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Evaluation of Soil Heavy Metals in Mulberry Orchards in Longchuan County, Yunnan Province, China

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Abstract

To grasp the characteristics of Pb, Cd, Cu and Zn in mulberry garden soil in Longchuan County, Yunnan Province, the single-factor pollution index method and multi-factor pollution index method were used to analyze the environmental quality of mulberry garden soil. The results showed that the Zn content in mulberry soils did not exceed normal water based on the soil pollution risk control standards for agricultural land, but the Cd content was high. The single factor pollution index of Pb and Cu did not exceed 2, and the exceedance rate of points was 16% and 24% respectively, while the single factor pollution index of Cd exceeded 3. The pollution of heavy metal Cd existed in the soil of mulberry garden. The average Pi values of soil heavy metals were ranked as Cd > Cu > Zn > Pb. Heavy metal combined pollution index of 6.58, pollution level of heavy pollution. Principal component analysis (PCA) of the four heavy metals showed that the two elements, Pb and Cu, were strongly correlated in their spatial distribution. Longchuan County mulberry soil heavy metal environmental quality evaluation, for the safe use of soil to provide a scientific reference basis.

Keywords

Longchuan County, Soil, Heavy Metals, Health Evaluation, Mulberry Field

1. Introduction

In recent years Longchuan vigorously develop emerging agriculture, in Longchuan County built a mulberry planting industry chain. Mulberry tree canopy broad and dense leaves, is a perennial foliage plants, it maintains normal growth and development need to take a lot of nutrients from the soil. An important indicator of environmental monitoring of mulberry origin is soil heavy metal in mulberry orchard, and scholars studying heavy metal related scholars generally believe that heavy metal content in soil is an important factor affecting the safety of agricultural products, and it is also one of the main factors affecting the heavy metal content in mulberry. This study analyzes and evaluates the heavy metals in mulberry soil to provide data support for the safe use of mulberry soil and improve the quality of mulberry leaves.

Soil heavy metal distribution and pollution sources are one of the hotspots of the current domestic research, in which there are more studies on heavy metal pollution of river and lake shores and farmland soils, for example, the heavy metal content and distribution of soil heavy metals in soils along the Longjiang River in Guangxi (Qin et al., 2019), farmland in Shanghai (Xie et al., 2010), cropland in Yunnan (Sun et al., 2006), farmland in Fujian (Qiu, 2011), and farmland in southeastern Yunnan (Zhang et al., 2020); while in Yunnan Province, studies were mainly carried out on the heavy metal content and distribution of soils along the Mantis River (Zhang et al., 2013), wetlands of the Dashanbao Black-necked Crane National Nature Reserve (Tan et al., 2016), and the periphery of the mining area (Zhang et al., 2019) and the sources and remediation of soil heavy metal pollution in Xuanwei City (Qin et al., 2022) and Wuding County (Qin et al., 2020). The results showed that the distribution of heavy metals was not uniform in different areas of Yunnan Province, and most of the farmland was free of heavy metal pollution, while some farmland had accumulation of As and Cr, and some farmland had accumulation of Cd, Cu, and Pb.

The current research for the evaluation of heavy metals in orchard soils mainly focuses on the study of citrus, apple, pear, grape, peach and kiwifruit orchards, etc. The study of peach orchard, pear orchard and vineyard soils in Nanjing found that the Cr exceedance rate of peach orchards was 12% (Huang et al., 2018), and the study of lingonberry orchard soils in three regions, Changchun, Zhuanghe and Weihai, found that there was a certain degree of Cd orchard soil accumulation (Jiang et al., 2009). After studying the heavy metal contents in the soil of Sichuan Hanyuan pear orchard (Han et al., 2007), major kiwifruit orchards in Guizhou (Qiu et al., 2019), and Gannan citrus orchards (He et al., 2014) and their contamination status, it was found that there were differences in heavy metal contamination among different orchards, with no accumulation of heavy metals in some orchards, some orchards with Cd, Cu accumulation phenomenon, some orchards have As, Cr accumulation phenomenon. The research on heavy metals in mulberry orchards mainly focuses on the distribution and enrichment of heavy metals by mulberry trees and the migration of heavy metals in mulberry trees, etc. The systematic research specifically aimed at the evaluation of heavy metals in mulberry orchard soils has rarely been reported. In this study, based on the risk control standard of soil pollution on agricultural land and the background value of agricultural soil in Yunnan Province, 25 soil samples from mulberry garden bases in Longchuan County were analyzed by using the single-factor contamination index method and Nemero contamination index method, and the evaluation of the environmental quality of heavy metals in mulberry garden soil in Longchuan County, Yunnan Province, was carried out, which provides a data reference for the safe use of the soil.

