Research on environmental chemical behaviour of heavy metals in atmospheric dustfall

Cadmium and lead contained in atmospheric dustfall are detrimental to the environment and human health. The research on the environmental chemical behaviour of cadmium and lead in atmospheric dustfall can contribute to the prevention or reduction of the occurrence of such environmental chemical hazards. Taking an economic zone in China as the research object, this paper analyzes the pollution situation and the chemical form of cadmium and lead in atmospheric dustfall and studies the relationship between the characters of dustfall and the specification of lead and cadmium by conducting the leaching experiment of dustfall. The results show that the contents of cadmium and lead in the economic zone are 1.64~7.8μg•g $^{-1}$ and 1.67~777μg•g $^{-1}$, respectively. The comprehensive pollution levels of cadmium and lead are mild contamination with the comprehensive pollution index being 1.72 and 1.84, respectively.

Keywords: *Atmospheric dustfall, heavy metal, environmental chemical behaviour.*

1. Introduction

The environment is essential for the survival and development of mankind and all other living things [1]. With the development of industry, the urban environment has been extensively affected by human activities, and the environmental problems caused by nature and human activities have attracted increasing attention [2]. The trace of heavy metal elements in the atmosphere have directly or indirectly affected humans, animals and plants: they can enter the lower respiratory tract of human body because of the small size, and they can also be absorbed by plants after the atmospheric dustfall falls into the soil through precipitation and dry deposition, thus causing great harms to human body [3].

Environmental scientists have recognized that the biotoxicity of heavy metals is related to the total quantity and determined by their morphological distribution to a greater extent[4]. Therefore, the relevant research on atmospheric dustfall in recent years has been a popular topic in the field of environment, geology, chemistry and other disciplines [5]. The previous studies have shown that the toxicity of lead and cadmium is elated to both its total amount and its specification in environmental media [6]. The cadmium and lead in atmospheric dustfall exist in various forms. The forms of cadmium and lead in atmospheric dustfall can be generally divided into exchangeable, carbonate-bound, Fe-Mn-bound, organic-bound and residual [7]. The migration, transformation, adsorption, and desorption capacities of cadmium and lead in different forms vary, thus leading to different biological effectiveness [8].

In conclusion, the research on the forms and pollution characteristics of cadmium and lead in atmospheric dustfall carried out in a large-scale economic zone collects basic environmental survey data including the cadmium and lead pollution status, air quality and environmental pollution level of the region and provides the scientific basis for the formulation of regional environmental pollution prevention and control policies in the economic zone, being positively significant to environmental protection.

2. Pollution status of cadmium and lead in atmospheric dustfall of the economic zone

To study the influence of environmental chemical behaviour, the atmospheric dustfall in different areas of the economic zone is collected, and the assay determination results of cadmium element contents in the atmospheric dustfall samples are shown in Table 1.

The atmospheric dustfall in different areas of the economic zone is collected, and the assay determination results of lead element contents in the atmospheric dustfall samples are shown in Table 2.

The background value of lead in the dustfall samples of this area is obtained to be 372μg•g^{-1} according to the mean value method. The single pollution index and the comprehensive pollution index are adopted to evaluate and obtain the lead pollution status in the atmospheric dustfall of the economic zone (Table 3).

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Table 1 Content of cadmium in Dustfall in economic area

Sample number	102#	110#	209#	262#	266#	273#
Content/ìg·g^{-1}	3.88	3.54	4.82	7.4	7.8	6.4
Sample number	501#	510#	530#	626-4#	801#	804#
Content/ìg·g^{-1}	6.32	2.99	3.13	8.52	1.64	2.82
Sample number	807#	828#	830#	1012#	1050-3#	1059-1#
Content/ìg·g^{-1}	1.77	3.27	6.28	1.9	2	5.7
Sample number	501#	501#	501#	501#	501#	501#
Content/ìg·g^{-1}	2.9	0.63	3.86	3.84	2.04	2.98

