Investigation of Farmland Soil and Wheat Heavy Metal Contamination Character in Jinding of Lanping

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Abstract. The contents of Cd and Pb in soil and wheat in Jinding of Lanping in Yunnan were investigated and sampled. And single pollution index method, comprehensive pollution index method and correlation analysis were used to evaluate heavy metal contamination in wheat and soil. Zone A is in the upper reaches of the Pijiang River, and the zone does not contain large mines, where soil in the farmland is not polluted by the heavy metals Cd and Pb. The soil in zone B is slightly polluted by Cd and Pb, and the over-standard rate of the Cd of the samples measured is 75%, and the over-standard rate of the Pb of the soil is 25%. The condition of soil polluted by two heavy metals is Cd > Pb, and the heavy metal pollution of the soil in this Zone is mainly affected by mining activities. Zone C is in the lower reaches of the Pijiang River, and the soil in Zone C is not polluted by Cd and Pb. The content of Cd and Pb in the wheat in Zone A reached the standard and was not polluted. The wheat in Zone B was not polluted by Cd and Pb. Although Cd and Pb in the soil in this Zone was over-standard, it could be concluded that Cd and Pb in the soil did not migrate to wheat. The wheat in Zone C was not contaminated by Cd and Pb.

Keywords: Jinding town, soil, wheat, heavy metal pollution

1. Introduction
Jinding of Lanping is located in the Lead-zinc mining Zone of Lanping, in which more than 80% of the mine is open cut [1]. A large number of heavy metal elements will cause damage to the surrounding environment of the mining Zone through mining sewage irrigation, dust leaching from tailing slag and other ways. The damage to soil environment is particularly serious, when soil pollution intensifies and heavy metals accumulate, it would bring adverse effects on crops, especially the quality of crops, which poses a great threat to consumers. There are many reports on heavy metal pollution of soil and vegetables in Jinding of Lanping, but few reports on the characteristics of heavy metal contamination in this Zone. In this paper, wheat and soil in Jinding of Lanping were collected and heavy metal Pb and Cd were detected. The heavy metal pollution in wheat grain and soil were evaluated with the method of single pollution index, comprehensive contamination index and correlation analysis. Which would provide certain reference basis for solving the problem of soil safety utilization, pollution prevention and control in mining Zone and food safety of local residents [2].
2. Materials and Methods

2.1. Sample Collection
Taking Jinding open-pit stope and 100,000-ton smelter as the center, the sampling sites were arranged to collect wheat and wheat planting soil, and 12 soil and wheat samples were collected respectively. Four sampling points were spread upstream along the Pijiang River, recorded as LP1-LP4, and designated Zone A. Four sampling points were arranged near the open stope, recorded as LP5-LP8, and designated as Zone B. Four points were spread in the downward direction of the Pijiang river, recorded as LP9-LP12, and designated Zone C, as shown in the figure.

2.1.1. Wheat Sample Collection. The wheat grains planted in a large Zone in the study Zone were collected, and 3 ~ 5 wheat grains were collected at each point by means of plum-pattern distribution points to merge into one sample. About 0.5 kg of each plant sample was collected to form a mixed sample. After the sample collection, put the wheat seeds into polythene plastic bag and tie the bag tightly. Samples were stored in a low temperature environment within 24h.

2.1.2. Soil Sample Collection. 12 mixed samples were collected from the surrounding soil of the wheat samples. The core sampler was used to collect soil, and the surface layer (0-20cm) soil was taken, and 6 ~10 mixed soil samples were taken from each sample point. The collected soil samples were repeatedly discarded according to the quarter method, leaving about 1.0kg at last. The foreign matter were removed, and the samples were packed into a cloth bag and sent to the laboratory for testing.
2.2. Sample Test
Soil and wheat samples were sent to Kunming Mineral Resources Supervision and Testing Center for testing, and the heavy metal content in wheat was detected by *Food Heavy Metal Detection Method (GB/T 5009)* [4]. The heavy metal content in soil samples was detected with *Technical Specification of Farmland Soil Environmental Quality Monitoring (NYT 395-2000)* [5].

2.3. Evaluation Methods and Standards

2.3.1. Evaluation Standards for Heavy Metal Pollution of Crops. National Food Safety Standard pollutant Limit in Food (GB2762-2012) was used as the heavy metal evaluation standard for wheat [6]. The contamination degree of heavy metal elements in wheat was evaluated by *Single Pollution Index Method*, and its calculation formula was [7], as shown in the equation (1):

\[ P_i = \frac{C_i}{S_i} \]  

\( P_i \) is the single contamination index of pollutant \( i \) in wheat; \( C_i \) is the measured concentration of pollutant \( i \), mg/kg; \( S_i \) is evaluation standard for pollutants, mg/kg; The quality grade is divided according to the \( P \) value, when \( P_i < 1 \), it means the sample is safe; when \( 1 \leq P_i < 2 \), it means slight pollution of the sample; when \( 2 \leq P_i < 3 \), it means that the sample is moderately polluted; when \( P_i \geq 3 \), it means the sample is heavily polluted.

