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Heavy Metal Distribution in The Farmland Surrounding Dahongshan Iron and Cooper Mine in Yunnan Province, China

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Abstract. Dahongshan Iron and Cooper mine in Yunnan Province are respectively the second and the third batch of National green mining pilot units. In order to test the green mine promoting effect and better drive other mining enterprises in Yunnan province to build green mines, we investigated the water body, farmland soil, vegetation and geological environment surrounding the mine in August 2016. By adopting both the single factor index method and Nemero multi-factor index method, the pollution indices were calculated to assess pollution extent. The Pi values of Cu and Ni of 4 soil samples in the 19 sampling points were greater than level 1 and slightly polluted, while the Pi values of one sampling point in Cu were greater than level 2, which was moderately polluted. From the comprehensive pollution index, one sample point was between 2-3, indicating that all soil crops were moderately polluted, and one sample point was between 1-2, indicating that the soil was lightly polluted and the crops began to be polluted. The two samples were all between 0.7 and 1, indicating that they were still clean and the remaining 15 samples were all less than 0.7, indicating that they were safe and uncontaminated. Some visible achievements have been made in the construction of green mines.

1. Introduction

Soil is not only the resource which human relies to survive but also an important component of environment. Cultivated land is closely related to human production and life, the health condition of farmland affects human health directly. However, the development of mining industry, as well as the imperfection of mining technology and management, makes it constantly have adverse effects on the surrounding farmland, among which heavy metal pollution is one of them. Especially in Nonferrous mine areas, due to sewage discharge, soil erosion and other reasons, some harmful metals are lost in the acidic wastewater, tailings accumulation and leaching process generated by mining, leads to excessive levels of heavy metals in the soil [1].

While many geological disasters are formed in mining, various environmental pollution problems in mining area are emerging day by day, Heavy metal pollution in soil is especially serious. Heavy metals in soil can migrate from soil to other ecosystem components, such as groundwater, plants, and affect human health through drinking water and food chains [2].

Mining activities will have a serious impact on the surrounding ecological environment, which is related to the safety, living and harmonious production of mines. Soil is an important medium to receive pollution, mine waste water pollutes soil, and exposed dust is also an important cause of surrounding soil pollution. In the current situation of resource shortage and strengthening environmental protection,



resource effect and environment effect must be combined to carry out research. Monitoring and evaluation of mine environmental quality is an important task for geoscientists and environmental workers [3].

Dahongshan copper and iron mine was awarded national green mine pilot unit by Ministry of Land and Resources of PRC in April 2013. Through carrying out Intensive use of mineral resources, scientization of mining method, energy-saving of production technology, standardization of enterprise management, landscaping of mining area environment construction and harmonization of mining area construction, the harmonious development of mining economy and ecological environment will be promoted. Focus on standardizing the construction of green mines, to establish standards and relevant measures for the construction of green mines according to the requirements of mineral resources planning, set up the model of green mines and promote the construction of green mines, make the construction of green mines a big step forward and develop the mining economy in a safe, environmentally friendly and sustainable way [4].

In August 2016, the project team investigated the water body, farmland soil, vegetation and geological environment surrounding Dahongshan Iron and Cooper mine, and investigate the mining enterprises, It provides a certain basis for increasing the publicity of building green mines and developing green mining, raising the public awareness, and mobilizing the enthusiasm and support of all sides.

2. Brief introduction of study area

Dahongshan Iron and Cooper mine is located in Jiasa Town of XinPing County, $101^{\circ} 73'52''\text{E}$ - $101^{\circ} 39'51''\text{E}$ and $24^{\circ} 04'58''\text{N}$ - $24^{\circ} 6'49''\text{N}$, the area of it is 15.2km^2 . The reserves of Dahongshan iron ore and copper reached large and super large scale, the proved and retained reserves of 424 million tons of iron ore and 1.55 million tons of copper metal, among which, the reserves of high-grad iron ore deposit were 1.61 million tons, accounting for 15.6% and 54.8% of the same reserves in Yunnan province respectively, and 625,800 tons of Rich copper with taste greater than 1%, accounting for 20% of copper rich in Yunnan province.

There are dry red soil, red soil in low-elevation area and yellow soil in the middle altitude area of the mining area. The valley below 800 meters is dry hot valley vegetation, mostly covered by scrub grass. More than 800 ~ 1100 meters is shrubs and sparse tree communities, the vegetation in the high altitude area is better, and there are cultivated land and economic fruit forests in each elevation range.

