



## Comparison of soil environmental quality assessment and heavy metal pollution remediation plan

Quan Li

*Henan Institute of Technology, Henan, China, email: quanli912@163.com*

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### ABSTRACT

To realize the quality evaluation of the soil environment and the remediation of heavy metal pollution, firstly, the pollution sources and quality evaluation methods of the soil environment are analyzed and discussed through the research methods of searching literature and materials, comparison and actual investigation. Secondly, the common pollution sources in the soil and the remediation methods currently used are listed, and the solutions are proposed. Finally, the land conditions in area A are investigated on the spot, and the results show that copper (Cu), arsenic (As), and mercury (Hg) in the soil of area A are polluted to varying degrees. Through the soil environmental quality assessment, it is found that copper element is heavily polluted. Using chemical remediation methods and montmorillonite and kaolinite as modifiers can effectively increase the pH of the soil, which reduces the content of copper in the soil, realize the restoration of the soil in area A, and effectively control heavy metal pollution.

*Keywords:* Soil environment; Heavy metals; Pollution; Remediation plan; Quality evaluation

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### 1. Introduction

Soil is an important resource for human survival, and the food and oxygen sources needed for human life are almost all related to soil [1]. Therefore, the safety of the soil environment has always been a concerned by experts and scholars in China and other countries, as well as the government and the media. In recent years, soil pollution incidents caused by industrial development have occurred from time to time. The global soil problem is also intensifying, mainly manifested in two aspects: one is the shortage of land resources, and the other is the serious problem of soil pollution. The problem of soil pollution has attracted the attention of experts, scholars and environmentalists from all over the world. The environmental problems and food safety problems caused by soil pollution have also been paid more and more attention to [2]. Soil is the natural carrier for the disposal of pollutants, and most pollutants are disposed

of in the soil finally. The wastewater, waste gas and solid waste produced in the process of industrial development eventually enter the soil and cause a serious impact on the soil environment. It will cause soil pollution when exceeds a certain limit. Especially in farmland soil, pollutants can continuously accumulate in the body through crop roots, enter the human body through the food chain, and ultimately cause harm to the human body. Therefore, soil pollution has become a worldwide problem, especially heavy metal pollution, which is difficult to degrade and easy to accumulate in the soil and has attracted more and more attention from experts and scholars in China and other countries [3].

The natural average content of heavy metals in soil and crust is originally very low, some of which are essential trace elements for plant growth. However, the large-scale use of pesticides and fertilizers and the excessive discharge of pollutants are mainly due to the landfill of garbage and sewage irrigation, which cause excessive heavy metals to

enter the soil, exceed the tolerance of the crops, and cause the crops to show symptoms of damage [4]. Heavy metals are not easy to be noticed by people in the initial stage of accumulation, which is a potential hazard. But once the toxic effect is more obvious, it is difficult to eliminate completely. In addition, heavy metals cannot be decomposed after entering the soil, and the transformation and enrichment of heavy metals are also difficult. Meanwhile, due to the complexity of the soil system, the treatment of soil heavy metal pollution has become very difficult. Soil is the direct source of nutrients for crops, so the degree of soil pollution is closely related to the quality of crops. If the important environment for the survival of crops—soil is polluted, it may lead to the accumulation of harmful substances in the crops [5].

To improve the environment of soil resources, relevant documents are consulted, the environmental quality of soil is investigated and evaluated in practice, and the pollution of heavy metal elements is studied. Remediation of soil areas heavily polluted by copper elements through chemical remediation methods has very important reference and guiding significance for areas with severely damaged soil conditions [6].

