Spatial Distribution and Evaluation of Heavy Metal Pollution in Soil Around Coal Gangue in Fengfeng Mining Area

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Abstract. Taking the soil around the coal gangue mountain in the Fengfeng mining area as the research object, 30 soil samples were collected in the east, southeast and southwest directions within 300m of the coal gangue mountain boundary, and the soil in the mining area was measured by inductively coupled plasma mass spectrometry. The contents of five heavy metals such as Cr, Pb, Cd, Cu and Zn were detected, and the spatial distribution characteristics, pollution status and ecological risk of heavy metals in the mining area were analysed. The results show that: (1) the five heavy metals content of Cr, Pb, Cd, Cu and Zn show different decreasing trend from the farther gangue heap and the increase of soil depth. (2) Referring to the background value of the national secondary soil environmental standard, among the five heavy metals in the soil, except for Cu and Cr, the average values of three heavy metals of Zn, Cd and Pb are higher than the soil background value; Single factor index evaluation results show that the Pb pollution is the most serious, followed by Cd pollution. The Nemero comprehensive index method shows that the surface soil is moderately polluted when the distance is zero in the three directions, and the rest places are mildly polluted. (3) According to the ecological risk assessment results, the order of potential ecological hazards of single heavy metals are ranked from strong to weak: Cd>Pb>Cr>Cu>Zn, and the soils are all slightly ecologically harmful.

1. Introduction

About 65% of China’s chemical raw materials, 75% of industrial and 85% of domestic raw materials are provided by the coal industry [1]. Coal resources play an important role in the development of China’s national economy and social progress. However, it is one of the most important ecological problems that coal gangue are formed by a large number of open piles of coal gangue in the open air caused by coal mining, transportation and use of coal. Coal gangue is a rock with lower carbon content associated with coal seam and harder than coal in the process of coal formation [2]. The gangue stacked in the open air will release heavy metals such as Pb, Zn, Cd, Cu and Cr from the coal gangue after raining and weathering [3]. Most of the heavy metals will enter the soil and spread through a series of routes. Cause pollution and destruction to the ecological environment.

The Fengfeng mining area is one of the important coal production bases in China. The coal gangue piles up into mountains in the mining area. In this paper, the contents of five heavy metals (Cd, Cr, Cu, Zn, Pb) in soil samples were detected by taking the soil around the coal gangue mountain in Fengfeng
mining area as the research object. The single factor index method, multi-factor index method and heavy metal pollution ecological risk assessment were used to evaluate and analyse the pollution and ecological risk of heavy metals around the coal gangue.

2. Materials and Methods

2.1. Research area Overview
The Fengfeng mining area is located at the border of Henan, Shanxi and Guizhou provinces, between the north latitude and the east longitude, between latitude 36°20’ to 36°40’ and east longitude 114°3’ to 114°18’. The Fengfeng mining area belongs to a semi-arid temperate continental monsoon climate with four distinct levels. Fengfeng mining area is one of the country's important coal production bases [4], characterized by abundant resources, shallow burial and high quality [5]. At its peak, the Fengfeng mine area reached a high output of 3.51 million tons of coal a year. The coal gangue in the Fengfeng mining area is piled up into mountains, with a storage capacity of 36.6 million tons, covering an area of about 1.05 million square meters. There are 17 coal gangue mountains in the mining area.

2.2. Collection and processing of soil samples
The sampling area is the coal gangue mountain in the Fengfeng mining area. Three sampling directions of ES, WS and E are selected in the mining area. The sampling points are selected at 0m, 40m, 80m, 150m and 300m respectively from the coal gangue, and Soil samples with different depths of 0-20cm and 20-40cm were selected at each sampling point. Bring the collected soil sample bag back to the laboratory, remove the foreign bodies such as stone particles and garbage in the soil sample after natural air drying, then grind them, pass through a 200 mesh nylon sieve, and finally seal then with bags for later use.

After the soil sample was pretreated by the automatic graphite digestion method, the contents of five heavy metals such as Cd, Cr, Cu, Zn and Pb in the solution were detected by inductively coupled plasma mass spectrometry.

