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Characterization of Soil Heavy Metal Pollution in a Mining Area in Southwest Yunnan

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ABSTRACT

This study takes a mining area in southwest Yunnan Province of China as the research object to study the pollution of heavy metals as, cadmium and mercury in the soil of a mining area in Jingdong County, Puer City, Yunnan Province. The single factor index method is used to calculate the multiple of cadmium, mercury and arsenic in each soil layer under different pH values in the mining area, and the Nemerol pollution index method is used to study the pollution characteristics. The results showed that the soil pollution degree of S4 soil layer at 50~150cm and the surface soil of S7 detection point reached the warning line; However, the soil pollution at other detection points and at different soil levels showed slight pollution. The conclusion shows that there is slight pollution in the soil within the assessment range, which needs attention and measures should be taken to reduce the risk of heavy metal pollution in the soil of the mining area.

KEYWORDS

Diggings; Soil Heavy Metals; Pollution Characterization; Single-Factor Index; Nemero Pollution Index.

1. INTRODUCTION

According to the literature, the heavy metal pollution of soil in China has been very serious, and the mining of mining areas and the stacking of tailings have greatly increased the pollution of heavy metals in soil. Wang Yan[1]and others summarized the prevention and control of soil heavy metal pollution in China's nonferrous metals industry, and summarized the prevention and control of soil heavy metal pollution in China's nonferrous metals industry in recent years. Xu Weijian[2]and others took the heavy metal pollution in the soil of a lead-zinc mining area in southwest China as the research object, and studied its heavy metal pollution characteristics using the single factor pollution index method and the Nemero comprehensive pollution index method. Sun Deyao[3]used the same method to analyze the spatial distribution of heavy metal pollution in the soil of a mining area in the mountain area of northern Hebei Province, and assessed the potential ecological risk of the mining area. Zhang Yongkang[4]evaluated the characteristics of soil heavy metal pollution in a copper nickel mining area by using the cumulative pollution index method and the single factor index method, and found that arsenic exceeded the standard, which is closely related to the background value of high soil heavy metals in the mining area. Fang Chuandi[5]analyzed the characteristics of heavy metal pollution in the soil of the mining area in the Yangtze River Economic Belt, and found that the middle reaches had the highest content of Cr, As, Ni, Cd, and Zn. Ran Hua et al[6]. studied the sources and spatial distribution of metals in abandoned arsenic mines, and assessed the risks of these metals to public health. The average concentrations of arsenic, cadmium, mercury, manganese, lead, antimony and thallium in the soil of the mining area are higher than the local average values. WU et al[7]. analyzed the current situation and main influencing factors of heavy metal pollution in Guangxi, Fujian, Liaoning and Yunnan provinces, analyzed the areas where heavy metal pollution exceeded the standard, and conducted a provincial analysis of heavy metal pollution in hot areas. The results showed that the concentration of heavy metals in soil in China increased from north to south, and it was typical in Northeast China; It is also common in the south of China, with heavy metals exceeding the standard in the central, southwest, south and other places. The heat map shows that mineral development and industrial production are the main causes of pollution in the most polluted provinces. Hu Qingjing[8]and others used the canonical correspondence analysis method to study the characteristics of soil heavy metal pollution caused by the collapse of the tailings dam of the lead-zinc mine on land use types. The results showed that the pollution in the study area was mainly lead, zinc and cadmium, followed by copper, of which the spatial distribution pattern of zinc and cadmium was more significantly affected by land use types, and cadmium had the highest environmental risk on paddy fields.

The situation of soil heavy metal pollution in Chinese mining areas is grim, and there is an urgent need to study the characteristics of the pollution and its migration and transformation planning, and to take effective measures for treatment and remediation. Therefore, this paper takes a mining area in southwestern Yunnan as the research object to study the degree and characteristics of soil heavy metal arsenic, mercury and cadmium pollution in the soil class of this mining area, in order to provide scientific basis for the prevention, control and management of soil heavy metal pollution in the mining area in China.

