

## Content Characteristics and Pollution Assessment of Cadmium, Lead, Mercury and Arsenic in Soil-Plant Systems in Hebei Isatis Root Producing Areas: Postprint

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### Abstract

Using a combined method of field investigation and laboratory analysis, this study examined the content characteristics of heavy metals Cd, Pb, Hg, and As in soil-plant systems and their accumulation characteristics in *Isatis indigotica* from Banlangen production areas in Anguo City and Yu County, Hebei Province, and evaluated the pollution status of Cd, Pb, Hg, and As in soils and herbs from these production areas, providing data support and scientific basis for the safe and rational development of herbal medicine production in this region. The results showed that there was little difference in the contents of heavy metals Cd, Pb, Hg, and As in soils from Banlangen production areas between Anguo City and Yu County, with coefficients of variation for soil heavy metal contents ranging from 11.70% to 97.65%. When evaluated against the Grade I standard values of the “Environmental Quality Standard for Soils” (GB 15618–1995), the comprehensive pollution index assessment results indicated that 45% of Banlangen planting areas had soil Cd, Pb, Hg, and As pollution at the warning limit level, while others were at the clean level; however, when evaluated against the Grade II standard values of the “Environmental Quality Standard for Soils”, both the single pollution index and comprehensive pollution index results for the planting areas were  $<0.7$ , indicating a clean soil environment. Additionally, the average contents of Cd, Pb, Hg, and As in the aboveground parts of *Isatis indigotica* (Daqingye) were  $0.22 \text{ mg} \cdot \text{kg}^{-1}$ ,  $0.89 \text{ mg} \cdot \text{kg}^{-1}$ ,  $0.04 \text{ mg} \cdot \text{kg}^{-1}$ , and  $0.25 \text{ mg} \cdot \text{kg}^{-1}$ , respectively, with heavy metal enrichment ability following the order  $\text{Cd} > \text{Hg} > \text{Pb} > \text{As}$ ; the mean contents of Cd, Pb, Hg, and As in the underground parts of *Isatis indigotica* (Banlangen) were  $0.14 \text{ mg} \cdot \text{kg}^{-1}$ ,  $0.57 \text{ mg} \cdot \text{kg}^{-1}$ ,  $0.04 \text{ mg} \cdot \text{kg}^{-1}$ , and  $0.26 \text{ mg} \cdot \text{kg}^{-1}$ , respectively, with heavy metal enrichment ability following the order  $\text{Cd} > \text{Hg} > \text{As} > \text{Pb}$ . The Pb, Hg, and As contents in all *Isatis indigotica* samples did not exceed the “Green

Industry Standards for Import of Medicinal Plants and Preparations” (WM2–2001); 9.09% of Daqingye samples had Cd levels exceeding the standard, and the average pollution index for Cd was >0.7, belonging to the warning limit pollution grade. Therefore, when evaluating the environmental quality of production areas for Chinese medicinal materials under GAP (Good Agricultural Practice), in addition to the fact that Banlangen production area soils fully comply with the Grade II standard for soil environmental quality, the inherent characteristics of Banlangen and Daqingye in absorbing and accumulating heavy metals should not be overlooked.

## Full Text

### Assessment of Cd, Pb, Hg and As Contamination in Soils and Plants in *Isatis indigotica* Cultivated Regions in Hebei Province

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## Abstract

This study investigated the concentrations and accumulation characteristics of cadmium (Cd), lead (Pb), mercury (Hg), and arsenic (As) in soils and *Isatis indigotica* (the source plant of Banlangen and Daqingye) from major production areas in Anguo City and Yuxian County, Hebei Province, using field surveys combined with laboratory analysis. The pollution status of both soils and herbal materials was evaluated to provide scientific support for safe and sustainable production of medicinal herbs in the region. Results showed that heavy metal concentrations in soils from both regions were similar, with coefficient of variation ranging from 11.70% to 97.65%. When evaluated against Class I criteria of the *Environmental Quality Standard for Soils* (GB 15618–1995), the Nemerow comprehensive pollution index indicated that 45% of the planting areas fell into