## 2. Method of soil quality assessment

### 2.1. Soil quality evaluation and current situation of remediation research

Soil pollution refers to pollutants produced by human activities that enter the soil in a variety of ways. The quantity and speed of pollutants exceed the capacity and purification speed of the soil and cause changes in composition and properties [7]. The accumulation process of pollutants gradually dominates, which destroys the natural dynamic balance of the soil and leads to the imbalance of the natural function and the deterioration of the quality of the soil. The result of soil pollution directly affects the growth and development of crops, results in a decline in the yield and quality of agricultural products, threatens human health through the food chain and reduces biodiversity. Soil pollution is concealed, latent, irreversible, and long-term, and causes a serious threat to social and economic development and human health. The investigation and research of soil pollution need to be carried out on the basis of grasping the background value of the soil environment [8]. The background value of the soil environment refers to the chemical composition or element content level of the soil when the soil is not or rarely affected by human activities.

### 2.2. Common methods of soil remediation

Soil remediation technology is a comprehensive technology involving multiple methods and multiple disciplines (Fig. 1). It usually costs a lot of money and has a long span of time and a high degree of social attention [9]. Physical, chemical, and biological remediation technologies all have strengths and weaknesses: physical remediation technology has a large workload, high energy consumption and requires specialized large-scale equipment, so the cost will be relatively high; Chemical remediation technology easily

destroys the ecological structure of the soil itself. Meanwhile, chemical remediation technology has high processing costs and the risk of secondary pollution; Biological remediation technology has a series of problems that the restoration process is slow, the toxicity of pollutant degradation intermediate products may exceed its own, and site conditions and environmental factors on the restoration efficiency and the restoration effect is unstable. The selection of remediation technology should be combined with the actual conditions of the contaminated site, economic costs, time period, later monitoring and other factors. For complex pollution, joint remediation technology can be used [10].

#### 2.2.1. Physical remediation technology

The physical remediation technology of soil pollution refers to the technology that separates or removes pollutants from the soil through physical means such as excavation, electric, and thermal desorption. Commonly used physical remediation technologies include soil replacement/incineration method, electrical remediation method, thermal desorption method, and gas-phase extraction technology. The physical remediation technology has the characteristics of the short cycle, wide application and simple operation [11,12]. However, physical remediation technology is prone to secondary pollution, destroys the internal ecological structure of the soil easily, and has high costs.

#### 2.2.2. Chemical remediation technology

Chemical remediation technology mainly reduces the mobility or effectiveness of pollutants by adding chemical amendments to the soil to absorb, dissolve, redox, complex or precipitate pollutants in the soil. Commonly used chemical remediation technologies are solidification/stabilization technology, soil leaching technology, chemical dehalogenation technology, and chemical oxidation/reduction technology, etc.

#### 2.2.3. Biological remediation technology

Biological remediation technology refers to relying on biological activities to reduce the concentration of toxic and harmful substances in the soil environment, so that the soil environment can be partially or completely restored to its original state. Commonly used biological remediation technologies are microbial remediation, animal remediation and phytoremediation [13].

## 2.3. Harm of heavy metal elements in soil

### 2.3.1. Arsenic (As)

As is generally listed as a possible biologically essential trace element. According to pot experiments, an appropriate amount of As can promote plant growth. For example, wheat, corn, cotton and soybeans are increased in production to stimulate the growth of rice and potatoes, radishes and peas, which play a role in optimizing varieties to a certain extent. Excessive As can easily cause plant poisoning. The initial symptom is that rolling up or withering of

leaves hinders the development of the roots. Furthermore, the tissues of the roots and leaves are destroyed and the plants die. As is used as a stimulant and strengthening agent to protect the body from the cold. A moderate amount of As can also promote the growth and development of poultry and livestock. Animals lacking As have slow growth, low immunity, and poor hair growth. Therefore, both humans and animals need As, but the required amount is less. The biochemical effects of excessive As in humans and animals are similar to the symptoms of poisoning. The main manifestations of excessive As are skin and mucosal lesions, common skin pigmentation, hyperkeratosis or verrucous hyperplasia, headache, muscle pain, fatigue and weakness. Excessive As can also cause skin cancer, lung cancer, neurasthenia and neuritis in some severe cases.

