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Analysis and Evaluation on Characteristics of Heavy Metal Pollution in the Coastal Farmland Soil along the Wuma River

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ABSTRACT

The thesis is aimed to provide a reference for the sustainable utilization of farmland soils along the Wuma River, an upstream tributary of the Chishui River in Guizhou Province. Geo accumulation index method, Nemero comprehensive pollution index method, and potential ecological hazard index method were used based on the experimental data for analyzing and evaluating the heavy metal pollution status of farmland soil along Wuma River. The results showed that: (1) The contents of heavy metals Ni, Cu, Zn, Pb and Hg in farmland soil exceeded the soil background values of 9.82%, 47.80%, 13.72% and 76.06% in Guizhou Province, respectively, but did not exceed the standard limit class II based on the environmental quality. (2). The pollutants of Pb and Zn in the research area mainly come from mineral exploitation, waste residue accumulation, and transportation. The enrichment of Cr and Cu may originate from the domestic garbage dumping and incinerated waste by residents along the coast and irrational agricultural activities. The main contents of Cd, As and Hg come from soil geochemistry. (3) The ranking of accumulations of eight heavy metals was $I_{Pb}>I_{Hg}>I_{Cu}>I_{Ni}>I_{Zn}>I_{Cr}>I_{As}>I_{Cd}$, among which Pb was non-moderately polluted and the remaining heavy metals were at the clean level; Nemero comprehensive pollution index showed that As, Cr, Zn, and Ni were mildly polluted, while Pb, Hg, and Cu were moderately polluted. The ranking of potential ecological risk levels for the eight heavy metals was Hg, Pb, Cu, Ni, As, Cd, Cr, Zn. The overall ecological risk level is mild.

INTRODUCTION

At present, farmland soils in China are threatened by various kinds of pollution, among which about 50 million mu farmland is moderately and severely polluted with 80% of the soil pollution by excessive contents of heavy metals (Wang et al. 2014, Chen et al. 2016). Heavy metal elements have unique environmental toxicological effects, so they cannot be degraded by microorganisms after entering farmland soil, and gradually accumulate in soil environment and organisms. They not only do harm to the quality and yield of crops but also cause potential harm to human health through the food chain (Massadeh et al. 2006, Zeng et al. 2010). In recent years, domestic and foreign scholars have investigated farmland soil in the basin many times. Marrugo-Negrete et al. (2017) surveyed 83 farmland soil samples from Sinú River in northern Colombia. The results showed that the average contents of Cu, Ni, Hg, and Zn were 1,149, 661, 0.159, and 1,365mg·kg-1, respectively, which exceeded the background values of soil in the same area. Influenced by the coastal industrial zone, Ni, Cu, and Zn were moderate to heavily polluted (Perveen et al. 2017). Based on the comparison and analysis of the contents of heavy metals in farmland soils along the upper and lower reaches of Swan River, an industrial area adjacent to Islamabad, Pakistan, it was found that the concentrations of Cr, Ni, Cd, Zn, Pb and Cu in the downstream were 149%, 131%, 176%, 139%, 224% and 182% of those in the upstream. Zhou et al. (2008) and Jin et al. (2017) investigated heavy metals in farmland along the Bijiang River in Yunnan Province and found that the concentrations of Pb, Cd, and Zn content could be regarded as serious pollution. Guo et al. (2017) evaluated the distribution characteristics and potential ecological risks of heavy metals in farmland soils along Xinqianghe River in a typical lead-zinc mining area. The results showed that there were many heavy metals in the coastal farmland where Cd dominated, with the existence of As, Cu, Ni, Pb, and Zn. Wu et al. (2011) investigated the contamination status of seven heavy metals in the surface soil of farmland around Puhe River, Hunhe River, Xihe River, and Shenfu Irrigation Canal in Shenyang. According to their investigation, Cd, Hg, and Zn pollution were found to be more common in these river areas.

It is thus clear that the pollution of heavy metals in river basins is becoming more severe. Therefore, researchers pay great attention to the environmental and ecological security of river basins in the current environment. However, there are few reports on the pollution of heavy metals in farmland in the upper reaches of Chishui River, Guizhou Province. Therefore, it is particularly important to investigate and evaluate the present heavy metals pollution in farmland soil in Chishui River Basin. This thesis conducted a study on the soil along the Wuma River, a tributary of the upper reaches of the Chishui River. The pollution status of 8 heavy metals, such as Ni, Cr, Cu, Zn, Pb, Cd, As, and Hg, was analyzed based on the field investigation and experimental analysis through the methods of the geo-accumulation index and Nemerow comprehensive pollution index. In addition, the potential ecological risk index method was used to assess the ecological risk of farmland soil in the basin. All the above methods were used to provide a reference for the sustainable use of farmland soil and the maintenance of sound farmland ecosystem in the basin.

