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HEAVY METAL MIGRATION CHARACTERISTICS AND POLLUTION RISK ASSESSMENT IN RECLAIMED LAND FILLED WITH FOREIGN SOIL AND COAL GANGUE

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Abstract: A positioning experiment of 5 years was conducted to explore the safety of heavy metal (HM) in reclaimed farmland filled with coal gangue in Chengcun mine area of Xinxiang City, China. The migration characteristics and ecological risk of soil HMs and health risk of crop were evaluated in reclaimed farmland. The results indicated that HMs in the reclaimed soil profile have a distribution pattern of high in surface and bottom soil layer but low in middle soil layer three years after reclamation. This suggests that HMs from the bottom coal gangue have migrated to the overlying soil layer and accumulated there. After five years of reclamation, the contents of HMs in reclaimed soil were higher than those in original foreign soil, especially the content of Cd that exceeded the risk screening value for soil pollution of agricultural land (SVSP). The contamination degree (CD) of all measured HMs in reclaimed soil reached moderate contamination level after five years of reclamation. However, the ecological risk assessment of soil HMs showed that the comprehensive ecological risk index (RI) of all measured elements in reclaimed soil was slight, only Cd showed a strong ecological risk. The HMs in wheat grains of reclaimed farmland did not exceed the grain limit standard, but were higher than those in regional normal soil. The analysis of crop risk indicated that the health risk index (HI) of adults and children exposed to multiple HMs was 1.98 and 2.70, respectively, which suggests that oral ingestion of wheat from reclaimed farmland poses a serious health risk, and the health risks to children are significantly higher than those to adults. Of all measured HMs, Cd and Zn in wheat are the main elements that cause health risks for local populations. Based on the above results, it can be concluded that it is not appropriate to grow crops on reclaimed farmland at present and may pose food safety risks.

Keywords: coal gangue, reclaimed farmland, heavy metal pollution, pollution risk evaluation

1. INTRODUCTION

Coal mining has made a great contribution to meet the national energy demand, but it has also caused great negative impact on the regional ecological environment. In particular, the land excavation and surface subsidence caused by coal mining have destroyed a large amount of farmland. Due to the lack of filling soil sources, the damaged farmland in many mining areas has not been effectively controlled, resulting in the degradation of farmland ecological functions and the decline of productivity (Darmody et al., 1989; Hu, 2022). Therefore, ecological management of damaged farmland in mining area is an effective way to alleviate the deterioration of ecological environment in mining area, and it is also an urgent task to achieve sustainable, healthy and coordinated development of economy and ecology in mining area. In addition, coal mining also brings a lot of solid waste - coal gangue, in which a large number of toxic HMs (such as Pb, Cr and Cd) are contained (Akcil & Koldas, 2005; Duan et al., 2021; Yang et al., 2016). Due to the insufficient utilization of coal gangue resources, a large amount of coal gangue is accumulated in the open for a long time, which not only occupies valuable land resources, but also releases a large number of toxic and harmful substances after the weathering of coal gangue. These toxic and harmful substances migrate to the surrounding water and soil through wind and water power, and eventually destroy the surrounding farmland ecosystem (Dang et al., 2021; Gopinathan et al., 2023; Hua et al., 2018; Verma et al., 2021). Therefore, ecological remediation of coal gangue stacking site is also an important measure to improve the environmental conditions of mining areas.

Using coal gangue as filling material to reclaim the cultivated land destroyed by excavation damage and mining subsidence, and reconstructing agricultural soil profile through soil covering, not only can reduce the environmental problems caused by coal gangue open-pit stacking, but also can restore the cultivated land destroyed by coal mining. Covering the coal gangue dump site with foreign guest soil can improve the ecological environment problems caused by the open dump, but the "secondary pollution" caused by coal gangue must be prevented and controlled when planting crops on this reclaimed soil. The "reconstructed soil" formed by covering the coal gangue with soil may be affected by the migration of HM elements such as Cd and Pb, thus bringing pollution risk to the upper reclaimed soil (reconstructed soil) (He et al., 2018). Soil pollution by HMs not only endangers regional plant growth (Jelea et al., 2023) and ecological security (Yang et al., 2011; Hafsi et al., 2024), but also contaminates the food chain and threatens human health through food intake (Lim et al., 2008). In recent years, some scholars have carried out fruitful research on the HM pollution assessment of reclaimed farmland filled with coal gangue (Song et al., 2023; Lu et al., 2018), However, due to different reclamation methods and coal gangue types, the conclusions are not consistent. In particular, there is a lack of relevant research on the migration characteristics of HMs and crop pollution risk in reclaimed soil. Therefore, it is of great theoretical and practical value to investigate the migration traits of HMs in reclaimed farmland filled with coal gangue, and to study and determine the ecological risks of soil pollution and health risk crop pollution in reclaimed land for repairing damaged land in mining area and ensuring the production of pollution-free agricultural products. Based on the analysis of the spatial distribution of HMs (such as Cu, Zn, Pb, Cr and Cd) in reclaimed soil, the soil potential ecological risk and crop pollution risk were evaluated in the reclaimed farmland filled with coal gangue, aiming to provide theoretical basis for the ecological environment in similar areas.