### 2.3.2. Cadmium (Cd)

Cd is considered a non-essential element for biology. But in the case of extremely low concentrations, Cd may also have the effect of stimulating the growth and development of organisms, which is conducive to the survival and development of life systems. Under normal conditions, Cd in the soil tends to be at a lower concentration than other elements, which has fewer toxic effects on plants. The main effect of Cd on human health is to inhibit the biochemical activity of a variety of enzymes and lead to proteinuria, diabetes and edema. It affects the calcium metabolism of bone, softens, deforms or fractures the bone, and causes bone pain. It is also easy to cause miscarriage, neonatal disability and death and leads to anemia or hypertension. Cd poisoning can also lead to the induction of bone cancer, rectal cancer, esophageal cancer and gastrointestinal cancer, necrosis of the testis, and affect the normal function of sex.

### 2.3.3. Mercury (Hg)

Hg is a toxic element with no biological effects on animals, plants and humans. When the content of Hg in the soil is too high, it will be harmful to plants and the leaves and stems will turn brown or black. In severe cases, the leaves and young buds will fall off and some plants will become shorter in height and the root system will not develop well. The human body can absorb mercury and its compounds through the respiratory tract, digestive tract or skin. Inorganic mercury is distributed in the body with the highest content in the kidney, followed by the liver, heart, and brain. The absorption rate of organic mercury in the digestive tract is very high. Organic mercury quickly degrades into inorganic mercury after entering the human body, so its distribution is the same as that of inorganic mercury.

### 2.3.4. Lead (Pb)

The Pb element in plants mainly affects the yield and quality of crops. When the concentration of Pb is low, it can stimulate certain plants. When the concentration is high, it can cause seedlings to shrink, grow slowly, edible parts remain toxins, and yield declines or even no harvest. Pb is not an essential element for the human body, its toxicity is hidden and effect is slow. After being absorbed, Pb

circulates in the blood. Except for the storage in the liver, spleen, kidney, brain and red blood cells, most of Pb exists in the bones as stable insoluble phosphates. The main manifestation of the toxicity of Pb to the human body is mental disorders and anemia caused by the absorption of small doses of Pb. Pb poisoning can cause arterial hypertension and renal insufficiency. Children are more sensitive to Pb than adults and are more susceptible to lead-induced encephalopathy.

### 2.3.5. Chromium (Cr)

Whether Cr is necessary for plants has not been confirmed, but it is one of the essential trace elements for the human body. The average content of Cr in the human body is 6.2 mg, and the normal per capita intake is 0.05–0.15 mg/d. Cr is widely distributed in various organs, tissues and body fluids in the body and is a necessary substance to maintain the metabolism of human sugar and fat. The proper amount of Cr helps the decomposition and excretion of cholesterol, and prevents coronary heart disease and atherosclerosis. Cr deficiency can lead to increased cholesterol content and shorten life, sweetness, make people more likely to lead to obesity, and severely cause diabetes and atherosclerosis.

### 2.3.6. Nickel (Ni)

Ni is an essential nutrient element for higher plants, but Ni is also a toxic element in excess. The concentration and distribution of Ni in the soil are affected by the parent material of the soil. The absorption of Ni by plants depends on the characteristics of the soil, the form of Ni and the characteristics of the plants.

### 2.3.7. Copper (Cu)

Cu participates in the photosynthesis of plants and is related to the formation of chlorophyll. Cu is absorbed by plants in the form of  $\text{Cu}_2^+$  and  $\text{Cu}^+$ . Cu catalyzes the redox reaction of plants, promotes the metabolism and synthesis of carbohydrates and proteins, and greatly enhances the cold and drought resistance of plants. Cu participates in the respiration of plants, affects the utilization of iron by crops, and can also avoid premature destruction of chlorophyll, which is beneficial to photosynthesis. When plants are lacking copper, the chlorophyll decreases, the leaves become chlorosis, the tips of the young leaves become yellow and dry, and finally the leaves fall off and the development of reproductive organs is destroyed.

