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Effect of Different Soil Amendments on Quality Improvement of Chemically Contaminated Soil Based on Biological Evaluation Method

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Chemical contamination is an important issue for large-scale soils in China, especially the contamination of chemical heavy metals. Under this background, this paper focuses on the experimental method to explore the effects of two soil amendments (lime and phosphate) on reducing soil heavy metal activity and improving soil quality. In this paper, the biological evaluation method was used to test the effects of different soil amendments by taking the soil conductivity, chlorophyll and heavy metal content in the plant as the main evaluation indicators. The research results show that the effect of different soil amendments is greatly related to the concentration of the soil amendment solution, of which 5% of lime water can effectively reduce the activity of heavy metal *Zn* in soil, but not effective on *Pb*; the concentration 7.5% of the phosphate solution can effectively reduce the activity of heavy metal *Pb* in soil but cannot reduce the activity of *Zn*. This provides an effective solution to the problem of heavy metal pollution in Chinese soil chemistry, especially the pollution of *Pb* and *Zn*.

1. Introduction

Soil is one of the natural resources that human beings rely on, and it is also a typical non-renewable resource (Alvarenga et al., 2008). The level of soil quality, or the composition of chemical elements in the soil, can seriously affect the output quality and quantity of the plants, and further endanger human health and survival (Cowan, 1976). According to surveys of land pollution in vast areas of China, the main threat to soil quality in China is chemical contamination, in which the most typical is heavy metal contamination. The sources of heavy metal contamination are diverse, including the exploitation of human mineral resources (Falloon, 1987), the combustion of energy resources such as oil and coal (Bailey, 2008), the use of phosphate fertilizers, lead-containing or mercury-containing pesticides, and non-standardized use of animal feed (Ren et al., 2007) etc. Just because of the above factors, in China there is more than 15% of the soil chemical heavy metal content exceeded, esp., excessive *Pb*, *Zn*, which has seriously affected China's grain yield and quality, and the annual direct food loss caused by chemical heavy metal pollution reaches more than 10 million ton. In addition, the contamination of chemical heavy metals in soil is not easy to control, and it has the characteristics of spreading with rainwater, seriously endangering human health, and leading to various diseases and deformities (Hall and Grossbard, 1972; Grandlic et al., 2009;). Therefore, how to prevent soil from chemical heavy metal pollution, especially how to treat large areas of soil that have been contaminated, has become one major difficulty for scientists. In this context, this paper attempts to explore the effect of lime and phosphate amendments on soil chemical heavy metal pollution through experiments, so as to provide theoretical ideas and practical basis for the management of soil pollution in China.

2. Amendment repair technology of Soil chemical contamination

The soil, as one ecological system, has certain self-recovery capacity (Hirth et al., 1997; Ike, 2018; Xie and Xiao, 2018). That is, within certain range, the soil can decompose pollutants into harmless chemical substances with the help of microorganisms. However, when the pollution reaches a certain level, the self-

recovery capacity of soil won't be able to function properly, and thus the external forces must be used (Korthals et al., 1998).
Currently, the chemical heavy metal contamination control of soil by external forces is mainly divided into physical and chemical methods. The physical method refers to the total replacement of contaminated soil. This method is only applicable to small contaminated plots, and therefore has limited scope and effectiveness (Webster and Dowdell, 1985). Chemical method refers to the use of soil amendment to repair soil. The principle is to add chemical agents to the soil, reduce the activity of heavy metal elements through the adsorption and precipitation of chemical agents, and ultimately reduce the harmful effects of heavy metals (Falloon, 1985; Zhang et al., 2018). In view of the current situation, chemical methods using amendments have the characteristics of quick response and large-area use, so it's more widely accepted.
There are many types of chemical soil amendments, which can be divided into organic amendment, microbial amendment, and inorganic amendment etc. For different types of amendments, the chemical element contents also vary, so they're suitable for the treatment of different types of chemical heavy metal contamination from the perspective of chemical reactions (Middleton and Smith, 1979). It's mentioned in Chapter 1 of this article that the heavy metal contamination in China's soil is mainly *Pb* and *Zn* pollution. Therefore, in order to achieve better experimental results and comprehensively consider the difficulty of interaction between different chemical elements, this paper mainly selects lime (*CaO*) and phosphate (M_3PO_4) as target amendments.

