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ASSESSMENTS OF ELEMENTAL CONCENTRATIONS OF PARTICLE MATTER IN ULAANBAATAR, MONGOLIA

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ABSTRACT

Air pollution is a growing problem in developing countries in the world and especially Mongolia. Particulate matter air pollution in Ulaanbaatar is several times higher polluted than the permissible level of Mongolian National Air Quality Standards 4585:2007 and the World Health Organization standards. Ulaanbaatar was in the list of the most polluted cities of world by World Bank. This study focused on the contents of the air particulate matter pollution in some districts of Ulaanbaatar, determination of the chemical composition of air borne samples and the source of those particles. Samples of fine and coarse fractions of particle matter were collected using a "Gent" stacked filter unit in two fractions of 0-2.2 μm and 2.2-10 μm sizes in a two semi residental areas from September 2012 to August 2013 of Ulaanbaatar, Mongolia. This paper analysis, fine and coarse concentration varied seasonally with meteorological changes.

Multi elemental analysis has been determined by Roentgen Fluorescence Analysis using SPESTRO XEPOS spectrometer.

Two sampling sites produce the air borne PM. In sampling site 1, Zuun Ail combustion generators generate the majority of pollution around 50.6% of household waste furnace to create high-temperature combustion of 21.6%. However, this net contribution to soil contamination near the lower value (5%) that arise around the vacuum environment in substantial amounts (14%), where is open around the buildings and residential areas, the soil is considered to be due to the construction. But the data points to the highway in the distance, where is 9 percent of contaminated of all vehicles smoke, exhaust is similar to the data collected in Ulaanbaatar.

From the sampling site 2, Nuclear Research Center (NRC) for the burning source of $PM_{2.5}$ pollution in the air around 25.5% of household waste furnace to create high-temperature combustion of 8.1 percent. But here the very high net contribution to the pollution of soil, is 31.6 percent. Today's emerging dust is around 15.2 percent, showing that motor vehicle pollution caused 19.7%.

Since the analysis was done on a sample-by-sample basis, it is possible to estimate the daily contributions of pollution sources and provide useful information based on a limited number of samples in order to address air quality management issues in Ulaanbaatar.

KEYWORDS: Pollution, Particle Matter, Source, Combustion

INTRODUCTION

Mankind's daily life is connected or interconnected to environmental change and air quality. Today, pollution is one of the world's most important issues. In recent years, air quality concerns have become one of the most important problems to be solved for the capital city of Mongolia, Ulaanbaatar: located at approximately 1300 meters above sea level, is the coldest national capital in the world, with an average annual temperature of -1. 3°C (29.7°F), and population of 1 million (Allen et al. 2013).

Population growth has been caused mainly by rural to urban migration has led to major increases in the capital city's air pollution emissions. Much of the population growth has been in the city's low-income ger (Mongolian national dwelling) districts where coal and wood are burned for heat. Given the long winters, coal use for cooking and heating is prevalent and the leading cause of air pollution.

Air pollutants can be classified as either primary or secondary. Primary pollutants are substances directly produced by a process, such as ash from coal combustion in a power plant or the carbon monoxide gas from a motor vehicle exhaust. Secondary pollutants are not emitted. Rather, they form in the air when primary pollutants react or interact.

An important example of a secondary pollutant is ground level ozone, one of the many secondary pollutants that make up photochemical smog. Note that some pollutants may be both primary and secondary: that is, they are both emitted directly and created from other primary pollutants. With special focus on particulate matter (PM), secondary PM consists of significant portions of Sulfates and Nitrates, which due to chemical transformation of SO_2 and NOx. Of these pollutants, the PM is one of the most critical pollutants responsible for the largest health and economic damages besides affects in visibility and weather condition.

Particulate matter pollution generally consists of a mixture of very small particles of dust, pollen, ash, soot, metals and other various solid and liquid chemicals found in the atmosphere. Particulate matter pollution is also categorized by size. Fine particles, such as those found in smoke and haze, are 2.5 microns in diameter and smaller. Fine particles are also referred to as $PM_{2.5}$. Inhalable coarse particles, such as those found near roadways and dusty industries, are larger than 2.5 microns and smaller than 10 microns in diameter. These inhalable coarse particles are referred to as PM_{10}. Fine particles ($PM_{2.5}$) are predominantly from combustion sources like vehicles, diesel engines and industrial facilities. Coarser particles are directly emitted from activities that disturb the soil including travel on roads, construction, mining, open burning or agricultural operations. Other sources include windblown dust, pollen, salts, brake dust and tire wear (Kothai et al. 2011).

