

Analysis of Soil Heavy Metal Pollution in Northern Shaanxi Coal Mine Area

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Abstract

Northern Shaanxi coal mine is an important energy base in Shaanxi Province, the ecological environment of this area is fragile, facing the huge opportunity of mining development, in the current "environmental protection priority" reality, it is urgent to find out the environmental background of this area, support the development of national energy strategy. The results showed that the contents of Hg, Cd, Pb and Cr were higher than the background values of soil in Shaanxi province, and the average contents of As, Zn and Cu were lower than the background values of soil in Shaanxi Province, but the maximum contents were 1.65, 1.01 and 2.16 times higher than the background values of soil in Shaanxi Province, respectively. The potential ecological risk assessment index shows that Hg has great potential ecological harm. Based on the cumulative effect of heavy metals in soil, we should pay close attention to the change of soil heavy metal concentration in the future mining development process to prevent the risk caused by heavy metal pollution.

Keywords

Coal Mine; Soil Heavy Metal Pollution; Northern Shaanxi.

1. Introduction

Coal is one of the important energy of human development and utilization, and also the most major energy in China. The development of economy needs to rely on the development and utilization of coal and other primary energy. The mining amount of Chinese coal accounted for about 74.3% of the total energy, and became the first coal producing country in the 21st century. As an area with rich coal reserves, the coal mining area in northern Shaanxi is often located around the town, which is an important area to support the development of its central town. However, while coal mining brings economic benefits to towns and local areas, it also causes many problems to the land ecological environment in coal mining areas, such as poor land fertility, small ecological capacity, low ecological carrying capacity, vegetation degradation, etc. The coal mine area in northern Shaanxi Province is an important ecological fragile zone, the key monitoring area and the key control area of national soil and water loss. At the same time, the coal mining area in northern Shaanxi has the characteristics of large coal storage, good coal quality, high thickness of coal seam and easy mining, so it is known as "China's Kuwait". More than 95% of coal production in China is underground mining. The subsidence caused by mining has resulted in the formation of ground cracks, subsidence basins, subsidence holes, subsidence

terraces and other surface damage phenomena. According to statistics, the subsidence rate of ten thousand tons of coal mining is 0.033~0.530 hm², and the average subsidence rate of every ten thousand tons of coal mining is 0.12 hm². According to the survey, the total subsidence area of the three coal mining areas of Shendong Company is 39.96 km². At present, Shenhua Shendong Company has formed a subsidence area of 43.33 km², accounting for 93.3% of the county's subsidence area [1]. The phenomenon caused by coal mining not only threatens the land resources in coal mining area, but also brings a series of ecological problems, such as the decline of soil quality, water loss, water pollution, air pollution, etc. [2-3]. With the shortage of cultivated land resources in our country, coal mining subsidence not only destroys the land resources in coal mining area, but also degrades the vegetation in coal mining area. Soil nutrient loss directly causes the decline of soil quality in the subsidence land, and also threatens the living environment of the residents around the mining area, especially the urban environment of the mining area.

There are many trace elements in coal [4], among which As, B, Ba, Be, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Sb, Se, Sn and Zn have great influence on the environment [5]. Therefore, the massive mining of coal resources will inevitably lead to the increase of heavy metal content in the soil around coal mining areas. Lu Jianheng et al. [6] evaluated the soil heavy metal pollution in Yongan coal mine area of Jilin Province, and the study showed that Cd and Cu in the soil were seriously polluted. Zhang Li et al. [7] made a study on soil pollution caused by heavy metals in coal gangue in the Loess Plateau coal mining area. The study showed that the content of heavy metals in soil was on the rise, and Cd, Pb and Zn showed strong migration. Therefore, heavy metal pollution was the main pollutant in the process of coal mining. Wang Li et al. [8] studied the characteristics of soil heavy metal pollution in Shenmu coal mine area and showed that soil heavy metal pollution around coal mine was affected by mining years, soil texture, wind direction and other factors, and heavy metals such as Cu, Cd and Cr were all polluted to different degrees. Therefore, it is urgent to master the heavy metal pollution of soil in coal mine area, and provide certain scientific basis for the evaluation and rational utilization of soil environment in local coal mine area.