3. Experimental method

3.1 Evaluation method of soil treatment effect

The evaluation methods of soil treatment effect can be divided into three types: chemical evaluation method, biological evaluation method, and microscopic detection and evaluation method (Jarvis and Jones, 1987). Among them, the chemical evaluation method refers to the separation of soil in chemical reagents, the detection of the content in different chemical components to observe whether meet the appropriate proportion; biological evaluation method refers to the use of living organisms, such as plants, to directly detect whether the soil is still contaminated by heavy metal contamination; if the plant is in good condition and no contaminants are detected in the fruit, it proves that the treatment effect is good; the microscopic evaluation method is to study the chemical heavy metal pollutant and judge whether it's still active in the soil by scanning electron microscope and X-ray method.
Considering that China's major chemical heavy metal contaminated soil belongs to farmland, the soil amendment must be able to remove the vitality of heavy metal elements, but cannot hinder the normal growth of plants, thus, in this paper, the biological evaluation methods was mainly used for evaluating soil treatment effects.

3.2 Experimental soil and contamination degree

The experimental soils in this paper were from the main grain-producing areas in Henan Province and Jiangsu Province. They were labelled as *HENAN* and *JIANGSU*. After testing, it's found that the contents of Pb and Zn in experimental soils of both provinces were significantly higher than normal values.

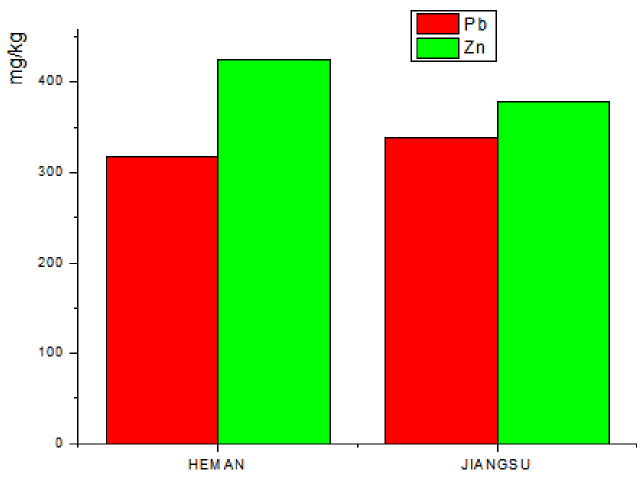

Figure 1: Heavy metal content in soil before experiment

4. Effect of different soil amendments on the quality improvement of chemically contaminated soil

In this paper, the lime water and phosphate solution with 2.5%, 5% and 7.5% content were mainly used respectively for the contaminated soil in the 6-month experiment, and the biological evaluation method was adopted to test its effect after the experiment. For the biological evaluation method, the selected plant was rape, and the test indicators included soil conductivity, chlorophyll and heavy metal content in the rapeseed. Before the experiment, the soil was divided into two groups: experimental group and control group. In the experimental group, the soil amendment was added, while in the control group, no operation was performed.

4.1 Effect of lime on chemical heavy metal contaminated soil

4.1.1 Effect of lime water with different concentrations on soil conductivity

The soil conductivity is the important information that reflects the plants growing environment (Bailey, 1991). Within a certain range, the increase in conductivity indicates an improvement in the growth environment. From the experimental results, regardless of soil from Henan or Jiangsu, the electrical conductivity of the soil sample in the experimental group was increased with the extension of the experimental period, but the conductivity of the sample added with 7.5% lime water exceeded the critical value of 2.4*μs/cm* at the end of experiment, indicating that 7.5% lime water shall damage the conductivity of the soil and is not suitable for use as a soil amendment.

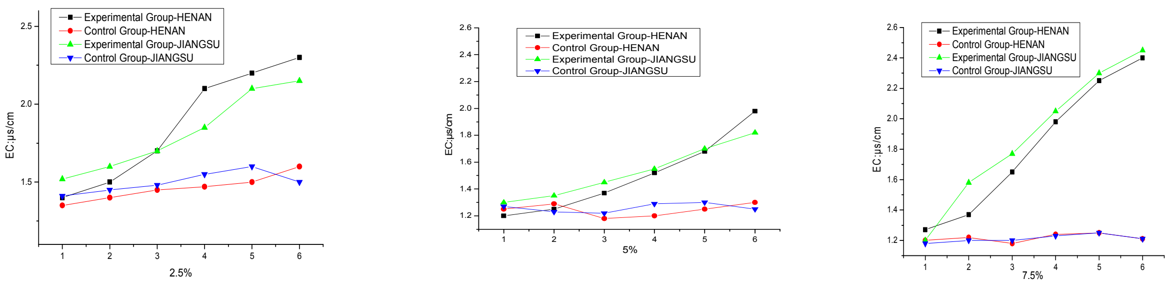

Figure 2: Electrical conductivity testing

4.1.2 Detection of chlorophyll content in plants

Chlorophyll content is an important indicator for the quality of plant growth (Grigatti et al., 2017). The experimental results showed that the changes in chlorophyll content of oilseed rape produced by the experimental group were not consistent. Compared with the control group, with 2.5% lime water as the soil amendment in the experimental group, there was no significant difference in the chlorophyll content of rapeseed; with 7.5% lime water in the experimental group, the chlorophyll content of rapeseed was significantly decreased; Only with 5% lime water as a soil amendment in the experimental group, the chlorophyll content of rapeseed was significantly increased. Thus, in terms of chlorophyll content, 5% lime water is more suitable as a soil amendment.

