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Distribution Characteristics of the Heavy Metal Cd in the Irrigation Water-Cultivated Soil-Fertilizer-Crop Ecosystem

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Abstract Shuangqiao Countryside of Neijiang City in hilly ground area in the midland of Sichuan Province was chosen as the study geographic area to survey and analyze the content distribution characteristics of the Cd in the irrigation water, ground water mud, surface layer cultivated soil, profile soil and the fertilizer which were often used in the locality, and in different crops set earth, fructification as well. The results showed that the content of Cd in the irrigation and ground water mud respectively comply with the national agriculture use irrigation standard and the contamination control standard value in agriculture use mud (GB4284 – 84) respectively. The average contents in the surface cultivated soil and each layer of soil profile are all above the background level of Chengdu economic region (44%), referring to a large scale pollution risk. The average value of Cd element in fertilizer was 1.81 μg/g, which was higher than the third class standard of national soil environment quality; The average content of Cd element in the crops' set earth was 0.410 – 0.439 μg/g, which was higher than the second class standard of national soil environment quality and there was a measure of cumulation; The average values of Cd in crops' fructificationwas all below the primary standard of national soil environment quality, and the bio-amplification coefficient sorting was CF(Cdpeanut) > CF(Cdcitrus) > CF (Cdrice) > CF(Cdcorn). Irrigation water had little influence on the soil Cd pollution, where fertilizer using was closely related to the Cd pollution in the surface cultivated soil in the survey area and had a certain influence on the Cd cumulation in the crops. The sorption and enrichment of crops' set earth and fructification was obviously different.

Key words Cd, Irrigation water, Soil, Fertilizer, Crop

Cd, as a kind of heavy metal element with high biological toxicity, accumulates in soil and remains in the crops' body, which would in return end up in human beings' body and pose potential threat to human being[1]. Many scientists have studied Cd pollution, but there are few researches on the distribution characteristics of Cd in irrigation-soil-fertilizer-ecological system of crops [2, 3]. According to the Shuangqiao Countryside in central Sichuan, the distribution characteristics of Cd in irrigation water, cultivated soil, fertilizer and crop in the study area were analyzed so as to provide scientific reference to the prevention of Cd pollution and reasonable adjustment of agricultural industrial structure.

The study area lies in Shuangqiao Countryside in Neijiang City in central Sichuan Province (104°50′ – 105°25′ E, 29°26′ – 29°50′ N) and the entire area occupies 118 100 hm^2. The territory is mainly moderate and shallow hills, which covers about 83.15% of the entire territory. The land is high in northeast and low in southwest; mostly between 350 and 400 m, and the relative height differs by 20 to 80 m. The rock is mainly sediment rock and shale. The soil is mostly purple soil and rice soil, which account for 52.53% and 45.82% respectively. The pH value in the soil is mostly moderate and little soil is acid. The climate is subtropical humid climate, as the annual highest temperature was 37.6 ℃, the lowest temperature – 1.2 ℃, annual average temperature 17.7 ℃, annual average relative humidity of air 83%, annual average sunshine hours 1 223.1 h and annual precipitation 1 106.9 min[4].

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1 Materials and methods

1.1 Sample collection The depth of surface soil sample was soil column of 0 to 20 cm. The average collection density of surface soil sample was 16 points/km^2. One sample referred to the collection of one column with five points within a radius of 20 m around the sample point. There were 225 soil samples. The dry sample was sifted through 20 meshes and was measured after putting it in the bottle and stirred evenly[5].

The depth of sample from soil vertical section was between 0 and 80 cm. The profile sample was collected incessantly every 20 cm. The sample layer was in the cultivation layer from 0 to 20 cm, plow sole from 20 to 40 cm, old cultivation layer from 40 to 60 cm, and ancient cultivation layer from 60 to 80 cm. 24 places of soil vertical section were collected and there were 96 samples in total. The section covered all the major land types in the study area (paddy field, vegetable field, forest, fruit garden, and the drought land) (Fig. 1, Fig. 2).

Five pieces of samples of irrigation water and cultivated soil were collected from the study area, as well as four kinds of mineral fertilizer which was often used by local farmers.

