Hazard of heavy metal pollution in farmland soil and its ecological risk assessment method

Zhaodi Ma *
School of Management, Tianjin University of Technology, Tianjin, China
*Corresponding author e-mail: mazhaodi@tjut.edu.cn

Abstract. The farmland soil heavy metal pollution, not only has a great harm to the crops, and also caused great influence to human life and health. False degree is high, due to the evaluation of traditional ecological assessment method for reliability is poor, so it is necessary to strengthen the farmland soil heavy metal pollution risk assessment method research. This study analyzes the harm of soil heavy metal pollution, and will affect soil environmental toxicity of heavy metal element coefficient to join in the form of weighting ecological assessment, combining with the degree of heavy metal pollution index, potential ecological harm index calculation, and then formulated and pollution level classification standards and the potential ecological harm level compared with complete ecological assessment.

1. Introduction
With the continuous development of industry and agriculture, more and more kinds of chemical substances are gradually applied in the process of crop production, leading to more and more serious soil pollution caused by heavy metals [1]. When the accumulation of heavy metals exceeds the tolerance of the soil, the biological toxicity contained in them will be activated and harm the environment. It is very important to study the risk of farmland heavy metal pollution and to measure the soil environmental quality by means of ecological assessment.

In the ecological assessment of agricultural soil heavy metal pollution risk, the assessment standard is the basis of soil environmental pollution assessment. Facing the complex soil pollution situation at the present stage, it is difficult to guarantee the assessment level of the early assessment methods at home and abroad. The potential influencing factors are ignored during the assessment period, resulting in a high degree of falsity of the assessment and poor reliability of the assessment methods. Therefore, based on the existing research data, the ecological assessment method of heavy metal pollution risk in farmland soil was designed to solve the problem of poor reliability of traditional methods.

2. Hazards of farmland polluted by heavy metals
Heavy metals can enter the farmland soil in a variety of ways, the initial accumulation is small, but does not appear, but long-term accumulation will appear enrichment phenomenon, when the enrichment reaches a certain concentration, it will seriously affect the growth and development of crops, crop production reduction, serious crop death [2]. Since the soil of farmland will be contaminated by heavy metals, and the food people eat is produced from farmland, so the food also contains heavy metals, which can indirectly harm the human body. The human body contains a variety of proteins and enzymes,
and heavy metals into the human body will combine with these substances, inhibit the activity of the enzyme, has a great damage to the structure of the protein, and then have a great impact on the health of the human body. In addition, lead in heavy metals can accumulate in the human body, and when it reaches a certain level, it can cause neurological disorders, anemia and other symptoms, while also causing great damage to kidney function [3].

3. Methods for ecological assessment of heavy metal pollution risk in farmland soil

3.1. Determine the ecological assessment index of heavy metal pollution risk

Farmland soil contains a variety of heavy metal elements, different heavy metal elements have different toxicity, the damage to the soil environment is not the same, with the increase of heavy metal toxicity, farmland soil ecological risk index gradually increased, causing harm to crops and human body. As a result, people need to introduce toxicity evaluation coefficient, when calculating the coefficient of the toxicity of heavy metals in soil, based on abundance principle, calculate the relative abundance of soil heavy metals in the environment medium degree, will get the total abundance degree, relatively abundant degree together through decomposition, a coefficient of the toxicity of heavy metals, It was added into the ecological assessment method in the way of weight to characterize the effects of soil heavy metal toxicity on soil ecological environment.

In the actual farmland soil environment, not all the heavy metals entering the soil can be absorbed by crops, and not all the heavy metals will harm human health. Among them, the content of some heavy metals does not exceed the standard, which has a regulating effect on the soil environment [4]. Only the part of heavy metals absorbed by crops in the soil will pose a risk to organisms. Therefore, for the ecological assessment of soil heavy metal risk, it mainly evaluates the risks posed by soil heavy metal pollution to crops and human health. Farmland soil pollution will decrease as the soil matures, and its risk characteristics have potential and persistence. According to the above characteristics, two kinds of evaluation indexes of farmland soil pollution were determined in this study.

The calculation formula of farmland soil pollution index is as follows:

$$S_1^i = \sqrt{\frac{S_{bio}^i}{S_o^i}}$$

Where, $S_{bio}^i$ is the limit of heavy metal content in the national vegetable standard, mg/kg; $S_o^i$ is the bioavailable content of heavy metals in soil, mg/kg; $S_1^i$ mainly considers the impact of soil heavy metal toxicity on the soil ecological environment, that is, the concentration of heavy metals absorbed by crops under normal circumstances.