2. MATERIALS AND METHODS

2.1. Study Area and Sampling

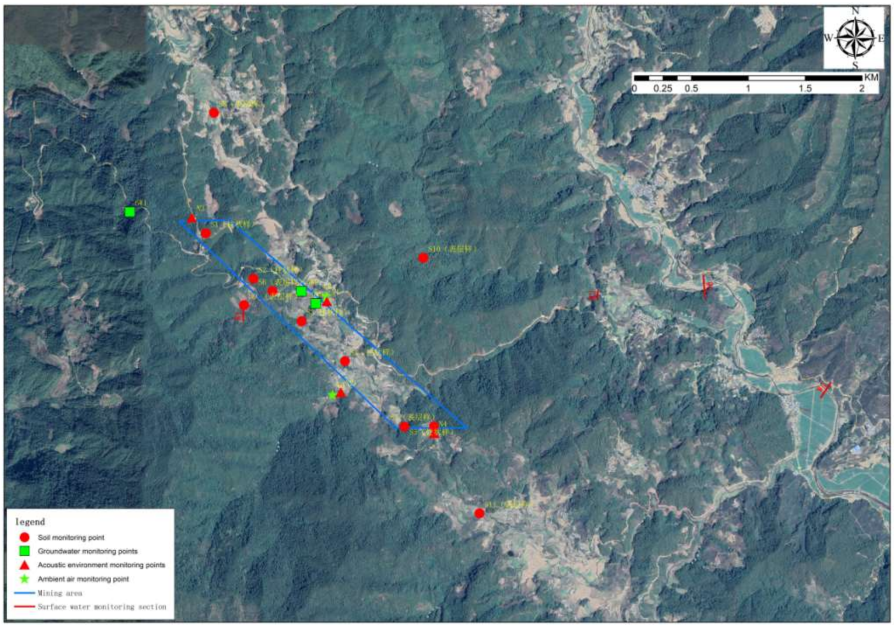

Figure 1. Map of sampling locations

In this study, a mining area in Jingdong County is under the jurisdiction of Pu'er City, Yunnan Province. It is located in the southwest of Yunnan, at the north end of Pu'er City, between E: 100 ° 22 ′ - 101 ° 15 ′, N: 23 ° 56 ′ - 24 ° 29 ′. The climate of Jingdong Yi Autonomous County is subtropical monsoon climate. Wood, mango and tea are the sources of economic income of Jingdong Yi Autonomous County, and Jingdong County of Puer City is also one of the main producing areas of Puer tea.

(b) The use of "serpentine sampling points" for sampling at the mine site, with samples taken from different soil layers at each sample site;

Soil samples were collected sequentially from the seven sample plots, with a total of 17 samples from different soil horizons. The layout of the study area is shown in Figure 1 below.

Soil samples were taken after sieving, digested by microwave digestion apparatus, and then the concentrations of cadmium, mercury and arsenic were determined by atomic fluorescence method. For the experiment, the

The water was distilled water, and the analytical quality control measures were taken by blank, parallel and standard substance control methods.

2.2. Data Processing

In this study, the screening value of soil pollution risk in the mining area in the Standard for Risk Management and Control of Agricultural Land Soil Pollution of Soil Environmental Quality (Trial) (GB15618-2018) is used as the assessment standard for the assessment of heavy metal pollution characteristics in the mining area soil. See Table 1.

Table 1. Screening Value of Soil Pollution Risk in Mining Area mg/kg

risk screening / Project	pH≤5.5	5.5<pH≤6.5	6.5<pH≤7.5
cadmium (Cd)	0.3	0.3	0.3
mercury	1.3	1.8	2.4
arsenic	40	40	30

The single-factor pollution index method and Nemero pollution index method were used to assess the heavy metals cadmium, mercury and arsenic in the soil of the mining area, and the results of the determination of the content of heavy metals in different soil layers were comprehensively evaluated, so as to make clear the influence of different soil layers and different soil pH on the level of soil pollution in the mining area.