MATERIALS AND METHODS

Survey on Research Areas

The Wuma River is an important tributary of the Chishui River in Renhuai, is part of the Yangtze River system. The Wuma River Basin is located in the southwest of Renhuai City (106.1-106.6°E, 27.5-27.8°N), and the boundary area between Guizhou and Sichuan provinces. It mainly consists of four townships, including Changgang, Luban, Wuma, and Maoba under the jurisdiction of Renhuai City, Guizhou Province. The total length of it is 39.3 km and an average annual discharge, 4.98 $m^3.s^{-1}$. The climate in the research area is the humid monsoon climate in the middle subtropical zone, with distinct seasons. The rain season and hot season are basically the same, the annual average temperature is 15.9-18.5 , and the annual average precipitation is 1,081mm. Main soil types can be divided into lime soil, yellow soil, purple soil, paddy soil, and yellow-brown soil. The main produced crops include rice, rape, maize, wheat, sorghum, and tobacco.

Sample Collection

From April to May 2017, a survey was carried out on the Wuma River Basin. According to the distribution of farmland in the basin, one sampling point was set every 1km along the basin, and the location information was recorded by GPS positioning within 1km from the riverbank. In the sampling process, based on the Technical Specification for Monitoring the Environmental Quality of Farmland Soil (NY/T 395-2000), five sub-sampling points were set up in the form of "plum blossom" or "serpentine" within the grid of 10m*10m. The surface soil from 0-20 cm was collected, and then mixed samples were formed. The soil samples were selected repeatedly by the four-point method and only about 1 kg was preserved. A total of 63 soil samples were collected. After air drying, grinding, and sifting (100 meshes), the soil was selected for determination and analysis (Bao 2007). The distribution of sampling points in the research area is shown in Fig. 1.

Sample Processing and Analysis

After using the tetra acid melting sample method (aqua regia, HClO4, HF) on an electrothermal plate at 140 for continuous heating and digestion, Copper (Cu), cadmium (Cd), lead (Pb), zinc (Zn), nickel (Ni) and chromium (Cr) were determined

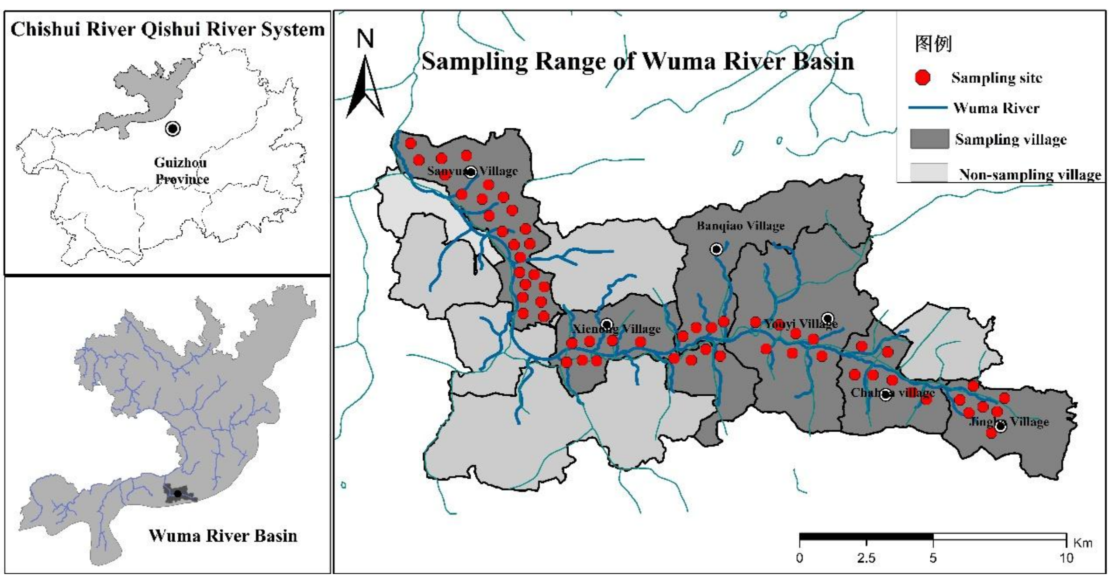

Fig. 1: Location of the research area and sampling sites.

