Status and risk evaluation of heavy metals in soil and traditional Chinese medicine in Longxi, Gansu Province, China

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Abstract. In order to study the pollution status of traditional Chinese medicine and soil heavy metal elements in Longxi, Gansu province, the content and pollution status of heavy metal elements in traditional Chinese medicine and its planting soil were evaluated by the method of field investigation and indoor analysis. The results showed that the total amount of Cd, Pb, Cu, Zn and Cr exceeded the soil background value in varying degrees, and the over standard rates were 100%, 100%, 67% and 33% respectively. The enrichment capacity of Codonopsis pilosula was Cr > Zn > Cd > Cu > Pb, Astragalus membranaceus was Zn > Cd > Cu > Pb > Cr, Scutellaria baicalensis was Zn > Cd > Pb > Cu > Cr. Health risk assessment shows that traditional Chinese medicine in the study area will not cause obvious harm to resident health.

1. Introduction
Soil heavy metal pollution is a multidisciplinary environmental problem in the world. Heavy metal pollutants can not only pollute the soil through mechanical migration and physicochemical migration, but also accumulate in the organism through biological migration, and then enter the human body through the food chain and various exposure pathways, affecting human health[1-2]. The development and utilization of Chinese medicinal materials have been paid much attention in recent years. With the rapid growth of the export trade of Chinese crude drugs in China, the excessive heavy metal content of traditional Chinese medicine has become a barrier to their development in the international market[3]. Existing studies have shown that heavy metal pollution of traditional Chinese medicine was widespread, which will seriously affect the safety of traditional Chinese medicine [4-5]. Longxi County has a wide range and a long history of traditional Chinese medicine planting, with Codonopsis pilosula (CP), Astragalus membranaceus (AM) and Scutellaria baicalensis (SB) for thousands of years. We selected three kinds of the above typical Chinese traditional medicine and its planting soil as the research object, the distribution characteristics of heavy metal content and the results of health risk were analyzed by using the method of systematic evaluation, in order to evaluate the pollution status and potential health risk.
2. Materials and methods
The samples were collected from two planting sites, Shouyang and Dexing town. A total of 18 surface planting soils (0-20 cm) were collected, and 6 Codonopsis pilosula, 6 Astragalus membranaceus and 6 Scutellaria baicalensis were also collected to analysis the heavy metals.

Determination of heavy metal in soil: 0.5000 g soil samples plunged in a 50 mL polytetrafluoroethylene crucible, then a small amount of distilled water weted after added 10 mL of hydrochloric acid, evaporated to 3 mL at low temperature, and cooled and added 10 mL of nitric acid, 10 mL hydrofluoric acid, 6 mL perchloric acid, and heated medium temperature for 1 h, continue to heat and gently shake to open the lid with a white, sticky, filter solution was mixed with 1:1 nitric acid solution and finally concentrated to 50 mL colorimetric tube. The content of heavy metals were detected by flame an atomic absorption spectrophotometer.

Determination of heavy metals in traditional Chinese Medicine: 1.000 g of sample put into a 50 mL polytetrafluoroethylene crucible, and added with a small amount of distilled water, then mixed with 20 mL of digestive solution for 12 h. The mixture heated at a high temperature until there is white smoke, dissolve to a white or light yellow color, then added a proper amount of distilled water, continue to heat and finally dissolve in 1% nitric acid solution into a 50 mL colorimetric tube at a constant volume for determination.