The purpose of this study is to investigate particulate matter air pollution in Ulaanbaatar, compare with the research conducted in 2008 to determine the level of chemical elemental composition and black carbon (BC) concentration data of PM sample collected at semi-residential site at UB. The local source profiles used in this analysis were obtained from a previous data analysis study (Salako et al. 2012) and the data set used for the analysis is from September 2012, through August 2013 the same sampling site (Sukhbaatar District) and Nuclear Research Center (NRC).

Previous work mainly focused on just in Zuun Ail location. In this study we used the same equipment previous research but was chosen second sampling site and compare with it.

By the comparing of the results of two-point measurements of the city with the results of September 2012 to August 2013, the annual average concentration of $PM_{2.5}$ has decreased by 58% from 296.5 µg/m^3 to 123.5 µg/m^3 and the an annual average concentrations of PM_{10} has decreased by 50% from 557.5 µg/m^3 to 276.1 µg/m^3, decreased by 50% and it looks the benefit from measures taken indication from the parliament and the government, city government to reduce air pollution.

That is why had to do this research and compare it with meteorological conditions and was monitored how depends on it.

The results of the research work have been compared with those obtained from PM analysis performed in an earlier study (Davy et al. 2011) to determine the changes of the seasonal process of air particulate matter pollution of the city and its mitigation measures the basis for the development of practical important and explore the source of those particles.

METHODS AND MATERIALS

Sampling

Our study of changes in the elemental concentration of $PM_{2.5}$ and $PM_{10-2.5}$ in some districts of UB began in September 2012 and ended in the August 2013, were investigated. Sampling was done using a “Gent” type stacked filter sampler (Hopke, 1985).

A portable particle analyzer, known as an optical particle counter (OPC, Model 1.108, GRIMM Inc.), specifically designed for $PM_{2.5}$ and PM_{10} ambient air sampling by optical techniques is used in the present study. Collecting fraction samples of particulate matter in the coarse particles (PM_{10}) and fine particulates ($PM_{2.5}$) size have been monitored using the GRIMM particles sampler.

The research to collect air particulate matter two extract fraction samples has the special work tapes, and fractions uses were collected GENT air pump system for sampling, and polycarbonate filter with 2 mm thick, 8 mm to filter $PM_{10-2.5}$ large particles and 0.4 mm hole filtration to filter less than $PM_{2.5}$ micron diameter air particulate matter. The sampler consists of a PM_{10} imfactor type size selective inlet and stacked filter unit assembly connected to a pump and gas meter. The stacker filter unit is made up of two filters in a series, the top filter (polycarbonate) collects the particulate size fraction samples between 10 microns and 2.5 microns. The bottom filter (polycarbonate) collects particulate matter 2.5 microns and less in aerodynamic diameter ($PM_{2.5}$ or fine fraction). The research has conducted at the points for 2 times a day for up to 24 hours by the air particulate matter fraction of the sample of by recovery.

PM Mass and BC Determination

The masses of the coarse and fine fraction samples were determined by weighing the filters before and after the exposure. The concentration of black carbon (BC) in the fine fraction of the samples is determined by reflectance measurement using an EEL-type Smoke Stain Reflectometer.

Multi-Element Analysis

Air samples have been determined and elemental concentrations were measured by Roentgen Fluorescence Analysis (RFA) using SPESTRO XEPOS spectrometer and up to 20 chemical elements content has been identified from Na to U. The contamination source has been determined by the result of element analysis. Data on the concentrations of sixteen elements, black carbon and mass were available for further analysis. To this end research is done on the data based on multivariate statistical methods used SPSS 22 program.

Meteorological Conditions

The meteorological data used in this study was obtained from a local meteorological station.