2. Materials and Methods

2.1. Test Methods

The test method of heavy metals and metalloid in soil samples is described as follow: Before using ICP-MS (Agilent 7700), the soils need to be completely decomposed. Digestion methods according to US EPA method 3050B with HNO₃-H₂O₂-HCl with the ratio of 3:1 (hydrochloric and nitric acids) for the heavy metal extraction. About 0.1000g of soil sample is collected in the digestion tube, and hold overnight. The samples were digested at the temperature of 40 °C, 80 °C, 120 °C and 140 °C for 1 hours, respectively. After cooling, the supernatant is filtered through a 0.45-micron filter to centrifuge tube for the further analysis. The concentration of Hg was digested by HNO₃-H₂SO₄. After that, atomic fluorescence Spectrometry (AFS-9760) at 253.65nm was used for the measurement. The study used standard reference material (GSS-8, GSS-10 and GSF-3) to assure the quality control. These materials are from the National Center for Standard Materials in China. The ratio of recoveries ranged between 90% and 110% for the elements throughout this study.

2.2. Evaluation Methods

The expressions are as follow (1)- (3):

$$C_f^i = \frac{c_s^i}{c_n^i} \quad (1)$$

$$E_r^i = T_r^i \times C_s^i \tag{2}$$

$$RI = \sum_{i=1}^n E_r^i \tag{3}$$

Among them, *RI* is calculated as the sum of E_r^i , which represents the PER index; E_r^i is the PER index for single element pollution; c_n^i is the background value of soil heavy metals and metalloid in Shaanxi Province; c_s^i is the tested values of elements in soils, mg/kg; T_r^i is the toxicity response coefficient of heavy metals and metalloid. Environmental background values and toxicity response coefficients are shown in Table 1. The classification results of the PER index are shown in Table 2.

Table 1. Environmental background values and toxic-response parameters of heavy metals in the soils.

Element	Cd	Cr	Hg	As	Pb	Cu	Zn	Ni
c_n^i (mg/kg)	0.76	62.5	0.063	11.1	21.4	21.4	69.4	28.8
T_r^i	30	2	40	10	5	5	1	5

Table 2. Classification of potential ecological risk coefficient (E_r^i) and risk index (RI).

Ecological Risk	Low Risk(A)	Moderate Risk (B)	Considerable Risk (C)	High Risk(D)	Significantly High Risk (E)
E_r^i	<40	40–80	80–160	160–320	>320
RI	<150	150–300	300–600	≥600	--

3. Research Results

3.1. Investigation on the Damage Status of Stonemason Coal Mine

Northern Shaanxi mason Bank coal mine for open-pit mining, production scale: 2 million t/a. It is located in Daliuta town stone masons bank, the geographical coordinates are 39°22 '59 "N, 110°10' 12" E. Mine land mainly consists of open-pit stope, stacking yard, mine safety construction and development, office and living facilities land, ore crushing station, mine road, temporary topsoil stacking site, etc. The total area of mine land damage is 81.6864hm², including 77.7989hm² of excavated damaged land and 3.8875hm² of crushed damaged land. Among them, cultivated land is 28.3798hm², forest land is 47.4810hm², mining land is 2.4723hm², residential land is 3.2942hm², and transportation land is 0.0591hm². The damaged land is distributed in the open pit of the west mining section, the road of the west mining section, the land for office and living facilities, and the ore crushing station. Cause excavation damage, compaction and other damage. The land to be damaged in the mining area is distributed in the stope of the east mining section, the excavation damage of the mining road in the east mining section and the ground compaction of the temporary storage site of topsoil.

