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A Comparative Study of the Contents of Cadmium and Chromium in Leaves of Seventeen Kinds of Road Greening Trees

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Abstract The greening trees can absorb heavy metal pollutants in the atmosphere. This study investigates the cadmium (Cd) and chromium (Cr) content in the leaves of 17 kinds of greening trees in Xinxiang City, China. The result shows that heavy metal content of the same greening tree in polluted area is more than that in clear area; that in autumn is more than that in spring; chromium content is more than cadmium content. Heavy mental content of different greening trees differ from each other, which ranks as follws: Populus alba > Acer mono > Populus tomentosa > Ligustrum quihoui > Ligustrum lucidum > Purple-leaf plum > Buxus megistophylla > Koelreuteria paniculata > Platanus acerifolia > Ailanthus altissima > Broussonetia papyrifera > Fraxinus > Sophora japonica > Photinia serrulata > Pittosporum tobira > Yucca gloriosa > Buxussinica. Chromium content ranks as follows: Acer mono > Populus tomentosa > Populus alba > Prunus ceraifera > Buxussinica > Photinia serrulata > Platanus acerifolia > Sophora japonica > Yucca gloriosa > Sophora japonica > Ligustrum quihoui Carr > Pittosporum tobira > Koelreuteria paniculata > Ligustrum lucidum > Altissima altissima > Fraxinus > Buxus megistophylla. The greening trees can be classified into three categories in term of cadmium and chromium content. The first category includes Populus tomentosa and Acer mono; Prunus ceraiferai, Platanus, Populus alba, Buxussinica and Photinia serrulata belong to the second category; the third category includs Fraxinus, Sophora japonica, Broussonetia papyrifera, Ailanthus altissima, Koelreuteria paniculata, Pittosporum tobira, Yucca gloriosa, Buxus megistophylla, Ligustrum lucidum and Ligustrum quihoui. Heavy metal contents in the leaves of greening trees are markedly different from each other in different function areas, seasons, and tree species.

Keywords: *road, greening trees, heavy metal, ICP-MS, cadmium and chromium contents*

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1. Introduction

With the rapid development of the society, the emissions of all sorts of heavy metal pollutants in the process of production and livelihood continue to increase. The heavy metal pollution is characterized with concealment, chronicity, cumulativity and irreversibility [1]. Different organs of greening trees are capable of absorbing and accumulating heavy metals. Heavy metal pollutants in the atmosphere entered the leaves through the stomata of greening trees leaves, and after a series of chemical reactions, the heavy metal ions are eventually translated into non-toxic materials [2]. In recent years, it has been commonly reported that a large number of scholars have used plants to monitor atmospheric environment [3-7]. Wang et al., [8] made an investigation of the capacity of forteen kinds of greening trees's accumulating heavy metal. Bi et al., [9] and Mu et al., [10] reported a study of the capacity of greening tree's accumulating cadmium and chromium in different cities and possess the ability to resist and absorb heavy metal pollutants in heavly polluted areas. Qiu et al., [11] proposed that the correlation index of the heavy metal content in leaves and foliar dust fall is above 70%. Ma et al., [12] revealed that heavy metal content in plant leaves in Guangzhou city was positively associated with the degree of atmospheric pollution, which agreed with many other scholars' studies [13,14,15]. Therefore, it can be concluded that the heavy metal content of that greening trees can be used as the indicator of atmospheric pollutants, and it can also be used to evaluate the environmental quality, judge the class of pollution, and provide a basis for the ecological restoration [16,17,18,19]. In this paper, we studied the absorptions of cadmium and chromium of 17 common trees from the northern China, in Xinxiang city, in order to provide a scientific basis for the selection of urban greening trees.

2. Materials and Methods

2.1. The Selection and Design of Greening Trees

Seventeen kinds of greening tree have been selected from three functional areas, namely clean area (Xinxiang University), polluted area (industrial area) and the downtown, in spring (May, 2011) and in autumn (October, 2011). To make a study of the cadmium, chromium content in greening tree leaves from different functional areas, we choose October in a year, because at that time, the cadmium and chromium content in old leaves is relatively stable. The selected seventeen kinds of greening trees respectively are Fraxinus (Fr), Sophora japonica (SJ), Broussonetia papyrifera (BP), Ailanthus altissima (AA), Koelreuteria paniculata (KP), Pittosporum tobira (PiT), Purple-leaf plum(PP), Yucca gloriosa (YG), Platanus acerifolia(PlA), Populus tomentosa (PoT), Populus alba(PoA), Acer mono (AM), Buxus megistophylla (BM), Buxussinica (Bu), Ligustrun lucidum (LL), Ligustrum quihoui(LQ), Photinia serrulata (PS).

