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IMPACT OF THE AMBIENT AIR PM2.5 ON CARDIOVASCULAR DISEASES OF ULAANBAATAR RESIDENTS

ABSTRACT. Mongolia is a landlocked country with a total land area of 1,564,116 square kilometers. The ambient annual average particulate matter (PM) concentration in Ulaanbaatar is 10–25 times greater than the Mongolian air quality standards (AQS). More than 40 percent of the nation's total population lives in Ulaanbaatar. The study aims at defining the relationship between the ambient air PM2.5 level and hospital admissions in Ulaanbaatar in 2011–2014. The pollution data included a 24-hour average PM2.5. The air was sampled daily and recorded by the national air monitoring stations located in Ulaanbaatar. The sampling frame of hospital admissions for cardiovascular disease (CVD) were the records of all outpatient hospitals of Ulaanbaatar. The data covered the period from January 2011 to January 2014. To test the differences of the results, appropriate statistical tests were employed. During 2011–2014, the highest concentration of PM2.5 was in the coldest period and the particulate matter level recorded was 3.7 times higher in the cold period than the warm period. The number of admissions for CVD were the highest during cold periods. Four days after exposure, the PM2.5 impact on hospital admissions weakened but there remained a positive correlation. For PM2.5, 100 $\mu g/m^3$ growth of the pollutant led to 0.65 % increase in the hospitalization for CVD on the exposure day. On the second day of exposure, 10 $\mu g/m^3$ growth of the pollutant led to 0.66 % increase; on the third day of exposure, 10 $\mu g/m^3$ growth of the pollutant led to 0.08 % increase of hospital admissions for CVD, and at the fourth day, such growth led to 0.6 % increase of CVD cases in 2011–2014 in Ulaanbaatar. In conclusion we may state that most incidences of CVD registered during the cold months in Ulaanbaatar in the last four years were a result of PM2.5 exposure. This shows that the PM2.5 exposure and hospital admissions for cardiovascular system chronic diseases are positively correlated. CVD in Ulaanbaatar residents was affected greater on the same and the third day of exposure.

KEY WORDS: PM2.5, exposure, CVD, health impact, Ulaanbaatar air pollution.

INTRODUCTION

Mongolia is a landlocked country with a total land area of 1,564,116 square kilometers. Steppes and deserts stretch in its southern and eastern parts, while mountains surround the northern and western parts. The country has extreme continental climates with long, cold winters and short dry summers. The average temperature in January and February is –20 °C, with winter night temperatures dropping to –40 °C (NSO 2015).

The atmosphere is a mixture of gaseous substance produced over the Earth's long history by biogenic, geologic, and atmospheric processes. By definition, air pollution is a mixture of solid, liquid, gaseous, and biological substances emitted to the atmosphere by natural and anthropogenic activities, which has detrimental effects on animals, human health, and economy (Godish, 2004).

The ambient annual average particulate matter (PM) concentration in Ulaanbaatar is 10–25 times greater than the Mongolian air quality standards (AQS) and is among the highest recorded measurements compared to any other world's capital. The Mongolian annual ambient air quality standard is 25 $\mu g/m^3$ for PM2.5 (MNS 2008).

More than forty percent of the total population of Mongolia lives in Ulaanbaatar (STU 2015). In 2014, over 184,000 households live in the "ger" areas of six central Ulaanbaatar districts and approximately 3,200 entities operated by the heating of low-pressure steam boilers in the capital. Eighty percent of air pollution comes from these pollution sources (CNAP et al 2014).

Particulate matter in the air of Ulaanbaatar is the main source of air pollution. According to the findings of relevant surveys, the content of particles (PM_{10} and $PM_{2.5}$) in household (indoor) air with furnaces is at the level which impacts negatively health (PHI 2007). Not many surveys have been conducted in relation to the PM2.5 level and health outcomes in Mongolia.

This study aims at defining the relationship between the ambient air PM2.5 level and hospital admission cases of Ulaanbaatar in 2011–2014.

MATERIALS AND METHODS

The data cover the period from January 2011 to January 2014.

Exposure data. The pollution data included a 24-hour average of PM2.5. The PM2.5 data come from a network of 2 monitoring stations. The air was sampled daily and recorded by the national air monitoring stations located in Ulaanbaatar. The air quality stations used an instrumental method, which utilizes automated equipment to analyze air quality.