Table 2 Content of lead in Dustfall in Chengdu economic area

Sample number	102#	110#	209#	262#	266#	273#
Content/ìg·g^{-1}	350	315	580	397	338	303
Sample number	501#	510#	530#	626-4#	801#	804#
Content/ìg·g^{-1}	777	328	365	317	321	334
Sample number	807#	828#	830#	1012#	1050-3#	1059-1#
Content/ìg·g^{-1}	167	308	465	208	549	759
Sample number	501#	501#	501#	501#	501#	501#
Content/ìg·g^{-1}	533	643	159	198	178	516

Table 3 Cadmium pollution in Dustfall in economic area

Sample number	102#	110#	209#	262#	266#	273#
P_{pb}	0.94	0.85	1.56	1.07	0.91	0.81
Pollution degree	Non polluting	Non polluting	Slight pollution	Slight pollution	Non polluting	Non polluting
Sample number	501#	510#	530#	626-4#	801#	804#
P_{pb}	2.09	0.88	0.98	0.85	0.86	0.9
Pollution degree	Non polluting	Non polluting	Slight pollution	Non polluting	Non polluting	Slight pollution
Sample number	807#	828#	830#	1012#	1050-3#	1059-1#
P_{pb}	0.45	0.83	1.25	0.56	1.48	2.04
Pollution degree	Non polluting	Non polluting	Slight pollution	Non polluting	Slight pollution	Medium pollution
Sample number	1060-1#	1060-3#	1201#	1202#	1250#	519#
P_{pb}	0.67	0.15	0.89	0.87	0.47	0.69
Pollution degree	Slight pollution	Slight pollution	Non polluting	Non polluting	Non polluting	Slight pollution

Table 4 Correlation coefficient between pH of different forms of cadmium and Dustfal in atmospheric dustfall

Cadmium specification	Commutative state	Carbonate state	Fe-Mn-oxide-bound-state	Organic bound-state	Residual state
Correlation coefficient	0.127	-0.114	0.077	-0.328	0.321

Table 5 Correlation coefficient between pH of lead and Dustfall in Dustfall in economic area

Leads pecification	Commutative state	Carbonate state	Fe-Mn-oxide bound state	Organic bound-state	Residual state
Correlation coefficient	-0.372	-0.298	-0.153	-0.139	-0.163

Table 6 Correlation coefficient between cadmium and total iron in Dustfall in economic area

Cadmium specification	Commutative state	Carbonate state	Fe-Mn-oxide bound state	Organic bound-state	Residual state
Correlation coefficient	-0.125	-0.262	-0.02	-0.0199	-0.005

Table 7 Correlation coefficient between lead and total iron in Dustfall in economic area

Leads pecification	Commutative state	Carbonate state	Fe-Mn-oxide bound state	Organic bound-state	Residual state
Correlation coefficient	-0.145	-0.024	-0.004	-0.0123	-0.110

TABLE 8 CORRELATION COEFFICIENTS OF CADMIUM AND TOTAL MANGANESE IN DUSTFALL IN THE ECONOMIC AREA

Cadmium specification	Commutative state	Carbonate state	Fe-Mn-oxide bound state	Organic bound-state	Residual state
Correlation coefficient	-0.0102	-0.2266	-0.0366	-0.01653	-0.1376

TABLE 9 CORRELATION COEFFICIENT BETWEEN LEAD AND TOTAL MANGANESE IN DUSTFALL IN THE ECONOMIC ZONE

Leads pecification	Commutative state	Carbonate state	Fe-Mn-oxide bound state	Organic bound-state	Residual state
Correlation coefficient	-0.1702	-0.0607	-0.046	-0.0338	-0.1865

3. Influence of the characters of atmospheric dustfall on the chemical specification of cadmium and lead

The factors that influence the occurrence form of cadmium and lead in atmospheric dustfall are mainly the pH value and iron and manganese contents of the dustfall [9], both of which are correlated with the chemical specification of cadmium and lead in atmospheric dustfall [10].

3.1 Influence of the pH value of atmospheric dustfall on the chemical specification of cadmium and lead

The pH value of soil is influential to the specification and transformation of cadmium in soil [11]. This section only discusses the correlation between the pH values of the atmospheric dustfall samples and the chemical forms of cadmium and lead in the dustfall.