Among the 67 pieces of samples, there were 24 pieces of rice, 21 pieces of oranges, 22 pieces of corn in dry field and 20 pieces of peanuts. The root and fruit were collected and put into plastic bag in case of evaporation. The orange samples were

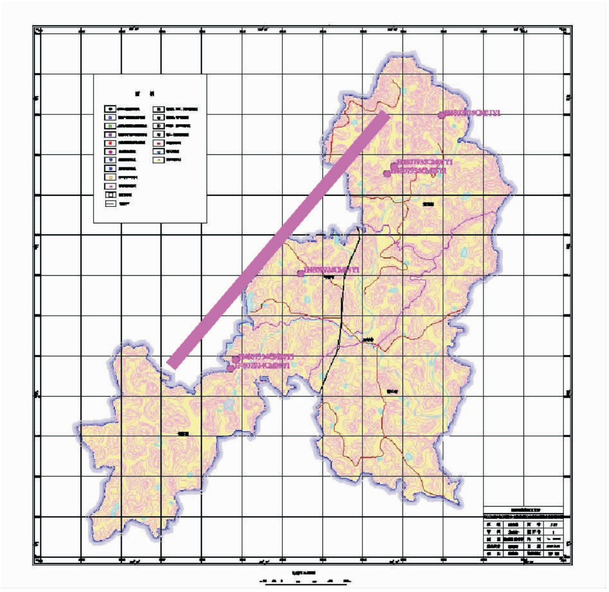

Fig. 1 Distribution of soil section in Shuangqiao Countryside

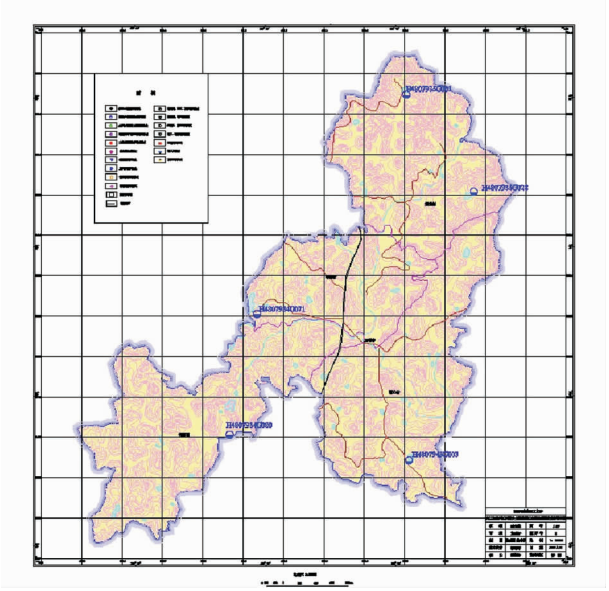

Fig. 2 Distribution of irrigation water and collected mud in the Shuangqiao Countryside

cleansed and parched by ionized water and were cut into pieces before measurement. Rice, peanut, and corn were parched to thresh in the lab, narrowed to 100 g before grinding into powder and sifting through 0.5 mm mesh for measurement[6].

1.2 Sample analysis method The heavy metal Cd in the soil sample was measured by ion assimilation method[6]. 210 g orange samples were put into the tub and rinsed through nitric acid and peroxide (30%) before being put into dryer around 120 to 140 ℃ for 4 hours. After it was cooled down to room temperature, the Cd in the sample was measured by graphite ion assimilation spectrum meter. The samples of rice, corn and peanut were changed into solution by dry ash method and were measured by graphite ion assimilation spectrum meter.

In order to explain the direct influence of the content of heavy metal in soil on the content of heavy metal in crops, the biological enrichment coefficient in edible part of crop was applied to describe the relevance of rice and roots soil[7]. The calculation formula was as follow:

Biological enrichment coefficient $(CF_i) = (C_b/C_c) \times 100\%$

In the formula, Cb was the concentration of elements in the organism and Cc was the concentration of root soil.

2 Results and analysis

2.1 Cd content in the irrigation water and collected mud

The pH of irrigation water was between 6.9 and 7.3 and the average value was 7.1. The Cd content was between 0.36 and 1.30 μg/g and the mean value was 0.53μg/g, which met the national standard of irrigation water for agricultural purpose. The amount of Cd in cultivated soil was between 0.24 and 0.86 μg/g and the mean value was 0.39 μg/g, which met the standard value of pollutants in agricultural mud (GB4284 – 1984)(pH≥6.5).

