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Research Article

Assessment of Heavy Metal Pollution Characteristics and Ecological Risk in Soils around a Rare Earth Mine in Gannan

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In order to explore the pollution of heavy metals in the soils around the mined rare-earth mines, this paper used the geoaccumulation index method, the Nemerow pollution index method, and the potential ecological risk index method during the high water period and the withered water period, respectively, to analyze and assess the pollution characteristics and ecological risks of Mn, Cu, Cr, As, Cd, Ni, Pb, and Zn in the soils of the study area. The results showed that all the eight heavy metals in the soil of the study area have accumulated to varying degrees, and the accumulation indices were Pb > Mn > Zn > Cd > Cu > Ni > Cr > As in descending order, with Pb and Mn accumulating most seriously. According to the results of the Nemerow pollution index, more than 25% of the sampling points in the soil were lightly contaminated, the Nemerow index of heavy metal Pb was greater than 2, which was moderately contaminated, and Cd was lightly contaminated in the withered water period. The potential ecological risk index showed that the heavy metal Cd was moderately ecologically hazardous, while the other seven heavy metals were all mildly ecologically hazardous. The heavy metals Pb and Mn in the soils of the study area were more seriously polluted, and there was also a certain degree of heavy metal Cd pollution during the withered water period, and the more seriously polluted areas were mainly located around the open pit of the rare-earth mines. Based on Java, the software platform of soil heavy metal pollution characteristics and ecological risk assessment around rare-earth mines is realized. The overall structure of the platform is designed, the background development framework is planned based on SSM, and the database is designed with SQL Server.

1. Introduction

As one of the technical problems in ecological restoration and environmental management of mines, the excessive heavy metal contamination of soil in mining areas has been a widespread concern of experts and scholars at home and abroad [1]. How to solve the problem of heavy metal contamination in soil left behind by mining has become an important part of the development of ecological protection in China, so the identification of its pollution characteristics and ecological risk assessment has become the first priority to solve the pollution problem. Heavy metal contamination of soils can cause health hazards through the food chain [2]. The occurrence of food safety problems such as “cadmium rice,” “blood lead,” and “cadmium wheat” in recent years has also sounded the alarm for the assessment and prevention of heavy metal pollution in soil [3]. When farmland is contaminated with heavy metals, these contaminants will enter the human body through the crops and thus cause harm to the human body. Some scholars have divided heavy metals into two parts according to the extent to which they are needed for crop growth: those that are extremely harmful to humans but less so for plant growth, such as Cd, Hg, and Pb, and those that are needed for both human and plant growth but are harmful to humans if they exceed certain standards, such as Zn and Cu [4].

Rare-earth mines, due to their special mining process, are extremely harmful to the ecological environment around the mines, especially in terms of heavy metal contamination of the soil. On the one hand, the heavy metals present in the massive piles of tailings may migrate to the soil, causing heavy metal contamination of the soil [5]. On the other hand, the residual leaching agent in the ore will displace heavy metal ions such as Fe^{2+}, Cd^{2+}, Pb^{2+}, Zn^{2+}, Mn^{2+}, and Cu^{2+}, which will migrate to the soil in and around the mine area under the natural action of rainwater washing, resulting in heavy metal pollution of the soil [6–8].

At present, the assessment methods of heavy metal pollution in soils at home and abroad are mainly summarized as index method, model method, GIS-based analysis method, and other mathematical methods [9–12]. The index method can reflect the relationship between the actual measured value and the background value of heavy metal concentration in the soil of the region more intuitively and is more widely used in the assessment of heavy metal pollution in soils [13]. Some scholars have suggested that heavy metal pollution in soils is a complex process and different assessment methods need to be selected according to different pollution situations. However, there are limitations in a single assessment method, so a combination of multiple assessment methods is adopted to make the assessment results more relevant to the actual situation [14]. In this study, a total of 146 soil samples were collected during the high and withered water periods. The geoaccumulation index method, the Nemerow comprehensive pollution index method, and the potential ecological risk index method were used to analyze and assess the pollution characteristics and potential ecological risks of heavy metals Mn, Cu, Cr, Cd, Ni, Pb, Zn, and As in the soil, so as to provide a reference for the formulation of heavy metal pollution control and prevention measures for soils in the study area. At the same time, the software platform is preliminarily planned and developed, which provides practical support for the application of the theoretical method of this study.

2. Materials and Methods

2.1. Overview of the Study Area. Gannan, the geographical abbreviation for the southern region of Jiangxi Province (the abbreviation of Jiangxi Province is “Gan.”), is mainly composed of 18 counties (3 districts, 13 counties, and 2 county-level cities) under the jurisdiction of the prefecture-level Ganzhou City, with an area of 39,379.64 km^2, accounting for about 25% of the total area of Jiangxi Province [15]. The region is rich in mineral resources, and Ganzhou is known as the “Kingdom of Rare Earth,” with the reserves of ionic heavy rare earths being the highest in China [16]. The study area is located in the East Asian monsoon region, with a mild climate, abundant light, heat and rainfall, belonging to the humid climate of the central subtropical monsoon. The average annual precipitation in the region is 1500–1600 mm, but the spatial and temporal distribution is uneven, with large interannual variations and uneven rainfall distribution, with the most rainfall in June and the least in November to December throughout the year. The soil types are paddy soil, tidal soil, purplish soil, red soil, and hilly yellow soil, with soil pH mostly between 5 and 6.