Morbidity data. The data for hospital admissions for cardiovascular disease (CVD) were the records of all outpatient hospitals in Ulaanbaatar. The ICD-10 disease classification system was used by each hospital's statistics department.

Data analysis. The data were analyzed using SPSS Version 21.0. For testing the differences in the results, appropriate non-parametric tests were used. Kruskal-Wallis one way analysis of variance, Mann-Whitney U tests, and Spearman correlation and linear regression were also used.

RESULTS AND DISCUSSION

Ambient air PM2.5 level, 2011–2014

Air quality of Ulaanbaatar in 2014, as measured by particulate matters (PM2.5), was 64 $\mu g/m^3$ (2.6 times higher than the permissible level of the Mongolian air quality standard). The average PM2.5 concentration from October 2013 to April 2014 was lower by 27 $\mu g/m^3$ (21 %) than the concentration measured from October 2012 to April 2013. During 2011–2014, the highest concentration of PM2.5 was during the coldest periods. The PM2.5 level was relatively high during cold periods because of high household (indoor) burning of raw coal during cold temperatures. The following histograms show a 24-hour average PM2.5 level in cold and warm seasons.

According to the survey of Delgerzul. L (2012) of ambient air around Ulaanbaatar's Sukhbaatar district, the annual average PM2.5 level was 375.09±722.6 $\mu g/m^3$.

In comparison to Delgerzul's survey, the average PM2.5 concentration in ambient air declined during cold periods by 2.29 times.

Basically, our study found that the PM2.5 level is 3.7 times higher in colder periods than warmer periods (warm 34.15±20.39 $\mu g/m^3$, cold 127.6±11 $\mu g/m^3$) (Table 1).

Actually, the mixture of particles is likely to vary within the study areas by size, number,

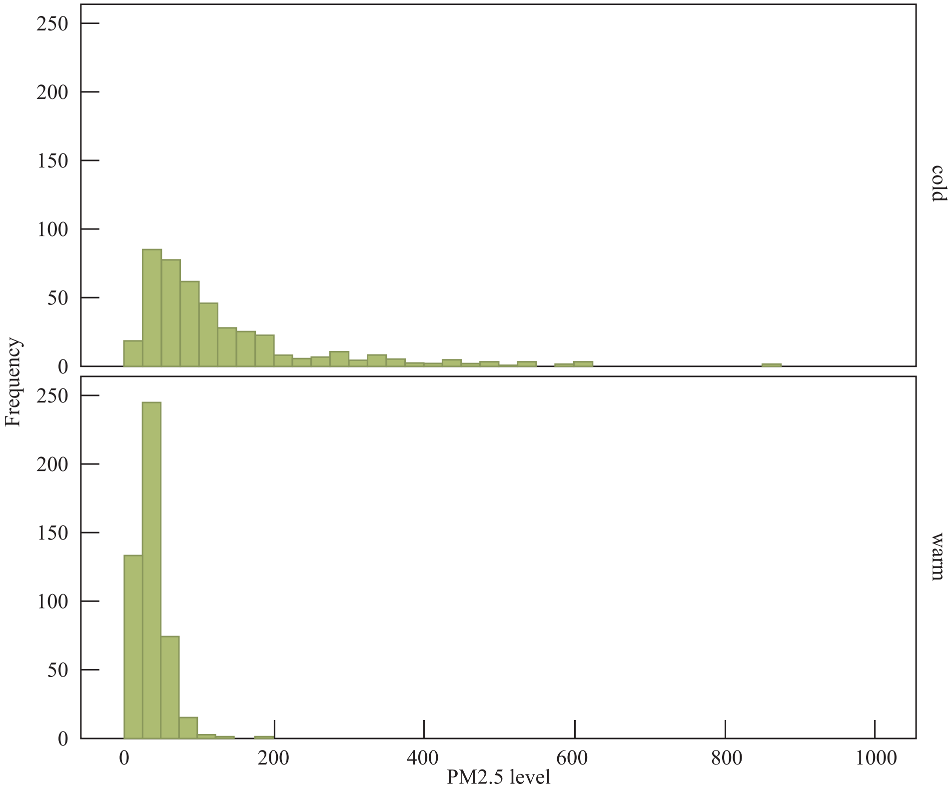

Fig. 1. Histogram of a 24-hour average PM2.5 level in Ulaanbaatar, 2011–2014.