2.3. Evaluation method
Based on the national soil secondary standards, the single factor index method, the Nemero comprehensive pollution index and the potential ecological hazard index were used to analyze and evaluate the status of soil heavy metal pollution in Fengfeng mining area.

2.4. Data processing
Data were entered in Excel for data analysis, and the results of the distribution of heavy metals were analysed and evaluated using origin 9.1.

3. Results and discussion

3.1. Spatial distribution characteristics of heavy metal soil in Fengfeng mining area
(1) Horizontal distribution characteristics of heavy metals in soil
By analyzing the data of two different depth soil layers at five different distances in three different sampling directions, the variation trend of five heavy metal contents can be obtained, as shown in Fig. 1.

It can be seen from Fig. 1 that when the soil depth is 0-20 cm, the contents of Cu, Zn, Cr, Cd and Pb in the soil presents different downward trends as the distance from the sampling center increases in the ES, E and WS directions. The contents of Cu, Zn, Cr, Cd and Pb in soil also showed different downward trends.
Figure 1. This is a figure with the heavy metal content in ES direction, the heavy metal content in E direction and the heavy metal content in WS direction.

(2) Vertical distribution characteristics of heavy metals in soil

Analysis of soil data at different depths with the same distance (0m, 40m, 80m, 150m, 300m from the center point) in three directions, the comparison of the detection results of five heavy metals at different depths and the trend of five heavy metal contents can be obtained.

According to the data analysis, in the soils with the same distance in the ES, E and WS directions of the Fengfeng mining area, the contents of five heavy metals such as Cu, Zn, Cr, Cd and Pb in the soil showed different decreasing trend with the increase of soil depth at the sampling point.

3.2. Soil pollution status of pollution evaluation

(1) Single factor index evaluation

According to the evaluation results in Table 1, the pollution of Pb element is the most serious, and there is moderate and slight pollution in all the five distances of the mining area. Secondly, the pollution of the element Cd is clean at a distance of 300m in three directions, and the rest are slight pollution; Zn, Cu and Cr elements are clean at different distances in three directions.

| Distance (m) | Soil layer (cm) | Cu  | Zn  | Cr  | Cd                  | Pb                      |
|-------------|----------------|-----|-----|-----|---------------------|-------------------------|
| 0           | 0-20           | clean | clean | clean | slight pollution    | Moderate pollution      |
| 20-40       | clean          | clean | clean | clean | slight pollution    | Moderate pollution      |
| 40          | 20-40          | clean | clean | clean | slight pollution    | Moderate pollution      |
| 0           | 0-20           | clean | clean | clean | slight pollution    | slight pollution        |
| 20-40       | clean          | clean | clean | clean | slight pollution    | slight pollution        |
| 80          | 20-40          | clean | clean | clean | slight pollution    | slight pollution        |
| 0           | 0-20           | clean | clean | clean | slight pollution    | slight pollution        |
| 20-40       | clean          | clean | clean | clean | slight pollution    | slight pollution        |
| 150         | 20-40          | clean | clean | clean | clean               | slight pollution        |
| 0           | 0-20           | clean | clean | clean | clean               | slight pollution        |
| 20-40       | clean          | clean | clean | clean | clean               | slight pollution        |

(2) Evaluation of Nemero comprehensive pollution index

Table 2. Evaluation results of soil heavy metal Nemero comprehensive index

| Distance (m) | Soil layer (cm) | Comprehensive pollution index | Pollution level |
|-------------|----------------|-------------------------------|-----------------|
| 0           | 20-40          | 2.09                          | Moderate pollution |
| 0           | 0-20           | 1.94                          | slight pollution |
| 20-40       | clean          | 1.77                          | slight pollution |
| 40          | 20-40          | 1.65                          | slight pollution |
| 0           | 0-20           | 1.53                          | slight pollution |
| 20-40       | clean          | 1.41                          | slight pollution |
According to the evaluation results in Table 2, the soil layer with a distance of 0-20 cm in the mining area is moderately polluted, and the rest are slightly polluted. It shows that the heavy metal pollution in the soil in the Fengfeng mining area is serious, and the distance from the central sampling point is from near to far, and the soil depth is decreasing from shallow to deep.