3.2. Investigation on Pollution Status of Coal Mine in Mason Bank

(1) Analysis of heavy metal content in soil

Based on the results of the tests, The contents of Hg, Cd, As, Pb, Cr, Zn, Ni and Cu in the surface soil of Masonpan mine range from 0.043 to 0.255, 0.44-2.23, 2.66-18.40, 11.80-42.80, 40.50 to 118.60, 18.90 to 70.10, respectively. 4.31-28.10, 4.96-46.25 mg/kg, the average contents of Hg, Cd, As, Pb, Cr, Zn, Ni, Cu were 0.128, 1.03, 4.73, 23.08, 76.22, 46.94,16.11,12.10mg/kg, respectively. The average contents of Hg, Cd, Pb and Cr in the study area were 2.03, 1.36, 1.11 and 1.23 times of the background values of soil in Shaanxi Province, respectively. The average

content of As, Zn and Cu was lower than the background value of Shaanxi Province, but the maximum content was 1.65, 1.01 and 2.16 times higher than the background value of Shaanxi Province, respectively.

The coefficient of variation (CV) of Hg and Cd contents in soil in the study area were 0.050 and 0.37, respectively, showing moderate variation, indicating that the contents of these two heavy metals were less affected by the outside world. The coefficient of variation (CV) of the contents of As, Pb, Cr, Zn, Ni and Cu were 2.81, 7.46, 18.00, 13.51, 5.44 and 5.64, respectively, showing strong variation (CV>0.50), indicating that the contents of these eight heavy metals may be affected by some local pollution sources. Skewness coefficient (SK) ranges from -3 to 3, and the larger its absolute value is, the greater the skewness degree is. When SK>0, it is positive skewness, and when SK<0, it is negative skewness. Kurtosis coefficient is the characteristic number that characterizes the peak value of probability density distribution curve at the average value. The skewness coefficient and kurtosis coefficient of Cd, As and Cu in the soil of the study area were high, indicating that these three elements were in a high accumulation state.

Table 3. Soil heavy metal content statistics of Stonemason Mine Area (n=25)

Parameter	Hg	Cd	As	Pb	Cr	Zn	Ni	Cu
Min (mg/kg)	0.043	0.44	2.66	11.80	40.50	18.90	4.31	4.96
Max (mg/kg)	0.255	2.23	18.40	42.80	118.60	70.10	28.10	46.25
Average (mg/kg)	0.128	1.03	4.73	23.80	76.22	46.94	16.11	12.10
Coefficient of variation (CV)	0.050	0.37	2.81	7.46	18.00	13.51	5.44	5.64
Coefficient of skewness	0.389	0.36	0.60	0.31	0.24	0.29	0.34	0.47
Kurtosis coefficient	0.808	1.91	1.39	0.76	0.36	-0.36	-0.01	2.90
Soil background value in Shaanxi Province (mg/kg)	0.063	0.76	11.1	21.4	62.5	69.4	28.8	21.4

(2) Characteristics of heavy metal pollution in soil

As can be seen from Table 4, the average values of the one-way pollution index (P_i) of heavy metals in the surface soil of the study area are Hg (2.03), Cd (1.14), As (0.59), Pb (1.11), Cr (1.22), Zn (0.68), Ni (0.56) and Cu (0.57), respectively.

The average value of each element in the study area is at or above the level of mild pollution, Hg is seriously polluted and in the moderate level, Cd, Pb and Cr are in the mild level of pollution, and other heavy metals are in the clean level. Among them, the sample points with Hg element single pollution index belonging to moderate pollution accounted for 21.52% of the total sample points, while those with Cd, Pb and Cr single pollution index belonging to mild pollution accounted for 43.04%, 55.70% and 77.22% of the total sample points, respectively. The NPI of 8 heavy metals in the surface soil of the study area ranged from 0.80 to 3.20, with an average value of 1.64, which was at a slightly polluted level. According to the results, heavy metal elements in the surface soil of the study area are affected by human activities, and Hg is the most important pollution factor.