3.1.1 Influence of the pH value of atmospheric dustfall on the chemical specification of cadmium

The data of the cadmium contents and pH values are obtained through the chemical test analysis of the 24 dustfall samples, and thus the correlation coefficients between the various forms of cadmium in atmospheric dustfall of the economic zone and the PH values are obtained by calculation [12] (Table 4).

It can be seen from Table 4 that the other three forms are negatively correlated with the values except that the exchangeable form and the iron-manganese oxide binding form are positively correlated with the values. The correlation co efficients between all forms of cadmium and the values are quite low.

3.1.2 Influence of the pH value of atmospheric dustfall on the chemical specification of lead

The data of the lead contents and pH values are obtained through the chemical test analysis of the 24 dustfall samples, and thus the correlation coefficients between the various forms of lead in atmospheric dustfall of the economic zone and the PH values are obtained by calculation [13] (Table 5).

It can be seen from the table that all forms of lead are negatively correlated with the values allowing correlation coefficient, which indicates that the correlation between all forms of lead and the pH value of the atmospheric dustfall is non-significant and the pH value of dustfall has unobvious influence on the lead specification.

3.2 Influence of the iron and manganese contents in atmospheric dustfall on the chemical specification of cadmium and lead.

The correlation coefficients between all forms of cadmium and lead and the total iron and manganese content are calculated according to the relevant data [14] (Tables 6,7,8,9).

Tables 6 and 7 show that the cadmium and lead in the chemical binding state of iron-manganese oxides are positively correlated with the total iron in the dustfall and that other forms of cadmium and lead are negatively correlated with the total iron in the dustfall. The correlation coefficients between all forms of cadmium and lead and the total iron in the dustfall are extremely low.

The correlation coefficients between lead and total iron contents [15] can be seen in Tables 8 and 9.

As can be seen from Tables 8 and 9, the cadmium and lead in the iron-manganese oxide binding state, organic binding state and residual state are positively correlated with total manganese in the dustfall, and other states of cadmium and lead are negatively correlated with total manganese in the dustfall. The correlation coefficients between cadmium and lead in all states and total manganese are extremely low, indicating the non-significant correlation between all forms of cadmium and lead and total manganese in the dustfall and the unapparent influence of total manganese on the specification of cadmium and lead.

4. The leaching experimental research

In this experiment, the uncontaminated atmospheric dust samples are 102#, 110# and 1202#, respectively, and the pH values of the acid rain are 2, 3.5, 5 and 5.6 respectively. The acidity is selected as the reference to examine the influence of acidrain on the migration performance of cadmium and lead [16] and thus to analyze the characteristics of their environmental chemical behaviour.

4.1 The leaching experiment on cadmium in the contaminated atmospheric dustfall

The samples 266#, 209# and 830# are adopted to carry out the chemical leaching experiment of lead in the contaminated atmospheric dust, and the research data are shown in Figs.1-3.

As can be seen from Figs.1-3, for the three cadmium-contaminated atmospheric dust samples 266#, 209# and 830#, the cadmium leached from the dastfall samples under the chemical conditions in 0-5 hours accounts for 66.38% -

