Analysis on the distribution characteristics and sources of soil heavy metals in suburban farmland in Xiangtan City

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Abstract. The rapid development of the economy will inevitably have an impact on the farmland soil environment. The content of heavy metal is increasing day by day, and the heavy metal can enter people's body through different channels and endanger people's health. Based on agricultural land and crop types in accordance with the regional land use classification, using the method of the Single Factor Index and Comprehensive Pollution Index, the pollution status of heavy metals in farmland soil in the suburbs of Xiangtan city was studied and evaluated. At the same time, we use SPSS software to analyze the four heavy metal elements (Cu, Zn, As and Pb) and analyze their possible sources. The results showed that the farmland soils in Erhuan Road and Zhubu Port were polluted, and the farmland soil in Shuangma (an old industrial district) was not polluted; for different crop lands, orchards and vegetable lands were not contaminated, but rape and rice lands were contaminated. Pearson correlation analysis showed that Cu, As and Pb might come from the same pollution source, while Zn might come from other sources. Waste water from a chemical plant, crop types, automobile exhaust and other human factors may be important sources of soil pollution in agricultural fields.

1. Introduction
Soil heavy metal pollution refers to the content of heavy metals in soil is obviously higher than its background value and national standard due to heavy metals being released into the soil through human activity, and leads to the decline of the ecological environment quality [1]. As a result, a large proportion of the food of urban residents comes from these crops, so the species and content of heavy metals in urban soils directly affect the types and content of heavy metals ingested by residents. Because the heavy metals are very difficult to degrade, if they enter the human body, they have great influence on the health status of the residents, it is important to study their distribution characteristics and sources.

A part of the heavy metal in soil from its parent material factors, the other part is mainly from industrial and mining production, waste discharged from residents' lives, sewage irrigation and pesticides in agricultural production, unreasonable use of chemical fertilizer, etc. [3]. In recent years, with the rapid development of urbanization in Xiangtan, the intensity of land resource development
and utilization in the urban fringe area has also increased significantly, and the pollution status of heavy metals in farmland soil has also increased.

Influenced by many factors, the sources of heavy metals in suburban farmland soils are complex, mainly including automobile exhaust, industrial waste, living garbage of residents, etc. Taking suburban farmland soils of Xiangtan as the research object, this paper studied the pollution and source of soil Cu, Zn, Pd, as from the regional distribution and crop type point of view to provide the reference for rational planning and scientific management of land resources.

2. Materials and methods

2.1. Geographical survey of the study area
Xiangtan, the smallest prefecture level city in Hunan Province, is located in the middle-eastern part of Hunan province (111°58′~113°05′E, 27°21′~28°05′N). The distance is 81km from north to south and 108km from east to west, with a total area of 5005.8 Km². The landforms are complex and undulating. Precipitation in Xiangtan is abundant, but the seasonal distribution is uneven. Usually, it is dry in autumn and easy to be affected by cold wave and gale in winter. Xiangtan is rich in heat resources, with an average temperature of 16.7-17.4°C. The vegetation is subtropical evergreen broad-leaved forest, mainly camphor trees and fir.

2.2. Sampling and processing of samples
In March 2017, the samples of surface soil in Zhubu Port (ZBP), Shuangma (SM), Beierhuan Road (BEHR), Furong Road (FRR), Dongerhuan Road (DEHR) were collected respectively. 25 samples were collected (Figure 1).

![Figure 1. Distribution of sampling sites.](image)

Sampling sites were sampled at random in each sampling area, and GPS is used to locate each site. Firstly, remove the litter on the soil surface, and then use the ring-knife to pick up the surface soil and put in the self-sealing bag. Place the soil samples for a week to dry naturally. Then place the samples in the dryer for 48 hours under 50°C to make sure the samples are completely dry.

In the laboratory, using the quarter division method, one of the samples was taken and ground through 100 mesh screens. Finally, ground samples are enclosed in the self-sealing bag.

