Ecological Risk Assessment of Typical Heavy Metals in Surface Dust in Z University

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Abstract. With the population increasing, the rapid development of social economy and the continuous improvement of industrialization level, heavy metal pollution becomes more and more serious nowadays. It is becoming more and more urgent to put forward feasible suggestions on the detection and assessment of heavy metals in the environment. Surface dust is an important environmental media, and people can easily intake pollutants from surface dust by daily life breathing, eating or skin contacting at any time anywhere, which will cause chronic harm to the human body directly or indirectly. In order to analyze the pollution of heavy metals in surface dust and assess the ecological risk, we take the campus of Z University as the research area. Through the investigation of the campus layout we've collected 23 effective surface dust samples. After sample digestion, the content of 4 kinds of typical heavy metal, such as Cd, Pb, Cu and Zn were determined by atomic absorption spectrometer ZEEnit700P. The method of index of geo accumulation and potential ecological risk index were used to analyze. It was concluded: 1. The average content of heavy metal elements Cd, Pb, Cu and Zn in surface dust in Z University is -0.143, 163.56, 76.90 and 106.96mg/kg respectively, which is -0.83, 6.13, 2.5 and 1.28 times as the soil background values of Hubei province, and the level sorting is Pb > Cu > Zn > Cd. The content of Pb is the highest in surface dust heavy metal pollution, which are contributed mostly by tire wear, vehicle emissions and construction content of heavy metals in surface dust in Z University. 2. Most area of Z University is in clean condition, except a sample point area is in or above moderate ecological risk level, the whole campus area is safe or only slight potential ecological risk.

1. Introduction

With the substantial increase in population and the acceleration of industrialization, environmental pollution problems have emerged one after another in recent years [1]. Cities are typical areas of human life and production activities, so environmental pollution in cities is very prominent. Urban surface dust is an important aspect of environmental pollution, which directly or indirectly affects environmental quality and endangers human health. Through scientific researches, many experts and scholars have discovered that the heavy metal content of urban surface dust is usually high, and human intake will affect the respiratory system and other functions. In particular, the heavy metal element lead has a significant impact on the growth and development of minors[2]. Studying the content of heavy metals in surface dust can better reflect the characteristics of life and production in the study area, and it has an important indicator for the environment and human health[3].
As the capital city of Hubei Province with severe particulates pollution, Wuhan has a serious surface dust pollution. Z University is located in Wuhan, with a large number of students on campus. Through studying the pollution status of heavy metals in surface dust, the content of several typical heavy metals in the campus will be figured out, then the sources of pollution and the ecological risks caused by heavy metals to the environment and humans will be analyzed. The experimental results can fully reflect the current status of heavy metal pollution in Z University, so we can put forward feasible suggestions for the control of environmental pollution and the improvement of environmental quality, which has scientific and realistic guiding significance for the development and construction of the city[3]-[4].

Surface dust was collected from various locations in Z University, and conducted pretreatment and digestion in the laboratory, and then measured with four typical heavy metals Cd, Pb, Cu and Zn by atomic absorption spectroscopy. Through the comparative analysis of the heavy metal content of dust samples and the soil background values, the areas with serious heavy metal pollution were found out and the sources of heavy metals were analyzed. According to relevant standards and the geo-accumulation index method, the ecological risk of heavy metals in surface dust was evaluated, and the potential hazards were pointed out.

2. Materials and methods

2.1. Overview of the study area

Wuhan City is located in the eastern part of the Jianghan Plain in China, its longitude value is 113°41′～115°05′east longitude and latitude is 29°58′～31°22′north latitude. It covers an area of 8494 square kilometers. As of the end of 2019, the permanent resident population is 11.121 million, of which the urban permanent population is 9,024,500. The climate of Wuhan is a humid subtropical monsoon climate with a lot of rainfall, and distinct four seasons, hot summers and cold winters[5].

