Accumulation of Cd in Ophiopogon Japonicus, Houttuynia Cordata and Duchesnea Indica, and Its Human Health Risk Assessment

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Abstract. In this paper, Chinese herbal medicines of Ophiopogon japonicus, Houttuynia cordata and Duchesnea indica were planted in the soil containing 0.847 mg/kg Cd, which is close to the grade III of Environmental Quality Standard for Soil in China (GB15618-1995). After growth a certain time, the Cd in the three plants were determined respectively. Then the human health risk of Cd intake via taking the herbal medicines was assessed using the internationally recommended method of health risk assessment, as well as accordance to the Standards of Import and Export of Green Medicinal Plants and Their Preparations (WM2-2001), and the Acceptable Daily Intake (ADI) of World Health Organization (WHO). The results showed that, after growth 90d, the Cd contents in the leaves and roots of O. japonicus and H. cordata, and all parts of D. indica were lower than the safe value of Green Trade Standards of Importing & Exporting Medicinal Plants & Preparations (WM2-2001), while that in stems of H. cordata was higher than the safe value. The human health risk of Cd in the three herbal medicines was in the order of H. cordata > O. japonicus > D. indica. Under the assumption of 30g as the average daily intake of the three herbal medicines for an adult, the maximum amount of Cd intake per person via O. japonica, H. cordata, and D. indica were 8.7μg, 10.5μg and 6.2μg respectively, which were lower than the allowable daily Cd intake value of WHO and the limit value recommended by the International Committee for Radiological Protection (ICRP). However, as the stem of H. cordata was slightly polluted after growth 90d in grade III soil, it was not recommended to use it as an edible Chinese herbal medicine.

Introduction

Herbal medicine is major part of traditional Chinese medicine and still playing an important role in clinic [1-3]. Guangxi is one of the resource areas of Chinese herbal medicine. Its planting area is 8200 acres, which accounts for about 1/5 of the total cultivated area in China[4-5]. However, heavy metals from industrial and agricultural production and automobile exhaust can contaminate the soil of cultivated land and then affect the quality of Chinese herbal medicines. Therefore, it is of significance to study the accumulation of heavy metals in herbal medicine plants and understand its impact on human health [6-8]. In this study, the herbs were planted on the soil containing 0.847 mg/kg Cd, which is close to the grade III of Environmental Quality Standard for Soil in China (GB15618-1995). The Cd content in all parts of the herbs was monitored and its contamination level was also evaluated. The impact of Cd in medicinal plants on human health was assessed based on the daily allowable intake (ADI) of World Health Organization (WHO) and the maximum level of human acceptable risk recommended by International Commission on Radiation Protection (ICRP).
Experimental

Instruments, Reagents and Materials

PinAAcle 900T Flame/graphite furnace atomic absorption spectrometer from PerkinElmer Corporation was used for Cd determination. Nitric acid, perchloric acid and hydrochloric acid were of GR grade, 1000 μg/mL Cd²⁺ standard solution was supplied by National Steel Material Testing Center of Steel Research Institute, the experimental water was ultrapure water. The test soil was collected from the planting base of Guangxi University. The moisture of the soil was 0.93%, pH was 6.87, organic matter content was 1.93%, total nitrogen content was 0.10%, total phosphorus content was 0.08%. The Cd content of the soil was 0.847 mg/kg, which was slightly lower than the grade III standard value (1.0 mg/kg) of Environmental Quality Standard for Soil in China (GB15618-1995). The Cd in the soil probably came from car exhaust and the use of pesticide.

Ophiopogon japonicus, Houttuynia cordata, and Duchesnea indica were collected from flower planting base of Guangxi University. The plants with good and stable growth condition were selected for the study.

Experimental Method

Sample Collection and Pretreatment. 12 seedlings of each herbal medicine with 10 cm height and good growth condition were selected and planted in flowerpots with 5 cm depth. The flowerpots were placed in outdoor and the plants were watered with ultrapure water. The leaves, stems and roots of the samples were collected after growth 30d, 60d and 90d, respectively. After washed, the samples were dried at 105 °C for 3h until their weight became constant, and then were stored in sealed bags.

Determination of Cd and Its Pollution Evaluation. The samples were digested by HNO₃-HClO₄ solution (V₁: V₂ = 5: 1), and Cd in samples was determined by graphite furnace atomic absorption spectrometry (GB/T599.15-2003).

The single pollution index method was used to evaluate the pollution of Cd in the plants. The single pollution index Pi was calculated by formula (1) [9-10]:

\[ Pi = \frac{Ci}{Si} \]  

(1)

Here , Pi is the single pollution index of Cd; Ci is Cd content in the sample; Si is the allowable limit of Cd, which is stipulated by the Green Trade Standard for Import and Export of Medicinal Plants and Preparations as Cd≤ 0.3mg·kg⁻¹. Among the Pi values, \( Pi < 0.7 \) represents a fine variety, \( 0.7 < Pi < 1.0 \) represents a safe range, \( 1.0 < Pi < 2.0 \) indicates a mild pollution, \( 2.0 < Pi < 3.0 \) is moderate pollution, and \( Pi > 3.0 \) is severe pollution.