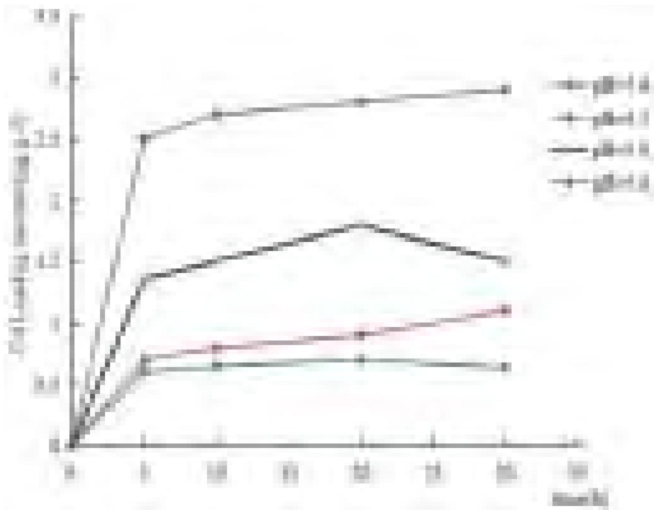

Fig.1 266# –Cdtime difference pH value map

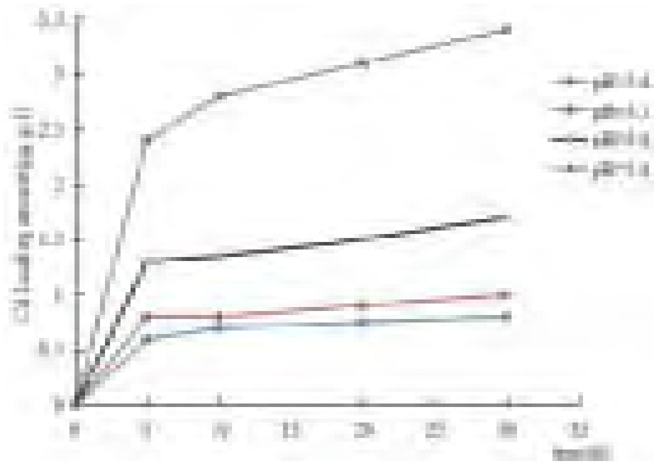

Fig.2 209# –Cdtime difference pH value map

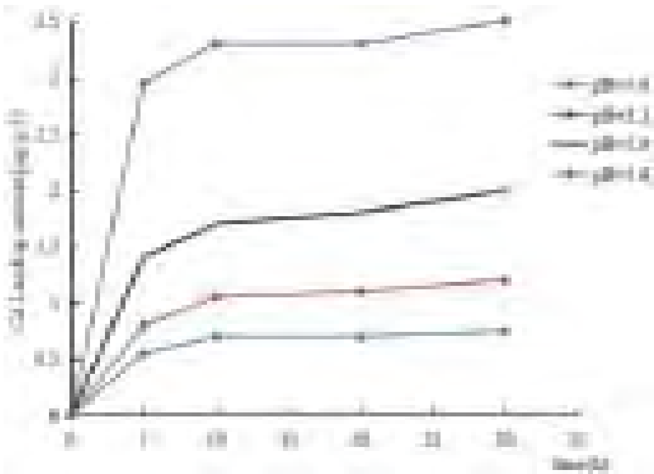

Fig.3 830# –Cdtime difference pH value map

83.98% of the total cadmium contents, which is 20%-40% higher than the proportion 46.88% - 67.65% of that from than on-polluted dustfall samples. The total cadmium content in the contaminated atmospheric dust is greater than that of the uncontaminated atmospheric dust.