by flame atomic absorption spectrometry (AAS-G800). Mercury (Hg) and arsenic (As) were digested by the aqua regia heating method and determined by atomic fluorescence spectrometry (AFS-E230). For the accuracy of the analysis, the national standard substance (GBW07309) was used for controlling the quality in the experimental process, and the parallel sample analysis was carried out. The test error was controlled within 5%.

Evaluation Methodology

Taking the background value of soil layer A in Guizhou Province as the evaluation criterion. The Muller cumulative index method (I_{geo}) and Nemero comprehensive pollution index method were used for evaluating the farmland soil pollution in the research area. Based on the Grade II standard (pH > 7.5) of the National Soil Environmental Quality Standard (GB15618-1995), the potential ecological risk index (RI) method proposed by Hakanson (1980) was used to assess the potential ecological risk. The toxicity response parameters of heavy metals T_r^i were adopted based on the reference values proposed by Hakansao (1980) (toxicity response coefficients of T_r^i to heavy metals As=10, Zn = Mn = 1, Cu = Pb = 5, Cr = 2, Cd = 30, Hg = 40) (Li et al. 2015) . The specific evaluation methods are shown in Table 1.

The pollution level I_{geo} is graded as follows: $I_{geo}\leq 0$ means pollution-free; $0<I_{geo}\leq 1$ means pollution-free-to-moderate pollution; $1< I_{geo}\leq 2$ refers to moderate pollution; $2< I_{geo}\leq 3$ means medium-to-heavy pollution; $3< I_{geo}\leq 4$ means heavy pollution; $4<I_{geo}\leq 5$ means heavy-to-seriously heavy pollution; and $I_{geo}>5$ means seriously heavy pollution. Nemerow's comprehensive pollution index is graded as follows: P≤0.7 means clean; 0.7<P≤1.0 means reaching the warning line; 1.0<P≤2.0 means slight pollution; 2.0<P≤3.0 means moderate pollution; P>3.0 means heavy pollution. The degree of single-factor ecological risk pollution E_r^i is divided into the following grades: $E_r^i < 40$ means mild pollution; $40\leq E_r^i <80$ means moderate pollution; $80\leq E_r^i <160$ means heavy pollution; $160\leq E_r^i <320$ means very heavy pollution; and $E_r^i \geq 320$ means seriously heavy pollution. The total potential ecological risk level R is graded as follows: R< 150 is mild; 150≤R<300 means moderate; 300≤ R<600 means strong; R≥ 600 refers to very strong.

RESULTS AND DISCUSSION

Analysis of heavy metals in soil, according to Table 1, show that the upper limits and bottom limits for contents of Ni, Cr, Cu, Zn, Pb, Cd, As, and Hg in farmland soil along the Wuma River Basin varied greatly, ranging from 11.02 to 70.95, 14.57 to 135.20, 9.24 to 80.20, 42.58 to 182.26, 18.34 to 87.13, 0.003 to 0.076, 3.18 to 18.91, 0.074 to 0.307mg·kg^{-1}, respectively. The average contents of heavy metals Ni, Cr, Cu, Zn, Pb, Cd, As, and Hg were 37.01, 64.55, 37.98, 93.70, 51.58, 0.013, 6.32, and 0.148mg·kg^{-1}, respectively. The average contents of Ni, Cu, Zn, Pb, and Hg exceeded the Guizhou Province's background values of 9.82%, 47.80%, 13.72%, and 76.06%, respectively. However, the average contents of all heavy metals did not exceed the grade II standard limit according to the national soil environmental quality.

Skewness is statistical data for the shape of data distribution, and kurtosis is statistical data for showing the steepness of all values in the population (Zhan et al. 2011). Based on the heavy metals statistical results of the research area, skewness and kurtosis coefficients of Zn, Cd, As, and Hg were larger, indicating that some soil samples presented high content and were highly accumulated. The coefficient of variation can reflect the average variation degree of heavy metal content in different sites. According to the classification of variation degree by Wilding (1984), Ni, Cd, Zn and Hg (coefficients of variations were 35%, 32%, 32%, and 28%, respectively) were moderate (ranged from 15% to 36%), while Cu, Pb, Cd and As (coefficients of variation were 40%, 38%, 72%, and 41%, respectively) were highly variable (Zang et al.

