	Residential/Commercial

Quality control and assurance were done by using a certified reference material (OEAS 44P) with the set range of heavy metal concentrations. The detection limits were obtained by analyzing five blank samples of background origin and were considered as analytical blanks.

2.4. Pollution assessment

2.4.1. Enrichment factor

In this assessment, trace element concentration is measured against a reference element as shown by the equation below: $EF = \frac{\left(\frac{C_{element}}{C_{reference}}\right)_{dust}}{\left(\frac{C_{element}}{C_{reference}}\right)_{crust}}$.

Where $C_{element}$ and $C_{reference}$ are the elemental and reference concentrations in the dust or crust samples. Several studies used elements such as Fe, Al, Mn, Ti, and Sr to be the reference elements [26–28]. In this study, Al is chosen to be the reference element due to its high natural occurrence and small influence in the anthropogenic sources. The enrichment factors of the different elements vary according to different pollution intensities (Table S1).

2.5. Statistical treatment

Principal component analysis (PCA), and hierarchical cluster analysis (HCA) using SPSS Statistics 26.0 was performed to identify the sources of heavy metals in aerosols collected in Meycauayan, Bulacan. Pearson's r correlation analysis was computed to identity correlation between parameters. These multivariate analyses are commonly performed in environmental pollution collected in air, soil, and water samples.

3. Results and discussion

3.1. Aerosol characterization

From the different stages of aerosol collection using the six-stage air sampling device, the last stage was only considered for elemental analysis, the particle size ranges from 0.65 to 1.1 μm. SEM-EDX analysis was first employed to determine particle size and elemental distribution present in all samples collected at varying sampling stations. Elements observed are C, N, O, Na, Mg, Al, Si, S, Cl, K, Ti, Mn, Fe, C, Zn, Br, Nb, Ba, Hg, and Pb (Fig. 1). Fourteen elements from the EDX analysis were further measured for their concentrations. Average concentrations of the potentially toxic elements collected from the atmospheric dust and aerosols at different sampling sites are summarized in Table 2. Heavy metals in descending order were Fe > Mn > Ti > Zn > V > Ni > Cu > Cr > Pb > Co > Hg > Cd representing the potentially toxic elements. The concentration levels are similar to other studies measured in the different municipalities and cities in the Philippines [7,25–28]. AQS1 (Caingin) showed high concentrations of Pb, Zn, Cr, Ni, and Hg while AQS5 (Langka) showed high concentrations of Ti and Cd. Mn and Fe concentrations are high in AQS6 (Sto Nino-Perez), and other measured metals (Cu, V, As, Co) are high in AQS7 (Sterling). The heavy metal concentrations observed showed variance in sampling locations. This suggests that these potentially toxic elements of atmospheric aerosols and dusts are higher compared to background values. Hg mean concentration measured showed higher than the reference value. No Hg detection were also observed in AQS3 (Calvario) and AQS4 (Camalig), where their land use classifications are residential/commercial and agricultural, respectively.

The amounts of Mn, As, and Cd are smaller than the reference values. This suggests that these elements may be considered as natural resources, while other elements beyond the reference values may have come from anthropogenic sources. Based on the coefficients of variation (CV), their variabilities are categorized as follows: CV < 0.2 (low variability), $0.2 \leq$ CV < 0.5 (moderate variability), $0.5 \leq$ CV < 1.0 (high variability), and CV ≥ 1.0 (extremely high variability) [21,22]. The variability in mean and standard deviation showed spatial changes in potentially toxic elements in Meycauayan, Bulacan. Zn and Fe showed the lowest variability. On

Table 2
Heavy metal concentrations (mg/kg) of atmospheric aerosols and dusts in Meycauayan, Bulacan.

Element	Range	Mean	Median	Standard Deviation	CV	Land Use Location
Cu	8.47–28.82	18.56	18.17	8.79	0.47	AQS7
Pb	0.53–6.48	3.18	3.40	2.12	0.67	AQS1
Zn	77.3–104.36	91.39	91.00	7.91	0.09	AQS1
Cr	11.05–24.05	15.69	15.07	3.65	0.23	AQS1
Ti	100.05–250.42	167.46	163.60	47.24	0.28	AQS5
V	24.5–88.2	57.05	59.56	20.14	0.35	AQS7
Hg	ND*-0.07	0.05	0.05	0.03	0.61	AQS1
Mn	109.52–432.12	236.03	217.11	100.63	0.43	AQS6
As	0.05–0.37	0.15	0.12	0.10	0.70	AQS7
Cd	0.01–0.06	0.04	0.04	0.01	0.37	AQS5
Co	0.82–2.04	1.45	1.36	0.46	0.32	AQS7
Fe	475–804	622	551	79.42	0.10	AQS6
Ni	9.82–44.21	27.49	30.50	11.25	0.41	AQS1

the other hand, Cu, Cr, Ti, V, Mn, Cd, Co, and Ni as moderate variability while Pb, Hg, and As has high variability. This reveals from the values of CV that the moderate and high variability of some heavy metals are influence of anthropogenic activities [23,24]. The low variability of Fe concentrations with the highest amount of concentration confirms its main use as reference element.