Table 2. Criteria for grading individual soil contamination levels

Pi	Pi≤1	1<Pi≤2	2≤Pi≤3	Pi>3
pollution levels	Non-pollution	light pollution	medium-contaminated	Heavy pollution

The environmental quality standard value (national secondary standard value index) is expressed, and the pollution index is calculated on the basis of the ratio of the measured value of heavy metal content to the evaluation standard, and the exceeding times of soil heavy metal are evaluated.

The one-factor index method is as follows.

$$Pi=Ci/Si$$

Si - single factor index, Ci - i pollution concentration, in mg/kg.

The Nemero pollution index method is shown in Tables 3.

Table 3. Nemero Pollution Index Method

	Description
Overview of method	It is possible to comprehensively evaluate the degree of contamination of cadmium, mercury and arsenic in soil by combining various heavy metal elements and taking into account the average and maximum values of the pollution index of individual elements.
Equation formula,	$Pn=\{[Pi(ave)^2+Pi(max)^2/2]\}1/2$ Pn is the Nemero pollution index of heavy metal element i, and Pi (ave) ^{2} is the average value of each pollution index of soil; Pi (max) 2 represents the maximum pollution index of soil heavy metal elements.
Meaning	$Pn<1$ is non pollution; If $1<Pn<2$, it is light pollution;
Evaluation criteria	$2<Pn<3$ is moderate pollution; $Pn>3$ is heavy pollution.

Considering that the Nemero pollution index method highlights the role of individual heavy metal elements on the environmental impact of the maximum factor, and can be integrated to evaluate the degree of pollution of soil by a variety of heavy metals, it is necessary to carry out a comprehensive analysis of the degree of pollution, the grading criteria are shown in Table 4.

Table 4. Criteria for grading the degree of integrated soil contamination

Level	P index number	Level	pollution levels
a	P comprehensive ≤ 0.7	Security	Cleaning
b	0.7 ≤ P integrated ≤ 1.0	The cordon	Clean
c	1.0 ≤ P synthesis ≤ 2.0	Not serious	Crop pollution
d	2.0 ≤ P synthesis ≤ 3.0	Middle level	Heavily polluted

3. RESULTS AND DISCUSSION

3.1. Study the Monitoring of the Current Status of Soils in Mining Areas

In the research test on the determination of cadmium, mercury and arsenic in the soil of the mining area, the summary results based on the pH pH measurement results of the sampling and detection points are shown in Table 5, 6.

Table 5. List of Soil Environment Status Monitoring (5.05 ≤ pH ≤ 5.90)

Points	Soil layers	Cadmium (mg/kg)	Mercury (mg/kg)	Arsenic (mg/kg)
S1	0~50cm 50~150cm 150~300cm	0.21 0.23 0.22	0.19 0.41 0.19	23.1 17.1 19.7
S2	0~50cm 50~150cm 150~300cm 0~50cm	0.21 0.24 0.26 0.25	0.48 0.82 0.33 0.24	7.93 8.39 11.3 21.8
S3	50~150cm 150~300cm 0~50cm	0.26 0.25 0.23	0.45 0.19 0.27	16.0 13.3 18.4
S4	50~150cm 150~300cm	0.24 0.26	0.49 0.34	25.1 38.3
S6	Topsoil	0.22	0.30	35.7
S7	Topsoil	0.16	0.45	5.16
risk screening values		0.3	1.8	40
compliance		Normol	Normol	Normol

Table 6. List of Soil Environment Monitoring S5 (4.30 ≤ pH ≤ 4.79)

program / Soil layers	Cadmium (mg/kg)	Mercury (mg/kg)	Arsenic (mg/kg)
0~50cm	0.24	0.48	7.57
50~150cm	0.24	0.15	4.27
150~300cm	0.21	0.13	5.87
Standardized values	0.3	1.8	40
ompliance	Normal	Normal	Normal

According to the above monitoring list of soil environment status in the mining area, the soil environment in the assessed area is good, and the soil monitoring projects outside the occupied area can all reach the risk screening value in accordance with the Standard for Risk Management and Control of Soil Environmental Quality, Agricultural Land and Soil Pollution (Trial) (GB15618-2018).