Table 1 The content of Cd in irrigation water and mud Cd μg/g

Sample	Range	Mean value	National standard irrigation water for agricultural purpose and standard value of pollutants in the sludge (GB4284 – 84) pH≥6.5
Irrigation water	0.36 – 1.3	0.53	≤5
Cultivated mud	0.24 – 0.86	0.39	≤20

2.2 Cd content in the surface soil As shown in Table 2, the Cd content in the surface soil was between 0.239 and 0.528 μg/g and the average content was 0.36 μg/g, which was 44% higher than the background value of soil in Chengdu Economic Zone. The variance value was 14%, which suggested that the Cd was unevenly distributed in the surface soil. $K_1 = 1.400$ reflected that the Cd content in the soil was richer than that in Chengdu Economic Zone. $K_2 = 1.458$ was the ratio of average content of Cd in the surface soil and corresponding value in deep layer, which indicated certain enrichment of Cd element in the surface soil. There was Cd pollution in 98.8% samples.

2.3 Characteristics of vertical distribution of Cd in the soil section According to the Cd content in each section layer, the Cd amount tended to decrease in the cultivation layer, plow sole, old cultivation layer and ancient cultivation layer (Fig. 3, Table 3). This indicated that the content of Cd in the surface soil reduced with the addition of soil depth and the Cd content in the deep soil varied little. The element in the deep soil reflected the background of elements in the soil. The addition of element in the soil was closely related to human activity. There was slight Cd pollution in 95.6% samples of soil section.

2.4 Content of Cd elements in the fertilizer The content of Cd elements in the fertilizer ranged from 1.75 to 1.87 μg/g and the mean value was 1.81 μg/g, which was far higher than the first grade, second grade and third grade of national soil quality (Table 4). Because that local farmer used to apply superphosphate and the Cd content in the fertilizer was high, the amount of superphosphate that farmers used reaches 200 kg/hm^2 every year, in other words the annual fertilized amount of Cd in superphosphate was 0.543 g/hm^2, which suggested certain relation between fertilizer and Cd pollution.

Table 2 Cd content in the soil in the surface μg/g

Range	Mean value	Standard deviation	Variable coefficient	Relative abundance		Chengdu Economic Zone	
				K1	K2	Content	Background value
0.239 – 0.528	0.36	0.05	0.14	1.400	1.458	0.06 – 20.7	0.25

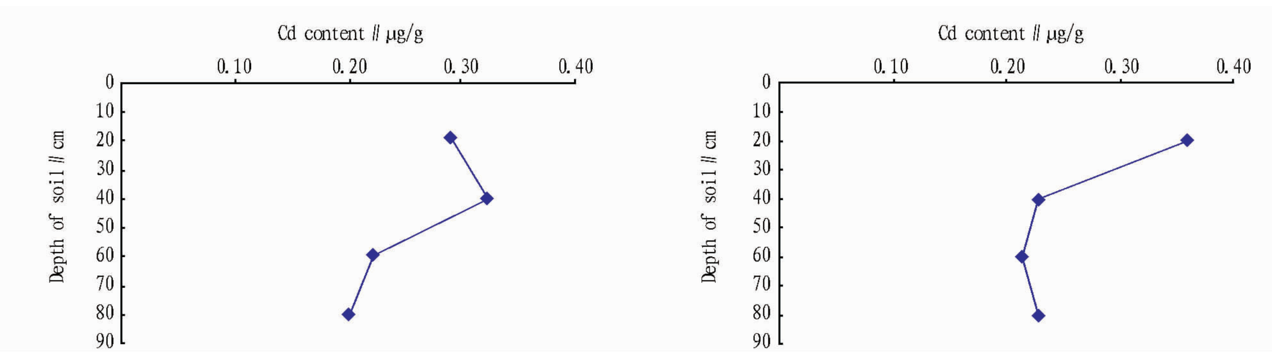

Fig. 3 Distribution characteristics of Cd of vertical section in paddy land (first) and dry land (second)