2. Materials and Methods

2.1. Overview of the Study Area

The geographic location of Longchuan County is 24˚08' - 24˚39' north latitude and 97˚39' - 98˚17' east longitude, with Myanmar in the west, Mangshi City in China in the east, Ruili City in China in the south, and Lianghe County and Yingjiang County in China in the north. The climate of Longchuan County is south subtropical monsoon, with sufficient rainfall, the average annual precipitation is 1595 mm; sufficient sunshine, the annual sunshine duration is 2316 h; warm climate, the average annual temperature is 18.9˚C; alternating wet and dry seasons, the rainy season is from May to October, and the dry season is from November to the following April, the average relative humidity is 79% per annum; it is located in the south of the Qinling-Huaihe River 0˚C isotherm south of the Qinling-Huaihe River, with no snow throughout the year. The highest altitude of Longchuan County is 2618.8 m, and the lowest altitude is 780 m. Part of the Gaoligong Mountain range passes through Longchuan County, forming the geomorphology of "three mountains, two dams and one valley" in Longchuan County, and Longchuan County is generally characterized by the topography of high in the northeast and low in the southwest. There are quarries around Sangyuan in Longchuan County, which are mainly engaged in the mining of construction stone.

2.2. Sample Collection and Preparation

A representative mulberry plantation planting base was selected in Longchuan County, and 25 mixed soil samples were collected by random sampling method, and the sampling points are shown in Figure 1. Bamboo paring knives were used to take the soil with depths ranging from 0 to 40 cm, which was mixed well and then rounded up by quadrature, and 1 kg of soil was retained to be stored in a plastic bag, labeled, and brought back to the laboratory. The retrieved soil was spread on clean kraft paper, allowed to air dry, debris such as stubs and stones were removed, crushed on the kraft paper with a wooden hammer, passed through a 1 mm and 0.25 mm nylon sieve, and encapsulated in polyethylene ziplock bags and labeled.

2.3. Measurement Methods

2.3.1. Sample Determination

The methods, instruments used, and standards implemented for sample testing are shown in Table 1. To ensure the quality of analysis, one blank sample was used for each batch, and soil standards [GSS-5, GBW (E) 070043] were used for quality control in sample digestion and loading to the machine for testing.