Although there are studies of potentially toxic elements in outdoor and street dusts, there are limited to no publications on heavy metals measured in different land use settings. The observed concentrations of heavy metals are within the range measured in other cities in Asia and the world [4–6,28]. The variations in the heavy metal concentrations suggests the possible effects from anthropogenic sources such as urbanization, human sources, traffic density, and types of fuels used.

3.2. Correlation between metals

Correlation heat map between heavy metals measured in all sampling stations are shown in Table 3. It can be observed that Ni, Cu, Pb, Zn, and Cr showed positive correlation indicating that they may have a common source and may be influenced by anthropogenic sources. Another group of heavy metals such as V, Hg, Mn, As, Fe showed similar positive correlation which may be influenced by traffic and industrial activities, Vanadium/steel products, and coal/fuel effluents [29]. Cd and Ti concentrations, on the other hand, showed negative correlation with other potentially toxic elements which may originate from soils and other solid wastes.

3.3. Principal component analysis and source apportionment

From the PCA, sources of the different elements measured were classified according to pollutants. Table 4 provides the rotated component matrix (VARIMAX). The percentage of variance and accumulated percentage for the four components were also added.

There are four components obtained with a cumulative percentage of 87.18. Component 1 is mostly dominated by Cu, Pb, Zn, As, and Ni which is 48.68% of the total variance. High amounts of Cu, Zn, and As were observed in comparison with reference elements. These elements are found in natural sources mainly dominated by mineral dust elements. Pb, Cr, Ti,Hg, Cd, and Ni has accounted the 18% of the total variance in Component 2. This component is a mixture of natural and anthropogenic sources hence the detection of Pb, Hg, Cd, and Ni. Traffic emissions, and incinerators are associated with these elements [30–32]. Higher Hg and Ni values (0.86 and 0.72, respectively) was observed in Component 2 compared to Component 1. Mercury is a contaminant that is widely used for commercial products such as thermometers, pressure gauges, solvents, reagents, and laboratory chemicals. Nickel elements in aerosols from the combustion of fossil fuels [33,34]. Hg and Ni has been commonly known as carcinogens that may generate quantity of reactive oxygen species and gene regulation which contribute to carcinogenesis [35,36]. Only Co and Cd have the highest contribution in the total variance of 11.71% in Component 3. The combustion of heavy fuel oils from industrial setting may have caused the high amounts of these elements. Co relates to calcites which is caused by weathering of minerals in soils [37,38]. Negative total variance of 8.80 in Component 4 were recorded with Zn, Cr, V, Mn, and Fe as major contributors.

3.4. Enrichment factor analysis

Enrichment factors of the elements observed in this study were calculated as displayed in Fig. 2. The trend observed based on the EF values are as follows: As < Cd < Co < Cr < V < Ni < Hg < Cu < Zn=Pb. These represents the overall contamination degrees of atmospheric aerosols and urban dusts in Meycauayan, Bulacan. EF values lower than 2 (Deficiency to minimal enrichment) were found for Cd, As, and Co indicating possible natural sources like crustal erosion [39]. V, Ni, Cr, and Ti ranges from 2 to 5, meaning moderate enrichment. Fuel oil combustion from plants and factories may be considered as contributors of contamination. Furthermore, EF values higher than 40 were computed for Pb, Zn, Cu, and Hg, suggesting that they have very high enrichment. Traffic emissions may explain the amounts of Cu, Zn, and Pb [40–42].

Table 3
Correlation Matrix of Heavy metals collected in Meycauayan, Bulacan.