3. Results and discussion

3.1. Soil properties and heavy metal content
The statistical results of soil heavy metal content are shown in Table 1. The total amount of Cd, Pb, Cu, Zn and Cr exceeds the background value of soil in the study area in varying degrees. The exceeded rates of Cd, Pb and Cu are as high as 100%, while those of Zn and Cr are 67% and 33% respectively. The CV is 22.11% -70.04%, all of which were of medium variation, indicating that the spatial difference of heavy metal content in the study area was small and the distribution was relatively uniform. Liu[6] studied heavy metal pollution of farmland soil in Dongdagou, Baiyin county, Gansu province, and found that Cd pollution was also the main pollution. At the same time, according to the national soil pollution survey bulletin, the over standard rate of agricultural soil is 19.4%, and Cd pollution ranks first. Fan[7] found that Cd emission of industrial wastewater was mainly concentrated in two major regions with Hunan and Gansu in China as the core. Therefore, it is speculated that the large-scale discharge of Cd containing wastewater and irrigation of Cd containing wastewater were the main sources for soil Cd exceeding the standard in the study area.

| Element | Min /mg·kg⁻¹ | Max /mg·kg⁻¹ | Average /mg·kg⁻¹ | Median /mg·kg⁻¹ | Standard deviation | variance | CV% | Background value /mg·kg⁻¹ |
|---------|--------------|--------------|------------------|-----------------|--------------------|---------|-----|-------------------------|
| Cd      | 4.60         | 10.45        | 6.93             | 6.83            | 1.53               | 2.35    | 22.11 | 0.12                    |
| Pb      | 54.65        | 129.05       | 99.23            | 108.90          | 24.38              | 594.49  | 24.57 | 18.80                   |
| Cu      | 47.00        | 197.50       | 89.12            | 72.38           | 43.38              | 1881.90 | 48.67 | 24.10                   |
| Zn      | 24.10        | 383.09       | 152.43           | 121.77          | 106.76             | 11397.94| 70.04 | 68.50                   |
| Cr      | 5.50         | 152.60       | 65.71            | 62.75           | 32.35              | 1046.80 | 49.24 | 70.20                   |

3.2. Heavy metal pollution in traditional Chinese medicine
The statistical results of heavy metal content of Chinese crude drugs are shown in Figure 1. The contents of heavy metals were as follows: Zn (3.95 mg·kg⁻¹) > Cr (1.41 mg·kg⁻¹) > Cu (0.60 mg·kg⁻¹) > Pb (0.48 mg·kg⁻¹) > Cd (0.10 mg·kg⁻¹) in Codonopsis pilosula, Zn (4.14 mg·kg⁻¹) > Pb (0.63 mg·kg⁻¹) > Cu (0.29 mg·kg⁻¹) > Cd (0.08 mg·kg⁻¹) in Astragalus membranaceus, and Zn (4.36 mg·kg⁻¹) > Pb (0.77 mg·kg⁻¹) > Cu (0.58 mg·kg⁻¹) > Cd (0.14 mg·kg⁻¹) > Cr (0.09 mg·kg⁻¹) in Scutellaria baicalensis. The
contents of Zn in traditional Chinese medicine were closely related to the efficacy of traditional Chinese medicine, so the contents of Zn in different traditional Chinese medicine were quite different. The average concentration of Cd in the soil of the study area was higher, but the content of Cd in traditional Chinese medicine was lower, presumably because of the low content of extractable Cd in the soil of the study area. Studies have found that the extractable heavy metals in soil are highly mobile, and their content is the main factor determining the migration capacity of heavy metals[8].

![Figure 1. Content of heavy metals in traditional Chinese Medicine.](image)

3.3. Characteristics of heavy metal enrichment in traditional Chinese medicine

The enrichment coefficient (heavy metal content in traditional Chinese medicine/heavy metal content in soil) is used to characterize the enrichment ability of traditional Chinese medicine to heavy metal. The results were shown in Table 2. From Table 2, the average enrichment capacity of CP was Cr>Zn>Cd>Pb, that of AM was Zn>Cd>Pb>Cu>Cr, that of SB was Zn>Cd>Pb>Cu>Cr. Zn and Cd have higher enrichment capacity in traditional Chinese medicine, while Pb has lower enrichment capacity, which is consistent with the research of Yu[9] on the enrichment capacity of heavy metals in vegetables in zinc smelting area. It is speculated that Zn and Cd have higher activity and are easy to be absorbed by plants, while Pb in soil has higher electronegativity, mainly in iron-manganese oxidation state and residue state, not easy to be absorbed by crops[10-11].