Table 1. Some descriptive statistics on the PM2.5 level and daily admission cases for CVD

	PM2.5 μg^3			CVD cases		
	Warm season	Cold season	Total	Warm season	Cold season	Total
Mean	34.15	127.60	80.08	54.13	79.63	68.42
Median	33	88	46.18	44	76	58.0
Std. Deviation	20.39	119.51	95.81	36.17	44.56	43.04
IQ Range	22	110	59	43	66.5	59
Minimum	2	14	2	10	10	10
Maximum	194	854	854	230	230	230
p value *	0.0001	0.0001				

* Mann-Whitney U test

and chemical composition. The toxicity of particulate matter depends on its chemical composition and size distribution. Fine particles (for instance, PM2.5) have been found to have bigger effects on health than PM10 (Bremner et al, 1999; Ha et al., 2001).

Cardiovascular disease admission, 2011–2014

The following figures show time sequence of seasonal cases of CVD. The number of cases increased in last 2 years and the highest number of cases was registered during the cold months (Fig 2).

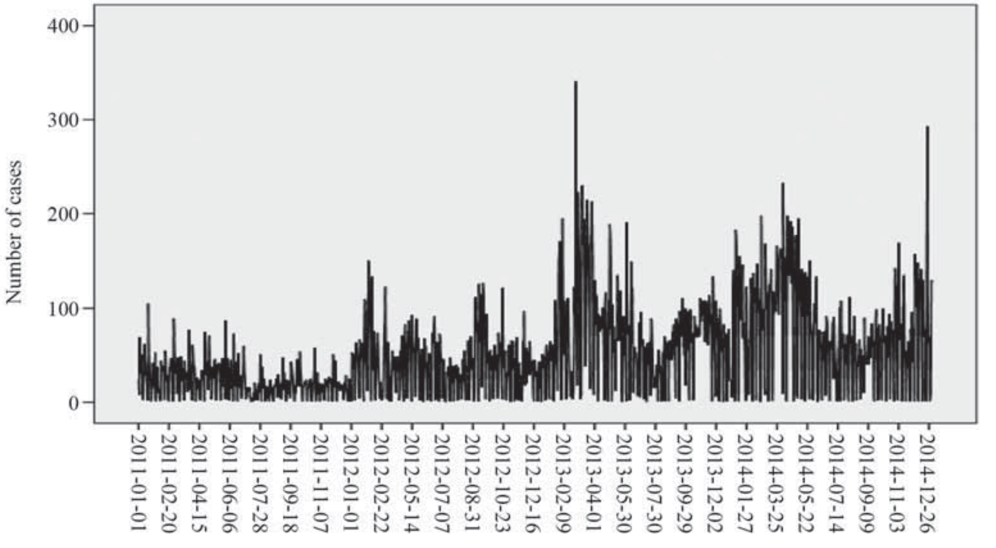

Fig. 2. Daily morbidity counts of CVD, by date, Ulaanbaatar, 2011–2014.

In spring, the most hospital admissions for CVD occurred, while during the summer months, the number of admissions declined. On the other hand, during cold periods, the most cases of hospitalization for CVD were registered ($r^2 = 34.6$, $p = 0.00001$) (Table 2).

Table 2. Distribution of CVD incidence, by season and gender, UB, 2011–2014

Seasons	Male	Female	Total
Summer (June 1–Aug 31)	5753 22.8 %	10157 24.6 %	15910 23.9 %
Autumn (Sep 1–Nov 31)	4400 17.5 %	7091 17.2 %	11491 17.3 %
Winter (Dec 1–Feb 28)	6771 26.9 %	10480 25.4 %	17251 26.0 %
Spring (Mar 1–May 31)	8254 32.8 %	13551 32.8 %	21805 32.8 %
Total	25178	41279	66457

The most common CVD of admitted cases in Ulaanbaatar during 2011–2014 were hypertension and ischemic heart disease (Fig. 3).