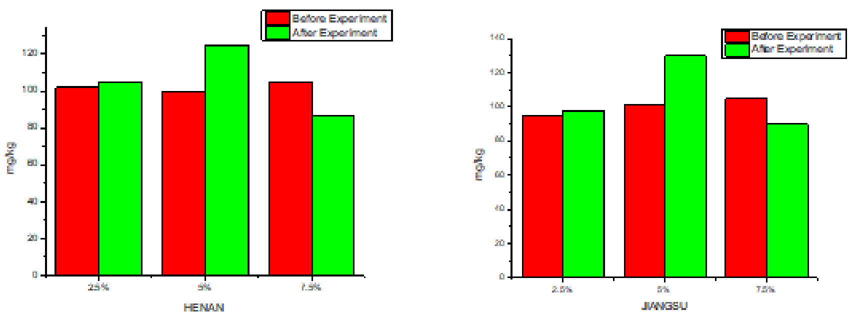

Figure 3: Chlorophyll content

4.1.3 Detection of heavy metals in plants

Pb and Zn content in plants can be directly used to measure the quality of plant growth. The experimental results indicate that lime water with different concentrations as the soil amendment has a significant reduction effect on the *Zn* content in plants, of which 5% lime water has the most significant effect. However, lime water has no significant effect on reducing *Pb* content in plants. There was no significant difference in *Pb* content between the experimental and control plants, which indicates that lime water is more effective in reducing *Zn* in soil, but not effective in reducing *Pb* in soil.

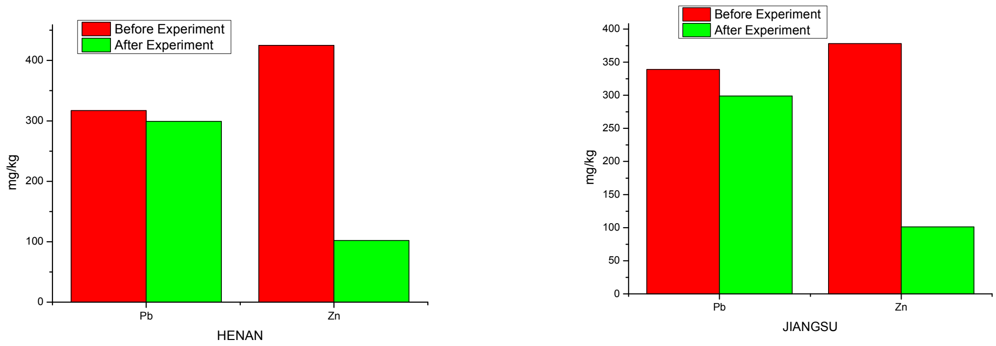

Figure 4: Heavy metal content in soil after experiment

4.2 Effect of phosphate on chemical heavy metal contaminated soil

4.2.1 Effect of different concentrations of phosphate on soil conductivity

The experimental results showed that the conductivity of the soil samples in the experimental group had different trends with the concentration of the phosphate solution. At the concentration of 2.5%, the soil conductivity in the experimental group did not change significantly. At 5% and 7.5% concentrations, soil conductivity increased as the experiment progressed, with conductivity increasing faster at 7.5% concentration. This indicates that in terms of electrical conductivity, 2.5% phosphate solution is not suitable for passivation, and 7.5% phosphate solution has the best passivation effect.