RESULTS AND DISCUSSIONS

The Contamination Concentration of Air Particulate Matter Pollution in Ulaanbaatar

At the Zuun Ail and NRC measurement point coarse and fine particle concentrations were collectived to provide a measurements during the period of September 2012 to August 2013. $PM_{10-2.5}$ and $PM_{2.5}$ fraction measurement samples determined the amount of PM air pollution in UB. The results are shown in Table 1.

Table 1: $PM_{2.5}$ and PM_{10} Concentrations at Sampling Areas

Particulate Matter	Average Concentrations of the PM (µg/m³) Zuun ail 2012-2013	NRC 2012-2013	MNS 4585:2007	Air Quality Guidelines WHO, 2005
$PM_{2.5}$	123. 5	117. 5	25	10
PM_{10}	276. 1	263. 7	50	20

Particulate matter concentrations were found to be extremely high at times with average PM_{10} concentrations measured at 263.7µg/m³ and 117.5µg/m³ (the Guidelines recommends 10µg/m³ for fine, and 20µg/m³ for course).

Fine particle ($PM_{2.5}$) average annual concentration was measured at 123.5µg/m³ and 117.5µg/m³. MNS 4585:2007 specified in (25µg/m³) 4.9 greater than, (50µg/m³) again 4.7 greater than, WHO Air Quality Guidelines from size (10µg/m³) 12.35 greater than, 11.75 greater than recommended standard respectively (Table 1).

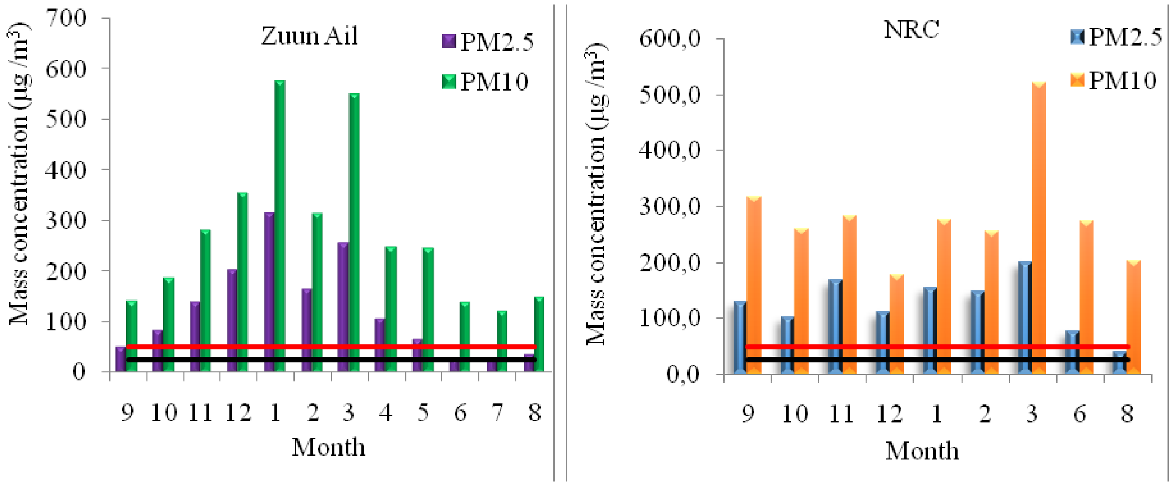

Figure 1: ab. $PM_{2.5}$ and PM_{10} Concentrations of the Average Monthly Change

The contamination concentration of PM pollution in UB, the monthly average air change around Zuun Ail and NRC are shown in Figure 1ab. There is high air pollution from October through May and extremely high from January through March. Fine particle concentration peaked during the winter (December, January, March). The monthly average concentration of PM_{10} is relatively higher 576.9µg/m³ than 549.9µg/m³ the average concentration of the other months from January to May. The average monthly maximum in 2012-2013 and from June through October months had uniformly low concentration levels (Figure 1ab).

Air pollutant concentration at the surface is strongly influenced by the characteristics of the source emission and the meteorological conditions of the atmosphere.