Assessment Method for Human Health Risk of Cd in the Herbal Medicines. Human health risk assessment refers to the possibility of predicting the harmful effects of environmental pollutants on the human body under specific contact conditions [11-12].

(1)Calculation of Daily Intake of Cd. The following formulas were used to calculate the daily intake of Cd and its accounted for percentage of daily allowable Cd intake (ADI):

\[ \text{Daily intake(μg/d)} = \text{average content of Cd in sample(μg/g)} \times \text{sample intake(g/d)} \]  

(2)

\[ \text{Daily intake accounted for percentage of ADI (％) = daily intake (μg/d)/ADI (μg/d) × 100％} \]  

(3)

Among them, the ADI of WHO was 60 μg/d.

(2) Risk assessment of human chemical carcinogenesis induced by dietary intake of Cd.

\[ R_{ig}^e = \frac{[1-\exp ( -D_{ig} \cdot q_{ig})]}{70} \]  

(4)

\[ D_{ig} = Q_i \cdot C_{ig}/60 \]  

(5)

Formula (4) is used to the assessment of human health risk of carcinogens, in which \( R_{ig}^e \) is an
average individual cancer year risk (a\(^{-1}\)) that causes health hazards by Cd intake; D\(_{ig}\) is the daily average exposure dose of carcinogen caused by Cd intake via feeding pathway in unit person weight (mg/kg d); q\(_{ig}\) is the carcinogenic strength coefficient of Cd intake (mg/kg d)\(^{-1}\), it takes 6.1 (mg/kg d)\(^{-1}\) in this formula; 70 is the average life span of the people in China.

In formula (5), Q\(_i\) is the amount of food consumed per day for an adult (kg/d); C\(_ig\) is Cd in Chinese herbal medicine (mg/kg); the average weight of the adult in China is 60 (kg).

In addition to the above formulas, SPSS 12.0 software was used for the statistical analysis of data.

Results and Analysis

The Content of Cd in the Herbal Medicines and Its Contamination Evaluation

Table 1 showed that, Cd content in each part of the plants increased with the increase of growth time. After growth 90d, the Cd content increased by 34.91% and 22.78% respectively in the leaves and roots of O. japonicus, increased by 14.20%, 51.74%, and 39.68% in the leaves, stems, and roots of H. cordata; and increased by 5.61%, 5.21%, and 4.02% in the leaves, stems, and roots of D. indica.

The data analysis with SPSS17.0 software showed that there was no significant correlation between Cd in leaves of O. japonicus and planting time, but the positive linear relationship between Cd in roots and planting time was significant, the regression equation was y=0.001x+0.232, R=0.959, P<0.041. The correlation between Cd in the leaves of H. cordata and the planting time was not obvious, but the Cd in stems and roots showed significant positive correlations, the linear regression equations were y=0.001x+0.217, R=0.970, P<0.03 and y=0.001x+0.197, R=0.968, P<0.032, respectively. There was no significant correlation between Cd in any parts of D. Indica and planting time.

<table>
<thead>
<tr>
<th>Time /d</th>
<th>O. japonicus leaves (mg/kg)</th>
<th>O. japonicus roots (mg/kg)</th>
<th>H. cordata leaves (mg/kg)</th>
<th>H. cordata stems (mg/kg)</th>
<th>H. cordata roots (mg/kg)</th>
<th>D. indica leaves (mg/kg)</th>
<th>D. indica stems (mg/kg)</th>
<th>D. Indica roots (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.106</td>
<td>0.237</td>
<td>0.176</td>
<td>0.230</td>
<td>0.189</td>
<td>0.178</td>
<td>0.192</td>
<td>0.199</td>
</tr>
<tr>
<td>30</td>
<td>0.113</td>
<td>0.245</td>
<td>0.187</td>
<td>0.241</td>
<td>0.230</td>
<td>0.182</td>
<td>0.195</td>
<td>0.204</td>
</tr>
<tr>
<td>60</td>
<td>0.139</td>
<td>0.260</td>
<td>0.198</td>
<td>0.297</td>
<td>0.251</td>
<td>0.184</td>
<td>0.203</td>
<td>0.203</td>
</tr>
<tr>
<td>90</td>
<td>0.143</td>
<td>0.291</td>
<td>0.201</td>
<td>0.349</td>
<td>0.264</td>
<td>0.188</td>
<td>0.202</td>
<td>0.207</td>
</tr>
</tbody>
</table>

After growth 90d, the Cd in the leaves of O. japonicus and H. cordata, in the roots of H. cordata, and in all parts of D. indica were lower than the limit value of 0.3 mg/kg which was stipulated in the Standard of Green Industry for the Import and Export of Medicinal Plants and Preparations. It indicated that when Cd content in soil is less than 0.847 mg/kg, the accumulation of Cd in the O. japonicus and D. indica is relatively small and the quality of the herbal plants is still good. However, under this condition, the Cd in stems of H. cordata increased from 0.230 to 0.349 mg/kg, which slightly exceeded the allowable limit value of 0.3 mg/kg.
Pollution index of Cd in Chinese herbal medicine.