2. MATERIAL AND METHODS

2.1. Overview of the research area

The reclaimed farmland filled with coal gangue in Chengcun mining area of Xinxiang city was selected as the research area. This area is located at the southern foot of Taihang Mountain, 26 km away from Huixian city, Henan Province, China. The regional landform is piedmont plain. Long-term coal mining has seriously affected the ecological, living and production environment of the region. In order to control the harm of coal gangue accumulation to the environment, the local government has used coal gangue as filling material to fill and reclaim the farmland destroyed by mining in the research area since 2017. The reclaimed farmland was first filled with about 7 m coal gangue, and then covered with about 70 cm foreign soil on its surface. After reclamation, the planting mode of the reclaimed farmland adopts the two-cropping planting mode of winter wheat and summer corn in one year.

2.2. Sampling and testing

2.2.1. Samples collection

In the process of land reclamation (2017 - 2018), samples of filling material such as coal gangue, foreign mulching soil (from the surrounding scattered barren grass and wasteland), and regional normal soil (from five fields with the same planting mode around the reclaimed farmland) were collected and brought back for experiment to be tested. After the completion of the land reclamation project, soil and plant samples were collected from five sampling points of reclaimed farmland at the wheat maturity stage in 2019a, 2021a and 2023a, respectively. Soil samples of 0 - 60 cm were collected at 20 cm intervals, and wheat grain samples were also collected at each sample site and brought back to the laboratory for testing. Flow chart of sample collection and testing is shown in Figure 1.

2.2.2. Sample test

The collected soil samples are air-dried after picking out plant roots, leaves, gravel and other debris. The air-dried soil sample is ground and screened 100 mesh before testing. The collected wheat grains are mashed after washing and drying, and put into sealed bags to be tested. The soil and plant samples to be tested were digested with nitric acid and perchloric acid. After digestion, the contents of Cr, Zn, Pb, Cd and Cu were measured by inductively coupled plasma Mass spectrometry (ICP-MS, USA).

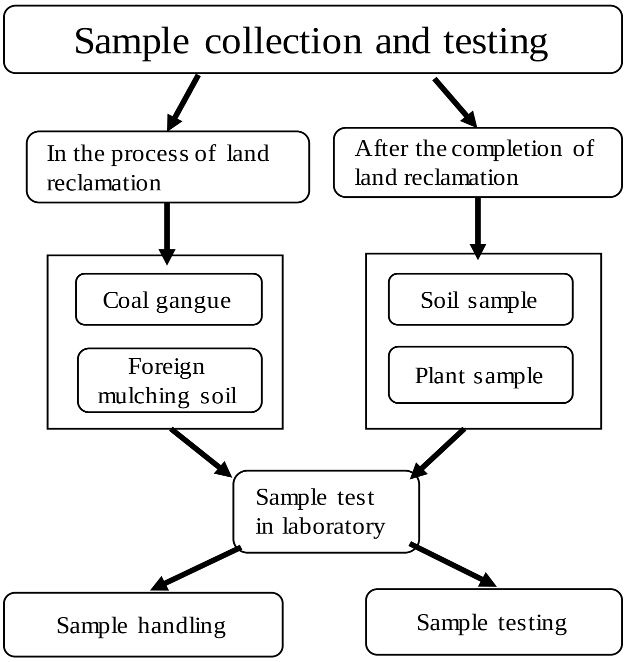

Figure 1. Flow chart of sample collection and testing.