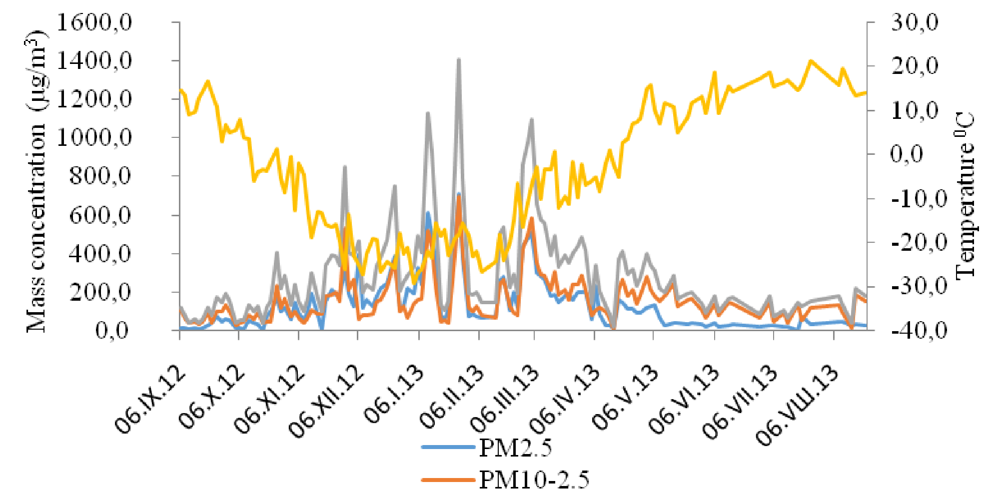

Figure 2: $PM_{2,5}$, $PM_{10\text{-}2.5}$ Zuun Ail Concentration in is a Temperature Dependent Relationship

According to Figure 2, depending on the ambient temperature during the cold seasons, air pollution increased from December to March. The PM generated from coal consumption grew and thus caused the incomplete combustion of coal around Zuun Ail households. Also there is high air pollution in March (large particulate matter 294.9µg/m^3). It may be the results of dust could be shown in Figure 3.

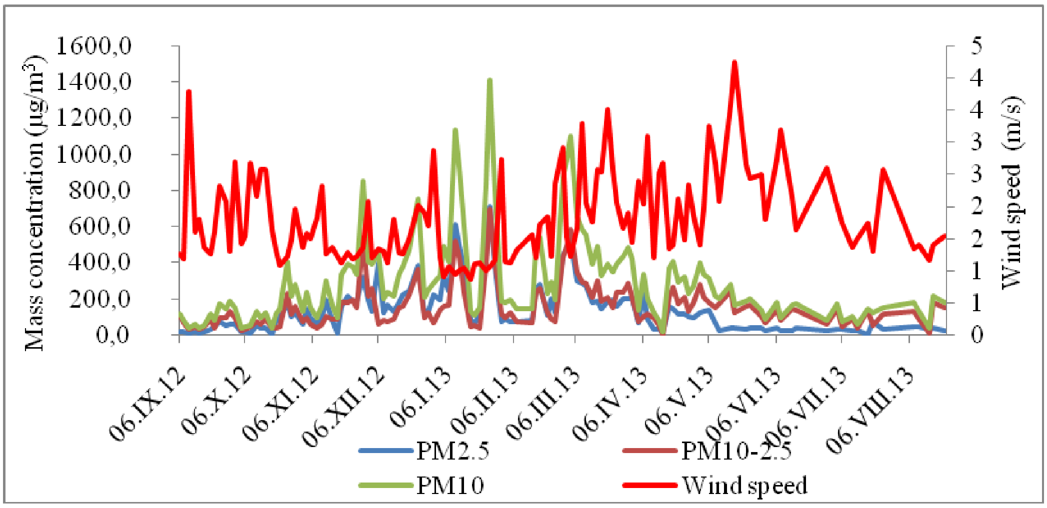

Figure 3: $PM_{2,5}$, $PM_{10\text{-}2.5}$, PM_{10} Zuun Ail Concentration with Wind Speed Dependent

Three meteorological and 12 hour radiosound data weather charts were used to characterize the atmospheric condition in UB during the measurement period of September 2012 to August 2013. Spring, autumn and winter in Mongolia are generally dry with spring and autumn the windiest seasons.