The calculation formula of concentration risk of farmland soil pollution is as follows:

$$S_2^i = \frac{S_o^i - S_1^i}{S_o^i}$$

Where, $S_o^i$ is the total amount of heavy metals in farmland soil, mg/kg; $S_2^i$ is the residue content of heavy metals in farmland soil, mg/kg; $S_1^i$ mainly considers the condition of $S_1^i$ and the potential bioavailable content that can be released for biological absorption under certain circumstances, and represents the concentration risk value of all the heavy metal speciation content that can be absorbed by plants.

After the above calculation, the ecological assessment of heavy metal pollution risk in farmland soil should be carried out, and the ecological assessment standard of heavy metal pollution risk should be developed to measure the risk degree of heavy metal pollution in farmland.
3.2. Formulate the ecological assessment level standard for heavy metal pollution risk
The establishment of evaluation grade standard includes two parts, namely, the soil heavy metal pollution degree and the ecological harm index grade. The calculation formula of pollution degree index is as follows:

\[
H = \log_2 \frac{\alpha}{1.5\delta}
\]

Where, \(\alpha\) is the actual measured heavy metal content in the soil, mg/kg; \(\delta\) is the background value of heavy metal content in local sediments, mg/kg.

The grade division of pollution degree is shown in Table 1.

| Level of risk | Pollution Index Range | The degree of pollution                  |
|---------------|-----------------------|-----------------------------------------|
| 6             | 5<H≤10                | Very serious pollution                   |
| 5             | 4<H≤5                 | Heavy - very heavy pollution            |
| 4             | 3<H≤4                 | Strong pollution                        |
| 3             | 2<H≤3                 | Moderate to strong pollution            |
| 2             | 1<H≤2                 | Secondary pollution                      |
| 1             | 0<H≤1                 | Light to moderate contamination         |
| 0             | H≤0                   | clean                                   |

The pollution index shown in Table 1 is taken as the weight to calculate the ecological harm level, and the potential ecological harm coefficient is calculated by combining the multi-element toxicity level. The calculation formula is as follows:

\[
G_i = S_i^1 \times H \times S_2^1
\]

\[
Z = \sum G_i
\]

Where, \(i\) is the serial number of heavy metal elements in farmland soil; \(G_i\) is the potential ecological harm index of a certain heavy metal element in farmland soil. \(Z\) is the potential ecological harm index of various heavy metals in the soil.

The ecological hazard assessment criteria are shown in Table 2.

| Ecological damage | Potential ecological harm index of single heavy metal element | Potential ecological harm index of various heavy metals |
|-------------------|---------------------------------------------------------------|-------------------------------------------------------|
| Slight            | <40                                                           | <150                                                  |
| Medium            | 40~80                                                         | 150~300                                               |
| Strong            | 80~160                                                        | 300~600                                               |
| Very strong       | 160~320                                                       | ≥600                                                  |
| Extremely strong  | ≥320                                                          | —                                                     |

Through the above classification standards, people should control the actual farmland soil heavy metal pollution risk and ecological harm, adjust in real time according to the assessment results, reduce the uncertainty of the assessment process, and ensure the safe use of farmland soil.

4. Experimental study

4.1. Survey of the test area and layout of sampling points
In this study, a large crop production base was selected as the test area, and one of the solar greenhouse and the open field near the greenhouse were taken as the test area. The centralized sampling area was
positioned with handheld GPS. The 0-20cm soil layer was collected from the sampling point at a certain distance, sealed and stored, and then brought back to the laboratory. During this period, a total of 12 soil samples were collected from solar greenhouse sampling points and open field sampling points. The distribution of collection points is shown in Figure 1.

![Figure 1. Test soil sample collection point.](image)

Table 3 shows the content of heavy metals in the soil collected at the sampling point of solar greenhouse, and Table 4 shows the content of heavy metals in the soil collected at the sampling point of open field.

**Table 3. Heavy metal content in soil of solar greenhouse**

| Sampling point number | Cd  | Cr  | Cu  | Pb  |
|-----------------------|-----|-----|-----|-----|
| A01                   | 0.12| 30.24| 25.57| 11.62|
| A02                   | 0.64| 42.06| 36.29| 17.62|
| A03                   | 0.42| 41.40| 36.96| 15.45|
| A04                   | 0.47| 37.64| 28.40| 15.55|
| A05                   | 1.10| 25.48| 36.42| 32.24|
| A06                   | 0.38| 62.50| 24.10| 23.48|

**Table 4. Heavy metal content in open field soil**

| Sampling point number | Cd  | Cr  | Cu  | Pb  |
|-----------------------|-----|-----|-----|-----|
| B01                   | 0.28| 33.25| 26.88| 18.55|
| B02                   | 0.61| 46.76| 26.61| 20.38|
| B03                   | 0.41| 38.99| 29.78| 14.03|
| B04                   | 0.44| 34.33| 34.54| 16.88|
| B05                   | 0.59| 22.96| 31.49| 28.85|
| B06                   | 0.44| 35.50| 33.88| 32.15|