Table 1: The assessment of geo-accumulation index, Nemerow comprehensive polluted index, and potential ecological risk index for heavy metals.

Index	Expression	Parameter
Geo-accumulation index	$I_{geo} = Log_2[C_n/(k \times B_n)]$	C_n =Content of heavy metal element n in the soil; B_n =Geochemical background value of heavy metal element n; K =Coefficient of variation of background values caused by different rocks.
Nemerow comprehensive polluted index	$P_{综合} = \sqrt{\frac{(C_i/S_i)^2_{\max} + (C_i/S_i)^2_{ave}}{2}}$	C_i=Concentration of soil pollutant i; S_i=Background concentration of soil pollutant i; $(C_i/S_i)_{max}$ =The maximum of single factor pollution index for soil pollutant i; $(C_i/S_i)_{ave}$=Average value of single factor pollution index for soil pollutant i.
Potential ecological risk index	$RI = \sum E_r^i = \sum (T_r^i \cdot C_r^i) = \sum (T_r^i \cdot \frac{C_m^i}{C_n^i})$	R = Comprehensive potential ecological hazard index of several heavy metals; E_r^i =Potential ecological hazard coefficient of a single heavy metal; T_r^i=Toxicity response coefficient for heavy metals; C_r^i =Pollution coefficient of this element; C_n^i=Evaluation criterion of this element.

2016). If the coefficient of variation exceeds 0.5, the spatial distribution of heavy metal content is not uniform, and the point source pollution may exist (Aguiguri et al. 2017). The coefficient of variation of heavy metal Cd in the soil of the research area was 0.72. It can be seen that the variation of heavy metal Cd was significant, indicating that Cd was more prone to be affected by some local pollution sources. The average value of soil pH value was 7.93 and was of weak alkalinity. The skewness, kurtosis, and coefficient of variation were -1.20, 0.55, and 0.12, respectively. Therefore, the distribution of soil pH value was uniform and no obvious acid-base anomaly was observed.

Relevance and Source Analysis of Heavy Metals in Soil

The heavy metals in soils come from not only the parent soil layer but also agricultural activities (including irrigation water, agriculture, fertilizer), atmospheric dust, and industrial pollution (Zhang et al. 2012). The correlation coefficients between heavy metals are indicators for the relationship among different pollution sources. Generally, heavy metals with higher correlation coefficients are dependent on each other and may have similar sources. Heavy metals with a low correlation coefficient have weak dependence and different sources (Hu 2014). The results from correlation analysis (Table 3) proved that there was a significant positive correlation between Cd and Hg and between As and Ni ($P < 0.01$), an obvious positive correlation between Zn and Cu, Pb, Cd, and As ($P < 0.05$), and a significant positive correlation between As, Cu, and Hg ($P < 0.05$) in farmland soil along the Wuma River. The above correlations between different elements indicate that the enrichment of these elements might come from similar sources.

Table 2: Statistic of heavy metal concentrations in the research area (n=63).

Elements	Max. ($mg \cdot kg^{-1}$)	Min. ($mg \cdot kg^{-1}$)	Avg. ($mg \cdot kg^{-1}$)	SDANN ($mg \cdot kg^{-1}$)	Skewness	Kurtosis	Coefficient of variation	Background value ($mg \cdot kg^{-1}$)	National standard ($mg \cdot kg^{-1}$)
Ni	70.95	11.02	37.01	12.99	0.18	-0.55	0.35	33.7	40
Cr	135.20	14.57	64.55	20.70	0.85	2.02	0.32	86.6	250
Cu	80.20	9.24	37.98	15.18	0.28	0.01	0.40	25.7	50
Zn	182.26	42.58	93.70	30.19	1.16	1.16	0.32	82.4	200
Pb	87.13	18.34	51.58	19.42	0.04	-1.21	0.38	29.3	250
Cd	0.076	0.003	0.013	0.01	5.06	33.75	0.72	0.133	1
As	18.91	3.18	6.32	2.59	2.70	10.20	0.41	13.3	20
Hg	0.307	0.074	0.148	0.04	1.75	5.14	0.28	0.102	1
pH	8.95	5.23	7.93	0.94	-1.20	0.55	0.12	—	—

Notes: 1) Background value of farmland soil in Guizhou; 2) Grade II Standard according to the National Soil Environmental Quality Standard (GB15618-1995) (pH > 7.5)

Table 3: Correlation coefficients of metals in soil.