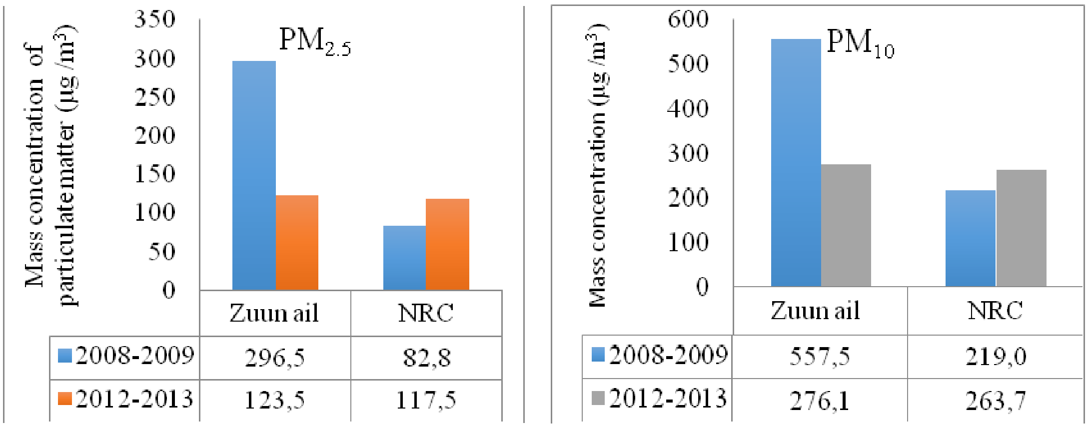

Figure 4: a. b Mass Concentrations Compared to the Previous Year from 2008 to 2009

Determination of Elemental Concentration in the Air Particulate Matter Samples

At both sites Zuun Ail and NRC fractions of 20 chemical elements in the ambient air $PM_{2.5}$ samples and $PM_{10-2.5}$. Si, Al, Ca, Fe, Ti, found in soil-derived components, such as high-grade (Table 2).

Table 2: The Average Elemental Concentration of Particulate Matter, 2012-2013

Elements	Average Concentrations in (ng/m^3)			
	ZuunAil		NRC	
	$PM_{2.5}$	$PM_{10-2.5}$	$PM_{2.5}$	$PM_{10-2.5}$
Mass	133654	155762	117452	146259
BC	5586	2373	8685	3482
Na	1940	3858	3017	5778
Mg	600	2197	1040	3383
Al	1211	7903	2119	13382
Si	1629	14423	3442	25153
P	260	333	282	360
S	3868	2036	5824	2412
Cl	300	661	361	891
K	244	1567	392	2795
Ca	309	3180	713	5546
Ti	143	315	159	481
Mn	57	105	63	151
Fe	269	2254	495	3962
Cu	12	21	13	22
Zn	47	49	68	69
Pb	17	6	26	13