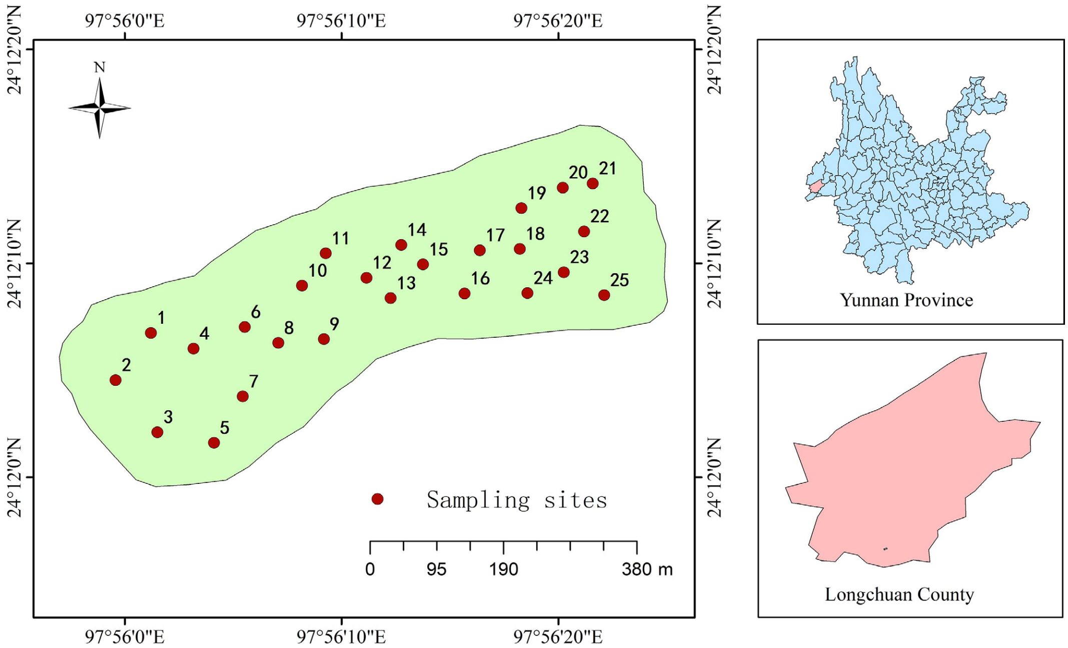

Figure 1. Longchuan County mulberry field sampling points.

Table 1. Soil sample testing methods.

Project	Analytical Methods	Instrument	Execution standard
pH	Glass Electrode Method	Orion-210 Acidity Meter	NY/T395-2000
Pb	Atomic Absorption Spectrophotometry	Z5000 Atomic Absorption Spectrophotometer	GB/T 17141-1997
Cd	Atomic Absorption Spectrophotometry	PE-1100B Atomic Absorption Spectrophotometer	GB/T 17141-1997
Cu	Atomic Absorption Spectrophotometry	Z5000 Atomic Absorption Spectrophotometer	GB/T 17138-1997
Zn	Atomic Absorption Spectrophotometry	Z5000 Atomic Absorption Spectrophotometer	GB/T 17138-1997

2.3.2. Evaluation Methods for Heavy Metal Contamination of Soil

1) Single-factor pollution index method:

$$P_i = C_i / S_i$$

where: P_i is the single-factor pollution index of the *i*th pollutant; C_i is the measured concentration of the *i*th pollutant; S_i is the evaluation standard of the ith pollutant. Single-factor pollution index method is a single pollutant in the soil measured value compared with the evaluation criteria, the ratio is the sub-index, used to indicate the degree of contamination of the pollutant in the soil, its principle is simple, easy to operate, is widely used to determine the main pollutants and the degree of harm (Qiu et al., 2019).

2) The Nemero Composite Pollution Index Method:

$$P_{is} = \sqrt{\frac{(P_{imax})^2 + (P_{iave})^2}{2}}$$

where: P_{is} the composite pollution index; $P_{imax}^3 = (C_i/S_i)_{max}^2$ is the square of the maximum value of a single pollutant in all soils; $P_{iave}^2 = (C_i/S_i)_{ave}^2$ is the square of the average value of a single pollutant in all soils.

The Nemero index method was used to calculate a comprehensive pollution index for evaluation to determine the overall quality of the soil environment, and the quality of the soil environment was graded according to the size of the Nemero index (Table 2). The Nemero index method covers the average and highest values of the single-factor pollution index, which can highlight the more polluted pollutants and give larger weights to the more serious pollutants, reflecting the overall quality of the soil environment in a more comprehensive way, and thus evaluating the quality of the soil environment in an objective way (Qiu et al., 2019).

Table 2. Soil pollution classification standards.

Classification	Single Factor Pollution Index	Composite Pollution Index	Pollution Degree	Pollution Level
I	Pi ≤ 0.7	PN ≤ 0.7	Security	Cleaning
II	0.7 < Pi ≤ 1.0	0.7 < PN ≤ 1.0	Alert level	Not yet clean
III	1.0 < Pi ≤ 2.0	1.0 < PN ≤ 2.0	Slightly polluted	Soil contamination exceeds background values and crops are beginning to be contaminated
IV	2.0 < Pi ≤ 3.0	2.0 < PN ≤ 3.0	Moderate pollution	Soil and crops are moderately contaminated
V	Pi > 3.0	PN > 3.0	Heavily polluted	Soil and crops are already heavily contaminated

The background values of Pb, Cd, Cu, and Zn contents in agricultural soils in Yunnan Province were 40.6 mg/kg, 0.218 mg/kg, 46.3 mg/kg, and 89.7 mg/kg, respectively. Part of the "Soil Environmental Quality Risk Control Standards for Soil Pollution of Agricultural Land (for Trial Implementation)" (GB 15618-2018) is shown in Table 3.