2.3.2. Evaluation Standards for Heavy Metal Contamination of Soil. The assessment of soil heavy metal over-standard was based on *Soil Environmental Quality Standard (GB15618-1995) Grade II (Dry crop, pH > 7.5)* [8].

Nemerow Comprehensive Pollution Index Method is used to evaluate the contamination of heavy metal elements in soil [2], as shown in the equation (2):

\[ P = \left\{ \left[ \frac{(C_i/S_i)_{\text{max}} + (C_i/S_i)_{\text{ave}}}{2} \right]^{1/2} \right\} \]

\((C_i/S_i)_{\text{max}}\) is the maximum single pollution index; \((C_i/S_i)_{\text{ave}}\) is the average single contamination index. Soil classification standards is showed in table 1.

| Grade division | P | Pollution grade | Contamination level                           |
|----------------|---|----------------|-----------------------------------------------|
| 1              | P≤0.7 | Safe         | Clean                                         |
| 2              | 0.7<P≤1 | Warning line | No pollution                                  |
| 3              | 1<P≤2  | Light pollution | Soil pollution exceeds the background value and crops begin to be polluted |
| 4              | 2<P≤3  | Medium pollution | The soil and crops are moderately contaminated |
| 5              | P>3   | Heavy pollution | Soil and crops have been seriously contaminated |

The data was entered into the system by Microsoft Office Excel 2010, and SPSS22.0 software was used for statistical analysis.

3. Result and Analysis

3.1. Status and Analysis of Soil Heavy Metal Pollution
Zone A is in the upper reaches of the Pijiang River, with no large mines surrounding it. According to table 2, the \( P \) value of the soil Cd is 0.61, and the soil is not polluted by Cd. The \( P \) value of Pb in the soil was 0.29, and the measured soil samples did not exceed the standard. The soil in Zone A was not polluted by heavy metal Pb, and the pollution level is safe.
From table 2, it can be seen that the soil in Zone B is slightly polluted by Cd and Pb in Jinding open pit, smelter and tailings pond. The over-standard rate of Cd value of the samples measured is 75%, the over-standard rate of soil Pb value is 25%, and the soil polluted by two kinds of heavy metals is Cd > Pb.

Zone C is in the lower reaches of the Pijiang River, with no large mines surrounding it. According to table 2, the soil in this Zone is not polluted by the heavy metals Cd and Pb.

Table 2. Characteristic parameters statistical results of heavy metals in soils of A, B, C zones.

| Partition | Heavy metal characteristic parameters | Cd     | Pb     |
|-----------|--------------------------------------|--------|--------|
|           | Maximum value (mg/kg)                | 0.45   | 117.54 |
|           | Minimum value (mg/kg)                | 0.04   | 54.48  |
| Zone A    | Average value (mg/kg)                | 0.26   | 86.793 |
|           | Standard deviation (mg/kg)           | 0.17   | 31.524 |
|           | Variable coefficient                  | 65.38  | 36.32  |
|           | Over-standard rate (%)                | 0      | 0      |
|           | P                                     | 0.61   | 0.29   |
|           | Maximum value (mg/kg)                | 0.83   | 365    |
|           | Minimum value (mg/kg)                | 0.57   | 312    |
|           | Average value (mg/kg)                | 0.69   | 342.75 |
| Zone B    | Standard deviation (mg/kg)           | 0.12   | 22.25  |
|           | Variable coefficient                  | 17.4   | 6.49   |
|           | Over-standard rate (%)                | 75%    | 25%    |
|           | P                                     | 1.27   | 1.01   |
|           | Maximum value (mg/kg)                | 0.45   | 290    |
|           | Minimum value (mg/kg)                | 0.08   | 45.4   |
|           | Average value (mg/kg)                | 0.28   | 187.1  |
| Zone C    | Standard deviation (mg/kg)           | 0.17   | 121.19 |
|           | Variable coefficient                  | 60.71  | 64.77  |
|           | Over-standard rate (%)                | 0      | 0      |
|           | P                                     | 0.62   | 0.70   |
|           | GB15618 Grade II dry crop standard (mg/kg) | 0.6   | 350mm  |

3.2. Status and Analysis of Wheat Heavy Metal Contamination

The content of Cd in the wheat in Zone A ranged from 0.12 to 0.18 mg/kg. As can be seen from table 3, the coefficient of variation of Cd in the wheat in Zone A was 191.94, indicating that the content of Cd in the wheat samples in Zone A was significantly different, the over-standard rate was 0, and the P value was 0.75, indicating that the wheat in the zone was not polluted by Cd. The Pb content of wheat in Zone A ranged from 0.11 to 0.27 mg/kg, the coefficient of variation was 38.89, the over-standard rate was 0, and the P value was 0.95, indicating that the wheat in the zone was not polluted by Pb.