2.2. The Sample Collection and Preparation

From 8:00-12:00 in the morning, and from 2:00-5:00 in the afternoon in 2011, the healthy greening trees in different functional areas are collected as the samples. The selected trees have high similarity in height, age, growth conditions and so on. In sampling point collect 3-4 of each species and choose 2-3 branch including the middle and lower parts in four different directions outside the crown for multipoint sampling. The collected blades are carefully sealed in a self-sealing plastic bag and handle back to the laboratory. At first, the leaves collected were washed with tap water, and then, they were immersed in the distilled water for six hours. The leaves were then washed off dust and other dirts. The leaves collected and deactivated in the oven for 30 minutes at 105℃. Then, at 75℃, it was dried to constant weight, and then it was grinded in the electric grinder, and powder sample was passed through a sieve with 40 meshes. The grinded sample was placed in a clean sealing bag.

A total of 0.5 g dry samples were accurately weighed, and then the samples were mixed with 10 mL acid (HNO_3:$HClO_4$, 4:1 v/v). The beaker was covered overnight and digested in an electric furnace at 75℃ till all the white fumes disappear. Increasing the temperature (below 150℃) till all the fumes ceases to be produced. At the end of the digestion process, the liquid was clear and colorless. During the whole process, it was warned that the samples should not be carbonized. In the absence of good digestion, a few milliliters of mixed acid liquid can be added into the beaker until the liquid was transparent. About 20 mL of water was added into the beaker, and the sample was heated to reduce the volume of liquid to about 2-3 mL, the sample was cooled. The beaker is washed with 2% nitric acid and the sample was transferred into test tube of 25 mL. Water was added into the tube to the scale for test. A blank solution is made in the same way but without the leaves.

2.3. Determination Method

The content of cadmium, chromium was measured by 2100 DV inductively coupled plasma emission spectrometer manufactured by Perkin Elmer (Waltham, MA, USA).

3. Results and Discussion

3.1. Analysis of the Cadmium Content and Chromium Content in Different Functional Areas

The content of cadmium, chromium in the leaves of greening trees were shown in Table 1 that are located in different function areas. The content of cadmium in polluted area is higher than that that in clean area in all the greening tress tested with the exception of Acer mono. The content of chromium in polluted area is higher than that that in clean area with the exception of ligustrum lucidum. In the polluted area, the rank of cadmium content is as follows: Acer mono > Populus alba > Ligustrum quihoui > Populus tomentosa > Purple-leaf plum > Buxus megistophylla > Broussonetia papyrifera > Sophora Japonica > Ailanthus altissima > Platanus acerifolia > Koelreuteria paniculata> photinia serrulata >Fraxinus > Photinia serrulata > Fraxinus > Pittosporum tobira > Yucca gloriosa > Buxussinica > Ligustrun lucidum. In the clear area, the rank of chromium content is as follows: populus alba > Acer mono > Populus tomentosa > Ligustrum quihoui > Purple-leaf plum > Fraxinus > Buxussinica > Ailanthus altissima > Platanus acerifolia > Koelreuteria paniculata > photinia serrulata > Buxussinica > Broussonetia papyrifera > Yucca gloriosa > Pittosporum tobira > Sophora Japonica > Ligustrun lucidum. However, the cadmium content of the same greening trees under different polluted conditions differ from each. Eleven kinds of greening trees, namely Fraxinus, Sophora japonica, Broussonetia papyrifera, Ailanthus altissima, Koelreuteria paniculata, Pittosporum tobira, Purple-leaf plum, Yucca gloriosa, Platanus acerifolia, Ligustrum quihoui and Photinia serrulata, the difference of cadmium content is highly significant. While for four kinds of greening trees namely Populus alba, Acer mono, Buxus megistophylla and Ligustrun lucidum, the difference of cadmium content is significant. For the remaining two kinds of greening trees, Populus tomentosa and Buxussinica, the difference of cadmium content is not significant. In the polluted area, the rank of chromium content is as follows: Acer mono > Populus alba > Ligustrum quihoui > Populus tomentosa > Purple-leaf plum > Buxus megistophylla > Broussonetia papyrifera > Sophora japonica > Ailanthus altissima > Platanus acerifolia > Koelreuteria paniculata > Photinia serrulata > Fraxinus > Pittosporum tobira > Yucca gloriosa > Buxussinica > Ligustrun lucidum.