Table 3. Part of the risk control standards for soil pollution on agricultural land (for Trial Implementation) for the quality of the soil environment.

pH	Pb (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
<5.5	70	0.3	150	200
5.5 - 6.5	90	0.3	150	200
6.5 - 7.5	120	0.3	200	250
>7.5	170	0.6	200	300

2.3.3. Data Processing

Data processing and analysis were performed using Excel 2016 and SPSS 19.0.

3. Results

3.1. Status of Heavy Metal Content in Soil of Mulberry Orchard

As can be seen from Table 4, the maximum value of Pb content in heavy metals in the soil of mulberry orchards in Longchuan County was 77.33 mg/kg, the minimum value was 28.00 mg/kg, and the average value was 50.25 mg/kg; The maximum value of Cd content was 4.57 mg/kg, the minimum value was 1.67 mg/kg, and the average value was 2.66 mg/kg; the maximum value of Cu content was 175.29 mg/kg, the minimum value was 34.19 mg/kg, and the average value was 107.21 mg/kg; and the maximum value of Zn content was 99.56 mg/kg, the minimum value was 3.69 mg/kg, the The average value was 57.85 mg/kg. Based on the risk control standards of soil pollution in agricultural land, there were 4 exceeding points of Pb, with an exceeding rate of 16% and an exceeding range of 1.59 - 7.33 mg/kg, 25 exceeding points of Cd, with an exceeding rate of 100% and an exceeding range of 1.37 - 4.27 mg/kg, 6 exceeding points of Cu, with an exceeding rate of 24% and an exceeding range of 0.70 - 25.29 mg/kg, and no exceeding situation of Zn. Zn did not appear to exceed the situation.

Table 4. Heavy metal content of mulberry soils in Longchuan County.

Sample no.	pH	Heavy metal measured value (mg/kg)			
		Pb	Cd	Cu	Zn
1	5.95	46.25	3.25	37.38	64.73
2	6.02	50.17	3.14	48.74	61.14
3	4.82	40.32	2.69	104.80	52.56
4	6.13	56.42	2.17	121.51	16.70
5	5.32	49.97	2.49	47.60	69.24
6	5.80	60.49	2.89	150.70	49.21
7	7.37	35.37	2.33	131.50	12.18
8	4.96	46.57	2.14	59.39	23.36
9	5.94	33.17	2.96	106.62	29.86
10	5.60	28.00	2.05	34.19	34.04
11	5.48	35.42	2.05	44.53	50.46
12	6.77	36.42	2.21	50.91	55.94
13	5.46	51.38	4.57	138.13	66.62
14	5.18	77.33	2.80	106.62	98.21
15	4.54	30.88	2.70	49.45	21.40
16	4.86	47.26	3.53	144.37	81.25
17	5.47	61.48	2.72	164.93	68.20
18	5.04	58.19	3.84	166.83	77.07
19	6.90	35.38	2.23	82.24	16.74

Continued

20	6.83	43.90	2.36	153.04	33.22
21	5.18	52.84	1.91	152.13	78.74
22	4.89	73.87	4.00	133.36	3.69
23	4.50	60.47	1.93	155.46	12.59
24	5.09	71.59	1.84	175.29	99.56
25	5.43	73.03	1.67	120.58	69.45
Average value (mg/kg)	5.58	50.25	2.66	107.21	49.85
Number of Exceeding Points (pcs)		4	25	6	0
Exceedance rate (%)		16	100	24	0