Impact of ambient PM2.5 on CVD of Ulaanbaatar residents

The research conducted in 2003 in major cities and towns of Mongolia found that respiratory diseases were caused by pollution. Its result

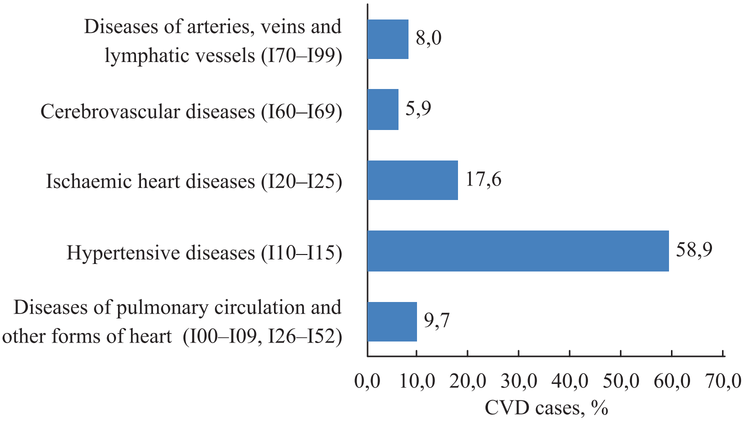

Fig. 3. Leading causes of CVD, Ulaanbaatar, 2011–2014.

shows the respiratory diseases have a direct moderate level relationship with carbon monoxide ($r = 0.538$ $p = 0.011$), sulfur dioxide ($r = 0.44$ $p = 0.019$), and nitrogen dioxide ($r = 0.34$ $p = 0.013$), respectively (PHI 2003).

According to the 2009 World Bank survey, PM2.5 and PM10 in the ambient air of Ulaanbaatar had a constant and strong correlation with hospital admissions for CVD. For PM2.5, 10 $\mu g/m^3$ growth of the pollutant led to a 0.8 % increase in CVD-caused hospitalization (WB 2009).

In this study, we estimated the correlation (Spearman's) between PM2.5 and CVD lag0-3. It was shown that after the fourth day of exposure, a weak positive correlation was observed (CVD lag0: $r = 0.13$, $p = 0.0001$, CVD lag1: $r = 0.21$, $p = 0.0001$, CVD lag2: $r = 0.12$, $p = 0.00001$, CVD lag3: $r = 0.09$, $p = 0.004$).

In 2011–2014 in Ulaanbaatar, on the first day of exposure, 2.7 %of hospitalizations for cardiovascular disease was due to PM2.5; on the second day, 2.2 %; on the third day of exposure, the rate of hospital admissions increased 2.8 %, and on the fourth day, CVD-caused hospitalizations were 2.1 %.

The impact of CVD was relatively low compared to the 2009 World Bank survey. For PM2.5, 10 $\mu g/m^3$ growth of the pollutant led to a 0.065 % increase in CVD- caused hospitalizations on the exposure day. On the second day of exposure, 10 $\mu g/m^3$ growth of the pollutant led to a 0.066 % increase in hospitalizations; on the third day of exposure,10 $\mu g/m^3$ growth of the pollutant led to a 0.08 % increase of CVD related hospital admissions, and on the fourth day, a 0.06 % increase in CVD cases (Fig. 4).

Many studies verify that CVD are caused by air pollution. For instance, scientists Dockery and Pope from Harvard University discovered that by reducing the content of PM10 in the air (until

