Risk assessment of heavy metal pollution in coal mining subsidence area

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Abstract: Underground mining is the main way of coal mining, which will form underground goaf and lead to ground collapse. Land in subsidence area is usually repaired by filling method. The purpose of this study is to evaluate the pollution characteristics and ecological risks of Cr, Ni, Cu, Zn, As, Hg, Cd and Pb in the reconstructed soil in different methods; to assess the health risks of heavy metals in soil and groundwater respectively; and to determine the possible sources of ecological and human health risks in the area. The results can help to provide basic research data on the distribution of heavy metal pollution, migration law, prevention and treatment of the gangue filling reconstruction site.

1. Introduction

Underground mining is the main way of coal mining, which will form an underground goaf and lead to ground collapse. Collapse land usually use filling method for soil repair, using coal gangue and fly ash as the medium of filling collapse land, can increase the reconstruction of soil permeability, permeability, improve soil moisture content, is beneficial to reduce the soil consumption and gangue and fly ash accumulation impact on the environment, also for the rational use of coal gangue and fly ash provides an effective way. When coal gangue and fly ash are affected by various physical and chemical factors such as leaching, weathering and soaking, the heavy metal elements occurring in them will be released to pollute the water quality and soil environment. The characteristics of heavy metal pollution mainly include a wide range of pollution, refractory, long duration and easy enrichment, which has been widely concerned around the world. When the soil is contaminated by heavy metals, it will not only affect the growth and development of crops, but also cause the pollution of agricultural products. More importantly, the human body may also cause the accumulation of heavy metals in the human body through the intake of agricultural products, endangering human health. Therefore, the evaluation of heavy metal content, spatial distribution and pollution degree in the mining area can provide the direction and reference for the selection of land reclamation and utilization mode in the future[1].

Huainan is an important national energy city. For a long time, coal mining, large surface area of subsidence, due to the coal mining subsidence of the land has exceeded 200 km2,80% of which is the cultivated land with good soil. Large area of coal mining subsidence area, the formation of low-lying uneven tidal flat land or perennial water surface, farmland damage, farmland sharply reduced, the natural ecological environment is seriously damaged. At present, 7,024.12 hectares of land in the subsidence area have been managed and utilized through the land reclamation project.

The objectives of this study are: (1) assessing the pollution characteristics and ecological risks of Cr, Ni, Cu, Zn, As, Hg, Cd, Pb, heavy metals in the reconstructed site; (2) assessing the health risks of heavy metals in soil and groundwater; and (3) quantitatively determining the possible sources of ecological and human health risks in the area. The results can help to provide basic research data on the distribution of heavy metal pollution, migration law, prevention and treatment of the gangue filling reconstruction site[2].

2. Materials and Methods

2.1 Overview of the study area

Huainan coal mine area is located in the northern part of Anhui province, with a total area of 9600 km ', the mining area is rich in coal, coking coal, gas coal, anthracite and natural coke and other coal. The mining area has four distinct seasons, mild climate, moderate rain, and typical warm temperate semi-humid monsoon climate in middle latitude areas. The annual average rainfall is 844.3 mm and the maximum is 1723.5 mm. The rainfall distribution is uneven, mainly in July to September, accounting for 75% of the annual precipitation; the annual evaporation is about 997.4 mm and the annual average relative humidity is 70%. The soil types are mainly tidal soil, mortar black soil, silt black soil and green loess[3].

2.2 Soil sampling and testing of the reconstructed site

To better understand the distribution of heavy metals in soil in reclamation areas, it is important to conduct soil sampling. This involves setting up a limited number of sampling stations to detect the concentration of heavy metals in the soil. By comparing these concentrations with soil environmental background values and quality standards, one can analyze and evaluate the levels of heavy metals in the area. This assessment is crucial for understanding the impact of these metals on both humans and crops.

After removing gravel and plant roots, the samples were naturally dried in the hood, ground by four minutes and screened through 100 mesh with HNO3, HClO4, H2O2 mixed acid (5:2:1), and the content of Cr, Ni, Cu, Cn, Pb, Hg, As was determined by inductively coupled plasma atomic emission spectrum (ICP-AES). In the test process, soil standard samples GBW07403 (GSS-3), blank samples and duplicate samples were used for quality control to meet the standard requirements[4].