Z University is located in Wuhan, at the corner of the two major transportation lines Minzu Avenue and Nanhu Avenue. There are Xiaona Lake inside, Wuming Lake and Yunshui Lake on campus, and Wuhan Nanhu Lake are nearby. There are many functional parts on campus, such as North Gate, East Gate, Nanyuan, West Gate, Huanhu, Binhu, Linhu, Central District and Jinfa District. Approximately 40,000 people including teachers, faculty, students and other residents live on campus. According to preliminary observations, there are a lot of vehicles and people coming in and going out of the school.

2.2. Sampling point layout and sampling analysis method

The heavy metals in the surface dust may be affected by human activities in various ways, which result in differences and diversities in content[6]. In order to make sample collection typical and representative, it is necessary to follow the principles below during the procedure of collecting samples in Z University:

1) The layout is based on the regional characteristics of Z University, which better reflects the spatial layout characteristics and is representative;
2) The nine parts of the campus have points, and the number of points in each part is reasonable and it can meet the needs of experimental analysis;
3) Deploy points away from sewers and trash bins.

With three distribution above principles[7], according to the research purpose, 30 sites were deployed on campus of Z University, including 3 in the North Gate and faculty's family area, 4 in Binhu and Dongmen District, 4 in the Central District, 5 in Nanyuan and Zhongyuan Avenue, 3 in Huanhu and Wenyong, 3 at the entrance of Xiyuan and Wentai Building, 4 in Huhu District, 4 in Jinfa District and Wenquan Building. The specific locations and coordinates of each sampling point are shown in Figure 1.
Although there are four distinct seasons in Wuhan, spring and autumn are relatively short, and summer is rainy. Therefore, the collection time of surface dust in this experiment was in winter. The sample collection was carried out in January, and a total of 23 samples were collected. In order to facilitate the collection and ensure the reliability of the samples, the collection of surface dust samples would be carried out under clear and windless conditions after maintaining at least a continuous week of sunny and dry weather. During the procedure, firstly the rocks, leaves and other debris on the ground were removed and the surface dust was swept into the polyethylene shovel. Then, the samples were put into a numbered polyethylene ziplock bag and stored in a sealed container. According to the surrounding environment, sampling was carried out repeatedly at 3 locations within a range of 10 square meters to form a mixed dust sample. At least 300g of dust was collected for each dust sample. At the same time, the relevant information of environmental characteristics was recorded such as the flow of people and traffic around the sampling point. Finally, 23 effective dust samples were obtained. After sampling, the collected samples were immediately transported back to the laboratory to avoid contamination.

The collected dust samples were placed evenly in a ventilated place, then dried naturally at room temperature. To remove the melon seed shell, sawdust, hair, cigarette butts and other fine impurities, the air-dried samples were passed through a 10-mesh standard nylon mesh sieve, then initial samples of surface dust could be obtained. Then the initial samples were passed a 100-mesh standard nylon mesh sieve, dust samples with a smaller particle size were obtained, which were compatible with microwave digestion. In this study, based on reference to relevant domestic and foreign literature and materials, combined with the conditions of the school laboratory, the method of microwave digestion was adopted to completely decompose the dust sample with nitric acid, hydrofluoric acid and hydrogen peroxide, the mineral lattices of the dust were completely destroyed, and the sample were digested. And the air-acetylene flame method in Atomic Absorption Spectrometry was selected to determine the heavy metal content in dust samples under the existing conditions of the laboratory. The instruments include Atomic Absorption Spectrometer (ZEEnit 700p, Germany Jeno Analytical Instruments Co., Ltd.), Topwave microwave digestion instrument (Germany Jeno Analytical Instruments Co., Ltd.), American Millipore Direct-Q5 pure water instrument, electronic balance (Mettler-Toledo Instruments Shanghai Co., Ltd.), electric heating constant temperature blast drying oven (Ningbo Jiangnan Factory), TD thermostat universal furnace (Gongyi Yingyu Yuhua Instrument Factory), etc.