The distribution of soil types around the sampling area is complicated due to its unique geographical location, climate type and local people's farming system, which can be divided into the following types :(refer to the information provided by field research and enterprises)

- Dry red soil: mainly distributed in Mangang river bank, it is a special tropical soil formed in the dry and hot climate.
- Latosolic red soil: the main soil in the mine. It is a typical soil in the bioclimatic climate of subtropical monsoon evergreen broad-leaved forest. Due to the strong leaching and Desilication alloying during soil formation, the soil has a distinct developmental level. The soil is acidic and phosphorous deficient. The colour of soil varies from brown to off-white depending on the mother rock.
- Red soil: mainly distributed in the mountains above the altitude of 1800 meters. It is the representative soil of subthermal region under the climate condition of high temperature and clear humidity. The soil is slightly acidic due to leaching and desilisitization, and the soil is reddish or brown in color, pelitic rock is mainly argillaceous rock.

- Paddy soil: along the bank of Jiasa river. It is a typical product of human activities, as a result of years of cultivation, irrigation and fertilization, the soil gradually changed the residual properties of the mother soil, and formed the special morphology of paddy field and corresponding physical and chemical properties, cultivation and production performance. Soil fertility was generally improved.

Undressed ore stone contain metal and metalloid elements is diversity, with copper, iron, silver, gold, platinum, palladium, arsenic, cobalt, lead, zinc, nickel, manganese, titanium, the content of iron and copper is the highest, the heavy metals (metals and metals of significant toxicity and biotoxicity) referred to in environmental pollution mainly include copper (Cu), arsenic (As), cobalt (Co), lead (Pb), zinc (Zn), nickel (Ni), etc. In this project, the heavy metal evaluation factors that have great influence on the surrounding environment quality of the mining area are as follows: arsenic (As), mercury (Hg), copper (Cu), chromium (Cr), cadmium (Cd), lead (Pb), zinc (Zn) and nickel (Ni).

3. Sample collection and testing

Soil sample sampling is centred on the mine. Based on the dominant wind, wind power, topography factors and the heavy metal pollution type of the sampling site in Dahongshan mining area, the sampling points are generally classified into three categories: the surrounding farmland of the mine, the surrounding farmland of the tailing mining area and the farmland around the concentrator. The locations and types of sampling points are shown in figure 1.

