Metal Components and Health Risk Assessment of Coarse Particulate Matter

Li Bai, Siyue Sun, Na Li and Chunyu Kang

ABSTRACT

In order to study the concentrations and health risk of heavy metals in different particulate matter in JingYue in ChangChun City, TSP samples were collected in different seasons from April to June in 2017. The results showed that the concentrations of particulate matter exceeded the standard. The concentrations of metals were Cd<Co<Cr<Cu<Ni<V<Mn<Pb>Zn<Sn<Al<Fe<Sb, Pb and Cd exceeded the standard. Through correlation and principal component analyses showed that the 14 metals mainly came from the coal sources, the dust sources and the second transmission industry sources. Enrichment factors showed that except for Mn, other metals had different degrees of enrichment phenomenon. The HQ values of 6 metals Mn, Ni, V, Cr, Cd and Sb were less than 1 which didn’t exist non-carcinogenic risk. The R values of Pb, Cr, Cd and Ni were less than $10^{-6}$, suggested the non-existence of carcinogenicity.1

INTRODUCTION

Since the 21st century, with the advance of industrialization, people's living standards improved constantly, human activities caused irreparable damage to the environment, one was the air pollution event which had a direct impact on people's lives. For example, the embassy event in Beijing in 2011 triggered China's "air revolution", the heavy pollution incident in North China in 2013 caused the visibility in many areas less than 500 m. Air pollution incidents caused serious damage to people's health. In order to study the metal components attached to coarse particulate

1 Li Bai, Siyue Sun, Na Li, Chunyu Kang, Key Laboratory of Songliao Aquatic Environment, Ministry of Education, Jilin Jianzhu University, Changchun, China,130118.
matter and their harm to human health, TSP samples in different seasons were collected from April to June and the health risk assessment was carried out by EPA.

**RESEARCH METHODS**

**Sample Collection And Analyses**

The sampling site was on the roof of the civil engineering building of Jilin Jianzhu University (43° 47, N, 125° 23, E). The sampling time was from April to June 2017, 8 a.m. to 4 a.m. the next day. Samples were collected by the medium flow sampler that the flow rate was 100 L / min. Sampling membranes using Swedish Munktell MK360 grade 90 mm films. Referred to HJ777-2015 for the determination of metal elements in air and exhaust particulates. The recovery rate was measured at 80 ~ 105%, which satisfied the requirement of sampling test.

**Enrichment Factors Calculation**

The enrichment factor [1] is the ratio of the measured value of the element in the sample to the background value to determine the impact of the element in the environment, the formula is as follows:

\[
EF = \frac{(C_i/C_n)_{sample}}{(C_i/C_n)_{background}}
\]  

In the formula: \( C_i \) and \( C_n \) are the concentrations of element \( i \) and reference element \( n \) in the sample and in local soil background (mg/kg). In this paper, Al was the reference element. If \( EF \) is less than 10, the samples are mainly from natural sources. If not, indicating that samples are affected by anthropogenic sources.

**Health Risk Assessment**

It was generally believed that the metals mainly through ingestion, respiration and skin contact to enter the human body. HQ and R represent non-carcinogenicity and carcinogenicity of heavy metals. The formulas are as follows:

\[
ADD_{mg} = C \times IngR \times EF \times ED \times CF \times BW \times AT
\]  

\[
ADD_{inh} = C \times InhR \times EF \times ED / BW \times AT \times PEF
\]  

\[
ADD_{derm} = C \times CF \times AF \times ABS \times EF \times ED \times EV \times SA / BW \times AT
\]
\[ HQ = \frac{ADD}{RfD} \quad (5) \]

\[ R = LADD \times SF \quad (6) \]

In the formulas: ADD—daily exposure dose of non-carcinogenic heavy metal, mg/kg.d; among them, ADDing on behalf of ingestion, ADDinh on behalf of inhalation, ADDderm on behalf of skin contact; C—concentration of heavy metal in particulate matter, mg/kg; IngR—ingestion rate, mg/d; InhR—respiration rate, m3/d; EF—exposure frequency, d/a; ED—exposure years, a; BW—average weight, kg; AT—average exposure time, d; CF—conversion factor, 10-6kg/mg; PEF—emission factor of particulate matter, m3/kg; AF—soil adhesion factor to skin, mg/cm2; ABS—absorption factor of skin; EV—daily exposure times, 1/d; SA—skin surface area in contact with contaminated media, cm2; RfD—non-carcinogenic contaminant reference dose, mg/kg.d. LADD—daily exposure dose of carcinogenic heavy metal, mg/kg.d. SF—carcinogenic strength coefficient of carcinogen, (mg/kg.d)-1. The corresponding parameter values are shown in [2-3].