2.3. Evaluation method of heavy metal pollution in surface dust

There are many current evaluation methods for heavy metal pollution in ground dust[8]. Considering that it is difficult to conduct a comprehensive scientific study if only one evaluation method is used,
two methods including the geo-accumulation index method and the potential ecological hazard index method are used to evaluate the heavy metal pollution of surface dust on the Z University[9].

The earth accumulation index method[12] was used to evaluate the degree of heavy metal pollution in the surface dust of Z University. The historical accumulation of heavy metals was put main emphasis by this method. It was originally used as a quantitative indicator to evaluate the degree of heavy metal pollution in sediments in water. At present, it is also used to evaluate soil heavy metal pollution by many scholars[13]. The evaluation is based on the geo-accumulation index method. The calculation formula is shown in formula 1.

$$I_{geo} = \log_2 \left( \frac{C_n}{k \times B_n} \right)$$

(formula 1)

In formula 1, $I_{geo}$ is the geo-accumulative index, $C_n$ is the actual measured value of heavy metals in the dust sample, and $k$ is a coefficient because of the variation of the chemical background value caused by the differences of sedimentary rocks in various regions, generally 1.5, and $B_n$ represents the average content of shale everywhere, that is, the background value. In this study, the environmental background value of heavy metals in soil in Wuhan is selected as the reference value. The background values of Cd, Pb, Cu, and Zn are 0.172, 26.7, 30.7, 83.6 mg/kg, respectively. According to the pollution degree classification standard, the heavy metal pollution degree of the surface dust could be evaluated. The classification of pollution index is shown in Table 1.

Table 1 Criteria for index of geo-accumulation

| Pollution index ($I_{geo}$) | Classification | Pollution degree |
|----------------------------|----------------|-----------------|
| < 0                        | I              | No pollution    |
| 0~1                        | II             | Mild to moderate pollution |
| 1~2                        | III            | Moderate pollution |
| 2~3                        | IV             | Moderate-strong pollution |
| 3~4                        | V              | Strong pollution |
| 4~5                        | VI             | Strong-extremely serious pollution |
| 5~10                       | VII            | Extremely serious pollution |

The potential ecological risk index method[14] specifically includes the potential ecological risk index of a certain heavy metal, the heavy metal toxicity response coefficient and the comprehensive potential ecological hazard index of a certain point. The calculation formula is shown in the following formula.

$$RI = \sum_{i=1}^{n} E_r^i$$

(formula 2)

$$E_r^i = T_r^i \times C_f^i$$

(formula 3)

$$C_f^i = \frac{C_i^a}{C}$$

(formula 4)

In formula 2, RI represents the comprehensive potential ecological hazard index of the sampling point, which describes the comprehensive value of the potential ecological hazard degree of multiple heavy metal pollutants at a certain sampling point. According to this comprehensive value, the pollution degree is divided into four levels, as shown in the table 2 [15]. $E_r^i$ represents the potential ecological risk index of a certain heavy metal, which can be divided into five levels of pollution, as shown in Table 2. In formula 3, $T_r^i$ represents the toxicity response coefficient of a certain heavy metal, and the toxicity response coefficients of Cd, Pb, Cu and Zn are 30, 5, 5 and 1, respectively. $C_f^i$ represents the pollution parameter of a certain metal, $C_i^a$represents the actual measured content of heavy metals in dust in the environment, and $C$ represents the reference value. This value is from the background value of soil heavy metals in Hubei Province. The background values of Cd, Pb, Cu, and Zn are 0.172, 26.7, 30.7, 83.6 mg/kg, respectively.

Table 2 Criteria for potential ecological risk of heavy metal pollutants in soil

| RI   | $E_r^i$ | Classification | Degree          |
|------|---------|----------------|-----------------|
| ≤150 | ≤40     | 1              | Minor ecological hazard |
150~299 40~79 2 Moderate ecological hazard
300~600 80~159 3 Strong ecological hazard
> 600 160~320 4 Very strong ecological hazard
-- > 320 5 Extremely strong ecological hazard

3. Results and discussion

3.1. The level of heavy metals in surface dust

Measuring the concentration of heavy metals in the surface dust samples by AAS, the content of heavy metal elements Cd, Pb, Cu and Zn in the surface dust of Z University could be obtained as shown in the figure 2.