Table 3 Changes of Cd element in the surface of soil μg/g

0 – 20 cm	20 – 40 cm	40 – 60 cm	60 – 80 cm	Background value of Chengdu Economic Zone
0.36	0.27	0.24	0.29	0.25

Table 4 Quality standard of soil (GB – 15618 – 95) mg/kg

Soil grade	First grade	Second grade			Third grade
pH value	Natural background	<6.5	6.5 – 7.5	>7.5	>6.5
Cd ≤	0.20	0.30	0.30	0.60	1.0

2.5 Content of Cd element in the crop The root and fruit of different crops have different effects on the assimilation and enrichment of Cd (Table 5). The Cd content was between 0.410 and 0.439 μg/g. Though it changed little, it was higher than that second standard of soil quality. The Cd content order was Cd peanut > Cd rice > Cd orange > Cd corn.

Table 5 Cd content in crops and enrichment coefficient μg/g

Sample name	Range	Mean value	Enrichment coefficient	
			Range	Mean value
Rice	0.004 – 0.010	0.007	1.21 – 2.23	1.4
Root soil of rice	0.367 – 0.515	0.436		
Corn	0.003 – 0.007	0.003	0.737 – 1.754	1.246
Root soil of corn	0.399 – 0.407	0.410		
peanut	0.108 – 0.149	0.118	25.1 – 33.2	28.40
Root soil of peanut	0.431 – 0.449	0.439		
Orange	0.005 – 0.027	0.018	3.701 – 4.677	4.295
Root soil of orange	0.401 – 0.435	0.419		

The absorption effect of peanut on Cd was significant, and the Cd content in the root soil of rice, corn, peanut, and orange was 62.3, 136.7, 3.7 and 23.3 times of that in the fruits. Therefore, the root soil of crop was also polluted by Cd and the Cd in the root soil was larger than that in the fruits, which suggested that the crops mainly absorb Cd in the soil through roots and then transport it to fruits.

The mean value of Cd in the four kinds of fruits was lower than the first grade standard of national soil environment quality. The average content of Cd in the fruit was from 0.003 to 0.118 μg/g and the order was $Cd_{peanut} > Cd_{orange} > Cd_{rice} > Cd_{corn}$, which indicated that the both corn and rice absorbed little Cd while the Cd in the peanut was relatively high. The biological enrichment coefficient was $CF_{Cd_{peanut}} > CF_{Cd_{orange}} > CF_{Cd_{rice}} > CF_{Cd_{corn}}$, which suggested that the absorption of peanut of Cd was strong, and the corn and rice had little influence on the enrichment of Cd.

3 Conclusions and discussion

The mean value of Cd in the irrigation water in the study area was 0.53 μg/g, which met the national agricultural irrigation water standard. The mean value of Cd in the cultivated mud was 0.39 μg/g, which met the pollutants control standard (GB4284 – 1984, pH≥6.5).

The average content of Cd in the surface soil was 0.36 μg/g, which was 44% higher than that in the background value of soil in Chengdu economic zone. Besides, there was Cd pollution in 95.6% of the surface soil and soil section sample. Cd accumulated in the surface soil and then decreased in the cultivation layer, plow sole, old cultivation layer and ancient cultivation layer. The Cd content in the cultivation layer was the highest.

The mean value of Cd in the fertilizer was 1.81μg/g, which was higher than the third grade standard of national soil environment.

The Cd content in the root soil was between 0.410 and 0.439 μg/g, which was higher than the second grade standard of national soil environment quality. The mean value of Cd in the crop fruit was smaller than the first grade standard of national soil quality. The average content of Cd in the fruit was between 0.003 and 0.118 μg/g and the order was $Cd_{peanut} > Cd_{orange} > Cd_{rice} > Cd_{corn}$. The biological enrichment coefficient was $CF_{Cd_{peanut}} > CF_{Cd_{orange}} > CF_{Cd_{rice}} > CF_{Cd_{corn}}$. The Cd enrichment coefficient in the peanut was the highest and the influence of corn enrichment was the minimum.

The Cd pollution in the surface soil and soil section in the irrigation water and the study area was not closely related. The superphosphate that farmers used to apply was closely related to the Cd pollution in the soil. The fertilizers should be applied to the crops scientifically, as the organism can increase the absorption of soil towards heavy metal and promote the CdS sediment in the soil.