the “warning limit” category, while the remainder were “clean.” However, using Class II criteria, all single pollution indices and comprehensive pollution indices were below 0.7, indicating clean soil conditions suitable for cultivation. In *I. indigotica* shoots (Daqingye), average Cd, Pb, Hg, and As concentrations were  $0.22 \text{ mg} \cdot \text{kg}^{-1}$ ,  $0.89 \text{ mg} \cdot \text{kg}^{-1}$ ,  $0.04 \text{ mg} \cdot \text{kg}^{-1}$ , and  $0.25 \text{ mg} \cdot \text{kg}^{-1}$ , respectively, with accumulation capacity following the order  $\text{Cd} > \text{Hg} > \text{Pb} > \text{As}$ . In roots (Banlangen), average concentrations were  $0.14 \text{ mg} \cdot \text{kg}^{-1}$ ,  $0.57 \text{ mg} \cdot \text{kg}^{-1}$ ,  $0.04 \text{ mg} \cdot \text{kg}^{-1}$ , and  $0.26 \text{ mg} \cdot \text{kg}^{-1}$ , respectively, with accumulation capacity following  $\text{Cd} > \text{Hg} > \text{As} > \text{Pb}$ . All samples complied with the *Green Trade Standards for Importing and Exporting Medicinal Plants and Preparations* (WM2–2001) for Pb, Hg, and As, though 9.09% of shoot samples exceeded Cd limits, and the average Cd pollution index exceeded 0.7, placing them in the warning limit category. Therefore, while soils in Banlangen production areas meet Class II soil environmental quality standards, the inherent heavy metal accumulation characteristics of both roots and shoots warrant careful consideration in Good Agricultural Practice (GAP) environmental quality assessments.

**Keywords:** *Isatis indigotica*; shoots (Daqingye); roots (Banlangen); heavy metals; pollution evaluation; accumulation and transfer

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## Introduction

Soil represents one of humanity’s primary natural resources and constitutes the essential material foundation for agricultural production. In recent decades, rapid industrial development, urban pollution, and increased use of agrochemicals have introduced heavy metals into soils through multiple pathways, including industrial waste discharge, pesticide and fertilizer misuse, and improper application of municipal sludge and domestic waste. These contaminants subsequently enter the food chain, posing significant threats to human health [1-3]. Many countries and regions have established strict limits for heavy metal content and pesticide residues in traditional Chinese medicines (TCM); products exceeding these safety thresholds are prohibited from sale and subject to destruction. Research has demonstrated that most Chinese herbal medicines contain measurable heavy metal concentrations [4-6], with some exceeding safety limits and creating green trade barriers for TCM in international markets [7]. Soil serves as a primary source of heavy metals in medicinal herbs, making it critical to control heavy metal (including the metalloid As) concentrations in cultivation soils to ensure herbal quality and safety [8].

While numerous studies have investigated heavy metal contamination in farmland [9-11], vegetable production bases [12-14], and mining areas [15-16], relatively few have focused on safety assessments of heavy metals in TCM cultivation regions [8,17-18]. Liu et al. [19] reported that both Banlangen (the underground part of *I. indigotica*) and Daqingye (the aerial part) sourced from cultivation areas or pharmacies showed higher As concentrations in aerial parts than in roots,

emphasizing the importance of controlling As accumulation in both plant parts for medicinal safety. Anguo City in Baoding and Yuxian County in Zhangjiakou represent major Banlangen production areas in Hebei Province. This study systematically collected soil and plant samples from these regions to analyze Cd, Pb, Hg, and As concentrations and their accumulation in Banlangen and Daqingye, evaluate pollution status, and provide data support and scientific guidance for safe and rational development of medicinal herb production.

### 1.1 Study Area Description

Anguo City (38°24 N, 115°20 E) is located in the heart of the North China Plain at an average elevation of approximately 36 m, with mean annual precipitation of 510.8 mm and a frost-free period of about 190 days. The dominant soil type is sandy loam alluvial cinnamon soil. The region cultivates 223 medicinal plant species across approximately 86.7 km<sup>2</sup> of dedicated farmland, producing over 70% of Hebei Province' s total commercial medicinal material output, earning it the titles “Medicine Capital” and “World’ s Premier Medicine Market.”

Yuxian County in Zhangjiakou (39°85 N, 114°57 E) is situated in northwestern Hebei Province at an average elevation of 912 m, with annual precipitation of 425 mm and a frost-free period of about 137 days. The sandy loam soils and large diurnal temperature variations support 3,300 hectares of TCM cultivation with annual yields reaching 8 million kg, making it suitable for growing *Tussilago farfara*, *I. indigotica*, *Anemarrhena asphodeloides*, *Scutellaria baicalensis*, and other medicinal species.