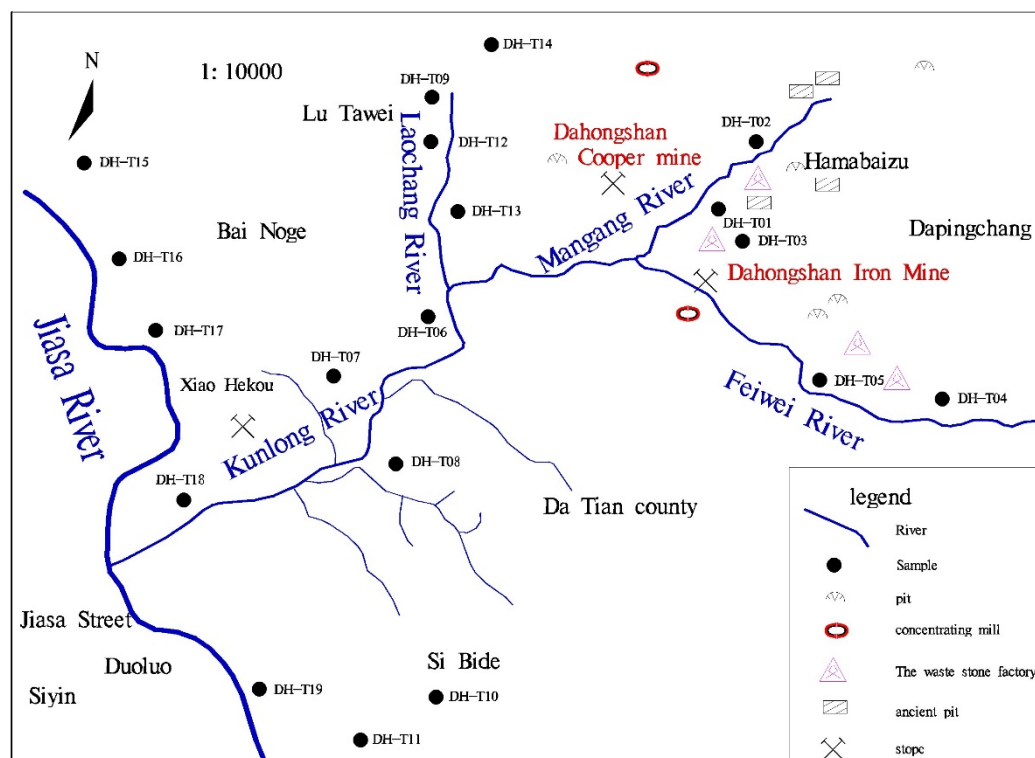


Figure 1. Diagram of Soil Sampling Points around the Dahongshan Mine

The soil was collected according to s-type sampling method, and the top layer (20 centimetres) soil was taken with wooden tools (to avoid metal pollution). 6-10 mixed soil samples were taken for each sample point, and about 1 kilogram of soil samples were retained by quartering method after blending. Air dry, crush and remove foreign material. After being crushed with the wooden bar, the samples were sieved through a 2 centimetres hole to remove the sand and plant residues above 2 centimetres, then about 10 grams was taken

by quartering method, and the samples were ground up to 100 mesh nylon screens. After screening, the sample is thoroughly mixed, then sent sample to testing centre.

Soil samples were sent to the Ministry of Land and Resources Kunming Mineral Resource Supervision Inspecting Center in China for testing and analysis. All testing procedures were conducted in strict accordance with *Environmental quality standard for soils (GB15618-1995)*. Table 1 Shows detailed analysis instruments and methods.

Table 1. List of soil sample analysis methods

Element	Method	Instrument model	Detection Limit
chromium	inductively coupled plasma mass spectrometry (ICP-MS)	iCAP Q(Semir, USA)	0.82mg/kg
cadmium	inductively coupled plasma mass spectrometry (ICP-MS)	iCAP Q(Semir, USA)	0.015mg/kg
lead	inductively coupled plasma mass spectrometry (ICP-MS)	iCAP Q(Semir, USA)	0.96mg/kg
total arsenic	atomic fluorescence spectrophotometry (AFS)	AFS 3100 (HaiGuang,China)	0.27 mg/kg
Total mercury	Cold atomic fluorescence photometer (CV-AFS)	XGY-1011(Institute of physical and chemical exploration, Chinese academy of sciences)	0.0004 mg/kg
copper	inductively coupled plasma mass spectrometry (ICP-MS)	iCAP Q(Semir, USA)	0.89 mg/kg
zinc	inductively coupled plasma mass spectrometry (ICP-MS)	iCAP Q(Semir, USA)	2.15mg/kg
nickel	inductively coupled plasma mass spectrometry (ICP-MS)	iCAP Q(Semir, USA)	0.44mg/kg

4. Evaluation Methodology

At present, Nemero index method is one of the most commonly used methods to calculate comprehensive pollution index in China and abroad. This method first finds the sub-index over multiple of each factor, and then finds the average of the sub-index. Calculate the maximum subindex and the average value. The single factor index method can determine the main heavy metal pollutants and their harm degree through single factor evaluation. It's usually expressed as a pollution index. Compared with the measured value of heavy metal content and the evaluation standard, the pollution index is calculated with the following formula:

$$P_i = C_i / S_i \quad (1)$$

Where P_i is measured Pollution index of heavy metal elements; C_i is Measured value of heavy metal content (mg/kg); S_i refers to national level 2 standard value in Soil environmental quality standard value. Single factor index pollution classification standard is shown in table 2.

The single factor index can only reflect the pollution degree of each heavy metal element, but cannot fully reflect the soil pollution status, while the comprehensive pollution index takes into account the average and maximum of single factor pollution index (table 3). The effect of heavy metal pollutants can be highlighted. The comprehensive pollution index calculation method is as follows:

$$P = \frac{\sqrt{P_{lave}^2 + P_{imax}^2}}{2} \quad (2)$$

where P is Nemero composite pollution index of soil sample, $P_{\max}$ is maximum value in Single Pollution index of heavy metal elements of soil sample, P_{ave} is mean value in Single Pollution index of heavy metal elements of soil sample.

Table 2. Soil pollution level classification standards

P_i Value	$P_i \leq 1$	$1 < P_i \leq 2$	$2 < P_i \leq 3$	$3 < P_i$
pollution level	Non-pollution	light pollution	middle level pollution	heavy pollution

Table 3. Soil comprehensive pollution level classification standards

Grade	Range of P values	Pollution degree	pollution level
1	$P \leq 0.7$	Safe	Cleaning
2	$0.7 < P \leq 1$	The alert level	slight cleaning
3	$1 < P \leq 2$	Mild Pollution	The soil was lightly contaminated and the crops began to be polluted
4	$2 < P \leq 3$	middle level pollution	Soil crops are moderately contaminated
5	$3 < P$	heavy pollution	Soil crops have been seriously contaminated

Note: data come from *national technical specifications for soil quality assessment*.

