Changes of soil physical and chemical properties and heavy metals after planting different plants

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Abstract. Through pot experiments, the changes of soil total nitrogen, available potassium, available phosphorus, organic matter, and pH, and the contents of heavy metals in the tested soils before and after planting were analyzed. The result showed that: Compared to before planting, the soil total nitrogen, organic matter, available phosphorus, and available potassium decreased in turn. The total nitrogen decline of soybean soil was the largest, and the organic matter decline of tomato soil was the largest. The decrease of soil Cd and Cr is obvious, Pb is the second, and the decrease of other heavy metals is less than 10%. The overall decline in heavy metals in tomato soil was the largest, followed by clover, and soybean the smallest. Correlation analysis showed that soil total nitrogen and organic matter were significantly positively correlated with Cd, and available potassium was significantly positively correlated with Cr. Increasing soil nutrient content can promote the effect of plants on soil heavy metal remediation.

1. Introduction

Urban soil is an important part of the urban ecological environment. It is the material basis on which human beings, animals and plants live, and plays an important role in maintaining the quality of human living environment and urban ecological functions [1,2]. Soil pollution refers to that human activities bring pollutants into the soil, causing the pollutants content in the soil to be significantly higher than the original content, and causing the deterioration of the ecological environment [3,4]. The Weidong New City project area is located in the fringe area of the eastern part of Weinan City, surrounding by many polluting enterprises such as chemical plants, medical waste disposal plants, and commercial stations [5-7]. Preliminary investigation showed that there was potential heavy metal pollution risk in the soil around the chemical plant [8,9]. Therefore, it is urgent to improve the urban soil pollution.

Studies show that different types of plants have certain effects on heavy metal absorption and enrichment [10,11]. Studies by Li Minghong [12] showed that soybean has better tolerance to cadmium contaminated soil, and the rhizosphere has a better absorption and enrichment effect on Cd. Studies by
Bian Wei [13] showed that the enrichment coefficient of heavy metals in soil by soybean was Cd > Cu > Zn > Pb. Pang et al [14] showed that tomatoes could absorb different levels of heavy metals in soil at different growth stages, and Cd was absorbed most in normal soil. Sun Nan et al [15] showed that clover has a certain removal effect on Cr, Pb, Cd and Hg in gold mine tailings soil. Dong Jifei et al [16] showed that the application of nitrogen fertilizer under cadmium stress could help clover to absorb Cd.

Existing studies have focused on the absorption and enrichment of different heavy metals by a single plant, while few comparative analyses have been conducted combining three types of plants, and most of them have not explored the correlation between soil physical and chemical properties and changes in heavy metal content. Therefore, this paper selects the soil around the chemical plant in the Weidong New City project area as the test soil, and selects clover, tomato and soybean as the test plants to analyze the heavy metal pollution status and the contents of soil heavy metals after planting three plants and its relationship with physicochemical properties, to provide some reference for the construction planning and treatment and restoration of the later project area.

2. Materials and Methods

2.1. Test materials
The test soil was selected from grassland soil around the Weidong Xincheng Chemical Plant, the sampling point were 34°29′52″, 109°32′43″, after removing surface stones, weeds and plant roots, a total of 50 kg of 5-30 cm surface soil was collected. Determined by laboratory, the tested soil pH was 7.87, slightly alkaline, and the initial nutrient content was 2.09 g/kg of total nitrogen, 600 mg/kg of available potassium, 11.06 mg/kg of available phosphorus. Also, the soil from the area without artificial interference was collected as a control, the sampling point were 34°30′11″, 109°33′11″.

2.2. Test design
Tomatoes, soybeans and clover were selected. The soil samples were naturally air-dried through a 5mm sieve and then placed in pots, 3 treatments, totally 9 pots. Each pot maintains a total weight of 3.5 kg and was compacted naturally. Selecting seeds that were full and uniform in size and free of insect bugs for seedling breeding. The seed burial depth was 1-2 cm. One week after emergence, the robust plants were selected for transplantation. The test site was located in the greenhouse of Qinling Field Monitoring Station of Shaanxi Provincial Land Consolidation Engineering Technology Research Center. Seedlings were raised on April 30, 2018, and harvested around July 10, and the temperature in the greenhouse changed from 25 to 35 °C. Irrigation was carried out at the right time every day.

2.3. Index determination
Four soil samples were drilled with 2 cm diameter soil in each pot, air dried and grinded them after mixing, then passed through 2 mm, 1 mm and 0.149 mm sieve to be tested. The soil nutrient content, organic matter, pH and 8 heavy metal contents before and after the tomatoes, soybeans and clover harvest were measured. Soil pH was measured by DELTA 320 pH meter (water-soil ratio 2.5:1). Organic matter was measured by potassium dichromate titration. The available potassium content was determined by 1 mol/L ammonium acetate extraction-flame photometer method. Available phosphorus content was determined by 0.5 mol/L sodium bicarbonate extraction-molybdenum antimony colorimetry. Total nitrogen was determined by Kjeldahl. Heavy metals Cr, Ni, Cu, Zn, Pb and Cd were measured by ICP-MS. Hg and As were measured by atomic fluorescence method.