3. Results and analysis

3.1 Heavy metal content in reconstructed soil

Heavy metal content in topsoil and coal gangue are shown in Table 1:

Tab.1 Distribution of heavy metal elements in reconstruct site soil

sampling point	Heavy metal name	Heavy metal content at different depths of reclamation land (mg / kg)	
		Oversurface (20-40cm)	Gangue layer (80-100)
①	As	0.99	8.342
	Cd	0.009	0.072
	Pb	29	20.375
	Cr	17.63	42.019
	Hg	0.0001	0.0002
②	As	2.45	7.586
	Cd	0.007	0.07
	Pb	17	18.313
	Cr	22.73	42.018
	Hg	0.0002	0.00022
③	As	0.008	8.947
	Cd	0.008	0.108
	Pb	26	19.438
	Cr	20.9	41.73
	Hg	0.0001	0.0002
④	As	1.47	9.48
	Cd	0.15	0.159
	Pb	20	20.688
	Cr	19.2	42.716
	Hg	0.0002	0.0002
⑤	As	0.006	8.589
	Cd	0.009	0.102
	Pb	22	19.703
	Cr	9.88	42.121
	Hg	0.0001	0.0002

Referring to the local soil background value and Soil Environmental Quality Standard, it can be seen from the above figure that the content of Hg, As, Cr, Cd and Pb did not exceed the soil environmental background value and did not exceed the Soil Environmental Quality Standard, and the soil of reclaimed land is very polluted by heavy metals[5-6].

3.2 Calculation of heavy metal pollution risk value in the reconstructed site

The pollution degree of different heavy metals in the soil is expressed by counting the intake of heavy metals, oral intake of heavy metals through skin respiration, through respiration, and drinking groundwater.

We can calculate the carcinogenic risk and non-carcinogenic value HQ of the intake of human body (adults and children) in different ways by different heavy metals in different depths (see Table 2).

Risk of heavy metal pollution in soil covering:

Tab.2 S oil layer (20-40cm) risk of heavy metal pollution value

feudal estate appearance drop		Children consume heavy metals				Heavy metal intake in adults			
		Normal years		Extreme years		Normal years		Extreme years	
		carcinogenic VAR	HQ	carcinogenic VAR	HQ	carcinogenic VAR	HQ	carcinogenic VAR	HQ
①	As	1.04E-06	0.4257	9.02E-06	1.9598	1.54E-06	0.2915	2.29E-05	1.4350
	Cd	2.62E-12	0.0005	7.85E-12	0.0022	9.82E-12	0.0003	3.37E-11	0.0016
	Pb	/	/	/	/	/	/	/	/
	Cr	/	0.2090	/	0.8647	/	0.1282	/	0.6169
	Hg	/	1.98E-05	/	8.17E-05	/	1.21E-05	/	5.83E-05
②	As	2.56E-06	1.0535	2.23E-05	4.8500	3.81E-06	0.7215	5.67E-05	3.5513
	Cd	2.03E-12	0.0004	6.10E-12	0.0017	7.64E-12	0.0003	2.62E-11	0.0012
	Pb	/	/	/	/	/	/	/	/
	Cr	/	0.2695	/	1.1148	/	0.1653	/	0.7954
	Hg	/	3.95E-05	/	0.0002	/	2.42E-05	/	0.0001
③	As	8.37E-09	0.0034	7.29E-08	0.0158	1.25E-08	0.0024	1.85E-07	0.0116
	Cd	2.32E-12	0.0005	6.97E-12	0.0020	8.73E-12	0.0003	2.99E-11	0.0014
	Pb	/	/	/	/	/	/	/	/
	Cr	/	0.2478	/	1.0250	/	0.1520	/	0.7314
	Hg	/	1.98E-05	/	8.17E-05	/	1.21E-05	/	5.83E-05
④	As	1.54E-06	0.6321	1.34E-05	2.9100	2.29E-06	0.4329	3.40E-05	2.1308
	Cd	4.36E-11	0.0089	1.31E-10	0.0368	1.64E-10	0.0055	5.61E-10	0.0262
	Pb	/	/	/	/	/	/	/	/
	Cr	/	0.2276	/	0.9417	/	0.1396	/	0.6719
	Hg	/	3.95E-05	/	0.0002	/	2.42E-05	/	0.0001
⑤	As	6.28E-09	0.0026	5.47E-08	0.0119	9.34E-09	0.0018	1.39E-07	0.0087
	Cd	2.62E-12	0.0005	7.85E-12	0.0022	9.82E-12	0.0003	3.37E-11	0.0016
	Pb	/	/	/	/	/	/	/	/
	Cr	/	0.1171	/	0.4846	/	0.0719	/	0.3457
	Hg	/	1.98E-05	/	8.17E-05	/	1.21E-05	/	5.83E-05