### 1.2 Sample Collection

Following a 1:1 soil-to-plant sampling principle and considering actual cultivation practices, representative and typical Banlangen plots were selected in Anguo City (sites A-G) and Yuxian County (sites H-K) [Figure 1: see original paper]. Soils were collected from the 0-30 cm plow layer using an “S” pattern, mixed uniformly, and subsampled by quartering. A total of 52 soil samples were collected (4-6 per site), sealed in plastic bags, and labeled.

Medicinal plant samples were collected during the autumn harvest season from the same plots. Aerial parts (Daqingye) and underground parts (Banlangen) of *I. indigotica* were harvested, sealed in ziplock bags, labeled, and dried to 50 g dry weight per sample, yielding 52 plant samples total.

### 1.3 Sample Preparation and Analysis

Soil samples were air-dried, debris removed, crushed with a wooden roller, and homogenized. Subsamples were sieved through 1 mm (18 mesh) nylon mesh, then ground in an agate mortar to pass through 0.15 mm (100 mesh) sieve before bagging.

Plant samples were washed with tap water to remove soil and debris, then rinsed

three times with distilled and deionized water. After air-drying, samples were oven-dried at 65°C to constant weight and pulverized using a micro-mill with plastic lining and stainless steel blades.

Both soil and plant samples were digested using HNO<sub>3</sub>-H<sub>2</sub>O in closed vessels [20], with Cd, Pb, Hg, and As concentrations determined by ICP-MS. National primary standard reference materials (soil: GBW07404; plant: GBW07603) were analyzed simultaneously for quality control, achieving recovery rates of 80–97%. All data were corrected using standard recovery rates.

## 1.4 Evaluation Methods

**1.4.1 Soil Cd, Pb, Hg, As Pollution Assessment** Following established methods [21], single pollution indices and the Nemerow comprehensive pollution index were applied to evaluate soil environmental quality in Anguo City and Yuxian County using standard values from relevant literature [22–23].

Soil environmental quality classification represents a fundamental component of soil quality assessment. The Nemerow comprehensive pollution index (P) classification system defines:  $P < 0.7$  as clean (safe);  $0.7 \leq P < 1.0$  as warning limit;  $1.0 \leq P < 2.0$  as slight pollution;  $2.0 \leq P < 3.0$  as moderate pollution; and  $P \geq 3.0$  as heavy pollution. The comprehensive pollution index is calculated as:

$$P_{\text{comprehensive}} = \sqrt{\frac{(\text{average of single pollution indices})^2 + (\text{maximum single pollution index})^2}{2}}$$

**1.4.2 Herbal Cd, Pb, Hg, As Pollution Assessment** Single pollution indices were calculated using safety limits from China's *Green Trade Standards for Importing and Exporting Medicinal Plants and Preparations* [24]. The formula is:

$$P_i = \frac{c_i}{S_i}$$

where  $P_i$  is the pollution index for each element,  $c_i$  is the measured concentration, and  $S_i$  represents the safety limits: 0.3 mg · kg<sup>-1</sup> for Cd, 5.0 mg · kg<sup>-1</sup> for Pb, 0.2 mg · kg<sup>-1</sup> for Hg, and 2.0 mg · kg<sup>-1</sup> for As.

## 1.5 Data Analysis

**Transfer coefficient** was calculated as the ratio of heavy metal concentrations in aerial parts to those in roots, representing the translocation capacity from root to shoot [20].

**Enrichment coefficient** was calculated as the ratio of heavy metal concentrations in plant tissues (aerial or root) to those in soil, indicating accumulation capacity within the plant [20].

Data were analyzed using Microsoft Excel 2003 and SPSS 17.0 statistical software.

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## 2.1 Heavy Metal Content Characteristics and Pollution Assessment in Banlangen Production Soils

### 2.1.1 Soil Cd, Pb, Hg, As Content Characteristics

Heavy metal concentrations in Banlangen production soils are summarized in . In Anguo City, soil Cd ranged from 0.10–0.23 mg · kg<sup>-1</sup> (mean 0.16 mg · kg<sup>-1</sup>), Pb from 12.14–27.86 mg · kg<sup>-1</sup> (mean 17.13 mg · kg<sup>-1</sup>), Hg from 0.024–0.391 mg · kg<sup>-1</sup> (mean 0.072 mg · kg<sup>-1</sup>), and As from 4.61–7.23 mg · kg<sup>-1</sup> (mean 6.03 mg · kg<sup>-1</sup>). Coefficients of variation ranged from 12.90% to 97.65%, with variability following the order Hg > Pb > Cd > As.