In the clear area, the rank of chromium content is as follows: Populus tomentosa > Acer mono > Populus alba > Buxussinica > Photinia serrulata > Purple-leaf plum > Platanus acerifolia > Ligustrun lucidum > Sophora japonica > Yucca gloriosa > Pittosporum tobira > Buxus megistophylla > Ligustrum quihoui > Sophora japonica > Koelreuteria paniculata > Fraxinus > Ailanthus altissima. Twelve kinds of greening trees, namely Fraxinus, Sophora Japonica, Broussonetia papyrifera, Koelreuteria paniculata, Pittosporum tobira, Purple-leaf plum, Yucca gloriosa, Platanus acerifolia, populus alba, Acer mono, Buxus megistophylla and Ligustrum quihoui, the difference of chromium content is highly significant. For the two kinds of greening trees, such as Ailanthus altissima, Populus tomentosa, the difference of chromium content is significant. For these following three kinds of greening trees, namely Buxussinica, Ligustrun lucidum, and Photinia serrulata, the difference of cadmium content is not significant. In summary, the results indicate that the cadmium and chromium content in the leaves of the greening trees in seriously polluted areas is higher. It can be concluded that the cadmium and chromium content is closely related to the concentration of atmospheric pollutants.

Table 1. Difference of Content of Cd and Cr between 17 greening trees in different areas (n=5, P=0.95)

Trees	Content of Cd ($mg.kg^{-1}$)		Content of Cr ($mg.kg^{-1}$)	
	Clear area	Polluted area	Clear area	Polluted area
Fr	0.090 ± 0.001	0.113 ± 0.003	1.138 ± 0.049	1.787 ± 0.017
SJ	0.008 ± 0.001	0.252 ± 0.009	1.915 ± 0.053	3.169 ± 0.023
BP	0.017 ± 0.004	0.255 ± 0.002	1.158 ± 0.008	2.232 ± 0.092
AA	0.055 ± 0.007	0.177 ± 0.004	0.982 ± 0.117	1.874 ± 0.023
KP	0.024 ± 0.002	0.138 ± 0.001	1.145 ± 0.018	2.548 ± 0.017
PiT	0.014 ± 0.001	0.080 ± 0.004	1.493 ± 0.017	2.883 ± 0.105
PlP	0.101 ± 0.001	0.339 ± 0.018	2.599 ± 0.050	6.574 ± 0.069
YG	0.016 ± 0001	0.065 ± 0.005	1.845 ± 0.019	2.911 ± 0.023
PlA	0.036 ± 0.011	0.168 ± 0.011	2.504 ± 0.067	3.312 ± 0.073
PoT	0.189 ± 0.008	0.404 ± 0.079	5.198 ± 0.334	7.966 ± 0.201
PoA	0.231 ± 0.013	0.501 ± 0.059	3.501 ± 0.345	7.177 ± 0.044
AM	0.216 ± 0.048	0.688 ± 0.041	4.666 ± 0.259	10.529 ± 0.309
BM	0.078 ± 0.017	0.287 ± 0.033	1.383 ± 0.039	1.870 ± 0.048
Bu	0.019 ± 0.002	0.039 ± 0.007	2.677 ± 0.317	2.628 ± 0.280
LL	0.005 ± 0.001	0.015 ± 0.002	2.258 ± 0.091	2.020 ± 0.053
LQ	0.119 ± 0.014	0.442 ± 0.039	1.204 ± 0.023	2.715 ± 0.081
PS	0.022 ± 0.002	0.130 ± 0.008	2.671 ± 0.257	4.181 ± 0.605

Key to abbreviations:
Fr: Fraxinus
SJ: Sophora japonica
BP: Broussonetia papyrifera
AA: Ailanthus altissima
KP: Koelreuteria paniculata
PiT: Pittosporum tobira
PP: Purple-leaf plum
YG: Yucca gloriosa
PIA: Platanus acerifolia
PoT: Populus tomentosa
PoA: Populus alba
AM: Acer mono
BM: Buxus megistophylla
Bu: Buxussinica
LL: Ligustrun lucidum
LQ: Ligustrum quihoui
PS: Photinia serrulata