	Ni	Cr	Cu	Zn	Pb	Cd	As	Hg
Ni	1							
Cr	0.077	1						
Cu	0.138	0.112	1					
Zn	-0.089	0.018	0.251*	1				
Pb	-0.202	0.017	-0.133	0.262*	1			
Cd	0.332**	0.109	0.17	0.256*	-0.051	1		
As	0.234	0.13	0.278*	0.253*	-0.148	0.559**	1	
Hg	0.198	0.059	0.13	0.233	-0.151	0.504**	0.281*	1

Notes: ** indicates a significant correlation at the 0.01 (bilateral) level, and * indicates a significant correlation at the 0.05 (bilateral) level.

Based on results of principal component analysis on heavy metals in farmland along the Wuma River, the chi-square value of the Bartlett spherical test was 76.518, and the degree of freedom df was 32 (usually df 30, so it had strong reliability). Therefore, the principal component analysis could be made. Table 4 shows that the variance contribution rate of principal component 1 is 29.924%. The positive load coefficients of Cd, As and Hg in principal component 1 are larger, and there is a significant correlation between Cd and As, Cd and Hg ($P < 0.01$), indicating that Cd, As and Hg may have similar sources. The variance contribution rate of principal component 2 is 17.165%. The positive load coefficients of Pb and Zn are larger, and the correlation between Pb and Zn is 0.05 in terms of confidence level. The variance contribution rate of principal component 3 is 12.661%. The larger positive loads of Cr and Cu show that the enrichment of the same principal component element comes from the same source.

According to the above statistical results (Table 2), the contents of Cd, As and Hg are not significantly different from the background values of soil in Guizhou Province. Therefore, it can be inferred that principal component 1 may be a natural source. The reason is that affected by karst geological origin, the Wuma River Basin has higher geological background contents of Cd, As, and Hg than other elements (Lian 2010). They all originate from the parent material of soil formation and are controlled by soil geochemistry. The average contents of Pb and Zn exceed the background values of soil. The contents of Cr and Cu greatly exceed the standard in some places. Therefore, principal components 2 and

Table 4: Analysis result of principal components of heavy metals in soil.

Items	Principal component 1	Principal component 2	Principal component 3
Ni	0.479	-0.499	-0.01
Cr	0.229	0.012	0.795
Cu	0.472	0.087	0.459
Zn	0.414	0.745	-0.048
Pb	-0.215	0.748	-0.015
Cd	0.816	0.039	-0.218
As	0.754	0.022	0.036
Hg	0.661	-0.001	-0.343
Eigen value	2.394	1.373	1.013
Variance concentration rate (%)	29.924	17.165	12.661
Cumulative variance contribution rate (%)	29.924	47.089	59.750

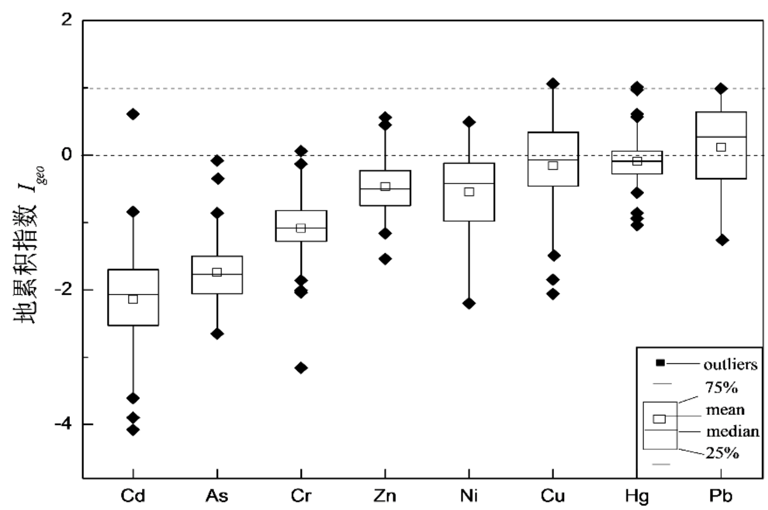

Fig. 2: The map of heavy metals of the index of geo-accumulation in the Wuma river.