### 2.3.8. Zinc (Zn)

Zn is one of the essential trace elements for living things. Zn is absorbed by plants in the form of  $\text{Zn}_2^+$  and promotes the healthy growth of branches and leaves. In nitrogen metabolism, Zn can well change the ratio of organic nitrogen to inorganic nitrogen, improve drought resistance and low temperature resistance, participate in the production of chlorophyll, prevent the degradation of chlorophyll, and form carbohydrates. When the plant is zinc-deficient, the leaves are chlorosis, photosynthesis is weakened, the internodes are shortened, the plants are short, the growth

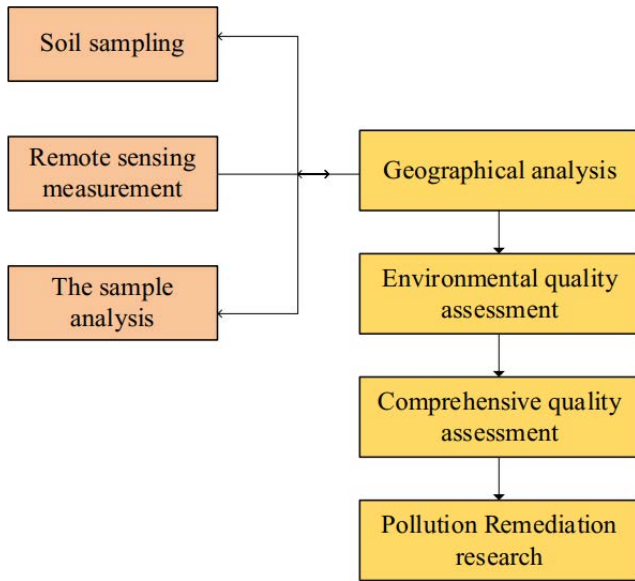


Fig. 1. The specific process of soil remediation.

is restricted, and the yield is reduced. Zinc deficiency in rice is manifested as “rice shrunken seedlings”, and zinc deficiency in fruit trees will make the leaves chlorosis, and small leaves and clusters often appear at the tip of the branches [14].

Table 1 shows the common heavy metal elements in soil and the main sources of pollutants.

2.4. Assessment of soil environmental quality

According to the standard value of soil pH grading, the environmental geochemical grade of soil pH is divided. According to the soil single pollution index, the environmental geochemical grade is divided into limit values. The secondary standard value of the element is obtained, and the individual pollution index  $P_i$  of each element is calculated. Then the single index soil environmental geochemical grade is divided, and the formula of the individual pollution index  $P$  in the soil pollutant  $i$  is calculated.

$$P_i = \frac{Q_i}{W_i} \tag{1}$$

where  $Q_i$  represents the measured concentration of index  $i$  in the soil, and  $W_i$  is the second-level standard value of the pollutant. Table 2 shows the standard values of soil environmental quality.

2.5. Research ideas

- Various existing geological data and results have been fully collected, sorted out, analyzed, and researched, including basic geology, minerals, hydraulic engineering, geochemistry, planning, and agriculture. Various types of hydraulic and environmental geological survey data and geochemical survey data are collected emphatically.
- Satellite and aerial remote sensing data processing technologies are used to pre-interpret regional geology, structure, geomorphology, environmental pollution, land use, and agricultural planting, etc. Then effective information is fully extracted, and the change data of the second national soil survey are updated in time.
- Various pollution sources that affect the geological environment are studied, the sources of pollution are tracked, the impact of pollution on industrial and agricultural production and residents’ lives is analyzed, and the pollution trend is predicted.
- In the administrative area, the top soil with the focus on cultivated land is used as the research object, and all land use types and soil types involved are covered. The sampled information data are imported into the current land use map, and the representativeness and rationality of the sampling points in the information system are analyzed.