3.2. Analyses on the Seasonal Variation of the Cadmium and Chromium Content in Leaves

Table 2 shows the seasonal variation of the cadmium and chromium content in seventeen kinds of leaves. It can be seen that the cadmium content is lower in spring and higher in autumn. Except Ailanthus altissima, Populus tomentosa, Buxus megistophylla and Ligustrun lucidum, the chromium content is higher in autumn than that in spring compared to other greening trees. The seasonal variation of cadmium content in leaves of the folloeing greening tree, which are Fraxinus, Sophora japonica, Ailanthus altissima, Koelreuteria paniculata, Pittosporum tobira, Purple-leaf plum, Yucca gloriosa, Buxus megistophylla and Ligustrum quihoui, is highly significantly. The seasonal variation of cadmium content in leaves of Broussonetia papyrifera, Platanus acerifolia, Populus tomentosa, populus alba, Acer mono, Buxussinica and photinia serrulata is significant. Only the seasonal variation of cadmium content in leaves of Ligustrun lucidum is not significant. The seasonal variation of chromium content in leaves of the greening trees, Fraxinus, Sophora japonica, Broussonetia papyrifera, Ailanthus altissima, Purple-leaf plum, Platanus acerifolia, Populus tomentosa, Populus tomentosa, Populus alba, Buxus megistophylla, Ligustrun lucidum and Photinia serrulata, is highly significantly in spring and autumn. The seasonal variation of chromium content in leaves of Yucca gloriosa and Ligustrum quihoui is significant. Only the seasonal variation of cadmium content in leaves of Pittosporum tobira is not spgnificant in spring and autumn. The low content of heavy metal pollutants in spring and autumn may be closely related to the physiological activities of the trees. In April and May, with the growth of the leaves, cadmium and chromium absorbed quickly spreads within the tree body and blades, which results in the lower concentration of heavy metal content. While, in autumn, with the growth of the leaves, the volume growth of leaves slows down; therefore, the cadmium and chromium content in leave slowly accumulates to the highest levels. Therefore, the cadmium and chromium content is higher in autumn than that in spring.

Table 2. Difference of Content of Cd and Cr by 17 kinds of greening trees in different seasons (n=5, P=0.95)

Trees	Content of Cd $mg.kg^{-1}$		Content of Cr $mg.kg^{-1}$	
	Spring	Autumn	Spring	Autumn
Fr	0.002 ± 0.000	0.111 ± 0.007	0.366 ± 0.034	2.170 ± 0.172
SJ	0.004 ± 0.001	0.037 ± 0.002	1.201 ± 0.025	2.541 ± 0.033
BP	0.020 ± 0.003	0.052 ± 0.004	1.127 ± 0.006	3.687 ± 0.084
AA	0.035 ± 0.004	0.132 ± 0.003	1.427 ± 0.069	2.923 ± 0.006
KP	0.043 ± 0.008	0.283 ± 0.016	0.624 ± 0.130	2.466 ± 0.020
PiT	0.003 ± 0.001	0.064 ± 0.005	2.146 ± 0.036	1.999 ± 0.244
PlP	0.002 ± 0.000	0.187 ± 0.005	3.579 ± 0.067	6.465 ± 0.061
YG	0.009 ± 0.001	0.036 ± 0.003	2.061 ± 0.030	2.362 ± 0.052
PlA	0.182 ± 0.001	0.228 ± 0.014	2.706 ± 0.033	4.458 ± 0.027
PoT	0.434 ± 0.014	0.629 ± 0.051	4.448 ± 0.162	8.356 ± 0.415
PoA	0.316 ± 0.020	0.593 ± 0.062	3.392 ± 0.112	6.615 ± 0.020
AM	0.044 ± 0.001	0.358 ± 0.071	5.377 ± 0.045	9.851 ± 0.231
BM	0.027 ± 0.001	0.164 ± 0.008	8.280 ± 0.505	1.464 ± 0.022
Bu	0.014 ± 0.000	0.047 ± 0.006	5.460 ± 0.005	7.766 ± 0.180
LL	0.151 ± 0.008	0.661 ± 0.037	6.101 ± 0.115	1.597 ± 0.009
LQ	0.123 ± 0.001	0.236 ± 0.046	4.359 ± 0.070	2.901 ± 0.202
PS	0.092 ± 0.002	0.117 ± 0.005	3.427 ± 0.056	4.236 ± 0.058