2.3. Evaluation method

2.3.1. Ecological risk assessment of reclaimed soil

The ecological risk index method proposed by Hankson was used to evaluate the potential ecological risk of reclaimed soil (Hankson, 1980; Maftei et al., 2014; Nalan et al., 2020). This method takes regional background value of soil elements as the evaluation standard, calculates the single ecological risk index (E_r^i) and comprehensive ecological risk index (RI) of all measured soil HMs, and classifies the soil pollution risk level according to the calculated ecological risk index value. The *RI* is calculated according to the following formula:

$$RI = \sum_{i=1}^{n} E_r^i = \sum_{i=1}^{n} T_r^i \cdot \frac{C^i}{C_b^i} \quad (1)$$

where E_r^i is the single ecological risk index of element *i*, and T_r^i is the toxicity coefficient of the element *i*, where Cu = 5, Zn = 1, Pb = 5, Cd = 30, Cr = 2. C^i is the content of element *i* in the sample and C_b^i is the background value of the element *i*. The classification standard of ecological risk level of HM pollution in reclaimed farmland (Wei et al., 2021) is shown in Table 1.

2.3.2. Contamination Degree assessment of reclaimed soil

The contamination degree (CD) proposed by Hakanson can assess the overall contamination in a specific area (Hankson, 1980; Beres et al., 2024). Its calculation formula is as follows:

$$CD = \sum_{i=1}^{n} CF \quad (2)$$

$$CF = C_{i\ element} / C_{i\ background} \quad (3)$$

where CF is the contamination factor, $C_{i\ element}$ represents the concentration of element *i* in the sample, and $C_{i\ background}$ is the background value of the element *i*. Four contamination levels were classified based on the CD results: CD < 6 (low contamination), 6 ≤ CD < 12 (moderate contamination), 12 ≤ CD < 24 (considerable contamination), and CD ≥ 24 (very high contamination).

2.3.3. Health risk assessment of consuming crop products

The health risk assessment model developed by the United States Environmental Protection Agency (USEPA, 1989) was adopted to evaluate the health risk of crop HMs pollution in reclaimed farmland. Based on calculating the average daily intake dose (ADD) of HMs in crops and comparing it with the daily reference dose (RfD) recommended by EPA, the health risk of crop HMs pollution was evaluated (Song et al., 2015). Its calculation formula is as follows:

$$ADD = C \times IR \times ED \times EF / (BW \times AT) \quad (4)$$

$$HQ = ADD/RfD \quad (5)$$

$$HI = \sum_{i=1}^{n} HQ_n \quad (6)$$

where *C* represents HM content in the sample ($mg \cdot kg^{-1}$); *IR* is ingestion rate, that is, the daily amount of the cereal product consumed by the human body ($kg \cdot person^{-1} \cdot day^{-1}$), the daily food intake of adults and children was 0.370 and 0.210 $kg \cdot person^{-1} \cdot day^{-1}$; *ED* is exposure duration (years), 24 and 6 years for adults and children, respectively, *BM* is average body

Table 1. Classification criteria of soil ecological risk levels.

E_r^i	Risk grade of E_r^i	RI	Risk grade of RI
$E_r^i < 40$	Slight	RI <150	Slight
$40 \le E_r^i < 80$	Medium	150 ≤ RI < 300	Medium
$80 \le E_r^i < 160$	Strong	300 ≤ RI < 600	Strong
$160 \le E_r^i < 320$	Very strong	RI ≥ 600	Very strong
$E_r^i \ge 320$	Extreme		

average (kg), adults and children are 60 and 25 kg, respectively; *EF* and *AT* are exposure frequency (365 days·year^{-1}) and the average contact time (d), respectively; *HQ* is the health risk quotient of a single metal; *HI* is the comprehensive health risk index of all measured metals in wheat grain. *RfD* is the reference value of daily intake of HM. When HI < 1, the health risk is considered to be small or negligible; When HI > 1, there should be concern for potential health risk.

3. RESULTS

3.1. HM content of filling materials and regional normal soil

The background characteristics of filling materials affect the soil characteristics and ecological function of reclaimed farmland. Clarifying the background characteristics of pollutants in filling materials is the prerequisite for evaluating the soil pollution risk of reclaimed farmland scientifically. The results of HMs content determination in filled coal gangue, foreign covered soil and regional normal soil are shown in Table 2. The contents of HMs (Pb, Cr, Cu, Zn and Cd) in foreign cover soil (average value) and regional normal soil (average value) were lower than the risk screening value for soil pollution of agricultural land (SVSP) in the risk control standards for soil contamination of agricultural land (GB 15618-2018) issued by the Ministry of Ecology and Environment, PRC. The contents of HMs in coal gangue (the average pH value is 7.46) are higher than those in regional normal soil, and also exceed regional background value of soil elements (Henan Province), especially the content of Cd exceeds the SVSP. It is clear that using coal gangue as filling material will bring potential pollution risk to reclaimed soil.