![Figure 2: Table of heavy metal content of various points on campus](image)

From the above figure, it can be seen that the cadmium content of heavy metals in the surface dust of Z University varies from -2.68 to 2.26 mg/kg, and the cadmium content is relatively small; The lead content varies from 102.64 mg/kg to 246.38 mg/kg, which are all larger than the background value, and fluctuate between 3.8 to 9.2 times the background value, which is seriously exceeding the standard. The copper content varies within the range of 24.68~218.32 mg/kg, they are different in various parts of the campus. The range of zinc content is between 58.45~181.3 mg/kg, and there is a big difference.

| Heavy metal | Average mg/kg | Minimum mg/kg | Max mg/kg | SD mg/kg | C. V % | Background value mg/kg |
|-------------|---------------|---------------|-----------|---------|--------|------------------------|
| Cd          | -0.143        | -2.68         | 2.26      | 1.192   | -8.335 | 0.172                  |
| Pb          | 163.56        | 102.64        | 337.58    | 50.59   | 0.309  | 26.7                   |
| Cu          | 76.90         | 24.68         | 218.32    | 62.99   | 0.819  | 30.7                   |
In table 3, the background values of heavy metals Cd, Pb, Cu and Zn are listed in the soil of Hubei Province in the 《Background Values of Soil Elements in China》 [15]. The coefficients of variation of each heavy metal element were analyzed according to the data in Table 3. The Cd content in Z University is negative, which shows no practical significance, and lead to a large difference. The absolute value of the coefficient of variation is the largest among the four heavy metals, so the coefficient of variation of Cd is not analyzed. In addition, the coefficients of variation of Pb, Cu and Zn content are all between 0.1 and 1, which is a moderate degree of variation. The larger coefficient of variation is Cu, which is 0.819, indicating that the distribution of Cu is relatively uneven, and the pollution of element Cu in the surface dust of Z University is obvious. Comparing the contents of four kinds of heavy metals with the background values, Pb, Cu and Zn are much higher than the background values. The content of Pb is 5.1 times, Cu is 1.5 times and Zn is 1.3 times. Therefore, the pollution severity ranking of heavy metals in surface dust on Z University is Pb > Cu > Zn > Cd.

3.2. Source analysis of heavy metals in surface dust
From the analysis of the contents of four different heavy metal elements[17], it is found that there are differences in the heavy metal content of each sampling point in Z University. For example, the Cd content of most sampling points is lower than the soil background value in Hubei Province, but the Pb content is seriously exceeded at all sampling points. It is found that the pollution degree of heavy metals in the surface dust has a great relationship with the source of heavy metals. There are many sources of heavy metals in dust, including natural sources and man-made sources, such as soil accumulation, atmospheric precipitation, traffic pollution, industrial pollution and engineering construction, etc[18].

The heavy metal elements Cd, Pb, Cu and Zn mainly come from human activities. Among them, Cd mainly comes from the wear of vehicle tires and brake linings in the nine places with high Cd content have more traffic flow; Pb mainly comes from automobile emissions and tire wear, especially the high Pb content on Zhongyuan Avenue, are also due to the high traffic volume. Cu and Zn mainly come from industrial sources. There are building construction, small bazaars and traffic arteries near the sampling points with high Cu and Zn content, and there are many vehicles coming and going.