RESULTS AND DISCUSSIONS

Concentration Analyses of Particulate Matter

The concentrations of TSP were shown in Figure 1. Referred to GB3095-2012, only on April 29th the TSP concentration exceeded the national ambient air quality secondary standard (300 μg/m3), and in the spring were higher than those in the summer which more than the national level standard (120 μg/m3). This might be because the spring heating period just ended, the particulate matter remaining in the atmosphere and the newly produced particles jointly determined the concentrations of particulate matter in the spring were generally higher than those in the summer. Spring had more static stability type days that was not conducive to the discharge of pollutants. Increasing concentrations of particulate matter and more harmful substances especially those metals threaten human health[4-5].
Concentrations And Sources Analyses of Metals

The concentrations of metals were shown in Figure 2, 3. The average concentrations were Cd<Co<Cr<Cu< Ni<V<Mn<Pb<Zn<Mg<Sn<Al<Fe<Sb. Referred to GB3095-2012, Pb exceeded the standard (0.5 μg/m3) on 4.26, 5.03 and 6.15 for 1-1.4 times; Cd exceeded the standard (0.005 μg/m3) for 2-50 times; the standard for Cr (VI) was defined as 0.000025 μg/m3, our study group measured the total Cr concentration, the data presented was for reference only. A certain concentration of Pb, Cd and Cr (VI) [6-8] could cause great harm to human health. Studies have shown that high concentrations of Co, Ni, V, Mn, Sn and Sb would also cause some harm to human body.

Correlation analysis showed that Pb, Ni, Cr, V, Cd, Co and Cu had a positive correlation; Sb and Fe, Al and Mg had a positive correlation; Mn and Fe, Al, Mg had a positive correlation; Sn had a significant negative correlation with metals other than Sb, Al, Zn and Mg. Combined with principal component analysis as shown in Table I. It analyzed that three factors could explain 92.901% of all variables. Component 1 explained the total variances of 61.819%, included V, Mn, Cr, Cd, Co, Cu, Ni, Sn and Pb; the loading rates of V, Mn, Cr, Cd, Co and Cu were relatively large (0.937-0.979), mainly from the coal sources and some industrial sources. Because there were no obvious industrial sources around the sampling site, it might be the contribution of atmospheric transmission. Component 2 explained the total variances of 23.201%, included Sb, Mg, Al, Fe. The loading rates of Sb and Mg in the component were higher (0.858 and 0.828). So component 2 mainly represented the dust sources. Component 3 contained only Zn, the loading rate was 0.879, the contribution rate was 7.881%, mainly from the coal sources.
Health Risk Assessment

Enrichment factors showed that except for Mn, other metals were enriched in different degrees. Among them, Ni, Cr, V, Cu, Zn had slight enrichment phenomenon, EF<100. Pb and Co had serious enrichment phenomenon, EF was between 100 and 150. Cd, Sb and Sn had extremely serious enrichment phenomenon, EF was between $10^4$ and $10^5$. Enriched metals may cause great harm to human health [9].

The HQ values of 6 metals were less than 1 which didn’t exist non-carcinogenic risk. The R values of Pb, Cr, Cd and Ni were less than $10^{-6}$, suggested the non-existence of carcinogenicity. The ingestion of R values for Pb and Cr were significantly higher than the respiration of R values and $CR_{Inh}>CR_{Inh}>Pb_{Inh}>Cd_{Inh}>Ni_{Inh}>Pb_{Inh}$. Through the above analyses, it was known that the metals attached to the coarse particles had a certain health risk to human health. Therefore, controlled particulate emissions and promulgated laws and regulations for improving air quality and maintaining human health were essential.

CONCLUSIONS

1. The concentrations of TSP in spring exceeded the national level standard (120 μg/m3), and exceeded the national ambient air quality secondary standard (300μg/m3) on April 29th. The metals existed excessive phenomenon, Pb exceeded...
standard for 1-1.4 times; Cd exceeded standard for 2-50 times. Correlation and principal component analyses showed that 14 metals mainly from coal sources, dust sources and second transmission industry sources.

2. The results of enrichment factors showed that Ni, Cr, V, Cu, Zn had slight enrichment phenomenon, EF <100; Pb and Co had serious enrichment phenomenon, EF was between 100 and 150; Cd, Sb and Sn had very serious enrichment phenomenon, EF was 104-105.

3. The HQ values of Mn, Ni, V, Cr, Cd and Sb were all less than 1 which didn’t exist non-carcinogenic risk. The R values of Pb, Cr, Cd and Ni were less than 10-6, suggested the non-existence of carcinogenicity.

REFERENCES