3.2. Distribution characteristics of HMs in soil profile of reclaimed farmland

The analysis of HMs in the overlying soil layer of reclaimed farmland shows that the content of HMs measured in 1 - 3 years after reclamation is lower than the SVSP, but higher than the average value of the original foreign soil. After 5 years of reclamation, the contents of Cd in each overlying soil layer were higher than the SVSP, the contents of Pb and Cr were higher than the average value of regional normal soil, and the contents of Cu and Zn were lower than the SVSP and regional normal soil, but higher than the average value of the original foreign soil. The distribution characteristics of HMs in soil profiles were different in different test years. After 1 year of reclamation, the content of HM elements in the upper layer are lower than those in the lower layer. After 3 - 5 years of reclamation, the content of each element is high in the bottom (40 - 60 cm) and surface (0 - 20 cm) soil, and low in the middle (20 - 40 cm) soil (Figure 2). It shows that HM elements in the bottom coal gangue of the reclaimed farmland gradually migrate to the overlying soil with the increase of reclamation years.

3.3. Ecological risk analysis of HMs pollution in reclaimed soil

It is of great significance to evaluate the ecological risk of soil HMs pollution in reclaimed farmland to ensure the production of pollution-free agricultural products. Taking the background value of soil element in Henan Province as the evaluation standard, the ecological risk assessment of soil HMs pollution shows that the comprehensive ecological risk index (*RI*) of all measured elements was slight in the three test years (Table 3). Although the *RI* of all elements in reclaimed soil was slight, the measured

Table 2. HM content (mg·kg^{-1}) of filling materials and regional normal soil.

Items		pH	Cd	Pb	Cr	Cu	Zn
Coal gangue	Max.	7.46	0.89	50.2	75.3	28.3	94.6
	Min.	6.96	0.32	46.8	69.3	22.5	90.6
	Aver.	7.16	0.42	47.2	72.0	23.0	92.0
Original foreign soil	Max.	7.43	0.09	19.7	63.8	19.8	67.3
	Min.	7.28	0.06	17.4	59.2	17.4	62.6
	Aver.	7.32	0.08	18.4	60.2	18.6	64.6
Regional normal soil	Max.	7.84	0.11	21.4	67.5	29.8	76.4
	Min.	7.59	0.07	20.5	60.3	18.4	70.3
	Aver.	7.76	0.09	20.9	64.3	26.8	74.6
SVSP		6.5-7.5	0.3	120	200	100	250
Background value of soil elements			0.09	19.6	63.8	19.7	74.2

SVSP: the risk screening value for soil pollution of agricultural land; Max: maximum value; Min: minimum value; Aver: average value.