Key to abbreviations:
Fr: Fraxinus
SJ: Sophora japonica
BP: Broussonetia papyrifera
AA: Ailanthus altissima
KP: Koelreuteria paniculata
PiT: Pittosporum tobira
PP: Purple-leaf plum
YG: Yucca gloriosa
PIA: Platanus acerifolia
PoT: Populus tomentosa
PoA: Populus alba
AM: Acer mono
BM: Buxus megistophylla
Bu: Buxussinica
LL: Ligustrun lucidum
LQ: Ligustrum quihoui
PS: Photinia serrulata

3.3. A Comprehensive Analysis of Cadmium and Chromium Content in the Leaves

To make a comprehensive analysis of cadmium and chromium content in leaves of 17 kinds of greening trees, a comparative study of the mean value were performed, which shows that the rank of the cadmium content is as follows: Populus alba > Acer mono > Populus tomentosa > Ligustrun lucidum > Purple-leaf plum > Buxus megistophylla > Ligustrum quihoui > Koelreuteria paniculata > Platanus acerifolia > Ailanthus altissima > Sophora japonica > Fraxinus > Sophora japonica > photinia serrulata > Pittosporum tobira > Yucca gloriosa > Buxussinica. The rank of the chromium content is as follows: Acer mono > Populus tomentosa > populus alba > Purple-leaf plum > Buxussinica > Photinia serrulata > Platanus acerifolia > Sophora japonica > Ligustrum quihoui > Broussonetia papyrifera > Yucca gloriosa > Pittosporum tobira > Pittosporum tobira > Ligustrun lucidum > Ailanthus altissima > Fraxinus > Buxus megistophylla.

The cadmium and chromium content in leaves of Populus alba, Acer mono and Populus tomentosa, are significantly different compared with others greening trees. According to the different absorption ability, the 17 kinds of greening trees used in this study were divided into three categories by the means of K-Means Cluster from SPSS 17.0 software (Chicago, IL, USA). Populus tomentosa and Acer mono fall into the first category. Purple-leaf plum, Platanus acerifolia, Populus alba, Buxussinica and Photinia serrulata fall into the second category. Fraxinus, Sophora japonica, Broussonetia papyrifera, Ailanthus altissima, Koelreuteria paniculata, Pittosporum tobira, Yucca gloriosa, Buxus megistophylla, Ligustrun lucidum, and Ligustrum quihoui fall into the third category.

4. Conclusion

The cadmium content is more than the chromium content in the same leaves. The difference in term of cadmium and chromium content in various kinds of leaves is highly significant. Those trees which are high in cadmium content are Populus alba, Acer mono, Populus tomentosa, Ligustrun lucidum and Purple-leaf plum. Those trees high in chromium content are Acer mono, Populus tomentosa, Populus alba, Purple-leaf plum and Photinia serrulata. The reasons for these differences are structure surface, the degree of moist, the distance between leaves, the nature of heavy metal, soil and climatic conditions. The cadmium and chromium content of 17 kinds of greening trees differ from each other with the seasonal change and difference of pollution sources. For example, in different pollution sources, the cadmium and chromium content in the same trees in polluted areas is different those in the clean areas, and the cadmium and chromium content in the same trees in spring is higher than those in autumn. In term of the categories of the cadmium and chromium content of 17 kinds of greening trees, Populus tomentosa and Acer mono fall into the first category. Purple-leaf plum, Platanus acerifolia, Populus alba, Buxussinica and Photinia serrulata fall into the second category. Fraxinus, Sophora japonica, Broussonetia papyrifera, Ailanthus Altissima, Koelreuteria paniculata, Pittosporum tobira, Yucca gloriosa, Buxus megistophylla, Ligustrun lucidum and Ligustrum quihoui fall into the third category. In order to reduce air pollution, beautify the environment, give priority to those trees that are good at absorption of pollution and resistance to pollution, and obtain the biggest environmental ecological benefit. The results show that Populus alba, Populus tomentosa and Acer mono are good at absorption of cadmium and chromium, which should be selected as the greening trees. Analysis of seasonal variation and different pollution sources are to be considered. Further research will be conducted for the analysis of the other elements.

Statement of Competing Interests

The authors have no competing interests.

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