5. Results and Analysis

5.1 Heavy metal content in soil samples

The statistics of soil heavy metal content and pH value were shown in table 4. The results showed that the maximum values of As, Cu, Cr, Cd, Pb, Zn and Ni in each soil sampling unit exceeded national top-grade level, while Hg did not exceed the standards. Most sample points such as, Cr, Cd, Pb and Zn are less than national top-grade level. Heavy metal accumulation exists in soil inside and around the mining area. On the one hand, the concentrations of different heavy metal elements are very different. The maximum value of the average concentration in the soil is Cu, and the maximum concentration is 156.46mg/kg, while the minimum concentration of Hg is 0.03 mg/kg.

5.2 Pollution analysis

The pollution index can be calculated by using the analysis method of Nemero index, as shown in table 5. According to the results of table 3 Soil pollution level classification standards, The P_i values of Cu and Ni in 4 soil samples were greater than 1 and slightly polluted, while the P_i values of Cu in 1 soil sample were greater than 2, which was moderately polluted. From the comprehensive pollution index, 1 sample point (DH-T01) was between 2-3, indicating that soil and crops were moderately polluted, and 1 sample point (DH-T03) was between 1-2, indicating that the soil was lightly polluted and the crops began to be polluted. The two samples (DH-T02 and DH-T18) were all between 0.7 and 1, indicating that they were still clean and the remaining 15 samples were all less than 0.7, indicating that they were safe and uncontaminated.

6. Conclusion

6.1. The distribution of heavy metal content is affected by human activities

The content distribution of Cu in the soil is most typical, characterized by Cu content is higher in KunLong river below Dahongshan mine area, copper content in gravel soil is the highest, which is

mainly affected by the mining mine activities in Dahongshan copper mine, such as copper mine waste rock field located in the eastern part of mine slope, hills, rivers, capacity of 150000 m³, it's almost full now. Long-term stacking and weathering will slowly release heavy metals into the surrounding soil. Especially, the release of Cu in waste copper ore is mainly accumulated in the Mangang River, which is closest to the mining area. The higher Cr in soil in the upper reaches of the Feiwei River may be affected greatly by the Mine drainage. Soil in orchards along the banks of Feiwei River and Kunlong River may be affected by fruit tree planting, drug application and sewage irrigation for a long time, and the soil contents of Cr, Zn and Pb are relatively high. When Zhang Min et al. (1996) studied the distribution of heavy metals in vegetable garden soil, they also found that the heavy metals such as Cu, Zn and Pb in vegetable garden soil were relatively high. Humic acid in organic fertilizer applied to soil could form chelates with heavy metal ions, thus making heavy metal ions more conducive to adsorption on soil minerals. The higher concentration of heavy metals in the soil of vegetable gardens along the river may be related to the application of more fertilizers, pesticides, livestock, poultry feces and the irrigation of sewage in the process of vegetable planting.

Table 4. Statistical table of heavy metal content and PH value in the soil of Dahongshan mine (mg/kg)