The content of wheat Cd in Zone B ranged from 0.18 to 0.2 mg/kg. As table 3, the variation coefficient of wheat Cd in Zone B was 4.2, the over-standard rate was 0, and the P value was 0.95, indicating the safety of wheat samples in this Zone. The Pb content of wheat in Zone B ranged from 0.24 to 0.3 mg/kg, the variation coefficient was 10.71, the over-standard rate was 0, and the P value was 0.93, indicating that the wheat in the Zone was not contaminated by Pb.
The content of Cd in the wheat in Zone C ranged from 0.09 to 0.17 mg/kg. According to table 3, the variation coefficient of Cd in the wheat in Zone C was 23.08, the over-standard rate was 0, and the P value was 0.65, indicating that the wheat in the zone was not contaminated by Cd. The Pb content of wheat in Zone C ranged from 0.12 to 0.21 mg/kg, the variation coefficient was 26.67, the over-standard rate was 0, and the P value was 0.5, indicating that the wheat in the Zone C was not contaminated by Pb.

Table 3. Heavy metal contents in corn (on fresh weight) and the ratio of samples exceeded standard.

| Partition | Heavy metal characteristic parameters | Cd     | Pb     |
|-----------|--------------------------------------|--------|--------|
|           | Maximum value (mg/kg)                | 0.18   | 0.27   |
|           | Minimum value (mg/kg)                | 0.12   | 0.11   |
|           | Average value (mg/kg)                | 0.149  | 0.18   |
| Zone A    | Standard deviation (mg/kg)           | 0.286  | 0.07   |
|           | Variable coefficient                 | 191.94 | 38.89  |
|           | Over-standard rate (%)               | 0      | 0      |
|           | P                                    | 0.75   | 0.6    |
|           | Maximum value (mg/kg)                | 0.20   | 0.30   |
|           | Minimum value (mg/kg)                | 0.18   | 0.24   |
|           | Average value (mg/kg)                | 0.19   | 0.28   |
| Zone B    | Standard deviation (mg/kg)           | 0.008  | 0.03   |
|           | Variable coefficient                 | 4.2    | 10.71  |
|           | Over-standard rate (%)               | 0      | 0      |
|           | P                                    | 0.95   | 0.93   |
|           | Maximum value (mg/kg)                | 0.17   | 0.21   |
|           | Minimum value (mg/kg)                | 0.09   | 0.12   |
|           | Average value (mg/kg)                | 0.13   | 0.15   |
| Zone C    | Standard deviation (mg/kg)           | 0.03   | 0.04   |
|           | Variable coefficient                 | 23.08  | 26.67  |
|           | Over-standard rate (%)               | 0      | 0      |
|           | P                                    | 0.65   | 0.5    |
|           |                                      | 0.2    | 0.3    |

3.3. Correlation Analysis of Heavy Metal Content in Wheat and Soil

3.3.1. Correlation Analysis of Cd Content between Wheat and Soil. According to figure 2, R=0.293, indicating that Cd content in soil in Zone A is not significantly correlated with Cd content in wheat. As can be seen from figure 3, R=0.390, indicating that there is no correlation between Cd content in soil in Zone B and Cd content in wheat. As can be seen from figure 4, R=0.585, soil Cd and wheat Cd in Zone C were positively correlated, and the correlation had statistically significance.
3.3.2. Correlation Analysis of Pb Content between Wheat and Soil. As can be seen from figure 5, $R=-0.72$, indicating that Pb content in soil in Zone A is negatively correlated with Pb content in wheat. From figure 6, $R=-0.48$, Pb content in soil Zone B is not significantly correlated with Pb content in wheat. It can be seen from figure 7 that $R=0.662$, indicating a positive correlation between Pb of soil and Pb of wheat in Zone C, and the correlation had statistically significance.
4. Discussion

1) Zone A is in the upper reaches of the Pijiang River, and there are no large mines on it. So the soil in the farmland is not polluted by the heavy metals Cd and Pb. The soil in Zone B is slightly polluted by Cd and Pb, and the over-standard rate of the Cd value of the samples measured is 75%, and the over-standard rate of the Pb in soil is 25%. The condition of polluted soil is Cd > Pb, and the heavy metal contamination of the soil in this Zone is mainly affected by mining activities. Zone C is in the lower reaches of the Pijiang River, and the soil in Zone C is not polluted by Cd and Pb.

2) The content of Cd and Pb in the wheat in Zone A reached the standard and was not polluted. The wheat in Zone B was not polluted by Cd and Pb. Although Cd and Pb in the soil in this Zone exceeded the standard, Cd and Pb in the soil could be transferred into wheat. According to figure 3 and figure 6, there was no statistically significant correlation between Cd and Pb contents in soil and wheat of Zone B, indicating that Cd and Pb contents in wheat grains in Zone B were not mainly derived from soil, which might be related to rainfall, mining dust and irrigation water. The wheat in Zone C was not contaminated by Cd and Pb. It can be seen from figure 4 and figure 7 that the contents of Cd and Pb in soil are correlated with the contents of Cd and Pb in wheat of Zone C. The results showed that the sources of Cd and Pb in soil of Zone C were consistent with those of wheat.

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