| Category            | Enrichment coefficient |  |  |  |  |
|---------------------|------------------------|---|---|---|---|
|                     | Cd | Pb | Cu | Zn | Cr |
| Codonopsis pilosula | Min | 0.011 | 0.003 | 0.005 | 0.007 | 0.003 |
|                     | Max | 0.026 | 0.009 | 0.015 | 0.030 | 0.460 |
|                     | Average | 0.017 | 0.005 | 0.007 | 0.018 | 0.091 |
| Astragalus membranaceus | Min | 0.004 | 0.002 | 0.006 | 0.006 | 0.002 |
|                     | Max | 0.015 | 0.014 | 0.011 | 0.125 | 0.015 |
|                     | Average | 0.010 | 0.007 | 0.008 | 0.050 | 0.005 |
| Scutellaria baicalensis | Min | 0.014 | 0.002 | 0.002 | 0.015 | 0.000 |
|                     | Max | 0.032 | 0.025 | 0.014 | 0.336 | 0.004 |
|                     | Average | 0.020 | 0.009 | 0.008 | 0.128 | 0.001 |

3.4. Health risk assessment of heavy metal pollution

Traditional Chinese medicine usually enter the human body after processing, and it is difficult to determine the daily intake. Therefore, the IR value uses the maximum daily dosage (CP 0.03 kg·d⁻¹;
AM 0.03 kg·d⁻¹; SB 0.01 kg·d⁻¹) specified in Chinese Pharmacopoeia (2015). The daily intake, hazard quotient value and hazard index of heavy metals are calculated as shown in Table 3. The risk index of a single heavy metal is far less than 1, and the health risk is low. The harm index of SB was the lowest, only 0.069, and the contribution rate of Pb was the highest (55.03%). The harm index of AM was 0.1901, and the contribution rate of Pb was the highest (46.97%). The hazard index of CP was the highest (0.3674), but still less than 1, in which the contribution rate of Cr was the highest (63.96%). The results of the study compared with the standard indicated that traditional Chinese medicine in the study area would not cause obvious harm to human health.

| Table 3. Add, HQ and HI ingested by traditional Chinese Medicine |
|---------------------------------------------------------------|
| **Codonopsis pilosula**                                        |
| Cd                | 0.00005 | 0.0500 | 13.61 |
| Pb                | 0.00024 | 0.0683 | 18.60 |
| Cu                | 0.00030 | 0.0075 | 2.04  |
| Zn                | 0.00198 | 0.0066 | 1.79  |
| Cr                | 0.00071 | 0.2350 | 63.96 |
| Cd                | 0.00004 | 0.0383 | 20.16 |
| Pb                | 0.00031 | 0.0893 | 46.97 |
| **Astragalus membranaceus**                                   |
| Cu                | 0.00030 | 0.0075 | 0.3674|
| Zn                | 0.00207 | 0.0069 | 3.63  |
| Cr                | 0.00014 | 0.0481 | 25.28 |
| Cd                | 0.00002 | 0.0231 | 33.41 |
| Pb                | 0.00013 | 0.0366 | 53.03 |
| **Scutellaria baicalensis**                                   |
| Cu                | 0.00010 | 0.0024 | 0.069 |
| Zn                | 0.00073 | 0.0024 | 3.51  |
| Cr                | 0.00001 | 0.0048 | 6.98  |

4. Conclusion
Five heavy metals in soil all exceed the standard. The content of Zn in traditional Chinese medicine is the highest, and Cr is the lowest. Traditional Chinese medicine generally has higher enrichment capacity for Zn and Cd, and lower enrichment capacity for Pb. Traditional Chinese medicine in the study area will not cause obvious harm to human health.

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