3.2. Evaluation of Soil Heavy Metal Pollution in Mulberry Orchards

3.2.1. Evaluation Results of the Nemero Composite Pollution Index Method Based on the Risk Control Standards of Soi

As can be seen from Table 5, all points of Zn single-factor pollution index in the soil of mulberry garden in Longchuan County did not exceed 0.7, and there was no Zn pollution in the soil of mulberry garden; all points of Pb and Cu single-factor pollution index were below 2, and the proportion of points exceeding the screening value of soil pollution risk of agricultural land was 16% and 20%, respectively; and all points of Cd single-factor pollution index exceeded 3, which indicated that there existed serious Cd pollution in the soil of mulberry garden. Cd pollution. The average value of heavy metal Pi of the soil was Cd > Cu > Pb > Zn. The highest value of heavy metal pollution index of mulberry orchard soil in Longchuan County was 11.27, the lowest value was 4.23, and the average value was 6.58, which indicated that all the points were heavily polluted.

Table 5. Evaluation results of Nemero integrated pollution index method based on soil pollution risk control criteria for agricultural land.

Sample no.	Single Factor Pollution Index				Nemero Composite Pollution Index (PN)	Pollution Level
	Pb	Cd	Cu	Zn		
1	0.51	10.83	0.25	0.32	7.94	Heavy
2	0.56	10.46	0.32	0.31	7.68	Heavy
3	0.58	8.95	0.70	0.26	6.60	Heavy
4	0.63	7.23	0.81	0.08	5.34	Heavy
5	0.71	8.30	0.32	0.35	6.12	Heavy
6	0.67	9.63	1.00	0.25	7.11	Heavy
7	0.29	7.75	0.66	0.05	5.70	Heavy
8	0.67	7.13	0.40	0.12	5.25	Heavy

Continued

9	0.37	9.86	0.71	0.15	7.24	Heavy
10	0.31	6.82	0.23	0.17	5.00	Heavy
11	0.51	6.82	0.30	0.25	5.02	Heavy
12	0.30	7.38	0.25	0.22	5.41	Heavy
13	0.73	15.25	0.92	0.33	11.21	Heavy
14	1.10	9.34	0.71	0.49	6.92	Heavy
15	0.44	8.99	0.33	0.11	6.59	Heavy
16	0.68	11.78	0.96	0.41	8.68	Heavy
17	0.88	9.05	1.10	0.34	6.71	Heavy
18	0.83	12.81	1.11	0.39	9.45	Heavy
19	0.29	7.43	0.41	0.07	5.45	Heavy
20	0.37	7.88	0.77	0.13	5.80	Heavy
21	0.75	6.38	1.01	0.39	4.76	Heavy
22	1.06	13.34	0.89	0.02	9.82	Heavy
23	0.86	6.44	1.04	0.06	4.79	Heavy
24	1.02	6.12	1.17	0.50	4.60	Heavy
25	1.04	5.58	0.80	0.35	4.18	Heavy
Average value	0.65	8.86	0.69	0.24	6.53	Heavy

3.2.2. Evaluation Results of the Nemero Composite Pollution Index Method Based on Background Values in Yunnan Province

As can be seen from Table 6, the single factor pollution index of Pb and Zn in the soil of mulberry orchard in Longchuan County was below 2 at all points, and the proportion of points exceeding the background value was 68% and 8% respectively; the single factor pollution index of Cu exceeded 0.7 at all points, and the proportions of the points with alert level, mild pollution, moderate pollution and heavy pollution were 12%, 24%, 32% and 32% respectively; the single factor pollution index of Cd exceeded 3 at all points, indicating that there was serious Cd pollution in the soil of mulberry orchard. points were more than 3, indicating the existence of serious Cd pollution in the soil of mulberry garden. The average value of heavy metal Pi of the soil was Cd > Cu > Pb > Zn, and the highest value of heavy metal pollution index of Longchuan Mulberry Garden soil was 15.53, the lowest value was 5.88, and the average value was 9.10, and all the points were heavily polluted.

3.3. Correlation Analysis of Soil Heavy Metal Content in Mulberry Orchards

As can be seen from Table 7, the Pearson correlation coefficient R of Pb and Cu in the soil of mulberry orchards in Longchuan County is positive, and the significant correlation coefficient is $P = 0.003$ which is less than 0.01, so that the highly

Table 6. Evaluation results of Nemero integrated pollution index method based on background values of Yunnan Province.