In Yuxian County, soil Cd ranged from 0.10–0.22 mg · kg<sup>-1</sup> (mean 0.12 mg · kg<sup>-1</sup>), Pb from 9.91–32.16 mg · kg<sup>-1</sup> (mean 13.30 mg · kg<sup>-1</sup>), Hg from 0.038–0.210 mg · kg<sup>-1</sup> (mean 0.088 mg · kg<sup>-1</sup>), and As from 6.52–9.83 mg · kg<sup>-1</sup> (mean 7.63 mg · kg<sup>-1</sup>). Coefficients of variation ranged from 11.70% to 47.97%, with variability following Hg > Pb > Cd > As. Overall, heavy metal concentrations were similar between the two regions, with soil coefficients of variation ranging from 11.70% to 97.65%.

When assessed against the *Environmental Quality Standard for Soils* (GB15618–1995), two Anguo soil samples exceeded Class I limits for Cd (0.21 and 0.23 mg · kg<sup>-1</sup>, exceeding by 5.00% and 15.00%, respectively), and two exceeded Class I limits for Hg (0.217 and 0.391 mg · kg<sup>-1</sup>, exceeding by 44.67% and 160.00%, respectively). In Yuxian, one sample exceeded Class I Cd limits (0.22 mg · kg<sup>-1</sup>, 10.00% over) and two exceeded Class I Hg limits (0.167 and 0.210 mg · kg<sup>-1</sup>, exceeding by 11.33% and 40.00%, respectively). All samples from both regions were below Class II standards, indicating compliance with soil quality requirements for TCM production specified in the 2002 *Good Agricultural Practice for Chinese Crude Drugs* [25].

### 2.1.2 Correlations Among Soil Cd, Pb, Hg, As

Heavy metal contaminants in soils of the same region and type may originate from single or multiple sources, with significant correlations typically indicating common sources [26]. Pearson correlation analysis () revealed significant positive correlations between As and Pb in Anguo soils ( $r = 0.425$ ,  $P < 0.05$ ) and highly significant correlations in Yuxian soils ( $r = 0.663$ ,  $P < 0.01$ ). No significant correlations were found between Pb and Cd, Hg and Pb/Cd, or As and Hg/Cd in either region ( $P > 0.05$ ), suggesting similar sources for As and Pb but independent sources for other elements.

### 2.1.3 Soil Pollution Assessment

Using both Class I and Class II standard values from the *Environmental Quality Standard for Soils*, pollution assessment results are presented in . Soil pH in Banlangen production areas ranged from 7.60 to 8.10. Based on Class I standards, all single pollution indices for Cd, Pb, Hg, and As were  $< 1.0$ , except for site B in Anguo where the Hg pollution index reached 1.06 (slight pollution). The Nemerow comprehensive pollution index indicated clean conditions at Anguo sites A, D, G and Yuxian sites I, J, K, while Anguo sites B, C, E, F and Yuxian site H fell into the warning limit category (45% of total sites).

According to China's TCM GAP requirements that cultivation base soils must meet Class II standards [25], assessment using Class II criteria showed all single and comprehensive pollution indices were  $< 0.7$ , classifying all sampling sites as clean and safe for TCM production.

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## 2.2 Heavy Metal Content and Pollution Assessment in *I. indigotica*

To determine whether herbs meet national quality standards when cultivated in compliant soils, we analyzed Cd, Pb, Hg, and As concentrations and accumulation capacities in Banlangen and Daqingye.

### 2.2.1 Cd, Pb, Hg, As Content in Aerial and Underground Parts

As shown in , Daqingye Cd concentrations ranged from 0.10–0.35  $\text{mg} \cdot \text{kg}^{-1}$  (mean 0.22  $\text{mg} \cdot \text{kg}^{-1}$ ), Pb from 0.51–1.29  $\text{mg} \cdot \text{kg}^{-1}$  (mean 0.89  $\text{mg} \cdot \text{kg}^{-1}$ ), Hg from 0.020–0.073  $\text{mg} \cdot \text{kg}^{-1}$  (mean 0.04  $\text{mg} \cdot \text{kg}^{-1}$ ), and As from 0.20–0.41  $\text{mg} \cdot \text{kg}^{-1}$  (mean 0.25  $\text{mg} \cdot \text{kg}^{-1}$ ). Coefficients of variation ranged from 32.28% to 74.60%, with Hg showing the greatest variability (74.60%).