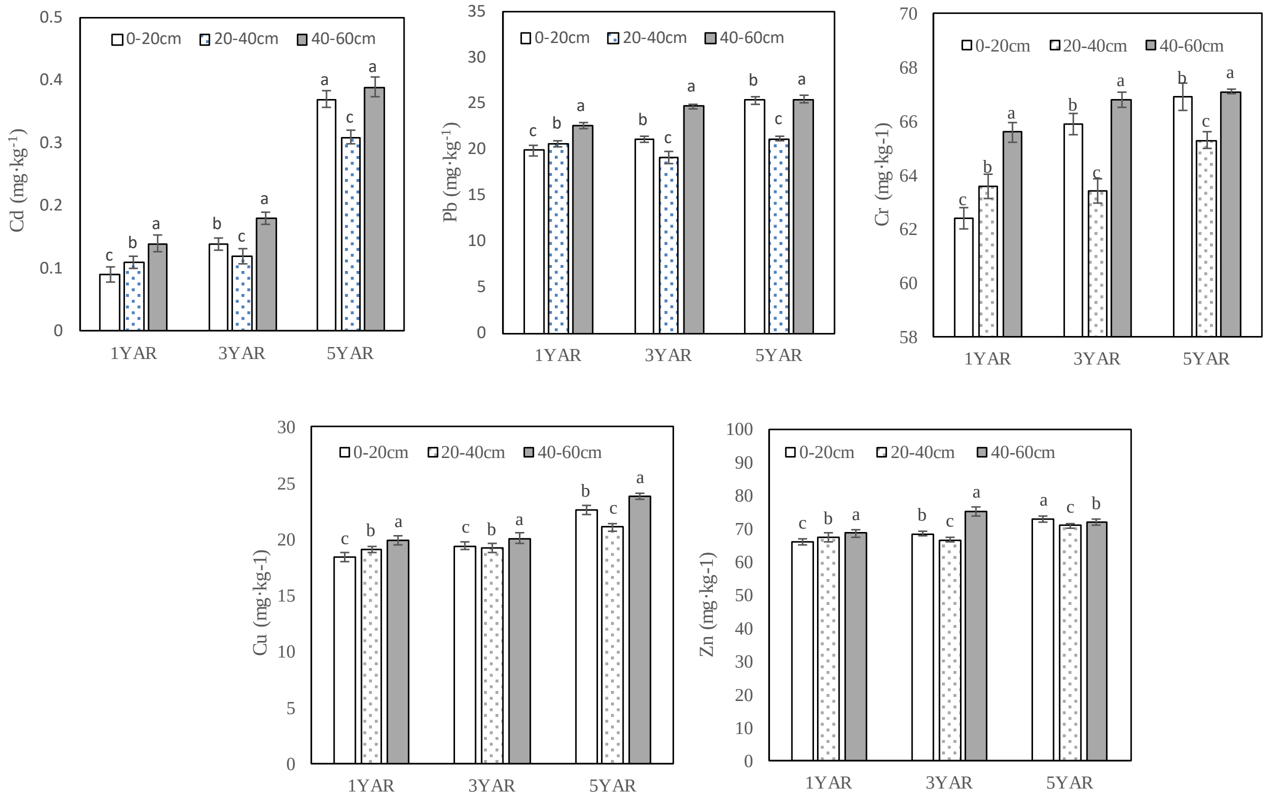

Figure 2. HM contents in different soil layers of reclaimed farmland. Different letters in the same reclamation year indicate significant difference between different soil layers (P<0.05). YAR: Year after reclamation.

Table 3. Ecological risk of soil HMs pollution in reclaimed farmland.

Elements			E_r^i					*RI*
			Cd	Pb	Cr	Cu	Zn	
Reclamation years	1	Index value	37.77	5.38	2.00	4.89	0.91	50.94
		Risk level	L	L	L	L	L	L
	3	Index value	48.67	5.52	2.05	4.96	0.94	62.14
		Risk level	M	L	L	L	L	L
	5	Index value	118.67	6.13	2.08	5.71	0.97	133.56
		Risk level	S	L	L	L	L	L

E_r^i: the single ecological risk of element *i*, *RI*: the comprehensive ecological risk of all elements. L: Light ecological risk, M: moderate ecological risk, S: strong ecological risk

Table 4. CD of soil HMs in reclaimed farmland.

Reclamation years	CF					CD
	Cd	Pb	Cr	Cu	Zn	
1	1.26	1.08	1.00	0.98	0.91	5.22/L
3	1.62	1.10	1.02	0.99	0.94	5.69/L
5	3.96	1.23	1.04	1.14	0.97	8.33/M

CF: the contamination factor; CD: contamination degree; L: low contamination; M: moderate contamination.

Cd content exceeded the risk value of agricultural soil pollution, and had strong ecological risk 5 years after reclamation. The risk level of other elements remains slight 5 years after reclamation. In addition, Table 4 shows the contamination degree (CD) of reclaimed soil in different reclamation years. In 1 - 3 years after reclamation, the CD of soil HMs was low contamination level, but after 5 years of reclamation, the CD of soil HMs reached moderate contamination level. Therefore, it is necessary to take effective measures in time to prevent the HMs content in reclaimed soil from exceeding the soil environmental quality standard.