2.3. Experimental methods
Using EPX-50 mobile X ray fluorescence spectrometer, which is made by Innov-X Company of the United States, the contents of different heavy metals were measured for each soil sample. EPX-50 has the advantages of convenient portability, high safety, high accuracy, easy to use and easy to operate. Meantime, the instrument does not damage the sample and can be measured repeatedly.
2.4. Assessment methods of heavy metal pollution

2.4.1. Single Factor Index. The Single Factor Index is mainly used to assess the risk of a kind of heavy metal pollution. Its expression is:

\[ P = \frac{P_i}{P_i^*} \]  

(1)

In the formula (1), \( P_i \) is the measured concentration of the pollutant \( i \); \( P_i^* \) is the environmental quality index of \( i \) in soil pollutant. If \( P \leq 1.0 \), it shows the content of this heavy metal is within its background value, and the soil is not contaminated; If \( P > 1.0 \), it shows the content of this heavy metal has exceeded its background value, and the soil is contaminated; the greater the value of \( P \) is, the higher the degree of soil contamination is [13]. Soil background values used in this study are shown in Table 1. Because soils in Hunan are mainly acid red soils, the second level standard values are selected as the background values in this study [11, 15].

| Level        | First degree | Second degree | Third degree |
|--------------|--------------|---------------|--------------|
| Natural background | <6.5          | 6.5-7.5       | >7.5         |
| As           | 15           | 30            | 25           |
| Cu           | 35           | 50            | 100          |
| Pb           | 35           | 250           | 300          |
| Zn           | 100          | 200           | 250          |

2.4.2. Comprehensive Pollution Index. When the soil quality in the assessed area is considered as a whole to compare with that of other areas, or the soil in the same area is polluted by many kinds of heavy metals simultaneously, the Single Factor Index should be integrated into one method in a certain way to reflect and evaluate the overall pollution situation [11]. The formula is as follows:

\[ P_{\text{comprehensive}} = \sqrt{\frac{(\overline{P}_i)^2 + (\max P_i)^2}{2}} \]  

(2)

In the formula (2), \( P_{\text{comprehensive}} \) is the Comprehensive Pollution Index; \( P_i \) is the average value of the indices of various pollutants in the soil; \( \max P_i \) the maximum of the single pollution index; \( \overline{P} \) is the mean of individual pollution index, and \( I \) is the soil Comprehensive Pollution Index. If \( I \leq 1 \), it indicates no pollution; If \( 1 < I \leq 2 \), it indicates a slightly polluted; If \( 2 < I \leq 3 \), it indicates a moderate pollution; If \( I > 3 \), it indicates a severe pollution [3] (Table 2).

| \( P_{\text{comprehensive}} \) | Level | Level | Level | Level | Level |
|-------------------------------|------|------|------|------|------|
| 0.7                      | Level I | Clean | Level II | Basically clean | Level III |
| 1.0                      | Level | Safety | Level | Alert Line | Slight pollution |
| 2.0                      | Level | IV | Level | Moderate pollution | |
| 3.0                      | Level | V | Level | Heavy pollution | |

| \( P_{\text{comprehensive}} \) | Level | Level | Level | Level | Level |
|-------------------------------|------|------|------|------|------|
| 3.0                      | Level | V | Level | Moderate pollution | |
| 4.0                      | Level | V | Level | Heavy pollution | |
2.4.3. Correlation analysis. Correlation analysis refers to the analysis of two or more variables that are relevant to assess the relative degree of the variables. The larger the rank value of the correlation coefficient is, the stronger the correlation is; the smaller the absolute value is, the weaker the correlation is [6]. Generally, the correlation intensity is: if the absolute value of the correlation coefficient is 0.8-1.0, the correlation is very high; $P_{\text{comprehensive}} = 0.6-0.8$ means highly correlated; $P_{\text{comprehensive}} = 0.4-0.6$ indicates moderate correlation; $P_{\text{comprehensive}} = 0.2-0.4$ means low correlation; $P_{\text{comprehensive}} = 0.0-0.2$ means extremely low correlation or no correlation.

3. Analysis and evaluation of heavy metal pollution

3.1. Evaluation according to the types of crops

3.1.1. Single Factor Index. The farmland soil was divided into rape land, orchard, vegetable land and rice land. Based on the national secondary standard, the Single Factor Index was used to assess the four elements of Zn, Pb, Cu and As.

The Single Factor Index of Zn and Pb in soils was less than 1, indicating no pollution; the Single Factor Index of Cu is more than 1 in rice soil, but less than 1 in other crops’ soils. This shows that rice soil has been polluted by Cu, and the other farmland is not polluted by Cu; rape and rice soils have been contaminated by As ($P > 1.0$), and for the soils of vegetable field, the Single Factor Index of As close to 1 and the indexes of the other soils were less than 1, indicating that the soil of these crops without pollution by As (Figure 2). As a whole, the soil in orchards and vegetable fields was not contaminated by Cu, Zn, As and Pb, while rape and rice land soils were polluted by heavy metals in different degrees.