3 may be influenced by artificial sources. Coastal farmland mainly depends on the Wuma River for irrigation. However, in the coastal area of the Wuma River, there is Tonglong Coal Mine, Sanyuan Coal Mine, and small-scale Pb-Zn Mine, etc. The waste residue produced in the process of mining and smelting combustion will bring about pollution in the rivers and coastal soil. In addition, due to the narrow landscape, No. 208 Provincial Road and No. 324 Village Road are close to the river coast. The wear and tear of vehicles and exhaust emissions will lead to the pollution of Pb and Zn in the farmland soil. Therefore, it is presumed that principal component 2 mainly comes from mineral mining and smelting, waste residue accumulation, irrigation, and transportation. Previous studies have shown that waste accumulation and incineration, transportation, and unreasonable agricultural activities may lead to the pollution of Cr and Cu (Zhao et al. 2015). Wuma Town in the middle and lower reaches of the Wuma River and the coastal villages in the upper reaches do not have a perfect waste treatment system. As residents along the river dump wasted pesticide bottles directly in the river or set them aside in the river bed for incineration, the river water and the surrounding environment are seriously polluted. At the same time, Cr and Cu have been accumulated in the farmland soil after river irrigation. Therefore, principal component 3 may be presumed to be mainly derived from the dumping and incineration of domestic waste by coastal residents, and unreasonable agricultural operations.

Assessment on Heavy Metal Pollution in Farmland Soil

The results of the geo-accumulation index (I_{geo}) of 8 heavy metals in farmland soils of the Wuma River Basin are shown in Fig. 2. According to the average of I_{geo}, 8 heavy metals are ranked as follows: I Pb>I Hg>I Cu>I Ni>I Zn>I Cr>I As>I Cd. Except forI_{geo}>0 of Pb which had no-to-moderate pollution, the I_{geo} of other heavy metals was less than 0 and in a clean level. Several locations of Pb, Hg, and Cu I_{geo}>1 had moderate pollution, indicating that there was point source pollution in farmland soil in the basin.

According to statistical results of the Nemero comprehensive pollution index of eight heavy metals in farmland soil of Wuma River Basin (Table 5), the *p*-value of Cd was under the warning level, indicating no pollution ($p < 1$). Cr, Zn, and Ni were slightly polluted ($1.0 < p \leq 2.0$), while Hg, Cu, and Pb were moderately polluted ($2.0 < p \leq 3.0$). Nemero comprehensive pollution index also takes into account the average and maximum values of single factor pollution index, so it can highlight the role of heavy metal pollutants (Wang et al. 2012). However, the evaluation results of the Nemero comprehensive pollution index basically conform to the cumulative evaluation results.

After calculation on E_r^i for single potential ecological hazard index for heavy metals in farmland soil along the Wuma River (see Fig. 3), the average potential hazard index of eight heavy metals was ranked as Hg > Pb > Cu > Ni > As > Cd

Table 5: Nemero comprehensive polluted index of heavy metals in soil.

Heavy metals	Cd	As	Cr	Zn	Ni	Hg	Cu	Pb
Comprehensive polluted of P value	0.41	1.06	1.22	1.76	1.68	2.36	2.43	2.44

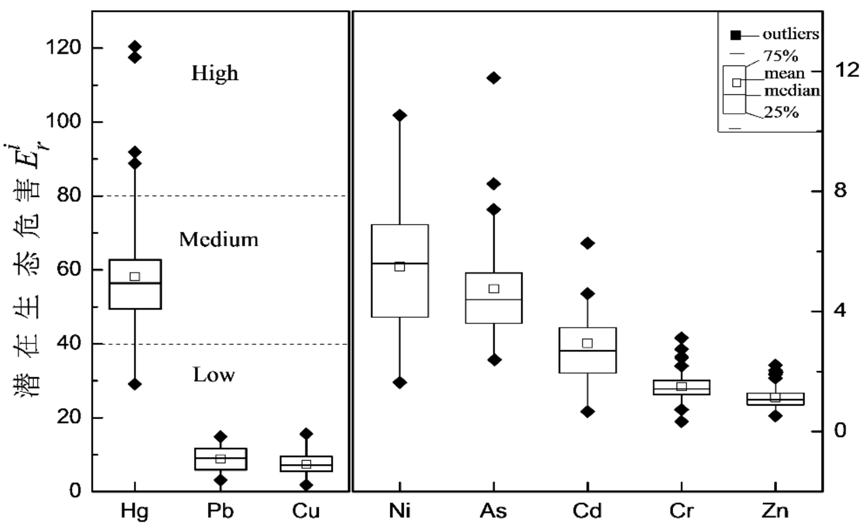

Fig. 3: The map of single potential ecological hazard indexes of heavy metals in soil.