Table 2  
Grade II standard value of soil environmental quality

| Element | pH < 6.5 | 6.5 < pH < 7.5 | pH > 7.5 |
|---------|----------|----------------|----------|
| As      | 40       | 30             | 25       |
| Cd      | 0.3      | 0.3            | 0.6      |
| Hg      | 0.3      | 0.5            | 1        |
| Pb      | 250      | 300            | 350      |
| Cr      | 150      | 200            | 250      |
| Ni      | 40       | 50             | 60       |
| Cu      | 50       | 100            | 100      |
| Zn      | 200      | 250            | 300      |

Table 1  
Main pollution sources of heavy metal elements in soil

| Element | Origin   |
|---------|--|
| As      | Residues containing As pesticides, sulfuric acid, pharmaceuticals, and biological wastewater |
| Cd      | Industrial wastewater and residues from smelting and electroplating                          |
| Hg      | Alkali industry wastewater, residue and mercury vapor  |
| Pb      | Industrial dyes, gasoline emissions and Pb-containing fertilizers                            |
| Cr      | Leather, electroplating and smelting industrial wastewater sludge                            |
| Ni      | Industrial dyes, electroplating and steelmaking industrial wastewater sludge                 |
| Cu      | Copper smelting industrial wastewater and Cu-containing pesticides                           |
| Zn      | Electroplating, dye industry wastewater sludge and Zn-containing fertilizer                  |

- Modern analytical testing equipment and technology are fully utilized, samples are analyzed and tested, and the quality of laboratory work is monitored through repeated samples and password samples.
  - Information technology and database technology are comprehensively used, and test results are analyzed and counted. The soil environmental quality level is evaluated, and the level and scope of pollution of various elements in the soil are extracted.
  - The principles and methods of currently more mature soil remediation technology are compared, and typical contaminated areas are selected. The best soil remediation technical plan is proposed after optimization, and economic and technical conditions are analyzed [15].
- Fig. 2 shows assessment of soil quality and the specific process of the heavy metal remediation plan in area A.

### 3. Comparison of soil quality evaluation and heavy metal pollution remediation

#### 3.1. Analysis of soil environmental quality evaluation results

According to the above evaluation method, Fig. 2 shows the evaluation results of the single index environmental quality grade of soil in area A.

The calculated  $P_i$  is compared with the data in Table 2 to know the soil environmental grade in the area. Fig. 3 shows the classification of soil environment according to different pollution levels.

Fig. 3 shows that among the 8 evaluation elements in the surface soil of the study area, except for Cu, the cleanliness level accounts for more than 90% of the area, and the cleanliness to light pollution level accounts for more than 99%. Except for the elements of Cu and Hg, there is only a certain degree of light pollution locally, accounting for less than 0.44%, and there is no moderately and heavily polluted surface soil. As element exists in certain moderately polluted areas locally, accounting for 0.42%. Hg element also exists in certain moderate and above polluted areas, which account for 0.44%. These indicate that most areas of the As and Hg elements in the surface soil are basically unpolluted, and only a slight to severe pollution of about 0.40% of the area exists locally. Cu element has the largest polluted area among the eight indicators, and its light, moderate, and severely polluted areas account for 8.55%, 1.77%, and 0.08% respectively, and the total of the three is 10.4%. The distribution area of Cu element cleanliness level accounts for 84.07%. Although Cu is the smallest compared to other elements, it still accounts for a larger proportion of the total area. This indicates that most of the Cu element in the surface soil of the study area is basically unpolluted, but locally exists 10.61% of the area is polluted to varying degrees. The above analysis shows that most of the surface soil in the study area is not polluted by heavy metals and will not cause damage to plants and the environment.

#### 3.2. Remediation plans

Table 3 shows the comparison of the effects of using three groups of chemical remediation plans to treat heavy metal pollutants in area A.

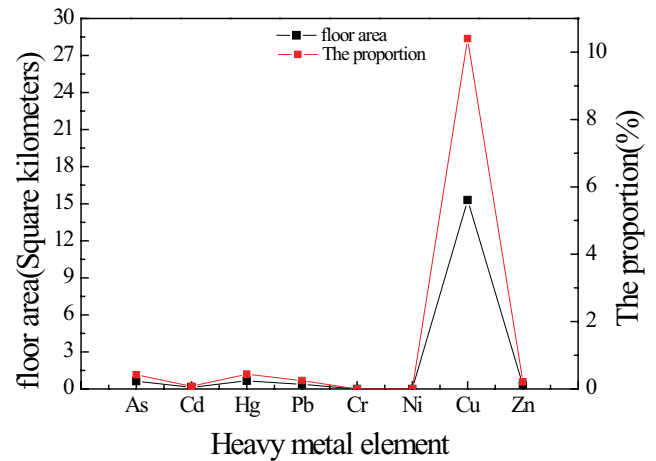


Fig. 2. Statistics on the proportion of soil area of general pollution and above in area A.