3.1.2. Comprehensive Pollution Index. Among the four types of agricultural land, the Comprehensive Pollution Index of rape soil, orchard soil and vegetable soil is 0.7-1.0, and their pollution levels are the Alert Line. However, the Comprehensive Pollution Index of soil heavy metal in rice land is between 1-1.2, which belongs to slight pollution (Figure 3).

![Figure 2](image1.png) **Figure 2.** Single Factor Index of heavy metals in different farmland soil.

![Figure 3](image2.png) **Figure 3.** Comprehensive Pollution Index of heavy metals in different farmland soil.

3.2. Evaluation according to farmland in different areas

3.2.1. Single Factor Index evaluation. The Single Factor Index analysis of agricultural land in different regions showed that the Single Factor Index of Zn and Pb were less than 1, indicating no pollution; the Single Factor Index of Cu is greater than 1 at Erhuan Road, indicating that the farmland near Erhuan Road has been polluted, but it is less than 1 at Zhubu Port and Shuangma, indicating the farmland is not polluted; the Single Factor Index of As in the soil near Zhubu Port and Erhuan Road is greater than 1, indicating that the farmland in these two areas has been polluted by As (Figure 4).
3.2.2. **Comprehensive Pollution Index evaluation.** The Comprehensive Pollution Index of Cu, Zn, As, and Pb in the soil of the old industrial districts, such as Zhubu Port and Shuangma, is between 0.7-1.0, and the pollution degree is the level II. Among them, the Comprehensive Pollution Index of Zhubu Port is close to 1 (Basically Clean/Alert Line). However, the Comprehensive Pollution Index of farmland soil near the Erhuan Road is between 1-1.2, and the pollution degree is the level III (slight pollution) (Figure 5).

![Figure 4. Single Factor Index of soil heavy metals in different districts.](image)

![Figure 5. Comprehensive Pollution Index of soil heavy metals.](image)

4. **Source analysis of heavy metals in soil**

Although the correlation coefficient is only a number, which measure the correlation degree of the different two variables and don’t fully determine whether a causal relationship exists, it is possible to speculate whether the sources of heavy metals are the same to some extent. If there is a strong correlation between them, then they may have the same origin, or sources may be different [13]. In this paper, SPSS software was applied to examine the correlation of different soil heavy metals to analyze their possible origins. The results are presented in Table 3.

|       | Cu   | Zn   | As   | Pb   |
|-------|------|------|------|------|
| Cu    | 1    | -0.76| 0.909| -0.885|
| Zn    | -0.76| 1    | -0.42| 0.369|
| As    | 0.909| -0.42| 1    | -0.998|
| Pb    | -0.885| 0.369|-0.998| 1    |

The correlation between the elements is very high. Among them, the absolute value of the correlation coefficient between Cu, As and Pb is between 0.80-1.0, meaning a very strong correlation; the correlation coefficient between Cu and Zn is between 0.60-0.80, and belongs to strong correlation; the absolute value of the correlation coefficient between Zn and As is between 0.40-0.60, which is a moderate correlation; however, the absolute value of the correlation coefficient between Zn and Pb is between 0.20-0.40, which is weakly related (Table 4.1). As a result, Pb, Cu and as may come from the same source of pollution, while Zn may come from other sources of pollution.

According to the above analysis, overall, as pollution is relatively serious. The cause may lie in Xiangtan is a developed nonferrous metal industry base in China. Although in recent years, Xiangtan City began to shut down some heavy industrial plants, the ecological environment is still difficult to fully recover in a short period of time. And for the other three heavy metals, different degrees of pollution have also been shown.

5. **Conclusion and discussion**

Results of Single Factor Index showed that the content of As was higher, which belonged to slight pollution, regardless of the districts or farmland types. However, Cu and Zn did not cause contamination. Comprehensive Pollution Index analysis showed that the Zn, Pb, Cu and As in the soil...
of orchard and vegetable land belonged to Level I, while in the paddy soil, Zn, Pb, Cu and As belonged to slight pollution. On the regional distribution, Shuangma is still clean, and Erhuan Road is light pollution.

From the possible sources of pollutants, Pb, Cu and As may come from the same pollution source, while Zn may come from other pollution sources.

From the possible sources of heavy metals, most sampling sites, which have higher heavy metal content, are located in the residential areas, paddy field and near the traffic line. Obviously, the contents of heavy metals in paddy soil and vegetable soil are relatively high, which may be related to the use of pesticides and irrational fertilization.

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