	Cu	Pb	Zn	Cr	Ti	V	Hg	Mn	As	Cd	Co	Fe	Ni
Cu	1	**0.59**	**0.72**	0.3	−0.36	**0.72**	0.35	0.43	**0.88**	−0.89	0.37	0.40	**0.79**
Pb	0.22	1	**0.81**	**0.73**	−0.37	0.07	**0.67**	0.27	0.34	−0.56	0	0.36	**0.88**
Zn	0.11	0.05	1	**0.69**	−0.46	**0.52**	0.28	**0.57**	**0.68**	−0.86	−0.05	**0.7**	**0.85**
Cr	0.56	0.10	0.13	1	0.21	0.24	**0.58**	0.47	0.11	−0.53	0.05	0.35	**0.75**
Ti	0.48	0.47	0.36	0.69	1	−0.01	0.27	−0.15	−0.43	0.29	0.17	−0.54	−0.15
V	0.11	0.89	0.29	0.65	0.99	1	−0.12	**0.66**	**0.8**	−0.85	0.41	**0.52**	0.43
Hg	0.50	0.14	0.59	0.23	0.60	0.82	1	−0.25	0.05	−0.15	0	−0.38	**0.72**
Mn	0.40	0.61	0.28	0.34	0.77	0.15	0.64	1	0.32	−0.74	**0.59**	**0.89**	0.3
As	0.02	0.51	0.14	0.83	0.39	0.06	0.92	0.54	1	−0.83	0.04	0.4	**0.61**
Cd	0.02	0.24	0.03	0.28	0.58	0.03	0.77	0.10	0.04	1	−0.35	−0.7	−0.76
Co	0.47	0.99	0.93	0.93	0.74	0.42	0.99	0.22	0.94	0.50	1	0.27	0.05
Fe	0.43	0.48	0.13	0.49	0.27	0.29	0.46	0.02	0.43	0.12	0.60	1	0.28
Ni	0.06	0.02	0.03	0.08	0.78	0.39	0.11	0.56	0.20	0.08	0.93	0.59	1

-The lower part is level of significance (0.05, two tailed).
-The higher part is the Pearson's correlation coefficient.

Table 4
Rotated Component Matrix (VARIMAX) for all data of Meycauayan, Bulacan.

Element	Component				Communalities
	1	2	3	4	
Cu	**0.85**	0.12	0.09	−0.30	0.85
Pb	**0.62**	**0.57**	−0.14	−0.34	0.86
Zn	**0.78**	0.10	−0.05	**−0.53**	0.91
Cr	0.33	**0.48**	−0.27	**−0.48**	0.64
Ti	−0.35	**0.84**	0.32	−0.01	0.93
V	0.39	0.43	0.09	**−0.65**	0.76
Hg	0.45	**0.86**	−0.08	0.08	0.96
Mn	0.18	0.08	0.28	**−0.93**	0.98
As	**0.79**	0.14	0.17	−0.32	0.78
Cd	−0.41	**0.47**	**−0.67**	−0.01	0.84
Co	−0.05	0.01	**0.96**	−0.04	0.92
Fe	0.31	−0.05	−0.02	**−0.93**	0.96
Ni	**0.53**	**0.72**	−0.06	−0.39	0.96
Total	6.33	2.34	1.52	1.14	
% of variance	48.68	18.00	11.71	8.80	
Cumulative %	48.68	66.67	78.39	87.18	

-PCA loadings >0.45 are shown in bold.

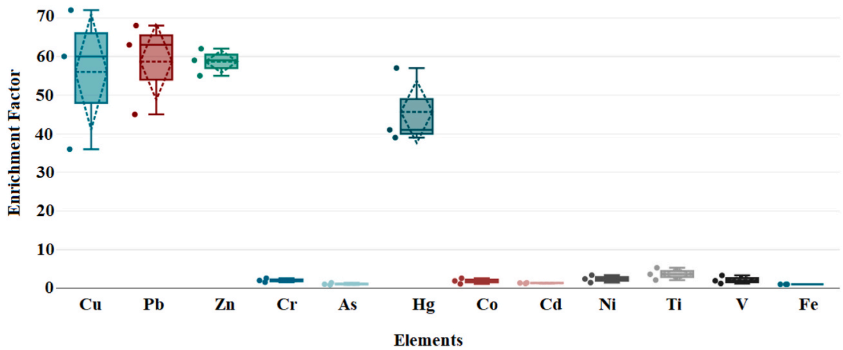

Fig. 2. Box and whisker plot of enrichment factors for all metals measured in the atmospheric aerosols and dusts in Meycauayan, Bulacan.

3.5. *Hierarchical cluster analysis of sampling stations*

Heavy metals analyzed above showed correlation and their possible natural and anthropogenic sources. Analysis on the clustering of elements based on the land use settings were performed using hierarchical cluster analysis with Euclidean distances. Clusters of elements in the different sampling stations were analyzed as shown in Fig. 3. There are three clusters which includes (1) AQS1-AQS2-AQS8; (2) AQS3-AQS4-AQS5; (3) AQS6-AQS7.

The first group of sampling stations (AQS1, AQS2, and AQS8) showed similar components of elements. AQS2 (Banga) and AQS8 (Malhacan) have the same land use setting as residential/and commercial while AQS1 (Caingin) has been tagged as reclaimed dumpsite. Heavy metals observed in these stations may have come from municipal solid wastes, electronic wastes, and small-scale industries in urban areas [38,43,44].