3. Results and analysis

3.1. Changes in soil nutrient content before and after planting
As shown in Figure 1, pH of the tested soil after harvest was 7.87~7.90, which was not significantly changed compared with that before planting. Soil organic matter (SOM) was 31.50 g/kg before planting, but decreased after harvest, with an average decrease of 9.4%, followed by tomatoes (12.5%)> soybeans
(9.4%) > clover (6.3%). After harvesting the three plants, the average total nitrogen content of was 1.82 g/kg, with an average decrease of 13.3%. The maximum decline in total nitrogen content in soybean soil was 15.6%, followed by tomatoes, 14.1%.

After harvest, the available potassium content had the smallest average decrease of 6.3%, of which the fastest available potassium content reduction was 8.4% for planting clover. The average content of available phosphorus in the soil after harvest was 9.79 mg/kg, with an average decrease of 9.1%. There was no significant difference in the soil available potassium decline after planting the three plants.

### 3.2. Changes of heavy metal content in soil before and after planting

The contents of heavy metals in the tested soil before planting were shown in Table 1. According to the risk control standard for soil contamination of agricultural land (GB15618-2018)[17]. The potential risk of heavy metals in the grassland soil around the chemical plant were relatively low, while compared with the soil in the control area, the heavy metals Hg, Zn, Cr, and Pb in the tested soil were 19.65, 1.61, 1.54, and 1.11 times of the background values, indicating that the tested soil was affected by human disturbance.

| Soil types         | Cr  | Ni  | Cu  | Zn  | Cd  | Pb  | As  | Hg  |
|--------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| the tested soil    | 60.73 | 33.65 | 27.39 | 99.95 | 0.25 | 26.42 | 9.79 | 0.79 |
| background value   | 39.49 | 39.90 | 31.90 | 61.94 | 0.25 | 23.90 | 15.60 | 0.04 |
| screening value    | 250.00 | 190.00 | 100.00 | 300.00 | 0.60 | 170.00 | 25.00 | 3.40 |

Figure 2 showed that after planting soybean, tomato and clover in the tested soil, the contents of eight heavy metals in the soil decreased to varying degrees. In terms of different heavy metals, the decrease in Cd in the soil was the most significant compared to before planting, with an average decrease of 19.7%, and the largest decrease in Cd in the soil for planting clover was 22.9%, followed by tomato and soybean. The average decrease in soil Cr was 15.5%, followed by clover > tomato > soybean. The decline of Pb in the soil planting tomatoes was only 18.3%, and the decrease of Pb in soils grown with clover and soybean was smaller. The other soil heavy metal contents decreased less than 10%, of which As decreased the smallest, with an average of only 2.2%. As for different plants, in the soybean soil, only Cd has the largest decrease, which was 16.9%, and the remaining heavy metals decreased less than 10%. In the soil planted tomato, Cd, Cr and Pb decreased more, and Hg decreased second. And in the soil planted clover, Cd and Cr decreased significantly, and other heavy metals decreased less than 10% after harvest. In sum, the overall decline in heavy metals in the soil planted tomato was the largest, followed by clover and soybean.
3.3. Correlation analysis

It can be seen from 2.1 that total nitrogen and organic matter content decreased significantly before and after planting soybeans, tomatoes and clover. And after harvesting 3 kinds of plants, among 8 kinds of heavy metals, the Cd and Cr contents in the soil decreased greatly. Figure 3 showed that soil total nitrogen was positively correlated with heavy metals and significantly positively correlated with Cd ($R = 0.93$). The available potassium was positively correlated with heavy metals and significantly positively correlated with Cr ($R = 0.99$). Soil available phosphorus was positively correlated with various heavy metals, and significantly positively correlated with Ni ($R = 0.99$) and Cu ($R = 0.95$). Soil organic matter (SOM) was positively correlated with its heavy metal content, available phosphorus and total nitrogen, and significantly positively correlated with Cd ($R = 0.96$). pH was positively correlated with heavy metal content (except Zn), but not significantly.

4. Conclusion

The result showed that after soybeans, tomatoes and clover were planted in the test soil, pH remained almost unchanged, the organic matter as a whole decreased, and the heavy metals in the soil planted tomato had the largest decline. Soil total nitrogen, available potassium, and available phosphorus were
all lower than before planting, with an average decrease of total nitrogen> organic matter> available phosphorus> available potassium, and total nitrogen decreased the most in the soil planted soybeans, while organic matter decreased the most in the soil planted tomatoes.

Compared with the soil in the control area, the contents of Hg, Zn, Cr, and Pb in the tested soil were greatly affected by human activities, but all of the heavy metals did not exceed the screening value of soil pollution risk for agricultural soil. After planting three kinds of plants, the decrease of Cd and Cr was obvious, followed by Pb, and the decrease of other heavy metals was less than 10%. The overall decline in heavy metals in soil planted tomato was the largest, followed by clover and soybean. Correlation analysis of the physical and chemical properties of the tested soil with heavy metals showed that soil total nitrogen and organic matter were significantly positively correlated with Cd, and available potassium was significantly positively correlated with Cr. Thus increasing the soil nutrient content can promote the effect of phytoremediation.

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