2.2. Sample Collection and Experimental Analysis. In this study, the sampling points were mainly arranged along the area of farmland affected by the rare-earth mine and the area of the open pit, and a total of 146 soil samples were collected for testing and analysis during the high and withered water periods in 2020, respectively. The sampling points were mainly selected in places with obvious characteristics of the soil type being mined, and the terrain was relatively flat, stable, and well vegetated; the distribution of the sample collection points is shown in Figure 1. When the authors collected soil samples, the depth and sampling points of each sampling site were basically uniform, with the sampler entering the soil perpendicular to the ground, the collection depth was 0–20 cm, and the spacing between collection points was 500–2500 m.

The collected soil samples were air-dried, ground, and sieved in the laboratory, and the content of Mn, Cr, Cu, Zn, Pb, Ni, Cd, and As in the soil was measured according to the regional geochemical sample analysis method (DZ/T0279-2016) using an ICAP6300MFC two-way observation plasma emission spectrometer (D466), an Agilent 7700x inductively coupled plasma mass spectrometer (D483), and an AFS-8800 dual-channel Atomic Fluorescence Photometer (D460) to measure the content of Mn, Cr, Cu, Zn, Pb, Ni, Cd, and As elements in the soil, as well as an FE28 PH meter (acidity meter) (D554) to measure the pH of the soil samples according to the agricultural soil testing standard (NY/T1121.2–2006).

2.3. Assessment Methodology

2.3.1. Geoaccumulation Index Method. The geoaccumulation index (I_{geo}) method, which determines the contamination of heavy metals by the relationship between the total concentration of heavy metals in the soil and the background value, is an effective way to determine the level of heavy metal contamination in the soil and to classify the level of contamination according to the value of the geoaccumulation index (I_{geo}). [17, 18] The geoaccumulation index equation is

$$I_{geo} = \log_2 \frac{w_i}{kB_i}, \tag{1}$$

where I_{geo} is the geoaccumulation index, dimensionless. w_i is the measured value of heavy metal i in the soil sample, mg-kg $^{-1}$; B_i is the background value of heavy metal i in the surface soil of Ganzhou City, mg-kg^{-1}; k is a coefficient characterizing the difference in soil background values due to differences in rock backgrounds in different places, and the value of k in this study is 1.5 [19, 20].

The assessment criteria are shown in Table 1.

2.3.2. Nemerow Comprehensive Pollution Index. The Nemerow pollution index is the most common method for comprehensive soil pollution assessment at home and abroad. The assessment method highlights the maximum pollution effect and is in line with the criteria of the maximum pollution level as the soil pollution level for soil

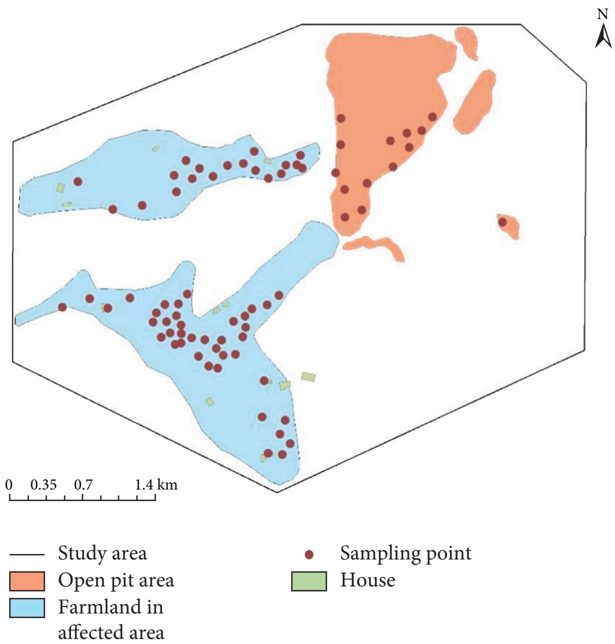

Figure 1: Distribution of soil sampling sites in the study area.

Table 1: Criteria for assessment of soil pollution with geo-accumulation index.

The values of I_{geo}	Class	The cumulative degree
$I_{geo} < 0$	I	Clean
$0 \le I_{geo} < 1$	II	Mild accumulation
$1 \le I_{geo} < 2$	III	Mild-to-moderate accumulation
$2 \le I_{geo} < 3$	IV	Moderate accumulation
$3 \le I_{geo} < 4$	V	Mild-to-heavy accumulation
$4 \le I_{geo} < 5$	VI	Heavy accumulation
$I_{geo} \ge 5$	VII	Severe accumulation

assessment in China. The Nemerow index is calculated by the following formula:

$$P = \frac{C_i}{S_i},$$
$$P_Z = \sqrt{\frac{P_J^2 + P_{i\max}^2}{2}}, \qquad (2)$$

where P is the one-factor index for that sampling point, dimensionless. C_i is the measured value of heavy metal i at that point, mg-kg^{-1}. S_i is the standard value of heavy metal i. In this study, S_i is the risk screening value of heavy metal i in the Soil Environmental Quality Standard (GB 15618-2018) (the background value of heavy metal Mn in the surface layer of Ganzhou soil is used), mg-kg; and P_Z is the Nemerow index for the point, dimensionless. P_J is the mean value of the single factor index at the point, dimensionless. $P_{i\max}$ is the maximum value of the single factor index for heavy metal i at the site [21–24], dimensionless; the assessment criteria for the Nemerow index are shown in Table 2.