### 3.3. Potential ecological hazard index evaluation

| Distance (m) | Soil layer (cm) | Ecological hazard coefficient of single heavy metal (Er) | RI value | Potential ecological risk degree |
|--------------|----------------|--------------------------------------------------------|----------|---------------------------------|
|              |                | Cu   | Zn   | Cr   | Cd   | Pb   |                  |
| 0            | 0-20           | 1.57 | 0.96 | 1.76 | 58.3 | 13.15 | Slight ecological hazard |
|              | 20-40          | 1.45 | 0.89 | 1.65 | 53.9 | 12.2  | Slight ecological hazard |
| 40           | 0-20           | 1.35 | 0.87 | 1.54 | 49.7 | 11.08 | Slight ecological hazard |
|              | 20-40          | 1.28 | 0.82 | 1.45 | 45.8 | 10.35 | Slight ecological hazard |
| 80           | 0-20           | 1.23 | 0.8  | 1.37 | 43   | 9.55  | Slight ecological hazard |
|              | 20-40          | 1.17 | 0.77 | 1.29 | 38.7 | 8.77  | Slight ecological hazard |
| 150          | 0-20           | 1.08 | 0.76 | 1.23 | 35.6 | 8.22  | Slight ecological hazard |
|              | 20-40          | 0.98 | 0.73 | 1.17 | 31.3 | 7.73  | Slight ecological hazard |
| 300          | 0-20           | 0.9  | 0.71 | 1.12 | 29.2 | 7.18  | Slight ecological hazard |
|              | 20-40          | 0.82 | 0.7  | 1.06 | 26.6 | 6.55  | Slight ecological hazard |

Calculate the potential ecological hazard coefficient and potential ecological hazard index of heavy metals around the coal gangue in the Fengfeng mining area, and then check the table to obtain the potential ecological risk degree, as shown in Table 3.

It can be seen from the evaluation results that there are slight ecological hazards in the heavy metals in the soil in the three directions of the Fengfeng mining area. Therefore, we must pay attention to protecting the environment in the mining area and avoid increasing the degree of ecological damage.

### 4. Conclusion

By studying the spatial distribution characteristics, pollution degree and potential ecological risk of heavy metal content in the soil around the coal gangue in Fengfeng mining area, the following conclusions are drawn:

1. Spatial distribution characteristics of heavy metal content:
   1. horizontal distribution characteristics: in the three directions of the soil in Fengfeng mining area, the content of Cu, Zn, Cr, Cd, Pb five heavy metals basically with the increase of sampling distance and show different decreasing trend. Horizontal distribution characteristics: The content of five heavy metals Cu, Zn, Cr, Cd and Pb in the three directions of the Fengfeng mining area basically decreased with the increase of sampling distance.
Vertical distribution characteristics: The contents of five heavy metals such as Cu, Zn, Cr, Cd and Pb in the soil with the same distance in the three directions of the Fengfeng mining area basically decreased with the increase of soil depth.

(2) Pollution degree analysis

① The single factor index evaluation results show that Pb pollution is the most serious, showing light pollution, followed by Cd pollution, and the other three directions of Zn, Cu and Cr are all clean.

② The evaluation results of the Nemero comprehensive index method show that the soil layer with a distance of 0-20 cm in three directions is moderate polluted, and the rest is slight polluted. It shows that the heavy metal pollution around the coal gangue mountain in the Fengfeng mining area is serious, and the distance from the center sampling point is from near to far, and the soil depth is decreasing from shallow to deep.

(3) Ecological risk assessment and analysis

The potential ecological hazards of a single heavy metal are ranked from strong to weak: Cd>Pb>Cr>Cu>Zn. There are slight ecological hazards in the soil in the three directions of the Fengfeng mining area. It is necessary to pay attention to protecting the environment in the mining area to avoid increasing the degree of ecological damage.

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