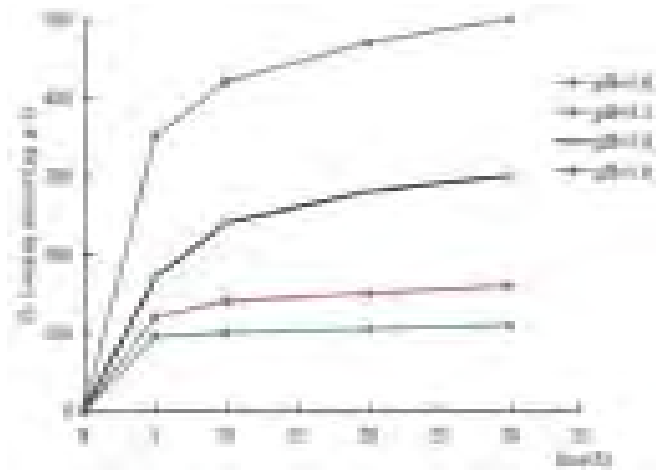

Fig.4 501 # –Pbtime difference pH value map

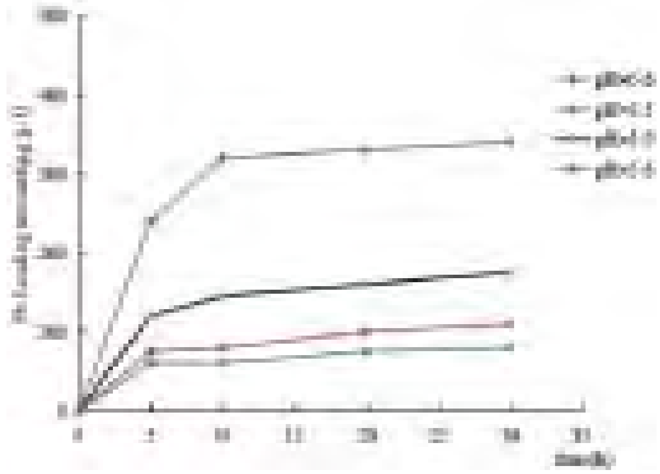

Fig.5 519 # –Pbtime difference pH value map

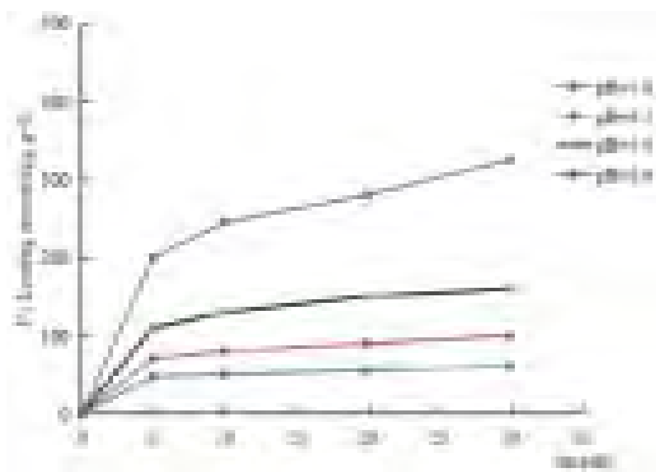

Fig.6 519 # –Pbtime difference pH value map

4.2 The leaching experiment on lead in the contaminated atmospheric dustfall

The samples 501#, 1060-3 # and 519 # are adopted to carry out the leaching experiment of lead in the contaminated atmospheric dust, and the research data are shown in Figs.4-6.

The curve trend in Figs.4-6 shows that for the three lead-polluted atmospheric dust samples 501#, 1060-3#, 519#, the lead leached from the dustfall samples under the chemical conditions in 0~5 hours accounts for 57.13% - 80.72% of the total lead contents, which is 20% higher than the proportion 55.76% - 64.64% of that from the non-polluted dustfall samples. The total lead content in the contaminated atmospheric dust is greater than that of the uncontaminated atmospheric dust, so the amount of lead leached by the acid rain from the polluted dust samples in 0~5 hours is greater than that from the uncontaminated samples. It shows that the polluted dustfall is more greatly influenced by acid rain and thus more detrimental to the environment. In the three periods of 5~10 hours, 10~20 hours and 20~30 hours, the leaching amount of cadmium and lead is decreasing successively, which is significantly smaller than that in the period of 0~5 hours.

5. Conclusions

The influence of the pH value, iron and manganese content in the dustfall on the specification of cadmium and lead was investigated. The results showed that the correlation with the cadmium and lead in the organic binding state is the most significant and that there is no significant correlation between all forms of cadmium and lead and the total iron and manganese, indicating that the chemical environmental behaviours are not closely related.

The results of the leaching experiments on the dustfall samples with the pH values being pH=2.0, pH=3.5, pH=5.0 and pH=5.6 showed that the cadmium and lead in the dust can be leached by acid solution through chemical reaction. The amount of cadmium and lead leached from the samples decreases with the increase of pH value, and the leaching amount of cadmium and lead is the largest when the pH value is 2.0. The leaching amount of cadmium and lead increases overtime with that in the period of 0~5 hours accounting for half of the total leaching amount and that in the period of 5~30 gradually becoming steady.

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