2.3.3. Potential Ecological Risk Index. The potential ecological risk index is a method proposed by the Swedish scientist Hakanson, which takes into account not only the content of heavy metals in the soil but also the toxicity level, the concentration of contamination, and the sensitivity of the environment to heavy metal contamination [25–30]. The expression is as follows:

$$\mathrm{RI} = \sum_{i=1}^{n} E_i,$$
$$E_i = T_i \times C_{f,i}, \qquad (3)$$

where RI is the composite potential ecological risk hazard index, dimensionless. E_i is the potential ecological hazard index of heavy metal i in the soil at the sampling site, dimensionless. $C_{f,i}$ is the ratio of the measured value of heavy metal i in the soil at the sampling site to the background value of heavy metal i in the surface soil of Ganzhou City, dimensionless. T_i is the toxicity response coefficient of heavy metal i, dimensionless, where the toxicity coefficients of Mn, Cu, Cr, As, Cd, Ni, Pb, and Zn are 1, 5, 2, 10, 30, 5, 5, and 1, respectively. [29] The assessment criteria for the comprehensive potential ecological risk index RI and the potential ecological risk index E_i [31–39] are shown in Table 3.

Table 2: Criteria for assessment of soil pollution with Nemerow pollution index.

The values of Nemerow pollution index	Pollution class	Pollution levels
$P_Z \le 0.7$	I	Clean
$0.7 < P_Z \le 1$	II	Moderately clean
$1 < P_Z \le 2$	III	Slightly polluted
$2 < P_Z \le 3$	IV	Moderately polluted
$P_Z > 3$	V	Heavily polluted

3. Results and Discussion

3.1. Characteristics of Heavy Metal Content in Soils

3.1.1. Characteristics of Heavy Metal Content in Soils during the High Water Period. The average contents of heavy metals Mn, Cu, Cr, As, Cd, Ni, Pb, and Zn in the soils of the study area during the high water period were 448.97, 18.92, 30.33, 3.00, 0.14, 13.13, 92.99, and 64.18 mg^{-}kg^{-1}, which were 1.85, 1.25, 0.88, 0.34, 1.56, 1.06, 2.72, and 1.11 times higher than the background values of heavy metal contents in the surface layer of soils in Ganzhou City, respectively, which can be seen in Table 4 [33]. Among them, the contents of heavy metals Cd, Cr, Cu, Ni, Zn, and As were all lower than the screening values for soil pollution risk on agricultural land (GB15618-2018), while 37 sampling points of heavy metal Pb exceeded the screening values for soil pollution risk on agricultural land, with an exceedance rate of 50.68%, and the maximum content value of Mn was 5.57 times higher than the soil background value. The above data indicate that there is a certain degree of contamination of heavy metals Pb and Mn in the soil during the high water period. The heavy metals in descending order of coefficient of variation are Cd, Cr, As, Mn, Pb, Cu, Ni, and Zn, with Cd having a coefficient of variation of 446%, which is a very

Table 3: Criteria for assessment of soil pollution with the potential ecological risk index.

The values of RI	The values of E_i	Pollution levels
RI < 150	E_i <40	Light pollution
150 ≤ RI < 300	40 ≤ E_i < 80	Moderate pollution
300 ≤ RI < 600	80 ≤ E_i < 160	Moderate-to-heavy pollution
600 ≤ RI < 1200	160 ≤ E_i < 320	Heavy pollution
RI ≥ 1200	E_i ≥320	Extreme-intensity pollution

Table 4: Characteristics of heavy metals in the soil surface layer of the study area.

Sampling time	Projects	Content ($mg^{-}kg^{-1}$) content ($mg^{-}kg^{-1}$)							
	Projects	Mn	Cu	Cr	As	Cd	Ni	Pb	Zn
High water period	Minimum value	164	3.54	3.6	0.96	0.025	2.23	45.1	42
	Maximum value	1354	44.7	135.8	13.4	0.27	27.9	377.6	95
	Average value	448.97	18.92	30.33	3.00	0.14	13.13	92.99	64.18
	Standard deviation	239.75	9.33	22.44	1.80	0.58	6.40	47.36	11.00
	Coefficient of variation	53%	49%	74%	60%	414%	49%	51%	17%
Withered water period	Minimum value	126	1.16	5.09	1.02	0.113	<2	35.7	32.4
	Maximum value	1111.3	41.7	71	12.2	0.541	24.2	214	96
	Average value	471.12	16.48	27.28	3.12	0.26	11.97	94.01	61.07
	Standard deviation	289.18	9.31	15.36	1.61	0.09	5.63	35.90	12.52
	Coefficient of variation	61%	56%	56%	52%	35%	47%	38%	21%
Background values for topsoil in Ganzhou		243	15.17	34.56	8.85	0.09	12.35	34.19	58.05
Background values for topsoil in Jiangxi		259	20.8	48.0	10.4	0.10	19.0	32.1	69.0
Background values for topsoil in China		540	20.0	53.9	9.2	0.07	24.9	23.6	67.7

strong variation. The larger the coefficient of variation value is, the more unevenly distributed the heavy metal is in the region and the greater the anthropogenic influence is [34, 35].