The second group consists of AQS4(Camalig) and AQS5 (Langka) which are in agricultural areas, and AQS3 (Calvario) which has a

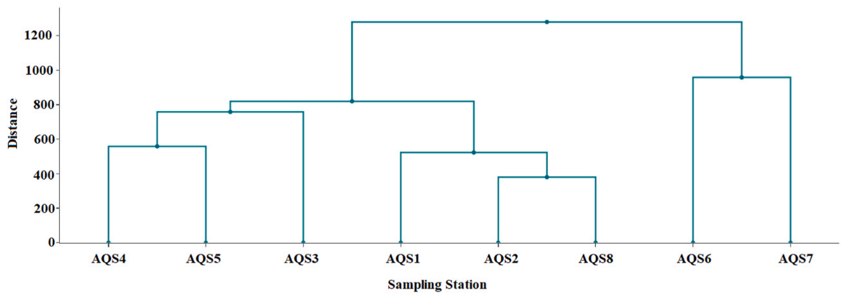

Fig. 3. Hierarchical dendrogram of 8 sampling stations.

residential/commercial setting. The set of elements observed in these stations may have come from residential effluents and agricultural run-off. The two groups of sampling stations are combined in one big group which may suggest that the elements observed are anthropogenic sources from human, traffic, and agricultural wastes.

The third group of sampling stations are AQS6 (Sto Nino-Perez) and AQS7 (Sterling) which are in industrial/commercial areas. This implies that the elements observed may have been influence of industrial and commercial effluents.

3.6. Environmental policy implications

Exposure to aerosol pollution in ambient air has been an emerging environmental risk factor for human health. Anthropogenic sources from different land use serves as the main contributor for air pollutant emissions in addition to natural emissions. Growing industrial activities leads to an urbanized community which can affect the environment. According to Philippine Clean Air Act of 1999 (Republic Act No. 8749) titled "An Act Providing for a Comprehensive Air Pollution Control Policy and for other Purposes" which aims to promote and protect the environment to attain sustainable development. It also aims to identify the primary responsibility of local government units to solve environmental problems. One of the air quality principles stated in the act that airsheds can help in the cleaning of the environment with air quality management and control [45]. Currently, there are three airsheds in region 3 where Meycauayan, Bulacan is located. This study shows the elements and heavy metal pollution in air caused by the industrial discharges found in Bulacan.

Our results suggest that the national government through local authorities should be strict in the implementation of several national and local laws in protecting the environment. Traces of elements related to carbonaceous aerosols, traffic and crustal materials, and industrial emissions (Tables 2 and 4, and Fig. 3) causes environmental problems that must be answered immediately. The variance in heavy metals vary in land use settings as observed in the different sampling stations. Our study is a three-way study report on the status of air, soil and water quality in Meycauayan, Bulacan. Heavy metal pollution in soil was recorded which may affect the ecological risk and heavy metal run-off to the different residential and agricultural sites [28]. Varying land use setting may cause environmental pollution in water, soil, and air which affects human health and the environment [46,47]. The local government of Meycauayan, Bulacan along with its neighboring cities and provinces should consider some of the key findings presented in this study for the creation of environmental laws and policies in the future.

4. Conclusions

Analysis of the elemental composition of aerosols collected in Meycauayan city during the summer period of 2016 were conducted in this study. Elemental distribution was performed using SEM-EDX analysis and was analyzed further for the concentrations of Cu, Pb, Zn, Cr, Ti, V, Mn, As, Cd, Co, Fe, and Ni. Total Hg concentrations were measured using Mercury analyzer. Based on the coefficients of variation along with the mean and standard deviation, spatial changes in potentially toxic elements were observed. PCA values showed variance in the four components with the cumulative percentage of 87.18. High amounts of Cu, Zn, and As are found in natural resources dominated by mineral dust elements which are grouped in Component 1. Component 2 consists of Pb, Cr, Ti, Hg, Cd, and Ni concentrations with possible mixture of natural and anthropogenic sources. The trend observed using EF values are as follows: As $<$ Cd $<$ Co $<$ Cr $<$ V $<$ Ni $<$ Hg $<$ Cu $<$ Zn$=$Pb. Pb, Zn, Cu, and Hg showed the highest enrichment which may be derived from traffic emissions, urbanization, and human effluents.

Heavy metals observed in Meycauayan, Bulacan can be classified into groups using HCA. AQS1, AQS2, AND AQS8 showed similar sets of elements. AQS4, AQS5, and AQS3, the second group, have the same land use setting as residential/commercial, and agricultural areas. The last group consists of AQS6 and AQS7 are categorized as industrial/commercial setting. The presence of heavy metals in Meycauayan, Bulacan at varying land use-land cover setting indicates the presence of environmental pollution not only in air but in water and soil. Effluents from traffic emissions, industrial and commercial activities are evident which requires immediate response from the local government of Meycauayan.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e19459.

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