No.	Soil sample	As	Hg	Cd	Cr	Cu	Ni	Pb	Zn	pH
1	DH-T01	9.08	0.028	0.080	78.3	203	52.3	8.58	48.5	7.98
2	DH-T02	14.3	0.029	0.058	67.5	128	39.7	17.9	54.9	7.83
3	DH-T03	17.9	0.030	0.12	156	161	48.8	27.5	55.5	7.85
4	DH-T04	16.0	0.035	0.16	92.9	54.6	44.4	30.9	90.6	7.36
5	DH-T05	15.5	0.042	0.17	96.6	52.2	43.5	29.1	90.2	7.32
6	DH-T06	14.0	0.049	0.21	109	71.7	46.9	37.8	119	7.68
7	DH-T07	12.6	0.038	0.12	70.6	81.7	32.0	23.0	73.7	8.00
8	DH-T08	10.3	0.031	0.11	42.7	24.8	18.2	59.7	48.3	7.18
9	DH-T09	8.6	0.047	0.051	48.5	23.4	22.2	17.5	90.8	7.28
10	DH-T10	13.6	0.020	0.066	72.0	25.2	29.2	21.9	54.8	4.87
11	DH-T11	11.1	0.019	0.087	80.7	41.5	34.6	26.0	76.6	7.04
12	DH-T12	10.1	0.031	0.066	48.3	33.7	19.6	17.0	47.8	7.67
13	DH-T13	9.90	0.039	0.12	37.2	30.1	17.3	14.6	51.9	7.34
14	DH-T14	7.15	0.038	0.057	56.5	23.8	19.8	18.1	58.4	6.56
15	DH-T15	11.8	0.027	0.085	50.1	24.4	18.5	22.6	33.7	5.99
16	DH-T16	13.5	0.031	0.086	59.6	37.4	29.4	18.5	59.1	7.03
17	DH-T17	14.5	0.026	0.16	79.6	65.6	36.4	50.7	78.5	8.34
18	DH-T18	12.2	0.061	0.29	117	91.5	55.0	37.5	153	6.48
19	DH-T19	17.7	0.028	0.088	75.3	34.5	31.2	38.6	71.0	7.39
	maximum	17.91	0.06	0.29	156.46	203.39	55.00	59.72	152.83	8.34
	minimum	7.15	0.02	0.05	37.19	23.37	17.29	8.58	33.73	4.87
	mean	12.62	0.03	0.11	75.76	63.62	33.63	27.23	71.38	7.22
	Median	12.58	0.03	0.09	72.03	41.46	32.00	23.00	59.09	7.34
	Standard deviation	3.02	0.01	0.06	29.43	50.74	12.40	12.90	28.50	0.81
	First-level standard of national soil	15	0.15	0.2	90	35	40	35	100	Natural background
	Second-level standard of national soil	20	1	0.3	300	100	50	300	250	<6.5
	Third-level standard of national soil	30	1.5	10	400	400	200	400	500	>6.5

Note: according to the soil environmental quality standard (GB15618-1995)

During the dry season, local residents planted rice in the riverbed in part of the Kunlong River. The soil in the paddy field might be continuously scoured and soaked for a long time due to irrigation water in the paddy field, and most soil elements in the paddy field migrated, so that the heavy metal content was relatively low. Thus it can be seen that human use of land often causes heavy metal content changes in soil. The degree of heavy metal pollution and the pollutant elements are also different depends on land-using type [5].

Table 5. Single pollution index and comprehensive pollution index of heavy metal in Soil

No.	Soil sample	P_i (As)	P_i (Hg)	P_i (Cd)	P_i (Cr)	P_i (Cu)	P_i (Ni)	P_i (Pb)	P_i (Zn)	comprehensive pollution index
1	DH-T01	0.45	0.03	0.27	0.26	2.03	1.05	0.03	0.19	2.21
2	DH-T02	0.72	0.03	0.19	0.23	1.28	0.79	0.06	0.22	0.92
3	DH-T03	0.90	0.03	0.40	0.52	1.61	0.98	0.09	0.22	1.47
4	DH-T04	0.80	0.04	0.53	0.31	0.55	0.89	0.10	0.36	0.49
5	DH-T05	0.78	0.04	0.57	0.32	0.52	0.87	0.10	0.36	0.48
6	DH-T06	0.70	0.05	0.70	0.36	0.72	0.94	0.13	0.48	0.57
7	DH-T07	0.63	0.04	0.40	0.24	0.82	0.64	0.08	0.29	0.41
8	DH-T08	0.52	0.03	0.37	0.14	0.25	0.36	0.20	0.19	0.17
9	DH-T09	0.43	0.05	0.17	0.16	0.23	0.44	0.06	0.36	0.13
10	DH-T10	0.68	0.02	0.22	0.24	0.25	0.58	0.07	0.22	0.27
11	DH-T11	0.56	0.02	0.29	0.27	0.42	0.69	0.09	0.31	0.29
12	DH-T12	0.51	0.03	0.22	0.16	0.34	0.39	0.06	0.19	0.16
13	DH-T13	0.50	0.04	0.40	0.12	0.30	0.35	0.05	0.21	0.15
14	DH-T14	0.36	0.04	0.19	0.19	0.24	0.40	0.06	0.23	0.10
15	DH-T15	0.59	0.03	0.28	0.17	0.24	0.37	0.08	0.13	0.20
16	DH-T16	0.68	0.03	0.29	0.20	0.37	0.59	0.06	0.24	0.27
17	DH-T17	0.73	0.03	0.53	0.27	0.66	0.73	0.17	0.31	0.36
18	DH-T18	0.61	0.06	0.97	0.39	0.92	1.10	0.13	0.61	0.78
19	DH-T19	0.89	0.03	0.29	0.25	0.35	0.62	0.13	0.28	0.45