Table 4. Ecological risk of heavy metals on the surface of the study area

Parameter	P_i								NPI
	Hg	Cd	As	Pb	Cr	Zn	Ni	Cu	
Min	0.68	0.57	0.24	0.55	0.65	0.27	0.15	0.23	0.80
Max	4.05	2.94	1.66	2.00	1.92	1.01	0.98	2.16	3.20
Average	2.03	1.14	0.59	1.11	1.22	0.68	0.56	0.57	1.64
Pollution levels	III	II	I	II	II	I	I	I	III

(3) Potential ecological risk assessment of soil heavy metal pollution

The potential ecological risk index (E) and RI of heavy metal elements at various points were calculated by taking the soil background value of Shaanxi Province as the reference ratio, and the ecological risk assessment was carried out according to the classification standard of potential ecological risk. The average value of E in the study area from large to small is Hg (81.01), Cd (34.13), As (5.90), Pb (5.56), Cu (2.83), Ni (2.80), Cr (2.44) and Zn (0.68). Except for Hg, the average value of potential ecological risk index of other heavy metals on the surface of the study area is <40, which is at the level of slight pollution. The potential ecological risks of Hg ranged from 27.30 to 161.90, with an average value of 81.01, indicating a high ecological risk. It can be seen that Hg is the most important ecological risk factor in the study area. The variation of RI in the study area ranged from 53.44 to 6400.00, and the average value of the comprehensive potential ecological risk index was 1336.49, indicating a high ecological risk (Fig. 1).

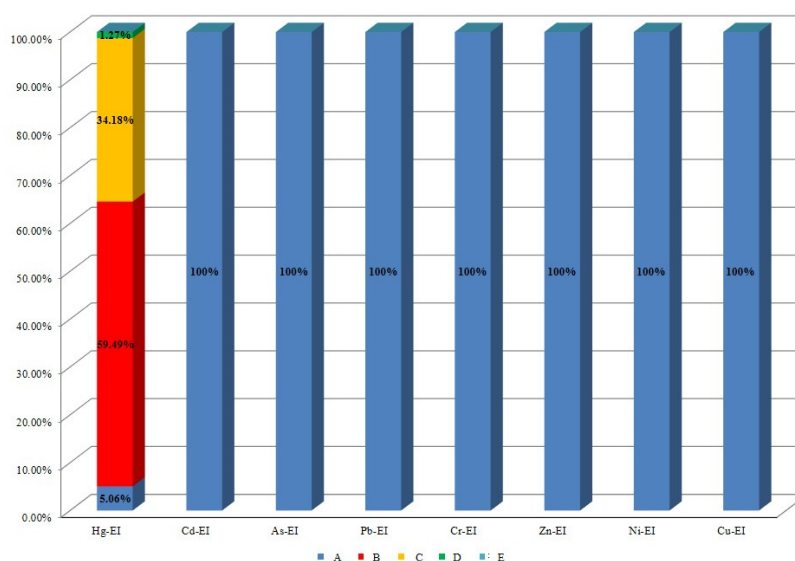


Fig 1. Potential ecological risk assessment of heavy metals on the surface of the study area

4. Conclusion

(1) The contents of heavy metals Hg, Cd, Pb and Cr in the study area were higher than the background values of the soil in Shaanxi Province, and the average contents of As, Zn and Cu were lower than the background values of the soil in Shaanxi Province, but the maximum contents were 1.65, 1.01 and 2.16 times of the background values of the soil in Shaanxi Province, respectively.

(2) Hg is in a moderate level of pollution, Cd, Pb and Cr are in a mild level of pollution, and the other heavy metals are in a clean level. Hg has great potential ecological hazards, which should be paid enough attention to, and certain pollution prevention and control measures should be taken.

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