Sample no.	Single Factor Pollution Index				Nemero Composite Pollution Index (PN)	Pollution Level
	Pb	Cd	Cu	Zn		
1	1.14	14.91	0.81	0.72	10.99	Heavy
2	1.24	14.40	1.05	0.68	10.63	Heavy
3	0.99	12.32	2.26	0.59	9.17	Heavy
4	1.39	9.95	2.62	0.19	7.47	Heavy
5	1.23	11.43	1.03	0.77	8.47	Heavy
6	1.49	13.25	3.25	0.55	9.92	Heavy
7	0.87	10.67	2.84	0.14	7.97	Heavy
8	1.15	9.82	1.28	0.26	7.28	Heavy
9	0.82	13.56	2.30	0.33	10.05	Heavy
10	0.69	9.39	0.74	0.38	6.93	Heavy
11	0.87	9.39	0.96	0.56	6.96	Heavy
12	0.90	10.15	1.10	0.62	7.53	Heavy
13	1.27	20.99	2.98	0.74	15.53	Heavy
14	1.90	12.86	2.30	1.09	9.64	Heavy
15	0.76	12.37	1.07	0.24	9.11	Heavy
16	1.16	16.21	3.12	0.91	12.07	Heavy
17	1.51	12.46	3.56	0.76	9.53	Heavy
18	1.43	17.63	3.60	0.86	13.14	Heavy
19	0.87	10.23	1.78	0.19	7.59	Heavy
20	1.08	10.85	3.31	0.37	8.15	Heavy
21	1.30	8.78	3.29	0.88	6.70	Heavy
22	1.82	18.36	2.88	0.04	13.61	Heavy
23	1.49	8.86	3.36	0.14	6.73	Heavy
24	1.76	8.42	3.79	1.11	6.52	Heavy
25	1.80	7.67	2.60	0.77	5.88	Heavy
Average value	1.24	12.20	2.32	0.56	9.10	Heavy

significant correlation between them is a positive correlation; the Pearson correlation coefficient R of Pb and Zn is positive, and the significant correlation coefficient is $P = 0.045$ which is less than 0.05, so that the significant correlation between them is a positive correlation. is positive correlation. Since Pb, Cu and Zn in the mulberry garden showed different degrees of correlation, it is known that the heavy metals Pb, Cu and Zn in the soil of mulberry garden in Longchuan County come from different kinds of composite pollution sources. As shown in

Figure 2, the goodness of fit R^2 of Pb and Cu was 0.31, and as shown in Figure 3, the goodness of fit R^2 of Pb and Zn was 0.16, which proved that the explanation of Pb for the variations of Cu and Zn was low, and that the contents of Pb, Cu, and Zn were more affected by anthropogenic activities.

Table 7. Correlation analysis among heavy metals in the soil of mulberry plantation in Longchuan County.

Heavy metals	correlation coefficient			
	Cd	Cu	Zn	Pb
Cd		0.474	0.595	0.562
Cu			0.388	0.003**
Zn				0.045*
Pb				

Note: "*" indicates a significant level of correlation ($P < 0.05$), and "**" indicates a highly significant level of correlation ($P < 0.01$).

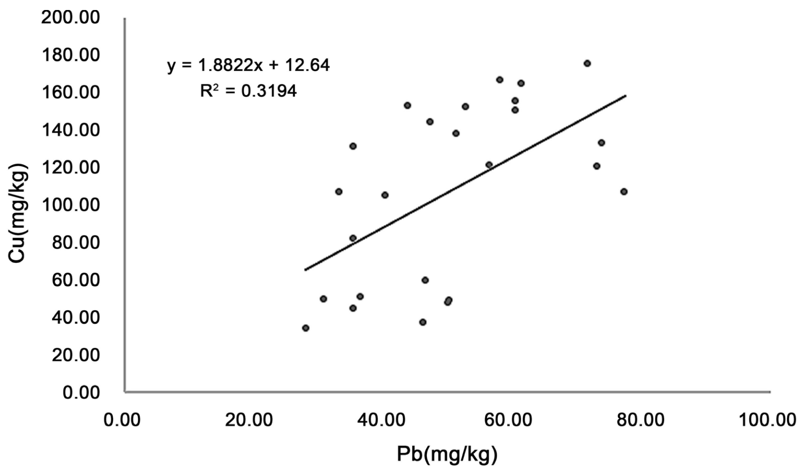

Figure 2. Linear fit of Pb and Cu heavy metal elements.