> Cr > Zn from maximum to minimum amount. According to the risk level of ecological hazards, the average potential hazard index of Hg was more than 40 and was at moderate risk. The E_r^i value of some sample points was between 80 and 160, indicating strong ecological hazards. The E_r^i values of the other 7 heavy metals, Pb, Cu, Ni, As, Cd, Cr, and Zn were 8.80, 7.39, 5.49, 4.76, 2.94, 1.49, and 1.14, respectively, so it can be seen that all the E_r^i values were less than 40, and at a slight potential hazard level. The comprehensive index *RI* of potential ecological hazards of heavy metals in farmland soils in the research area ranged from 56.34 to 183.59, with an average value of 90.21, showing a slight potential ecological hazard as a whole.

After integration of 3 evaluation methods, it was concluded that the accumulative degree of Pb, Cu, and Hg in farmland soil and the comprehensive pollution index of Nemerow were higher in the research area. Although Pb and Cu were highly contaminated, the potential hazards caused by their toxicity were relatively low. Hg had a low pollution degree but relatively high potential toxicity. The pollution degree of Cr and Zn was higher than their potential toxicity.

Potential ecological hazard coefficients are slightly different from the results of the geo-accumulation index method. The reason is that the two evaluation methods have different focuses. The geo-accumulation index method mainly targets the influence of geochemical behavior, emphasizing the influence of exogenous sources on the enrichment of heavy metals through the anthropogenic and natural background values of heavy metals (Yu et al. 2013). In addition to the contents of heavy metals, the ecological hazard index also takes into account the varied environmental toxicity among different heavy metals, but it emphasizes more on the ecological risk of heavy metals and therefore can bring much healthier ecosystems. It is thus clear that the combination of various evaluation methods can provide a more comprehensive and reasonable understanding of heavy metal pollution and hazards in farmland soils in the research area.

CONCLUSION

Through the test, analysis, and evaluation on heavy metal pollution in farmland soil along the Wuma River, the following main conclusions are drawn:

1. In terms of the contents of heavy metals in farmland soil, the average contents of Ni, Cu, Zn, Pb, and Hg exceeded the background values of 9.82%, 47.80%, 13.72%, and 76.06% in Guizhou Province, respectively. Therefore, it can be concluded that all these heavy metals tended to accumulate, but the average contents of all heavy metals did not exceed the limit of the national grade II soil environmental quality standard.
2. The analysis of results of principal components show that Cd, As and Hg mainly come from natural sources and are influenced by geochemistry, with higher background values. Pb and Zn pollution is mainly because of mineral mining and smelting, waste residue accumulation, irrigation, and transportation. The enrichment of Cr and Cu may mainly come from dumped domestic waste, waste incineration from coastal residents, and unreasonable agricultural activities.
3. The geo-cumulation evaluation results showed that $I_{Pb}>I_{Hg}>I_{Cu}>I_{Ni}>I_{Zn}>I_{Cr}>I_{As}>I_{Cd}$. Among them, Pb was in no-to-moderate pollution, and I_{geo} of the rest of heavy metals was in clean level. Pb, Hg, and Cu pollution could be observed in some places. The results of the Nemerow comprehensive pollution index showed that As, Cr, Zn, and Ni were slightly polluted, while Pb, Hg, and Cu were moderately polluted. The calculation of the ecological hazard coefficient showed that the overall ecological risk was mild. The risk of Hg was moderate. At the same time, the potential ecological hazards of 8 heavy metals were ranked as Hg > Pb > Cu > Ni > As > Cd > Cr > Zn from strong to weak level.
4. At present, despite relatively low ecological hazards of the Wuma River Basin, the awareness of relevant departments are expected to be aroused for establishing and perfecting ecological protection measures in the mining areas of the Wuma River Basin, strengthening environmental protection training for coastal residents, properly solving the problems of random stacking of open-pit coal slag and pesticide residue pollution, and improving the centralized treatment system of coastal production and domestic waste. Only in this way, can the ecological environment of the Wuma River Basin develop in a more positive direction.

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