According to the *Green Trade Standards* [24] (Cd 0.3  $\text{mg} \cdot \text{kg}^{-1}$ , Pb 5.0  $\text{mg} \cdot \text{kg}^{-1}$ , Hg 0.2  $\text{mg} \cdot \text{kg}^{-1}$ , As 2.0  $\text{mg} \cdot \text{kg}^{-1}$ ), only Daqingye from Anguo site G exceeded Cd limits (0.35  $\text{mg} \cdot \text{kg}^{-1}$ , 16.67% over the standard), while all other samples complied.

Banlangen Cd concentrations ranged from 0.04–0.23  $\text{mg} \cdot \text{kg}^{-1}$  (mean 0.14  $\text{mg} \cdot \text{kg}^{-1}$ ), Pb from 0.44–0.77  $\text{mg} \cdot \text{kg}^{-1}$  (mean 0.57  $\text{mg} \cdot \text{kg}^{-1}$ ), Hg from 0.010–0.083  $\text{mg} \cdot \text{kg}^{-1}$  (mean 0.04  $\text{mg} \cdot \text{kg}^{-1}$ ), and As from 0.18–0.36  $\text{mg} \cdot \text{kg}^{-1}$  (mean 0.26  $\text{mg} \cdot \text{kg}^{-1}$ ). Coefficients of variation ranged from 37.52% to 121.17%, with variability following Hg  $>$  Cd  $>$  As  $>$  Pb. All Banlangen samples complied with the *Green Trade Standards* limits.

### 2.2.2 Pollution Assessment of Banlangen and Daqingye

Based on the *Green Trade Standards* [24], pollution indices are presented in . Average pollution indices in Daqingye followed Cd  $>$  Hg  $>$  Pb  $>$  As, while in

Banlangen they followed  $Cd > Hg > As > Pb$ . Only Daqingye from Anguo site G showed Cd pollution index  $> 1$  (1.18), indicating slight Cd contamination. All other samples had indices  $< 1.0$ , showing no contamination. Coefficients of variation for pollution indices ranged from 25.00% to 87.54%, with Hg showing the greatest variability due to its reactive nature.

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## 2.3 Accumulation and Transfer Characteristics

### 2.3.1 Enrichment Characteristics

Enrichment coefficients for Banlangen and Daqingye are shown in . Average enrichment coefficients in aerial parts followed  $Cd > Hg > Pb > As$ , while in roots they followed  $Cd > Hg > As > Pb$ . Pb and As enrichment coefficients were  $< 0.08$  at all sites, indicating weak accumulation of these elements. Hg enrichment coefficients exceeded 1.0 only at Anguo sites E (1.981) and F (1.037) in roots, with most other values  $< 1.0$ . Coefficients of variation ranged from 19.16% to 107.92%, with Hg showing the greatest variability. Cd demonstrated the highest enrichment capacity, suggesting that soil Cd concentrations require stricter control in Banlangen cultivation areas.

### 2.3.2 Transfer Characteristics

Transfer coefficients from root to aerial parts are presented in . Average transfer coefficients were 1.92 for Cd, 1.59 for Pb, 2.24 for Hg, and 1.00 for As, following the order  $Hg > Cd > Pb > As$ . The maximum Cd transfer coefficient (3.75) occurred at Anguo site G, while the maximum Hg transfer coefficient (5.97) occurred at Anguo site D. Coefficients of variation ranged from 24.25% to 80.56%, with variability following  $Hg > Cd > Pb > As$ .