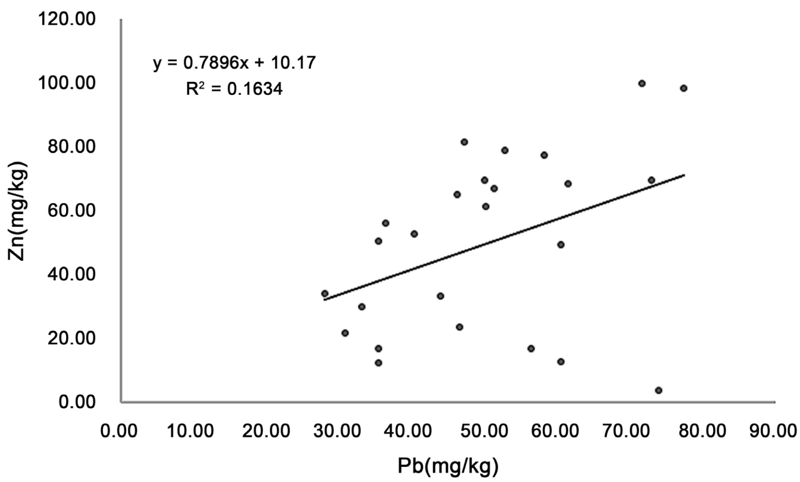

Figure 3. Linear fit of Pb and Zn heavy metal elements.

The KMO test was performed on the soil heavy metal concentrations, resulting in a KMO value of 0.525, which is greater than 0.5, indicating that the sample data are suitable for principal component analysis (PCA). Table 8 shows that two principal components were extracted and rotated with the following variance contributions: 43.32% (P1), 25.56% (P2). The variance contribution of the two principal components together explained 68.88% of the total variance.

Table 8. Principal component analysis of four kinds of target elements in the study area.

Target Element	Pre-Rotation Factor		Post-Rotation Factor	
	P1	P2	P1	P2
Pb	0.87	0.11	0.87	0.13
Cd	0.36	−0.68	0.37	−0.68
Cu	0.86	−0.12	0.86	−0.11
Zn	0.35	0.73	0.33	0.73
Contribution rate (%)	43.33	25.55	43.32	25.56
Cumulative Contribution (%)	43.33	68.88	43.32	68.88

P1 is dominated by Pb and Cu, indicating a strong correlation between the spatial distribution of these two elements, which may reflect a common source of these two elements in the soil.

P2 is almost entirely dominated by Zn, indicating that Zn may have a relatively independent source.

4. Discussion

4.1. Basic Characteristics of Heavy Metals in Mulberry Soil in Longchuan County, Yunnan Province, China

Based on the risk control standards for soil pollution in agricultural land, there were four exceedance points of Pb, with an exceedance rate of 16% and an exceedance range of 1.59 - 7.33 mg/kg, and there were six exceedance points of Cu, with an exceedance rate of 24% and an exceedance range of 0.70 - 25.29 mg/kg. Through the Principal Component Analysis (PCA), there was a strong correlation between the spatial distributions of the two elements, Pb and Cu, and there might be a common source. By principal component analysis (PCA), the two elements, Pb and Cu, had a strong correlation in spatial distribution and might have a common source, and the main factor affecting the Pb and Cu contents of mulberry orchard soils was the soil-forming parent material (Borůvka et al., 2005). There were 25 exceedance points of Cd, with an exceedance rate of 100%, and the range of the exceedance was 1.37 - 4.27 mg/kg, which indicated that there was a certain degree of accumulation of Cd in soils of the mulberry orchards of Longchuan County, and the existence of exogenous Cd inputs. The external sources of Cd in agricultural soils are mainly the accumulation of atmospheric deposition and the use of organic fertilizers such as phosphorus fertilizers and animal and poultry manure (Wang et al., 2005).