According to the results in Table 7, 8, the excess multiple of heavy metals cadmium, mercury and arsenic in the soil of the mining area is calculated by using the single factor pollution index. The content of heavy metals cadmium, mercury and arsenic in the soil of 5.05 ≤ ph ≤ 5.90 or 4.30 ≤ pH ≤ 4.79 is up to the standard, indicating that the heavy metal pollution in the soil environment of the mining area is in a safe state, and no heavy metals cadmium, mercury and arsenic are found Mercury and arsenic exceed the standard.

Table 7. Preview of Single Factor Index Measurement Results (5.05 ≤ pH ≤ 5.90)

Point soil layers		Cadmium (mg/kg)	Mercury (mg/kg)	Arsenic (mg/kg)	Average (mg/kg)
0~50cm		0.7	0.11	0.58	0.46
S1	50~150cm	0.77	0.23	0.43	0.48
150~300cm		0.73	0.11	0.49	0.44
S2	0~50cm	0.7	0.27	0.20	0.39
50~150cm		0.8	0.46	0.21	0.49
150~300cm		0.87	0.18	0.28	0.44
0~50cm		0.83	0.13	0.54	0.50
S3	50~150cm	0.87	0.25	0.40	0.51
150~300cm		0.83	0.11	0.33	0.42
0~50cm		0.77	0.15	0.46	0.46
S4	50~150cm	0.8	0.27	0.63	0.57
150~300cm		0.87	0.19	0.96	0.67
S6	Topsoil	0.73	0.17	0.89	0.60
S7	Topsoil	0.53	0.25	0.13	0.30
Risk screening values		0.3	1.8	40	—
Compliance		Normal	Normal	Normal	—

Table 8. Single factor index preview table of S5 test results (4.30 ≤ pH ≤ 4.79)

Program / Soil layers	Cadmium (mg/kg)	Mercury (mg/kg)	Arsenic (mg/kg)	Average (mg/kg)
0~50cm	0.8	0.27	0.19	0.42
50~150cm	0.8	0.08	0.11	0.33
150~300cm	0.7	0.07	0.15	0.46
Standardized values	0.3	1.8	40	—
Compliance	Normal	Normal	Normal	—

3.2. Nemero Pollution Index Method

Table 9. Preview of Nemero Pollution Index (5.05 ≤ pH ≤ 5.90)

Points	Soil layers	Max	Mean	the value of the composite index	Soil Composite Pollution Index	The level of contamination
S1	0~50cm 50~150cm 150~300cm	0.7 0.77 0.73	0.46 0.48 0.44	1.07 1.12 1.07	1.0 ≤ P synthesis ≤ 2.0 1.0 ≤ P synthesis ≤ 2.0 1.0 ≤ P synthesis ≤ 2.0	light pollution light pollution light pollution
S2	0~50cm 50~150cm 150~300cm 0~50cm	0.7 0.8 0.87 0.83	0.39 0.49 0.44 0.50	1.03 1.14 1.15 1.16	1.0 ≤ P synthesis ≤ 2.0 1.0 ≤ P synthesis ≤ 2.0 1.0 ≤ P synthesis ≤ 2.0 1.0 ≤ P synthesis ≤ 2.0 1.0 ≤ P synthesis ≤ 2.0	light pollution light pollution light pollution light pollution
S3	50~150cm 150~300cm 0~50cm	0.87 0.83 0.77	0.51 0.42 0.46	1.19 1.12 1.11	1.0 ≤ P synthesis ≤ 2.0 1.0 ≤ P synthesis ≤ 2.0 1.0 ≤ P synthesis ≤ 2.0	light pollution light pollution light pollution
S4	50~150cm 150~300cm	0.8 0.87	0.57 0.67	0.99 1.27	0.7 ≤ P integrated ≤ 1.0 1.0 ≤ P integrated ≤ 2.0	The cordon light pollution
S6	Topsoil	0.73	0.60	1.17	1.0 ≤ P synthesis ≤ 2.0	light pollution
S7	Topsoil	0.53	0.30	0.88	0.7 ≤ P integrated ≤ 1.0	The cordon