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## Discussion

Heavy metal concentrations in Banlangen production soils from Anguo City and Yuxian County showed similar levels, with coefficients of variation ranging from 11.70% to 97.65%. These results contrast with Qin et al. [17], who reported much greater variation (6.6%-70.4%) among 11 GAP bases in Guizhou Province. Such regional differences in variability reflect geographical and environmental heterogeneity. While Class II standard evaluation indicated all soils were clean and suitable for cultivation, Class I assessment revealed that 9.09% of sites exceeded Hg limits (slight pollution) and 45% fell into the warning limit category. These two standards serve different purposes: Class II acts as a critical threshold indicating potential contamination risk, while Class I reflects accumulation of exogenous heavy metals. Some scholars argue that Class II standards may be too general for China's diverse soil conditions and question whether they adequately ensure herbal quality [27]. Therefore, safety limit standards for TCM

GAP bases should be revised according to specific geographical locations, soil properties, and climatic conditions, necessitating systematic research on herbal safety.

Regarding heavy metal content in *I. indigotica*, all samples except some Daqingye met green trade standards. Notably, at sites where Daqingye Cd exceeded limits, corresponding soil and root Cd concentrations remained within standards, suggesting that aerial part contamination may result from fertilization, irrigation, atmospheric deposition, or other factors requiring further investigation. Han et al. [4] and Chu et al. [8] reported widespread Cd, Pb, and Hg exceedances in various TCM species, indicating that heavy metal contamination is a common concern requiring species- and region-specific investigation.

Current soil quality assessments for TCM cultivation typically rely on national soil environmental standards without considering differential heavy metal uptake and translocation among species. This study found the highest Cd enrichment coefficients in both Banlangen (0.946) and Daqingye (1.599), while Pb and As coefficients were  $< 0.1$ . Li et al. [28] reported Pb enrichment coefficients 0.2 for *I. indigotica* and other herbs in Gansu, with Banlangen showing the strongest Pb accumulation. Chu et al. [8] found high Cd accumulation in *Aster tataricus* and *Anemarrhena asphodeloides*, and high Hg accumulation in *Glehnia littoralis*. Chen et al. [29] reported enrichment coefficients  $< 1$  for As, Pb, Cd, Hg, and Cr in *Panax notoginseng*, while Liu [30] found Cd enrichment coefficients of 0.01–0.08 in wild medicinal herbs, substantially lower than those observed for *I. indigotica* in this study. These findings demonstrate that heavy metal accumulation in medicinal herbs is influenced by both plant-specific and metal-specific characteristics, as well as environmental conditions.

To ensure safety of Banlangen and Daqingye, it is essential to: (1) maintain compliance of soil, air, and irrigation water with national standards; (2) strictly control exogenous heavy metal inputs through careful fertilizer and pesticide management and reduction of industrial pollution; and (3) prevent contamination during post-harvest storage, processing, and transportation. Such comprehensive controls throughout the production chain are necessary to develop green TCM products.

## Conclusions

1. Heavy metal concentrations in Banlangen production soils from Anguo City and Yuxian County were similar, with coefficients of variation ranging from 11.70% to 97.65%. Using Class I criteria of the *Environmental Quality Standard for Soils* (GB 15618–1995), 45% of cultivation areas fell into the warning limit category, while the remainder were clean. Using Class II criteria, all single and comprehensive pollution indices were  $< 0.7$ , indicating clean soil conditions.
2. In *I. indigotica* aerial parts (Daqingye), average Cd, Pb, Hg, and As con-

centrations were  $0.22 \text{ mg} \cdot \text{kg}^{-1}$ ,  $0.89 \text{ mg} \cdot \text{kg}^{-1}$ ,  $0.04 \text{ mg} \cdot \text{kg}^{-1}$ , and  $0.25 \text{ mg} \cdot \text{kg}^{-1}$ , respectively, with accumulation capacity following  $\text{Cd} > \text{Hg} > \text{Pb} > \text{As}$ . In underground parts (Banlangen), average concentrations were  $0.14 \text{ mg} \cdot \text{kg}^{-1}$ ,  $0.57 \text{ mg} \cdot \text{kg}^{-1}$ ,  $0.04 \text{ mg} \cdot \text{kg}^{-1}$ , and  $0.26 \text{ mg} \cdot \text{kg}^{-1}$ , respectively, with accumulation capacity following  $\text{Cd} > \text{Hg} > \text{As} > \text{Pb}$ .

3. All Banlangen and Daqingye samples complied with the *Green Trade Standards for Importing and Exporting Medicinal Plants and Preparations* (WM2–2001) for Pb, Hg, and As. However, 9.09% of Daqingye samples exceeded Cd limits, with average Cd pollution index  $> 0.7$ , placing them in the warning limit category.

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*Note: Figure translations are in progress. See original paper for figures.*

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