It is worth noting that, in addition to the influence of natural factors such as soil-forming parent material, anthropogenic activities are also the main cause of soil heavy metal pollution in mulberry orchards in Longchuan County (Li et al., 2024). Therefore, Longchuan County needs to explore the specific causes of soil pollution in depth in the future, and to curb and control the pollution emission from the source, so as to promote the sustainable protection and improvement of soil environment.

4.2. Evaluation of Soil Heavy Metal Pollution in Mulberry Orchards

Excessive heavy metal Cd in the soil of mulberry gardens has a certain degree of influence on the germination of mulberry seeds and the growth of mulberry trees. The effects of heavy metals Cd and Pb on the germination of mulberry seeds of two varieties, Jisang No. 3 and Luzha No. 1, were investigated in terms of their exposure to external conditions and their effects on the biomass of mulberry seedlings during the growth process (Gao et al., 2020). The results showed that Cd and Pb inhibited the germination of mulberry seeds and were more toxic to the young embryonic roots of mulberry than to the more mature embryonic roots. The biomass of seedlings decreased with the increase of Cd and Pb treatment concentrations; a pot experiment was used to study the growth of mulberry trees under different concentration gradients of Cd and the uptake enrichment capacity of saplings for Cd content during growth (Pan, 2016). The results showed that the plant height and biomass of mulberry trees in the planted orchard showed a pattern of increasing and then decreasing as the Cd content in the soil increased with the gradient; and the stress effect of Cd on the plants had an impact on photosynthesis during the growth process, affecting the accumulation of nutrients in the plants as well as their transformation, thus affecting the growth of the plants. And the size of the Cd content in the planting soil has a direct correlation with the amount of Cd content on the roots, stems, leaves and other parts of the plant, and with the increase of the concentration of Cd treatment in the soil, the Cd content on the roots, stems, leaves and other parts of the mulberry plant also gradually increased. The results of this study showed that the single-factor pollution index Pi of Cd in the soil of mulberry gardens in Longchuan County, Yunnan Province, all exceeded 3, and there was serious Cd pollution in the soil of mulberry gardens. In the subsequent management of mulberry orchards, the application of Cd-containing pesticides, animal manure and other organic fertilizers should be strictly controlled to avoid more serious pollution.

5. Conclusion

1) Under the risk control standards of soil pollution in agricultural land Longchuan County mulberry garden soil heavy metal Pb, Cu, Zn content in most points did not exceed the normal level, but Cd content greatly exceeded the normal level, the average value of 2.66 mg/kg.

2) Based on the risk control standards of soil pollution in agricultural land, the single-factor pollution index of Zn in the soil of mulberry garden in Longchuan County did not exceed 0.7, the exceedance rate of Pb and Cu was 16% and 20% respectively, the single-factor pollution index of Cd was more than 3, and there was serious Cd pollution in mulberry garden soil, and the average value of heavy metal Pi of the soil was ranked as Cd > Cu > Pb > Zn; the average value of the comprehensive pollution index PN was 6.53, and all points were heavily polluted.

3) Based on the background values in Yunnan Province, the exceedance rates of Pb, Cu, and Zn in the soil of mulberry orchards in Longchuan County were 68%, 8%, and 88%, respectively; and the mean value of the integrated pollution index PN was 9.10, with all points being heavily polluted.

4) The four heavy metal elements in the soil of mulberry garden in Longchuan County showed highly significant positive correlation between Pb and Cu, and significant positive correlation between Pb and Zn, indicating that the heavy metals Pb, Cu, and Zn in the soil of mulberry garden in Longchuan County came from different types of composite pollution sources.

5) The principal component analysis (PCA) of four heavy metal elements in the soil of mulberry orchards in Longchuan County extracted two principal components (P1 and P2), P1 was mainly dominated by Pb and Cu, indicating that there was a strong correlation in the spatial distribution of these two elements, which may reflect that these two elements in the soil have a common source. P2 was almost completely dominated by Zn, indicating that Zn may have a relatively independent source.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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