3.1.2. Characteristics of Heavy Metal Content in Soils during the Withered Water Period. The average contents of heavy metals Mn, Cu, Cr, As, Cd, Ni, Pb, and Zn in the soils of the study area during the withered water period were 456.24, 16.48, 27.28, 3.12, 0.26, 11.97, 94.01, and 61.07 $mg^{-}kg^{-1}$, respectively, which were 1.94, 1.09, 0.79, 0.35, 2.89, 0.97, 2.75, and 1.05 times higher than the background values of heavy metals in the surface soils of Ganzhou City, as shown in Table 4 [35, 36]. Among them, the content values of the heavy metals Cr, Cu, Ni, Zn, and As were all lower than the screening value of soil pollution risk on agricultural land (GB15618-2018). 37 sampling points of Pb exceeded the screening value of soil pollution risk on agricultural land, with an exceedance rate of 50.68%, 15 sampling points of heavy metal Cd exceeded the risk screening values for soil contamination on agricultural land, with an exceedance rate of 20.55%, and the maximum value of heavy metal Mn content was 4.57 times higher than the background value of the soil. The above data indicate that there is a certain degree of pollution of heavy metals Pb, Cd, and Mn during the withered water period. The heavy metals in descending order of coefficient of variation are Mn, Cu, Cr, As, Ni, Pb, Cd and Zn, with Mn having the largest coefficient of variation of 61%. Some studies have shown that a coefficient of variation of over 50% indicates that the spatial distribution of this heavy metal content is very heterogeneous and the possibility of point source pollution exists [36].

3.1.3. Differential Characteristics of Heavy Metal Content in Soil during the High and Withered Water Periods. The mean values of Cu, Cr, Ni, and Zn in the soils of the study area were lower in the withered water period than in the high water period, while the contents of the heavy metals Mn, As, Cd, and Pb were higher than in the rich period. The above data show that the content of heavy metals in the soils of the study area fluctuates to a certain extent between the high and withered water periods, with the average content of Cd in the withered water period being 1.86 times higher than that in the high water period, while the content of the other seven heavy metals fluctuates less. The heavy metal pollution in the soil during the high water period is mainly Pb and Mn, while the heavy metal pollution in the soil during the withered water period is mainly Pb, Mn, and Cd. Cd pollution occurs in the withered water period compared to the high water period, and the Cd pollution in the soil during the withered water period is mainly distributed in the open pit mining area of the mine.

3.2. Assessment of Heavy Metal Contamination of Soils

3.2.1. Geoaccumulation Index Assessment. The geo-accumulation index values for the heavy metals Mn, Cu, Cr, As, Cd, Ni, Pb, and Zn in the soil during the high water period were 0.15, −0.51, −1.15, −2.32, −0.15, −0.74, 0.74, and −0.46, respectively, while the geoaccumulation indix values for Mn, Cu, Cr, As, Cd, Ni, Pb, and Zn in the soil during the withered water period were 0.10, −0.89, −1.21, −2.23, −0.86, −0.88, 0.78, and −0.54, respectively, as shown in Table 5. Except for the heavy metal As in the withered water period, the accumulation of heavy metals Mn, Cu, Cr, Cd, Ni, Pb, and Zn occurred to varying degrees in the high and withered water periods; see Figures 2 and 3. Among them, the accumulation of heavy metals Pb and Mn was the highest and that of As was the lowest. 95.89% and 97.26% of the sampling sites showed varying degrees of accumulation of heavy metal Pb and 53.43% and 45.21% of the sampling sites showed varying degrees of accumulation of heavy metal Mn during the high water and withered water periods, respectively.

3.2.2. Comprehensive Assessment of the Nemerow Pollution Index. The results of the Nemerow pollution index show that 39.72% of the sampling points were under alert and 26.03% were lightly polluted during the high water period; 39.72% of the sampling points were under alert and 30.14% were polluted to varying degrees during the dry water period, of which 28.77% were lightly polluted and 1.37% were moderately polluted; see Figure 4. The Nemerow pollution index values for Cu, Pb, Zn, Cr, Ni, Cd, and As were 0.68, 2.03, 0.39, 0.66, 0.36, 0.71, and 0.24, respectively, during the high water period and 0.63, 2.19, 0.40, 0.36, 0.32, 1.22, and 0.22, respectively, during the withered water period, as shown in Table 6. The heavy metal Pb was moderately polluted, and Cd was under alert during the high water period and lightly polluted during the withered water period. The Nemerow pollution index of Mn was evaluated according to the Ganzhou soil surface background value as the standard value, and its Nemerow pollution index values were 4.16 and 3.51 during the high water period and withered water period, respectively, indicating that there is also a certain degree of Mn pollution in the soil.

3.2.3. Potential Ecological Risk Index Method. The comprehensive potential ecological risk index RI and potential ecological hazard index E_i were calculated based on the potential ecological risk hazard index formula; see Table 7. According to the comprehensive potential ecological risk index RI, all the sampling sites in the study area were mildly ecologically hazardous during the high water period, 82.19% of the sampling sites were mildly ecologically hazardous during the withered water period, and 17.81% of the sampling sites were moderately ecologically hazardous. According to the potential ecological hazard index E_i, the heavy metals Mn, Cu, Cr, As, Ni, and Zn were all mildly ecologically hazardous; Pb was mildly ecologically hazardous in 98.63% of the sampling sites during the high water period, moderately hazardous in 1.37% of the sampling sites, and mildly hazardous in all sampling sites during the withered water period. Cd was mildly ecologically hazardous in 36.99% of the sampling sites during the high water period, moderately ecologically hazardous in 58.90% of the sampling sites, and moderately to heavily ecologically hazardous in 4.11% of the sampling sites, while it was lightly ecologically hazardous in 1.37% of the sampling sites during the withered water period, moderately ecologically hazardous in 53.42% of the sampling sites, moderately to heavily ecologically hazardous in 43.84% of the sampling sites, and heavily ecologically hazardous in 1.37% of the sampling sites. Although the content of the heavy metals Pb and Mn in the soil was high, their toxicity coefficient values were small and therefore the ecological hazard risk was low. The potential ecological hazard index for the heavy metal Cd was evaluated to be high due to the large toxicity coefficient values of Cd.