Table 10. Nemerol pollution index measurement (4.30 ≤ pH ≤ 4.79)

Points	Soil layers	Max	Mean	Composite index value	P value	Contamination
S5	0~50cm	0.8	0.42	1.10	1.0 ≤ P synthesis ≤ 2.0	light pollution
	50~150cm	0.8	0.33	1.06	1.0 ≤ P synthesis ≤ 2.0	light pollution
	150~300cm	0.7	0.46	1.07	0.7 ≤ P integrated ≤ 1.0	light pollution

Table 9, 10 shows that the comprehensive index value of soil environmental quality is determined by the pollution level of cadmium, mercury and arsenic in the soil of the mining area after calculating the Nemero pollution index. When the pH value in the soil is 5.05 ≤ ph ≤ 5.90, the soil at S4 is in the 50~150cm layer soil and S7 topsoil, and the soil pollution degree reaches the warning line; In addition, the pollution degree of heavy metals such as cadmium, mercury and arsenic in the soil of other sites belongs to light pollution.

When the pH value of the soil at S5 point is 4.30 ≤ pH ≤ 4.79, the soil pollution degree of heavy metals cadmium, mercury and arsenic in the soil is slightly polluted.

3.3. Evaluation of Soil Contamination Status

The single factor index is used to evaluate the over standard multiple of soil, and the Nemero comprehensive pollution index is used to comprehensively evaluate the pollution level of cadmium, mercury and arsenic in soil. According to the test results of soil environmental quality in Table 5,6 above, it is concluded that the contents of heavy metals cadmium, mercury and arsenic in the soil around the mining area meet the soil environmental quality standards, and the soil environment within the assessment range is slightly polluted. The average values of heavy metals cadmium, mercury and arsenic in each soil layer of the mining area are calculated by the single factor index method in Table 7 and Table 8. Combined with the Nemero pollution index, the pollution degree of soil in the mining area reaches the warning line in Table 9 and Table 10 at the S4 soil layer of 50~150cm and in the surface soil of S7 detection point; However, the soil pollution in other detection points and in different soil layers shows that the pollution degree of heavy metals in the soil is slightly polluted.

4. DISCUSSION

According to the results of this study, the content of heavy metals cadmium, mercury and arsenic in the soil around the mine reached the soil environmental quality standard, and the soil environmental quality within the mining area was assessed to be mildly polluted.

The area of contaminated soil is increasing rapidly, and the composition of soil pollution is becoming increasingly complex. There is a great demand for comprehensive and effective remediation technology of contaminated soil. It is known that the soil in the mining area has been slightly polluted through soil testing in the current mining area. Therefore, in order to ensure the safety and sustainable use of these soils, it is necessary to conduct a comprehensive investigation and testing of these soils. The risk value in the national standard (GB15618-2018) is selected in this study to determine the soil pollution at different levels of the detection points. The single factor index is used to calculate the excess multiples of cadmium, mercury and arsenic in the soil, and use the Nemero pollution index to make an objective assessment of the pollution degree, so as to ensure the reduction of heavy metal pollutants in the environmental quality or the removal of some heavy metals, so that the content of heavy metals in the soil will not pose a potential threat to human health.

After the investigation and assessment of heavy metal pollution in the soil of the mining area, it can be concluded that the heavy metals cadmium, mercury and arsenic do not pollute the soil in the mining area, and the safety of soil quality is related to the safety of crops and the living environment.

Therefore, for the existence of heavy metals in the soil has a certain degree of sedimentation and hazardous, in the industrial and agricultural production activities, we should always take into account the hazards of heavy metal pollution of the soil, do a good job of preventing and controlling heavy metal pollution of the soil in the mining area.

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