The data in Table 3 showed that the contents of heavy metals Cd and Cu in the soil were higher than the corresponding soil background values. Among them, the content of heavy metals Cd exceeded the limit of the Soil Environmental Quality Risk Control Standard for Agricultural Land (Trial) (GB 15618-2018). The data in Table 4 showed that the background value of heavy metals Cd was high, among which, the content of Cd in some soils exceeded the limit of the Soil Environmental Quality Risk Control Standards for Agricultural Land Pollution (Trial) (GB 15618-2018), while the other three heavy metals did not exceed the limit. In the following, the actual situation mentioned above is taken as the test standard, and different evaluation methods are used for test comparison.

4.2. Analysis of test results

In this study, the falsity of the assessment method was taken as the assessment standard. In the same environment, different ecological assessment methods were used to evaluate the sampling points. The
Test results were compared with the actual pollution levels to analyze whether the different ecological assessment methods were reliable. In the meantime, the calculation is carried out according to the sampling points respectively, and the specific results are shown in Table 5.

| Serial number | An evaluation method based on grey clustering | The evaluation method proposed in this paper |
|---------------|---------------------------------------------|---------------------------------------------|
|               | Cd   | Cr   | Cu   | Pb   | Cd   | Cr   | Cu   | Pb   |
| A01           | III  | III  | III  | I    | II   | 0    | 0    | 0    |
| A02           | III  | I    | 0    | I    | III  | 1    | 0    | 1    |
| A03           | IV   | II   | 0    | II   | II   | 1    | 1    | 1    |
| A04           | IV   | II   | I    | II   | III  | 1    | 1    | 0    |
| A05           | II   | 0    | II   | I    | II   | 0    | 1    | 1    |
| A06           | III  | III  | III  | II   | II   | 0    | 0    | 0    |
| B01           | IV   | I    | 0    | II   | I    | 0    | 0    | 0    |
| B02           | II   | II   | I    | II   | III  | 1    | 0    | 0    |
| B04           | III  | I    | 0    | II   | II   | 0    | 1    | 0    |
| B05           | IV   | 0    | II   | II   | I    | 0    | 0    | 1    |
| B06           | III  | I    | 0    | IV   | II   | 0    | 0    | 0    |

In Table 5, 0 means clean, I means slight pollution, II means moderate pollution, III means strong pollution, and IV means very strong pollution.

According to the actual distribution of soil heavy metal content, more than half of the solar greenhouse soil samples Cd content reached a medium pollution level, other heavy metal elements were in a clean state. In the open field soil samples, the content of Cd in the soil at all sampling sites reached mild to strong contamination levels, while other elements were in a clean state. Analysis results of table 5 shows that two methods of evaluation on Cd elements of assessment more accurate, for the other three elements, based on the grey clustering evaluation method to evaluate the pollution index is high, seriously polluted, do not tally with the actual situation, and the paper design evaluation method of pollution index is low, its basic in clean and level, compared with the actual situation. To sum up, the ecological assessment method of heavy metal risk in farmland soil designed in this paper is closer to the reality, with a very low degree of false assessment and higher reliability. This method is superior to the traditional assessment method based on grey clustering.

5. Conclusion
This paper focuses on the study of soil heavy metal pollution, mainly analyzes the ecological harm of farmland soil heavy metal pollution, and evaluates the degree of soil heavy metal pollution and ecological harm. It provides a new method for risk assessment of heavy metal pollution in farmland soil. Heavy metal pollution in farmland soil is very harmful, and corresponding protection and remediation measures should be implemented.

References
[1] Chen W P, Yang Y, Xie T. Challenges and Countermeasures for Heavy Metal Pollution Control in Farmlands of China. Journal of soil, 2018(2): 261-272.
[2] Zhou X. Research progress of passivation remediation technology for heavy metal pollution in farmland soil. Theoretical Research in Urban Construction, 2017(11): 224.
[3] Wu Z W, Zhang X Y. A review on remediation and safe utilization of heavy metal pollution in farmland soil in China. Construction Engineering Technology and Design, 2017(13): 5538.
[4] Chen S B, Wang M, Li B B. Current situation and problems of heavy metal pollution control in farmland soil in China. Earth Science Frontiers, 2019(06): 35-41.
[5] Xue L Y et al. Hazard and remediation technology of heavy metal pollution in farmland soil. Agriculture and Technology, 2020(13): 41-42.