4. Software Platform

4.1. Overall Structure. The user requirements of heavy metal pollution characteristics and ecological risk assessment platform contain functional and nonfunctional requirements [40–43]. Functional requirements analysis is based on the most basic in-depth study of the functions required by the system, that is, the requirements with specific contents and functions that the system must contain. From the perspective of system nonfunctionality, nonfunctional requirements analysis mainly covers the development and use principles of the system and the characteristics of the system.

As shown in Figure 5, the platform is divided into four functional modules: system login module, heavy metal pollution characteristics and ecological risk monitoring module, heavy metal pollution characteristics and ecological risk standard evaluation module, and heavy metal pollution characteristics and ecological risk early warning module.

Nonfunctional analysis mainly restricts the platform from the perspectives of performance, availability, and maintainability [44–47].

(1) Security. User authentication and data required by the system need to be encrypted in the transmission process, and the security of users and data needs to be effectively guaranteed.
(2) Compatibility and flexibility. The system can operate on different types of terminal equipment, support multiple hardware platforms, and support information sharing with data of other systems.
(3) Real time and effectiveness. The data transmission and display shall be effective in real time. When the data is obtained, the background will automatically start the online assessment and evaluation calculation.
(4) Maintainability. The system shall adopt the principle of high coupling and low cohesion, with high independence between modules for later modification and maintenance.

The overall structure of the platform is shown in Figure 6. The structures of heavy metal pollution characteristics and ecological risk standard evaluation and ecological risk standard evaluation modules are divided into three parts:

Table 5: The geoaccumulation index of the heavy metals in soils.

Sampling time	The average values of geoaccumulation index							
	Mn	Cu	Cr	As	Cd	Ni	Pb	Zn
High water period	0.15	−0.51	−1.15	−2.32	−0.15	−0.74	0.74	−0.46
Withered water period	0.10	−0.89	−1.21	−2.23	−0.86	−0.88	0.78	−0.54

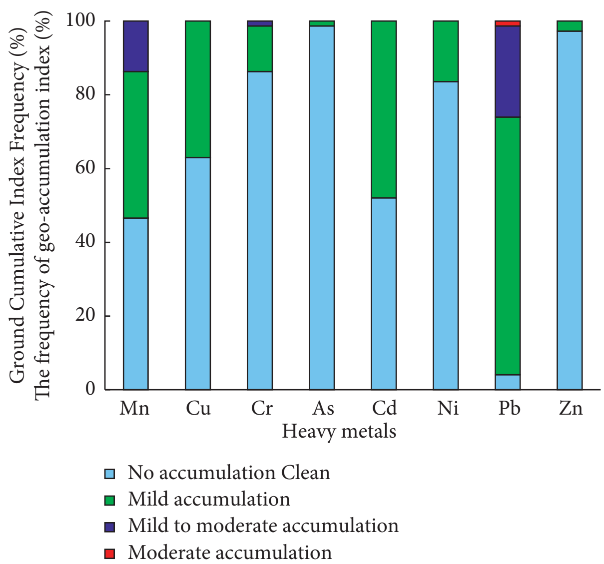

Figure 2: Frequency distribution of geoaccumulation index of heavy metals in the high water period.

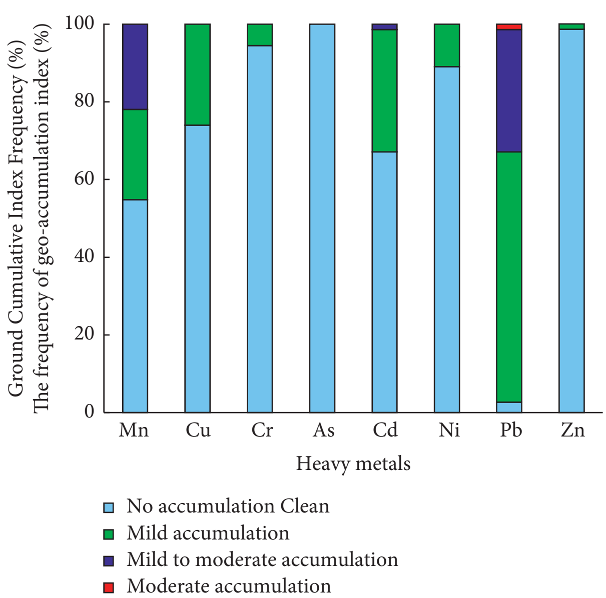

Figure 3: Frequency distribution of geoaccumulation index of heavy metals in the withered water period.

monitoring layer, transmission layer, and user layer. Each monitoring section of the monitoring layer can monitor the type and concentration of heavy metal pollution targets.