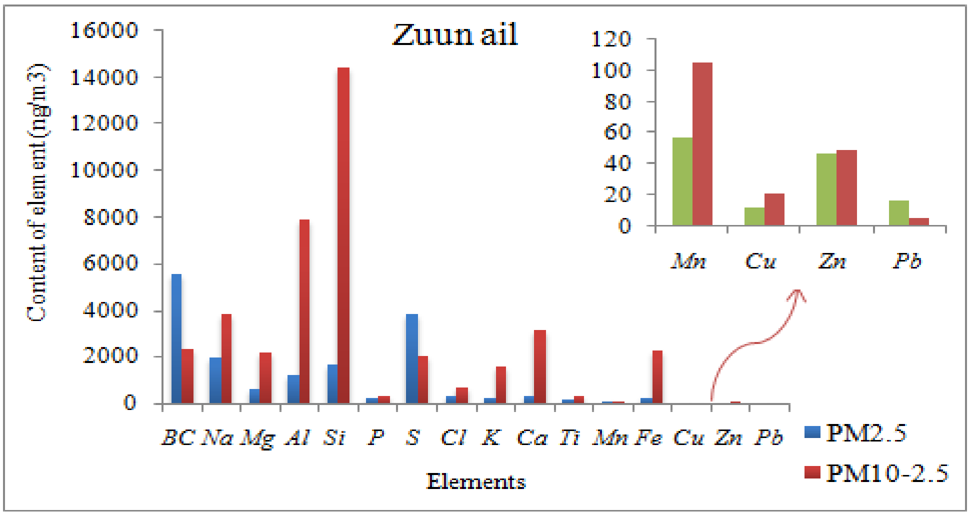

Figure 5a: PM Elemental Concentration of the Zuun Ail

Near the NRC there are fine particulate pollution ($PM_{2.5}$) and its samples containing a high level of black carbon (BC) and sulfur (S) and the products of combustion. The results of the ger`s from small scale stoves and also smoke from the thermal plant). It shows high level of concentration (Figure 5a). Through the results of the samples there are basic elements such as Al, Si, Ca, Ti and Fe which constitute soil that dominates in both fine and coarse particles in the atmosphere. Airborn soil originating from crystal matter is dominated by Al and Si along with Ca, Ti and Fe however, this is not only caused by the dust from the soil, the wind, but most of these elements are especially fine particles of combustion products that are related to human activities and the fine fraction contains elements. In addition, Na, Mg, P, Mn elements contained in all the samples and also contained a mixture of soil. Ni, Cu, Zn and Pb are contained with low-grade in any samples, but heavy elements is detected in the relatively large number of samples and those are usually contained in soil and generate from motors of vehicles, emission of vehicle brake parts and garbage combustion. (Figure 5b).

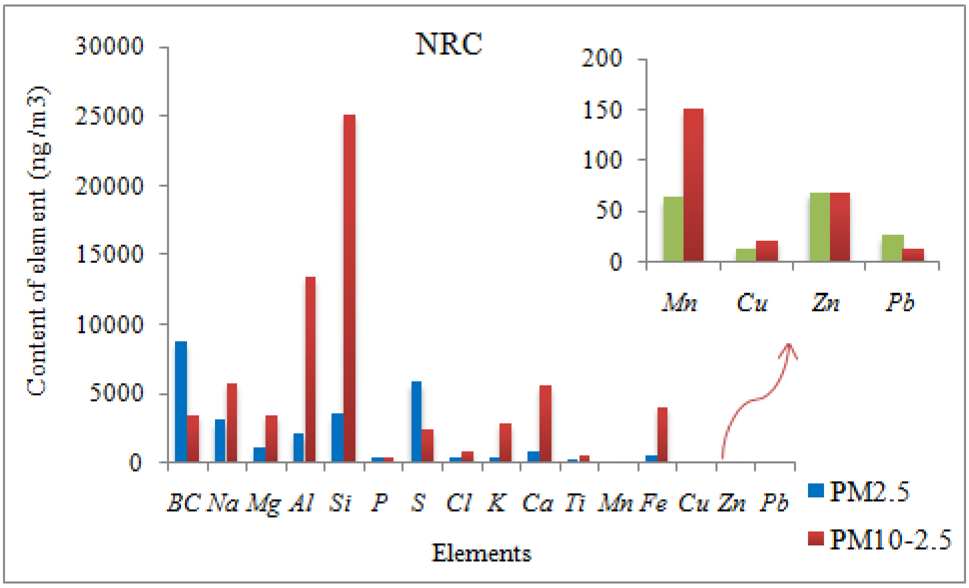

Figure 5b: The Elemental Concentrationof the PMin NRC

We suggest there are two distinct coal combustion source types are present in the UB combustion characteristics.

Identifying the Source of Air particulate Matter Pollution and to Define its Contributions to Air Pollution

Figure 6 is made by EMF analysis using the elemental analysis results in air samples. Through the analysis of positive matrix factoring, Soil, Combustion-1 (furnace), Combustion-2 (power plant, small size stove, BC), dust (buildings and roads work and other) and vehicles, are they five patterns of pollution sources that have been identified. The average mass contributions of each of the sources to ambient coarse particle concentration are shown in Table 3 and the source profiles are presented in Figure 6.