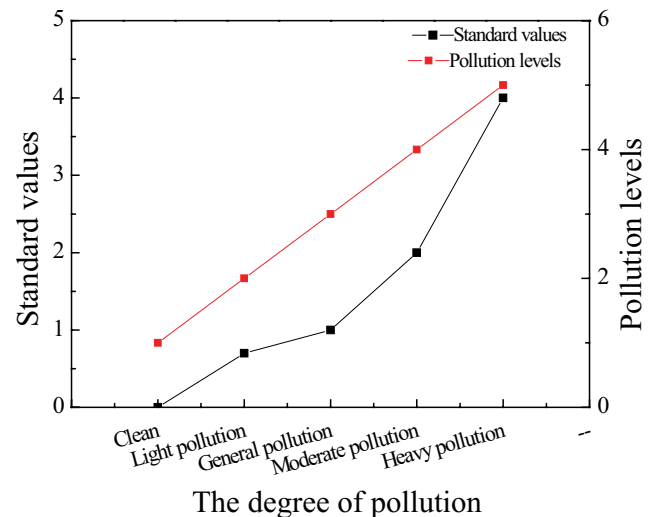


Fig. 3. Classification of soil environment.

The experimental results show that the use of modifiers nano-montmorillonite and kaolinite has a good removal effect on Cu in the solution. In contrast, montmorillonite has higher adsorption capacity and adsorption affinity parameters than kaolinite. Under the three acidification measures, the exchange state, carbonate state, iron-manganese oxide combined state and organic state of Cu in the soil all increase with the decrease of pH, while the residual state is the opposite. As the effective state increases, the plant's absorption of Cu gradually increases. Montmorillonite and kaolinite are added respectively, the effectiveness of Cu can be effectively reduced, so that the effective state of Cu is converted to the residual state and the absorption of Cu by plants is hindered. The land in area A is mainly acid soil, and nano-type kaolinite and montmorillonite have a good removal effect on dissolved Cu. Therefore, when the soil is in a saturated state, chemical remediation technology is used and nano-kaolinite or montmorillonite is added to reduce the effectiveness of Cu and achieve the purpose of soil remediation.

Table 3  
Remediation plans and effect comparison

| Remediation plans                        | Pollutants | Remediation effect   |
|--|------------|--|
| Improver<br>(montmorillonite, kaolinite) | Cu         | Soil pH is significantly increased, and the Cu content in the soil solution is reduced   |
| Cathodic control fluid                   | Cu         | Low-molecular weight organic citric acid can effectively enhance the mobility of metal ions and accelerate the absorption of Cu elements |
| Improver (animal feces)                  | Cu         | pH of the soil is significantly increased, but it can only be maintained for about a year  |

#### 4. Conclusions

To evaluate the quality of China's soil environment, soil contaminated by heavy metals is restored, and soil pollution sources and quality evaluation are briefly summarized. Meanwhile, the hazards of heavy metal elements are briefly introduced, and a plan for soil environmental quality assessment and heavy metal pollution restoration is formulated based on the actual situation. Area A is used as an actual experimental field for testing. It is found that the Cu element pollution in the soil in Area A is the most serious, and the chemical remediation method is the most effective way to prevent it. The shortcoming is that how to accurately determine the ratio of kaolinite and montmorillonite in soil remediation technology needs to be further studied. Meanwhile, the heavy metal pollution in area A is only Cu element, and more heavy metal pollution remediation plans need to be further studied by scholars.

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