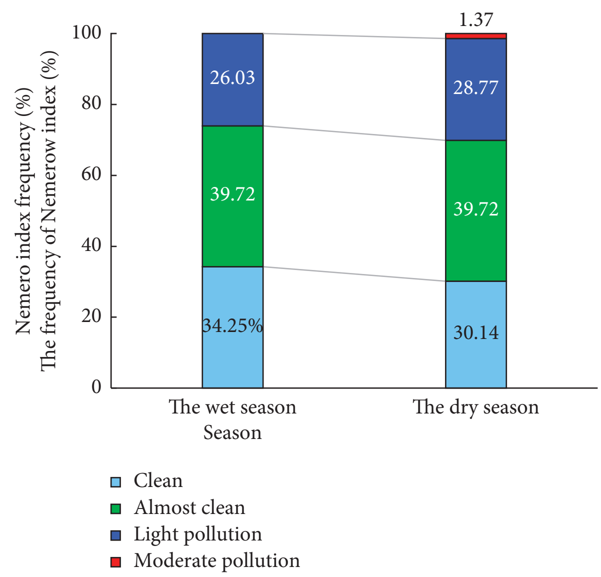

Figure 4: Frequency distribution of Nemerow pollution index of heavy metals in the study area.

Table 6: Nemerow pollution index of the heavy metals in soils.

Sampling time	P_i						
	Cu	Pb	Zn	Cr	Ni	Cd	As
High water period	0.68	2.03	0.39	0.66	0.36	0.71	0.24
Dry period	0.63	2.19	0.40	0.36	0.32	1.22	0.22

Different sensors transmit the monitoring data to the data center through the environmental monitoring collector. In the development and design of the platform, the required monitoring data are obtained from the database interface, and the monitoring information and calculation results are displayed on the front-end display screen of the mobile application through model calculation on the back of the platform.

4.2. SSM Background Development Framework. SSM framework includes two open-source frameworks, Spring and MyBatis [45–47]. Spring architecture is based on a container that uses JavaBean attribute and can develop any Java application. The core idea of Spring is IOC (inversion of control), which gives Spring the right to create objects without having to "new" an object by themselves. Spring provides unique data access abstraction and transaction management abstraction and can provide a consistent model in various underlying transactions such as JDBC. Spring

Table 7: Potential ecological risk index of the heavy metals in soils.

Sampling time	Projects	Comprehensive potential ecological risk index RI	Potential ecological hazard index E_i							
			Mn	Cu	Cr	As	Cd	Ni	Pb	Zn
High water period	Minimum value	31.00	0.67	1.17	0.21	1.08	8.33	0.90	6.60	0.72
	Maximum value	129.83	5.57	14.73	7.86	15.14	90.00	11.30	55.22	1.64
	Average	77.94	1.88	6.24	1.76	3.39	45.28	5.31	13.60	1.11
Withered water period	Minimum value	62.97	0.52	0.38	0.29	1.15	37.67	0.83	5.22	0.56
	Maximum value	203.60	4.57	13.74	4.11	13.79	180.33	9.80	31.30	1.65
	Average	118.15	1.94	5.43	1.58	3.52	86.23	4.85	13.75	1.05

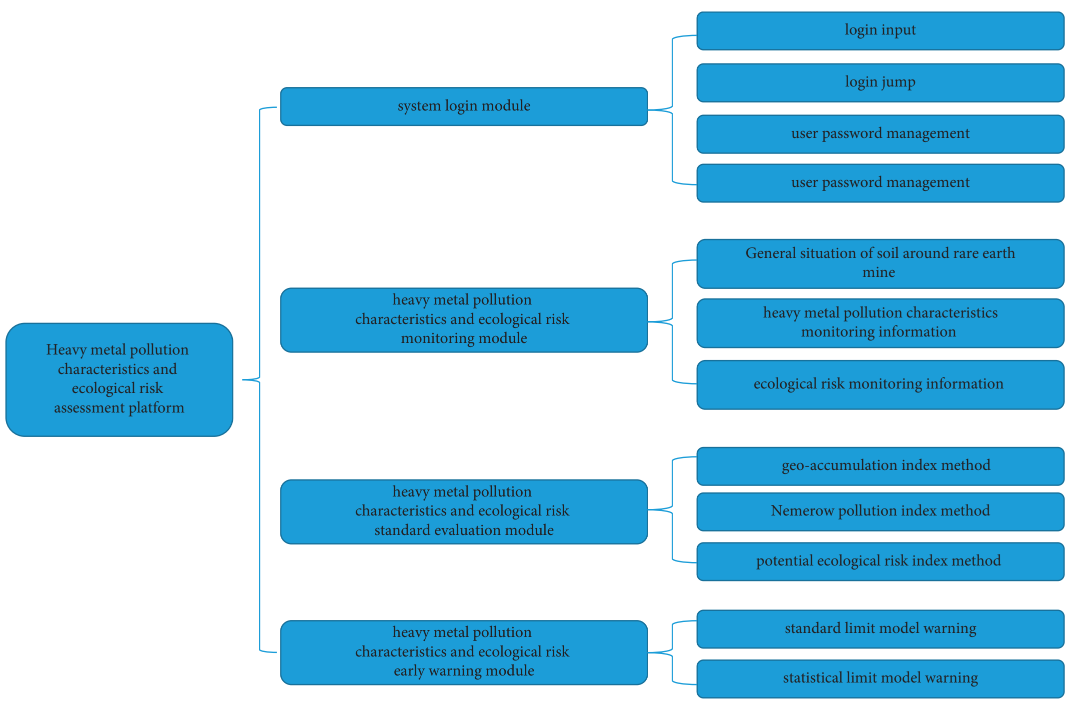

Figure 5: Functional modules of the platform.

framework solves the complexity of enterprise development and makes J2EE development easier to use.