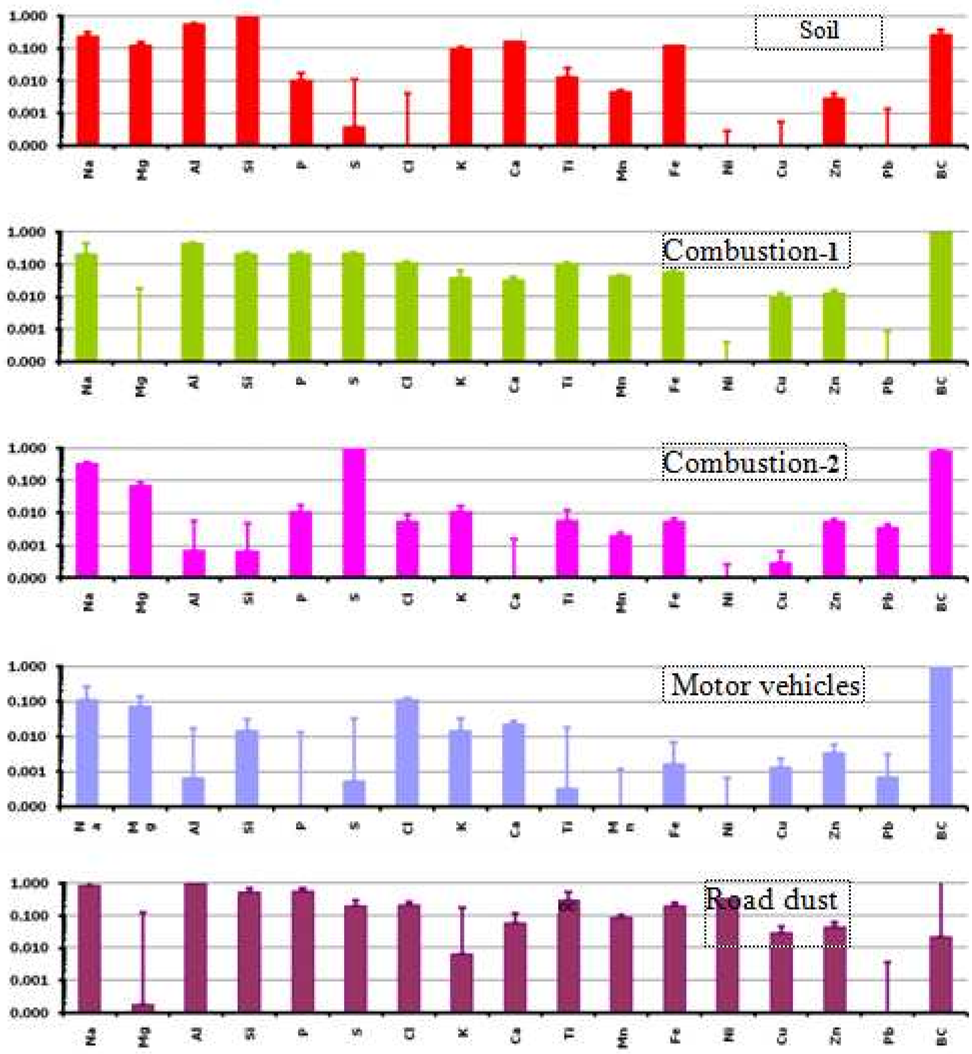

Figure 6: Source Related Classification of the Elements Profiles for $PM_{2.5}$ Samples

Table 3 presents the comparison of the estimated average source contribution obtained from EMF analysis for the fine PM using the same chemical composition data sets of all the samples. In the case of fine PM, several differences were noted.

Table 3: Measurement of $Pm_{2.5}$ Particles in its Source Point Pollution Contribution

	$PM_{2.5}$ Source of Pollution	Contribution to Pollution(%)	
		NRC	Zuun ail
1	Combustion -1	25. 5	50. 6
2	Combustion -2	8. 1	21. 6
3	Soil	31. 6	4. 9
4	Road dust	15. 2	13. 9
5	Motor vehicles	19. 7	9. 1

Around theNRC there may have been a lot of pollution from the soil. This profile contains S and BC as well as other soil components (Boulter 2006). Air pollution related to human activities, indicate similar results showing in the two locations. In the location around Zuun Ail and it is surrounding areas, there is re-development of ger districts and new buildings, in and around the location of NRC there is construction in progress and in proximity to this point there is a dirty road passes. For the vehicles near the NRC there is the east route and central road of the city that passes on either side of it (Table 3).