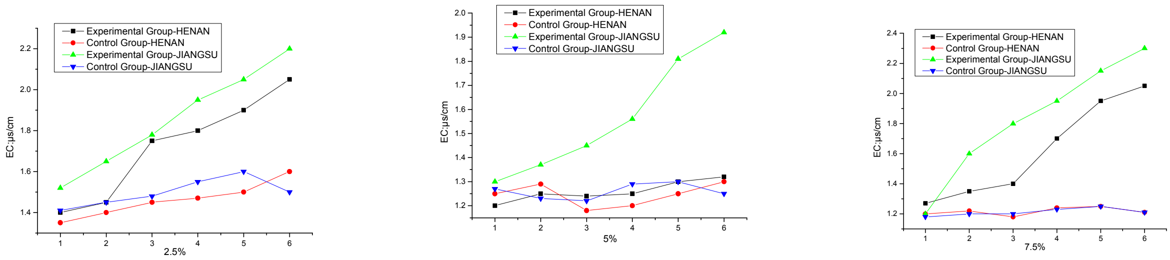

Figure 5: Electrical conductivity testing

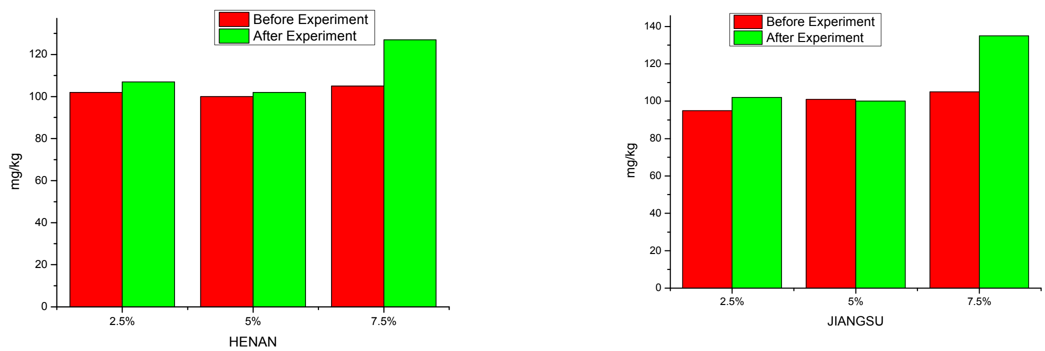

Figure 6: Chlorophyll content

4.2.2 Detection of chlorophyll content in plants

The experimental results showed that the chlorophyll contents of the plants in the experimental group changed inconsistently. Compared with the control group, with 2.5% and 5% phosphate solution as the soil amendment in the experimental group, there was no significant difference in the chlorophyll content of rapeseed; only with 7.5% phosphate in the experimental group, the chlorophyll content of rape increased significantly. In terms of chlorophyll content, 7.5% phosphate solution is more suitable as a soil amendment.

4.2.3 Detection of heavy metals in plants

The experimental results show that the phosphate solution significantly reduces the *Pb* content in the plant, and 7.5% of the phosphate solution has the most significant effect. However, it has no significant effect on reducing the *Zn* content in plants. There was no significant difference in Zn content of plants between the experimental group and control group, which indicates that phosphate is more effective in reducing Pb in soil, esp. at the concentration of 7.5% it has the best effect, but it's not effective on reducing Zn in soil.

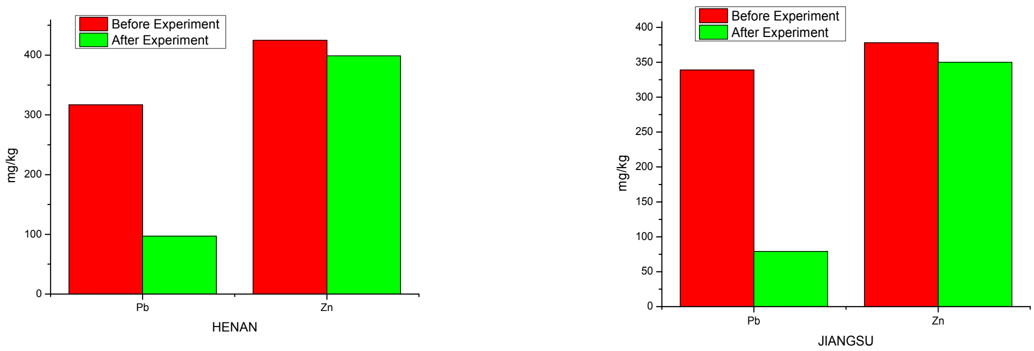

Figure 7: Heavy metal content in soil after experiment

5. Conclusions

In order to alleviate the heavy metal contamination in soil, this paper mainly studies the effect of two soil amendments (lime and phosphate) on reducing the activity of *Pb* and *Zn* in soil and improving soil quality by using the chemical evaluation method. The main conclusions are as follows:

(1) The soil amendment does have the effect of reducing soil heavy metal activity and improving soil quality, which largely depends on the type and concentration of the soil amendment.

(2) The lime can reduce the activity of heavy metal *Zn* in soil, and the effect is best at the concentration of 5%, but it cannot reduce the activity of *Pb* in soil.

(3) Phosphate can reduce the activity of heavy metal *Pb* in soil, and the effect is best at the concentration of 7.5%, but it cannot reduce the activity of *Zn* in soil.

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