MyBatis is an encapsulation of JDBC, which makes the underlying operation of the database transparent. It only needs to provide SQL statements, avoiding manually setting parameters and obtaining result sets. MyBatis supports customized SQL, stored procedures, and advanced mapping. MyBatis uses XML to configure and map files, builds SqlSessionFactory instances, obtains SqlSessions, and executes mapped SQL statements. Its functions are divided into API interface layer, data responsibility layer, and basic support layer.

MVC, namely, model view controller, is a framework that integrates model, view, and controller into independent programs. It provides loose coupling between these three elements, reduces code repeatability, simplifies grouping development, and provides a clear logical framework for software design and development.

(1) *M* refers to the model side, including DAO classes and databases. DAO accesses the database to manipulate data and abstract business logic into a model.

(2) *V* refers to the visual layer, which visualizes the data model and renders it in the user interface.

(3) *C* is the controller, which can update the model to the view layer. It is not only the link between the model layer and the view layer but also the bridge between the user and the system. It receives and processes the

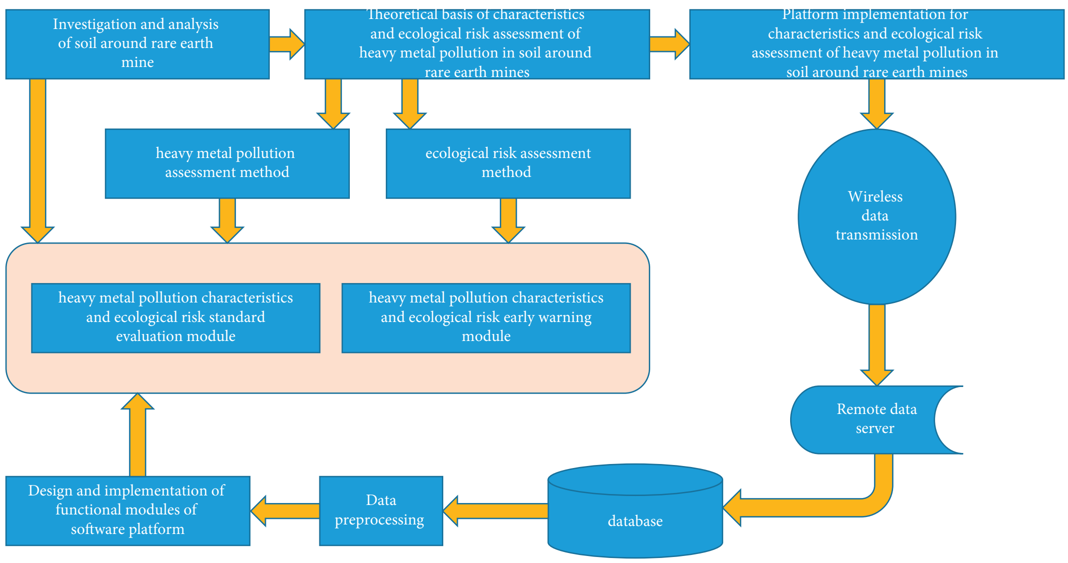

Figure 6: The overall structure of the platform.

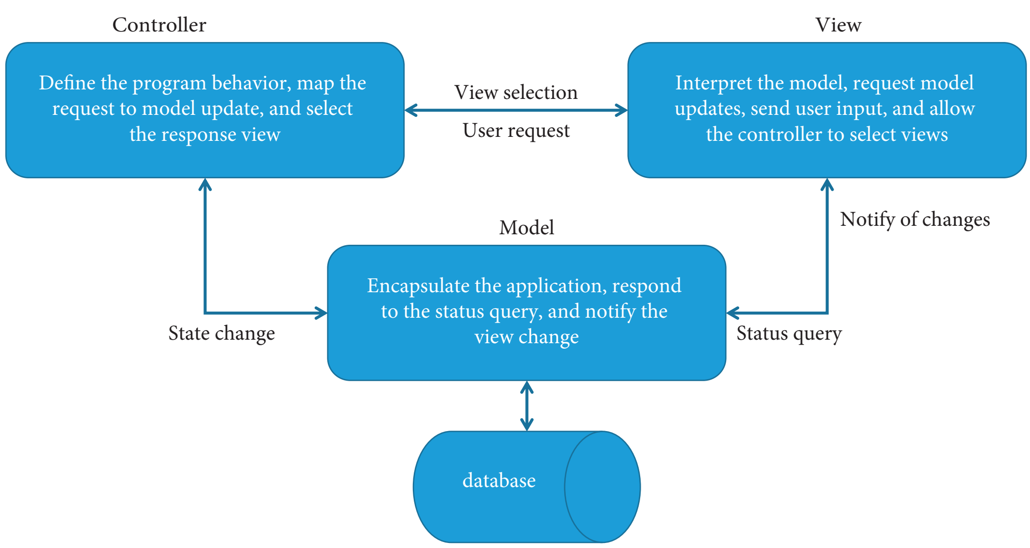

Figure 7: MVC component relationship.

response to the user's request, calls the DAO method to obtain the required data from the database, processes the library, and then returns to JSP for display in the view layer.