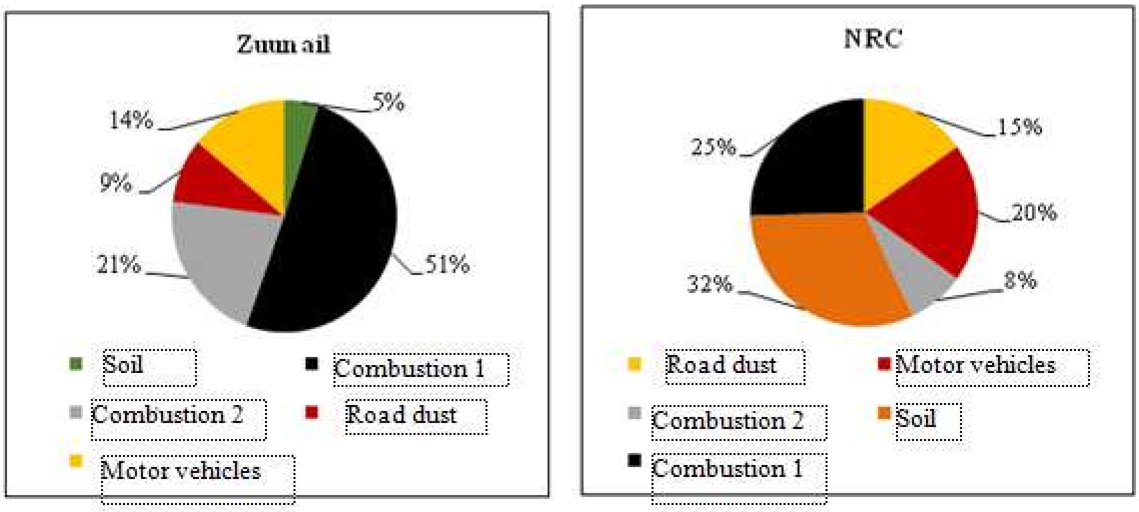

Figure 7: $PM_{2.5}$ in the Air around the Selected Point of Generation (2012-2013)

The first source profile was identified as a coal combustion source contribution for the coarse fraction and this contains the majority of BC, a significant sulphur component. The time series plots of the per sample mass contributions of the PM_{10-25} coal burning source contributions peaked during winter indicating that it was likely due to emissions from the local coal combustion sources. A third crustal mattersource, labelled as soil, has also been identified as originating from crustal matter land. The primary distinction between the two soil profiles is that theroad dust source has a significantly higher BC component.

The fourth source has been identified as local road dust component as this profile contains BC and most of the zinc along with elements typical of crustal matter.

The fifth source has been identified as originating from motor vehicles as a similar separation of elemental components associated with fine particle motor vehicle emissions. The motor vehicle (mixed diesel and gasoline engine exhaust) source profile is characterized by the high BC and S (Salako et al. 2012). This source is also mixed with the crustal elements, Mg, Al, Si, and Fe, suggesting the vehicular exhaust is mixed with re-suspended road dust.

CONCLUSIONS

Particulate matter ($PM_{2.5}$) annual average concentration is 123.5µg/m^3 and 117.5µg/m^{3}and it has 5 times more than MNS 4585:2007, and 11-12.5 times more than the measurement specified from the Air Quality Counsel of WHO. The annual average concentration of PM_{10} is 276.1µg/m^3, 263.7µg/m^{3}and it is 5.2-5.8 times higher than Mongolian standards, 13.2-14.5 times higher than the amount specified from the Air Quality Counsel. By the research, for the population health assessment of the air quality, the indexes of 2 points indicate at a high risk for health.

In addition, air pollution may depend on the wind. From January through March has the highest concentration than other months. Wind speed is constant in cold seasons and it increases in March and it may be the reasonto increase soil dust emissions.

An EMF analysis result shows UB's air pollution sources in the territory of the two different points have variety as shown by the data.

Measures to reduce air pollution in the city is not only from smoke, but it is can be the air pollution depends on other sources. Dust measures should be regarded as a defined contribution source of particulate pollution.

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