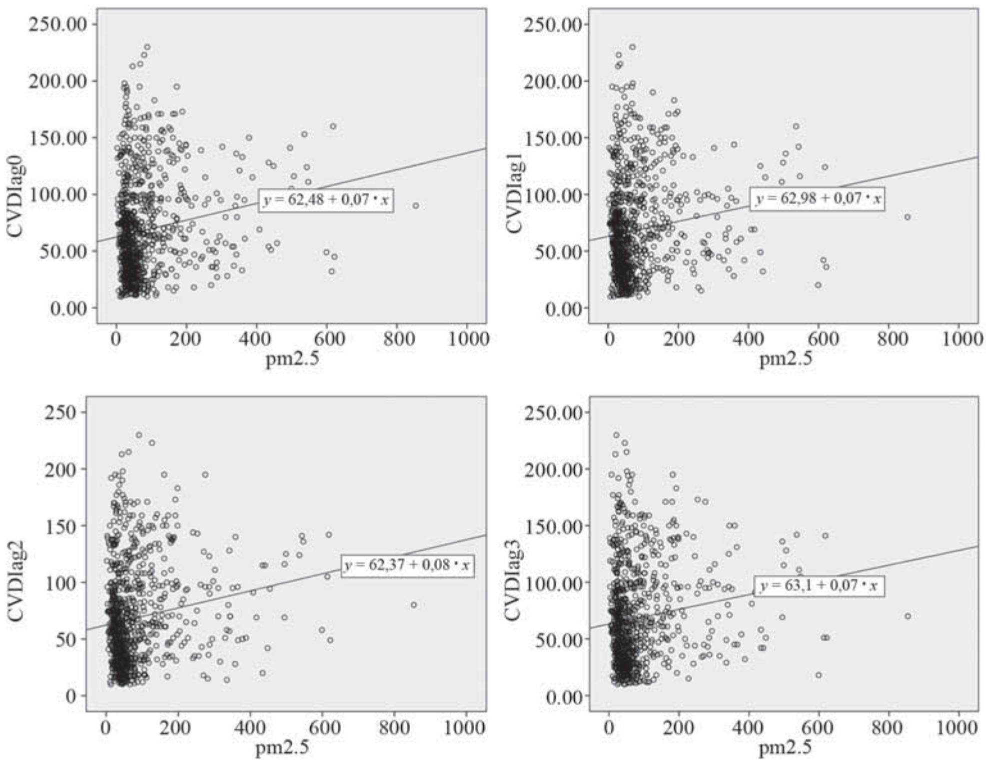

Fig. 4. Scatter diagram of Spearman correlation between CVD lag0-3 and ambient air PM2.5 annual level.

the standard rate), CVD-related mortality can be reduced by 15 percent (Dockery et al 1994; Pope et al 2002).

Similar findings were found in a survey conducted by Enkhjargal et al (2010), which showed the percentage of combined effects on respiratory diseases in the winter season is 52.9 for average temperature, humidity, nitrogen dioxide and PM10; the percentage of combined effects on cardiovascular diseases in the winter season is 37.2 for average temperature, humidity, nitrogen dioxide and PM10; the percentage in autumn is 5.4 for PM10 only, and the percentage in summer is 17.4 for wind speed and average temperature, while in autumn, the percentage of combined effects of sulphur dioxide, nitrogen dioxide, and PM10 is 25.4.

Time-series analysis

Variability of the PM2.5 level and acute disease admissions declined from 8.0 % to 3.9 % during days of 1–3 (lag0–lag3), respectively. In this variability, the highest PM2.5 level and acute CVD admissions was observed on the first day (8.0 %) and the lowest variability was observed on the third day (3.9 %). For the total acute admissions and the PM2.5 level, only lag0 significant correlation (4.0 %, $p = 0.02$) was observed. Variability significantly increased for chronic disease admissions and particular matter. Variability of chronic CVD admissions and the PM2.5 level was increasing to the second day (lag 2) (lag0, 12.1 %, $p = 0.00001$ – lag2, 15.9 %, $p = 0.000001$) and on the third day (lag 3) it decreased to 10.1 % ($p = 0.0003$).

Variability of chronic CVD admissions and the PM10 level was increasing to the second day (lag 2) (lag0, 10.91 %, $p = 0.0002$ – lag2, 11.1 %, $p = 0.0002$) and on the third day, (lag 3) it decreased to 7.1 % ($p = 0.0003$) (Table 1). Variability of chronic CVD and the PM2.5 level was the lowest on the first day (lag0, 6.5 %, $p = 0.004$) and the highest on the third day (lag3, 15.0 %, $p = 0.0001$). Variability of chronic CVD and the PM10 level was higher than variability of chronic CVD and the PM2.5 level in all 4 days. The highest variability was observed on the second day (lag1, 19.3 %, $p = 0.000001$) and the lowest was observed at the first day (lag0, 15.3 %, $p = 0.0001$).

CONCLUSION

Most incidences of CVD registered during cold months in Ulaanbaatar in the last 4 year were the result of ambient air PM2.5. However, the impact of exposure to other air pollutants and meteorological factors in Ulaanbaatar should be taken into consideration. Ambient air PM2.5 exposure positively influences chronic CVD admissions to hospitals. The hospitalizations for CVD in Ulaanbaatar residents were higher on the first and the third day of exposure. ■

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