3.4. Health risk analysis of crop HMs pollution

HMs in the soil can easily accumulate in the human body through the food chain and threaten human health. Therefore, the Limits of Pollutants in Food (GB 2762-2022) issued by the Health Commission of the People's Republic of China clearly stipulate the limits of various HM elements in food. The analysis of HMs in wheat grains from different reclamation years showed that the contents of all measured HMs did not exceed the limit standard. However, the HMs content in wheat grains of reclaimed farmland was higher than that of regional normal farmland (Table 5). The health risk assessment of crop shows that the health risk index (*HI*) of HMs in wheat grains for adults and children is greater than 1 after 5 years of reclamation (Table 6), which suggests that long-term consumption of wheat from reclaimed farmland poses a serious health risk. The HI of adults and children exposed to multiple heavy metals was 1.98 and 2.70, respectively, which indicated children were exposed to higher health risks than adults. In adults and children, the health risk quotient of a single element (HQ) caused by oral intake of HM in wheat was Zn > Cd > Cu > Cr > Pb. Of all measured HMs, the HQ caused by Zn and Cd for children and adults account for 59.52 % and 59.60 % of the total HI, respectively. Therefore, Zn and Cd in wheat grains are the main metal elements that cause health risks for local populations. It is clear that crop planting in reclaimed farmland filled with coal gangue will bring health risks to local people. Therefore, it is necessary to regularly determine the HMs content in crop and take effective measures in time to prevent them from exceeding food safety quality standards and avoid health risks arising from dietary intake of HMs.

Table 5. HM content ($mg\cdot kg^{-1}$) in wheat grains from reclaimed farmland.

Items		Cd	Pb	Cr	Cu	Zn
Limits of Pollutants in Food (GB 2762-2022)		0.1	0.2	1.0	10	50
Regional normal farmland		0.026d	0.036d	0.065c	1.48c	27.8d
Farmland of different reclamation years	1	0.031c	0.052c	0.078b	1.52c	29.6c
	3	0.053b	0.065b	0.095a	2.06b	30.7b
	5	0.082a	0.079a	0.101a	2.96a	32.8a

Different letters indicate significant difference between different reclamation years (P<0.05).

Table 6. Health risks of heavy metal intake from wheat grains from reclaimed farmland.

HMs	ADD ($mg\cdot kg^{-1}\cdot d^{-1}$)		Rfd ($mg\cdot kg^{-1}\cdot d^{-1}$)	HQ		HI	
	Adults	Children		Adults	Children	Adults	Children
Cd	5.06×10^{-4}	6.89×10^{-4}	1.0×10^{-3}	0.506	0.689		
Pb	4.87×10^{-4}	6.64×10^{-4}	3.5×10^{-3}	0.139	0.190		
Cr	6.23×10^{-4}	8.48×10^{-4}	3.0×10^{-3}	0.208	0.283	1.98	2.70
Cu	1.83×10^{-2}	2.49×10^{-2}	4.0×10^{-2}	0.456	0.622		
Zn	2.02×10^{-1}	2.76×10^{-1}	3.0×10^{-1}	0.674	0.918		

ADD: average daily intake dose; Rfd: reference dose. HO: hazard quotient, HI: total exposure hazard index.

4. DISCUSSION

Coal mining often brings a lot of ecological and environmental problems to the region, especially mining subsidence and open stacking of coal gangue (Hu, 2022). Mining subsidence not only destroys a large amount of cultivated land, but also affects the regional hydrological characteristics. Therefore, it is two important measures for ecological improvement of mining area to control the subsidence land and the coal gangue stacking site. Using coal gangue as filling material to reclaim the subsidence land can accelerate the comprehensive treatment process of coal gangue and restore the large area of farmland destroyed by mining subsidence. Although the farmland destroyed by mining subsidence can be restored by filling coal gangue and covering it with soil, with the passage of time, HM elements will be released from the coal gangue into the soil solution, and migrate from the lower soil to the upper soil under the action of plant root absorption and straw return to the field (Chen et al., 2012; Guo et al., 2008), thus bringing soil pollution risk to the reclaimed farmland. This study showed that the content of HMs in reclaimed farmland after 3 years of reclamation were higher than those in the original foreign soil, and the distribution of HMs in soil profile showed high content in the surface and bottom layers and low in the middle layers, which was consistent with the relevant research conclusions of Yao et al. (2010) and Kang et al. (2022). The reason for the high content of HMs in the surface soil is that the crop roots absorb HM elements in the deep soil and enrich them in the surface soil through the return of straw to the field

(Xu et al., 2021; Jing et al., 2021), while the high content of HMs in deep soil is due to the fact that the soil in this layer is connected with the coal gangue and absorbs a large amount of HMs leaching from the coal gangue through capillary phenomenon. Previous studies have shown that soil capillary phenomenon can make deep soil water carry HM elements released by coal gangue to the upper layer, and the closer the soil is to the coal gangue, the more its HM content increases (Kang et al., 2022). This study also shows that the HMs released by the coal gangue layer have been enriched in the deep soil and the top soil of the reclaimed farmland.