Fig. 1 shows that, after 90 days of growth, the pollution index of Cd in O. japonicus was between 0.48~0.97, the pollution degree was in the order of roots > leaves; the pollution index of Cd in H. cordata was between 0.67~1.2, and the degree of pollution in turn was stem > root > leaf. The pollution index of Cd in D. indica was in the range of 0.63~0.69, and the degree of pollution was in order of root > stem > leaf.

The Effect of Cd in Chinese Herbal Medicine on Human Health Risk

Daily Intake of Cd by Diet and Its Proportion in ADI. Under the assumption that the daily intake of herbal medicine for an adult (weight 60 kg) was 30 g, the human health risk was evaluated by the ratio of Cd intake to ADI based on the statistical analysis of Cd in the three herbal medicine samples. The results were listed in Table 2.

Table 2 showed that, the order of daily intake of Cd in the three herbal medicines by dietary route was in turn of H. cordata > O. japonicus > D. indica. Among them, the average daily intake of Cd in O. japonicus per capita was in the range of 1.1~8.7 μg/d, which was accounted for 1.8~14.5% of ADI; the average daily intake of Cd in H. cordata per capita was in the range of 1.8~10.5 μg/d, accounted for 3.0~17.5% of ADI; the average daily intake of Cd in D.indica per capita was in the range of 1.8~6.2 μg/d, accounted for 3.0~10.3% of ADI.

Even though the average daily intake amount of Cd via taking the three herbal medicines was less than the limit amount of WHO (60 μg/d), the intake of Cd may cause a certain risk to human health, and one should pay attention to it.

Table 2. The daily intake of cadmium and its proportion of ADI in Chinese herbal medicine.

<table>
<thead>
<tr>
<th>Name</th>
<th>Daily Cd intake (μg/d)</th>
<th>Daily intake accounted for percentage of ADI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ophiopogon japonicus</td>
<td>1.1~4.3</td>
<td>3.0~10</td>
</tr>
<tr>
<td>Houssuyinia cordata</td>
<td>1.8~6.0</td>
<td>3.0~9.3</td>
</tr>
<tr>
<td>Duchesnea indica</td>
<td>1.8~5.6</td>
<td></td>
</tr>
<tr>
<td>Ophiopogon japonicus</td>
<td>1.8~7.2</td>
<td>3.0~10</td>
</tr>
<tr>
<td>Houssuyinia cordata</td>
<td>1.9~6.1</td>
<td>3.2~17.5</td>
</tr>
<tr>
<td>Duchesnea indica</td>
<td>2.0~6.2</td>
<td>3.2~13.2</td>
</tr>
</tbody>
</table>

Risk Assessment of Human Chemical Carcinogenesis Induced by Dietary Intake of Cd. The calculations results obtained with formula (4) showed that the annual average personal carcinogenesis risk values of Cd in the three Chinese herbal medicines were in the range of 1.54×10^{-6}~ 1.27×10^{-5} (a^{-1}), 2.55×10^{-6}~1.52×10^{-5}(a^{-1}), and 2.59×10^{-6}~ 9.02×10^{-6}(a^{-1}), respectively, which were lower than the limited value of 5×10^{-5}(a^{-1}) recommended by the International Commission on Radiological Protection (ICRP).
Conclusion

(1) When *O. japonicus*, *H. cordata*, and *D. indica* were planted in the soil closed to grade III of Environmental Quality Standard for Soil in China (GB15618-1995) for 90d, the Cd contents in leaves of the three herbas and in the roots of *O. japonicus* and *H. cordata* were in the scope of safety, while that in the stem of *H. cordata* already reached mild pollution.

(2) The results of risk assessment showed that the effects of Cd in three Chinese herbal medicines on human health risk caused by dietary route were in turn of *H. cordata* > *O. japonicus* > *D. Indica*. The average daily intake amount of Cd via taking the three herbal medicines was less than the ADI of WHO, even so, the intake of Cd even a small amount is still of a certain risk to human health and one should pay attention to it.

(3) The assessment of human chemical carcinogenesis risk caused by Cd intake showed that the maximum annual personal carcinogenic risk of Cd in three plants was below the limit value of ICRP.

(4) As the stem of *H. cordata* was mildly contaminated after 90d growth in the grade III soil, it was not recommended to use it as an edible Chinese herbal medicine.

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References