6.2. The Chinese government carries out the green mine construction, Dahongshan copper and iron mine take an active part in the construction

The State Council included the targets and tasks of green mine construction in the national plan for mineral resources in 2008. In 2010, the State Council promulgated the Guidance on the implementation of the national plan for mineral resources development of green mining construction green mining work. The outline of the 12th five-year plan has raised the construction of green mines to the national strategic level. In local areas, we should optimize the layout of mines, make efficient use of resources, protect and control the environment of mines, and effectively promote the construction of green mines step by step. With the continuous progress of green mining construction, the government, enterprises and society have made great efforts to build green mines and set up a number of advanced enterprises to take the lead [6], Dahongshan iron ore and copper mine are typical examples. From the current national green mining pilot units, involving energy, ferrous metals, non-ferrous metal and non-metal industries, including state-owned, private and foreign-funded enterprises [7].

Under the background of the green mine construction, the core is the efficient utilization and recycling of resources in Dahongshan mining companies, according to the principle of reduction, reuse, recycling, economic benefits, social benefits and environmental benefits simultaneously, via a number

of technical renovation, in conserve resources, Reduce environmental pollution, Optimize the three rate (dilution rate, recovery rate, ore dressing recovery rate), circular economy work has made remarkable achievements.

6.3. Cut off sewage irrigation and improve soil heavy metal pollution

Sources of heavy metals in soil include natural weathering of minerals, which tend to cause low levels of heavy metals, and human activities, which are the main factors causing heavy metal pollution in soil. Sewage irrigation generally refers to the use of municipal sewage, commercial sewage and industrial wastewater after a certain treatment for farmland irrigation. As a result of the rapid development of urbanization, a large amount of industrial sewage is discharged into the river channels, and many heavy metal ions enter the soil when the polluted river water is used for irrigation, leading to the increase of heavy metal content in the soil year by year [8].

In order to avoid environmental pollution caused by ore dressing plant, underground production and domestic sewage, recycle production and domestic sewage, Dahongshan iron and cooper mine has built a 72246.8 m³/d production and domestic sewage treatment plant, realizing the complete recycling of production and domestic sewage.

In August 2012, Dahongshan iron mine invested 63.99 million yuan in the construction of tailings backwater project, which improved the recycling level of water resources in the mine, further saved water resources, and effectively protected the environment to meet the requirements of national technical policies on energy conservation and emission reduction and clean production standards. The water intake cost of the tailings return water system is 1.36 yuan /m³, which is 1.2 yuan /m³ less than that of the riverside water intake (2.56 yuan /m³). Under the support of the government, economic benefits, social benefits and environmental benefits have been met. The project won the state grants funds for the prevention and control of heavy metal pollution of 10 million yuan [9].

By 2016, pit wastewater and tailings wastewater were all recycled. After the waste rock is out of the pit, part of it is used for building materials, and part of it is used for Ore dressing system reprocessing. The tailings, through grading and filling the underground goaf, have created greater economic benefits, environmental benefits and social benefits, and at the same time effectively prevented the mine goaf collapse, prevented the overburden collapse, destroyed the surface, villages and farmland, and effectively protected the surface ecological environment. The construction and management and maintenance costs of tailings ponds are saved, the land area of tailings ponds is reduced, the air pollution caused by surface tailings dust and the water pollution in the downstream of tailings dam are reduced, not only the tailings are fully utilized, but also the surface ecological environment is effectively protected.

Project team in the study of water, through data collection, research and take water samples nearby rivers, according to the Ecological geochemical assessment analysis of sample technical requirements (trial) in China geological survey geological survey technology standard (DD2005-03) in to test, use Nemero index method, according to different pollutants concentration in different types of water quality standards, as well as the various points measured pollution concentration, F value was calculated for the Composite index score of various water sample, and the results showed that all the sampling points were excellent. Compared with the data 8 years ago, the sampling analysis results showed that the excess rate of heavy metal was already very low, and the general condition of previous pollution was improved [10].

The results of soil sampling also showed from the comprehensive pollution index, 1 sample point (DH-T01) was between 2-3, indicating that soil and crops were moderately polluted, and 1 sample point (DH-T03) was between 1-2, indicating that the soil was lightly polluted and the crops began to be polluted. The two samples (DH-T02 and DH-T18) were all between 0.7 and 1, indicating that they were still clean and the remaining 15 samples were all less than 0.7, indicating that they were safe and uncontaminated. The contamination of farmland soil has also improved

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