Agricultural production, food safety and human health will be directly or indirectly affected by soil pollution, especially soil pollution by HMs (Chen et al., 2021). On the one hand, HMs affect the structure and function of soil ecosystem by affecting soil microflora and microbial processes. On the other hand, when soil HMs are absorbed by plants, they not only affect crop quality, but also bring health risks to human body after entering the human body (Kawatra & Bakhetia, 2008; Okedeyi et al., 2014). This study indicated that the contents of all measured HMs in reclaimed soil are higher than those in the average value of original foreign soil after 5 years of reclamation, especially the Cd content were higher than the SVSP. The ecological risk assessment of soil HMs pollution shows that although ecological risk of other HMs and the *RI* of all measured elements were slight 5 years after reclamation, Cd in soil had strong ecological risk. In addition, the evaluation of contamination degree (CD) for soil HMs showed the CD of all measured HMs in reclaimed soil reached moderate contamination level after 5 years of reclamation. These results indicated that the reclaimed farmland is at risk of HMs pollution, especially Cd pollution, which should be paid more attention with the increase of reclamation years.

In recent years, many studies have been conducted on the ecological risks of soil HM pollution (Qi et al., 2022; Ma et al., 2015; Raj et al., 2017). However, it is often found that the evaluation results of soil pollution are inconsistent with those of crop pollution during the evaluation of farmland HM pollution (Zhang et al., 2015). The accumulation of HMs in crops is not only related to the total amount of soil HMs, but also closely related to the physical and chemical characteristics of soil and the existence form of HMs in soil, and the absorption characteristics of HMs in different crops are also very different (Madejon et al., 2006). It is clear that it is one-sided and unscientific to evaluate the HM pollution of farmland simply by taking the HM content in soil as the evaluation standard. Only comprehensive evaluation of HM accumulation in crops and soil can scientifically reflect the real level of farmland pollution. Intake of crop products as food is the most direct and major way for HMs in soil to enter the human body and pose health risks (Hough et al., 2004). In this study, although the HMs content in wheat grain of reclaimed farmland did not exceed the limit standard in grain issued by China's Health Commission, their contents are higher than those in the surrounding normal farmland. Therefore, long-term consumption of wheat from reclaimed farmland is likely to pose health risks to people. Through the analysis of health risk index (HI) of crop, it can be seen that HMs in crop grains from reclaimed soil will pose health risks to human body, and the health risks to children are significantly higher than those to adults. Of all measured HMs, Cd and Zn in wheat grains are the main metal elements that cause health risks for local populations. It is necessary to take effective measures in time to prevent HMs in reclaimed farmland from exceeding the limit standards and avoid health risks arising from dietary intake of HMs.

5. CONCLUSIONS

1) After 5 years of reclamation, the HMs in the coal gangue have migrated to the overlying soil layer and the distribution characteristics of HMs in the reclaimed soil profile are high in the surface and deep layer, and low in the middle soil. The HMs content in filled coal gangue exceed regional background value and original foreign soil, especially the content of Cd. The Cd concentrations in reclaimed soil were higher than the SVSP, and the contents of other elements were higher than those in original foreign soil.

2) Based on the background value of the element in regional soil, the contamination degree (*CD*) of the measured HMs in reclaimed soil reached moderate contamination level after 5 years of reclamation. However, the ecological risk assessment of soil HMs showed that the *RI* of the measured elements in reclaimed soil were slight 5 years after reclamation, but Cd in reclaimed soil had strong ecological risk.

3) After 5 years of reclamation, the content of HMs in wheat grains from reclaimed farmland was higher than those of wheat from regional normal farmland. The *HI* of adults and children exposed to multiple HMs was 1.98 and 2.70, respectively, consumption of wheat from reclaimed farmland poses serious health risk, and children were exposed to higher health risks than adults. Of all the measured elements, Cd and Zn in wheat are the main elements that cause health risks for local populations.

4) It is not appropriate to grow crops on reclaimed farmland at present. It is necessary to take effective measures in time to prevent HMs in reclaimed farmland from exceeding the limit standards and avoid health risks arising from dietary intake of HMs.

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