As shown in Figure 7, the basic idea is that the controller receives the user's request, decides how to process it, calls the data interface in the model layer through the DAO, processes and modifies the data, and sends it to the view layer for presentation. When the data of the model layer changes, it will be transmitted to the view layer in the form of time notification, and the view layer will modify the user interface accordingly.

4.3. Database Design. The database can be regarded as an electronic warehouse, which stores an organized and shareable data set for a long time in a certain way. Users can add, delete, modify, and query the data in the file. This study uses relational database and SQL Server for database operation. By combining the required data, it is determined that the monitoring data information table, heavy metal pollution characteristics and ecological risk assessment table, and heavy metal pollution characteristics and ecological risk early warning table need to be established, and the field name, identifier, type and length, null value, and primary key of each table are designed and compiled as shown in Tables 8–10.

Table 8: Monitoring data information table structure.

Serial number	Field name	Identifier	Type and length	Primary key
1	Soil area number	JC_CD	Varchar (40)	Y
2	Soil area name	JC_NM	Varchar (40)	
3	Initial section	JC_QS	Varchar (40)	
4	Termination section	JC_ZZ	Varchar (40)	
5	Soil target	JC_MB	Int	
6	Time	JC_TM	Date time	
7	First monitoring value	JCZ_1	Decimal	
8	Second monitoring value	JCZ_2	Decimal	

Table 9: Heavy metal pollution characteristics and ecological risk assessment table structure.

Serial number	Field name	Identifier	Type and length	Primary key
1	Soil area number	JC_CD	Varchar (40)	Y
2	Soil area name	JC_NM	Varchar (40)	
3	Soil target	JC_MB	Int	
4	Time	JC_TM	Date time	
5	First monitoring value	JCZ_1	Decimal	
6	Second monitoring value	JCZ_2	Decimal	
7	Assessment level	KH_DJ	Int	
8	Assessment index	KH_ZB	Char	
9	Assessment method	KH_FF	Char	
10	Geoaccumulation index method	KH_GIM	Char	
11	Nemerow pollution index method	KH_NPIM	Char	
12	Potential ecological risk index method	KH_PERIM	Char	
13	Compliance rate	KH_DBL	Decimal	

Table 10: Heavy metal pollution characteristics and ecological risk early warning table structure.

Serial number	Field name	Identifier	Type and length	Primary key
1	Soil area number	JC_CD	Varchar (40)	Y
2	Soil area name	JC_NM	Varchar (40)	
3	Over standard warning index	YJ_CB	Char	
4	Excess multiple	YJ_BS	Varchar (40)	
5	Time	JC_TM	Date time	

5. Conclusion

The main findings of this study include the following:

(1) The contents of heavy metals Cr, Cu, Ni, Zn, and As in the soils of the study area were all lower than the risk control screening values for agricultural land, 50.68% of the sampling sites exceeded the risk control screening values for agricultural land soils for the heavy metal Pb, and 20.55% of the sampling sites exceeded the risk control screening values for agricultural land soils for Cd during the withered period. The maximum value of Mn content was 5.57 times higher than the soil background value, and its contaminated sites were mainly located in the sampling area of the mine open pit, indicating that the mining of rare-earth mines has caused a certain degree of enrichment of heavy metals in the soil.

(2) The results of the geoaccumulation index assessment showed that the accumulation of heavy metals Mn, Cu, Cr, As, Cd, Ni, Pb, and Zn in the soils of the study area occurred to varying degrees, and the geoaccumulation indices of these eight heavy metals were, from largest to smallest, $Pb > Mn > Zn > Cd > Cu > Ni > Cr > As$, with the accumulation of Pb and Mn being the most serious.

(3) The assessment results of the Nemerow pollution index showed that 26.03% and 28.77% of the sampling points in the study area were lightly polluted during the high water period and the withered water period, respectively, with one sampling point being moderately polluted during the withered water period. The Nemerow pollution index values for Pb, Cd, Cu, Cr, Zn, Ni, and As were 2.11, 0.97, 0.66, 0.51, 0.40, 0.34, and 0.23 respectively, with Pb being moderately polluted, Cd and Cu being in the alert

state, and the other four heavy metals being in the clean state.

(4) The results of the assessment of the potential ecological risk index showed that only the heavy metal Cd was moderately contaminated in the soil of the study area, while the other seven heavy metals such as Cu, Cr, and As were all lightly contaminated.

(5) The accumulation of heavy metals Pb and Mn in the soils of the study area was relatively serious, and there was also heavy metal Cd pollution during the withered water period, but the toxicity coefficients of Pb and Mn were small, and their potential ecological risks were small, while the potential ecological risks of Cd were large. The authors suggest that land use planning in the study area should take full account of the contamination of heavy metals in the soil and take a certain degree of antipollution measures, vigorously advocate clean mining, gradually reduce the damage to the ecological environment caused by traditional mining techniques, and emphasize the development of the concept of "treatment and recovery while mining." At the same time, the local climate conditions are combined with the selection of suitable plant or microbial species to explore the promotion of bioremediation of the soil, advocating the concept of mine ecological restoration of green mines and green restoration.

The software platform planned and developed by this research institute can provide practical support for the application of the theoretical methods of this research.

Data Availability

The data set can be accessed upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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