Risk of heavy metal pollution in the gangue layer (See Table 3):

Tab.3 G angue layer (80-100cm) risk of heavy metal pollution value

feudal estate appearance drop			Children consume heavy metals			Heavy metal intake in adults		
		Normal years		Extreme years		Normal years	Extreme years	
		carcinogenic VAR	HQ	carcinogenic VAR	HQ	carcinogenic VAR	HQ	carcinogenic VAR	HQ
①	As	8.73E-06	3.5871	7.60E-05	16.5136	1.30E-05	2.4565	0.0002	12.0916
	Cd	2.10E-11	0.0043	6.30E-11	0.0177	7.89E-11	0.0026	2.71E-10	0.0127
	Pb	/	/	/	/	/	/	/	/
	Cr	/	0.4981	/	2.0608	/	0.3056	/	1.4704
	Hg	/	4.32E-05	/	0.0002	/	2.65E-05	/	0.0001
②	As	7.93E-06	3.2619	6.91E-05	15.0165	1.18E-05	2.2338	0.0002	10.9954
	Cd	2.03E-11	0.0041	6.09E-11	0.0171	7.63E-11	0.0025	2.62E-10	0.0122
	Pb	/	/	/	/	/	/	/	/
	Cr	/	0.4981	/	2.0608	/	0.3056	/	1.4704
	Hg	/	4.32E-05	/	0.0002	/	2.65E-05	/	0.0001
③	As	9.36E-06	3.8473	8.16E-05	17.7113	1.39E-05	2.6346	0.0002	12.9686
	Cd	3.13E-11	0.0064	9.39E-11	0.0264	1.18E-10	0.0039	4.03E-10	0.0189
	Pb	/	/	/	/	/	/	/	/
	Cr	/	0.4947	/	2.0466	/	0.3035	/	1.4603
	Hg	/	4.45E-05	/	0.0002	/	2.73E-05	/	0.0001
④	As	9.92E-06	4.0765	8.64E-05	18.7666	1.48E-05	2.7916	0.0002	13.7413
	Cd	4.61E-11	0.0094	1.38E-10	0.0389	1.73E-10	0.0058	5.94E-10	0.0278
	Pb	/	/	/	/	/	/	/	/
	Cr	/	0.5064	/	2.0950	/	0.3107	/	1.4948
	Hg	/	4.32E-05	/	0.0002	/	2.65E-05	/	0.0001
⑤	As	8.98E-06	3.6932	7.83E-05	17.0020	1.34E-05	2.5291	0.0002	12.4492
	Cd	2.97E-11	0.0061	8.91E-11	0.0251	1.12E-10	0.0037	3.82E-10	0.0179
	Pb	/	/	/	/	/	/	/	/
	Cr	/	0.4993	/	2.0658	/	0.3064	/	1.4740
	Hg	/	4.35E-05	/	0.0002	/	2.67E-05	/	0.0001

4. Conclusion

(1) Through the collection and analysis of samples of topsoil, gangue layer and groundwater in a coal gangue filling and reclamation site in Huainan City, the topsoil layer and gangue layer showed no signs of pollution; compared with the drinking water quality standard, the concentration of relevant elements in groundwater did not exceed the standard.

(2) Using the technical guidelines of risk assessment of site pollution in China, the content of As in the surface soil of coal gangue filling reclamation land will cause significant adverse non-carcinogenic effects on the residents on the reclaimed land, and other heavy metal elements will not cause significant adverse non-carcinogenic effects on the residents on the reclaimed land.

(3) As and Cr in the gangue layer in the reclamation area are highly likely to cause obvious non-carcinogenic harm to the residents on the reclaimed land, and the other elements will not cause obvious adverse non-carcinogenic effects to the residents on the reclaimed land.

(4) The heavy metals in the groundwater in the reclaimed area will not cause carcinogenic or non-carcinogenic hazards to the local residents.

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