3.3. Evaluation of heavy metal pollution in surface dust
According to the calculation formula of the earth accumulation index method, the evaluation result of the earth accumulation index of heavy metals in the surface dust of Z University is obtained, as shown in Table 4.

| Statistics | Cd  | Pb   | Cu   | Zn       |
|------------|-----|------|------|----------|
| Average    | I geo | Grade | I geo | Grade | I geo | Grade | I geo | Grade |
| Minimum    | I geo | Grade | I geo | Grade | I geo | Grade | I geo | Grade |
| Max        | V geo | Grade | V geo | Grade | V geo | Grade | V geo | Grade |

From Table 4, it can be seen that the accumulation degree of various heavy metal elements in the surface dust of Z University is different, and the pollution degree is also different. Among them, the average accumulation index of Cd element is classified as clean and pollution-free, and there are different pollution degrees between different sampling points. Cd in the surface dust at most sampling sites is in a non-polluting state. Among them, the accumulation index of the sampling points in front of the 4 buildings in the central district is 3.131, and the pollution level has reached Grade V, which belongs to the category of heavy pollution. The average accumulation index of Pb in the surface dust is 2.03, which is a moderate pollution. The spatial distribution of lead in the surface dust on the campus is relatively uniform, and the pollution degree between different sampling points is not very different. It is generally mild pollution and moderate pollution. The average accumulation index of heavy metal Cu in surface dust is 0.74, which belongs to light pollution. The Cu content in surface dust at most sampling sites is in a lightly polluted state; the average accumulation index of Zn in
surface dust is negative, which belongs to clean and pollution-free.

All in all, the surface dust on Z University is mainly affected by the heavy metal Pb, followed by the heavy metal Cu pollution. Except for a few different sampling points, the campus is basically not affected by the heavy metal Cd pollution.

3.4. Potential ecological risk assessment
According to the calculation formula of the potential ecological risk of heavy metals, the potential ecological hazard degree, comprehensive potential ecological risk index and ecological risk level\([19][20]\) of the four heavy metal elements on the surface dust of Z University are obtained, as shown in Table 5.

Table 5 The potential ecological risk index and level of heavy metals in dust of Z University

| Statistics     | \(E_{ri}\) and Ecological risk level | \(E_{ri}\) and Ecological risk level |
|----------------|-------------------------------------|-------------------------------------|
|                | Cd   | Pb   | Cu   | Zn   | Cd   | Pb   | Cu   | Zn   | RI and Ecological risk level |
| Average        | -1   | 30.63| 1    | 12.52| 1    | 1    | 1    | 44.43| 1                            |
| Minimum        | -1   | 19.22| 1    | 4.02 | 1    | 0.70 | 1    | 23.94| 1                            |
| Max            | 394.2| 5    | 46.14| 2    | 35.56| 1    | 2.17 | 478.07| 3                            |

Regarding the potential ecological risk index \(E_{ri}\) of a certain heavy metal element, the potential ecological hazards of heavy metal elements Zn and Cu are relatively light, while the heavy metal elements Cd and Pb still have relatively large ecological risks. From the comprehensive potential ecological hazard index RI of these four heavy metals, the potential ecological hazard level of Cd, Pb, Cu and Zn in the surface dust of the South Campus is level 1, which is a minor hazard, but the RI index of some sampling points is the maximum reached 478.03 respectively, which is a level 3 risk level with strong ecological hazards.

The above analysis shows that in Z University, the heavy metals Cd and Pb have a moderate degree of ecological hazard, except for a certain point. The overall area is basically free or only slightly exposed to potential ecological hazards.

4. Conclusion
The average content of heavy metal elements Cd, Pb, Cu and Zn in the surface dust of Z University is -0.143, 163.56, 76.90 and 106.96 mg/kg, which are respectively -0.83, 6.13, 2.5 and 1.28 times of the soil background value in Hubei Province. The content level is distributed is Pb > Cu > Zn > Cd. Surface dust is most seriously polluted by the heavy metal element Pb. The wear of vehicle tires, exhaust emissions, and construction contribute to the heavy metal content of surface dust on the Z University. Certain preventive measures should be taken to prevent potential hazards in this area; most areas in Z University are in a clean state, except for the heavy metals Cd and Pb at a certain point that have a moderate degree of ecological hazard, the overall area is basically free or only subject to slight potential ecological risks.

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