The Cd amount in the fruits of crops came from the soil and the roots of peanut and rice absorbed lots of Cd. The Cd enrichment in the fruits of peanut was the most distinct one. Therefore, when Cd pollution was found in lots of soil in the study area, the local government should choose crops that can resist pollution and should improve plantation structure. It is suitable to plant corn and rice because both absorb little Cd and the Cd in the fruit is relatively little, while it is inappropriate to plant peanut as the enrichment effect in the fruit of peanut is distinct.

References

[1] CHEN HM. Soil—Heavy metal pollution in plant system[M]. Beijing: Science Press, 1996. (in Chinese).
[2] XU YX, PENG PH, CHEN WD. On heavy metal pollution and ecological risk assessment in surficial soil of Shuangqiao Rural of Neijiang City in Sichuan Province[J]. Journal of Anhui Agricultural Sciences, 2008, 36(5): 1997 –1998. (in Chinese).
[3] HUANG L, WANG K, PENG PH, *et al*. The risk evaluation about the contents of heavy metals in soil in Shuangqiao Village of Neijiang City[J]. Computing Techniques for Geophysical and Geochemical Exploration, 2011, 36(9): 33 –40. (in Chinese).
[4] BAO SD. Soil and agricultural chemistry analysis[M]. The 3rd ed. Beijing: China Agriculture Press. (in Chinese).
[5] LI RM. On agricultural geological and geochemical evaluation method[M]. Beijing: Geological Publishing House, 2007. (in Chinese).
[6] JIN Y, HE DW. Review on pollution assessment of heavy metals[J]. Nonferrous Metals, 2007, 59(2): 100 –103. (in Chinese).
[7] HUANG J. Territorial distribution and environment capacity of cadmium and lead in agricultural land of Chongqing and their response to acid rain[J]. Chongqing: Southwest Agricultural University, 2004: 5. (in Chinese).
[8] ZHANG L, CHEN CC, LIU QY. On soil pollution control method[J]. Transactions of the Chinese Society of Agricultural Engineering, 1992, 8: 90 –99. (in Chinese).
[9] ZHENG YM, LUO JF, CHEN TB, *et al*. Cadmium accumulation in soils for different land uses in Beijing[J]. Geographical Research, 2005, 24(4): 542 –548. (in Chinese).
[10] XIE ZM, LI J, CHEN JJ, *et al*. Study on guidelines for health risk to heavy metals in vegetable plantation soils in China[J]. Asian Journal of Ecotoxicology, 2006, 1(2): 172 –179. (in Chinese).

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population size of cattles and horses, but also reduce the threats of black bears. But with the increasing animal populations, the quantity of cattles and horses has exceeded the carrying capacity of local environment. The maximum number of cattles and horses in Tongle pasture was only about 200 previously, and maintained at around 100, but the figure increases to more than 500. The explosion of cattles and horses not only destroys local pasture, but also results in a lack of animal feeds. As a result, about 20 cows ran to Kangpu pasture for food in August, 2011, leading to a dispute between two villages.

All in all, as a carrier of traditional Lisu culture, the vertical agricultural system in Tongle Village faces various challenges, for example, how to deal with the relationships between economic development and ecological and cultural conservation has become a tough task for the government, scholars and also the villagers. A win-win situation of economic development and cultural conservation can only be realized based on the vertical agricultural system by improving the utilization rate of local lands and forest, and increasing the farmers' incomes, and only in this way can the agriculture take a path of sustainable development.

References

[1] LU LS. Chinese stereoscopic agriculture mode[M]. Henan Science and Technology Press, 1993:3. (in Chinese).
[2] Culture center of Diqing Tibetan Autonomous Prefecture, Intangible cultural heritage protection center of Diqing Tibetan Autonomous Prefecture, Intangible cultural heritage protection catalogue of Diqing Tibetan Autonomous Prefecture (volume one)[M]. The Nationalities Publishing House of Yunnan, 2010 –08: 13, 27. (in Chinese).
[3] Yezhi Town committee of the Communist Party of China, sponsored by Yezhi Town people's government. General situation of the first, second, third and fourth groups in Tongle Village of Yezhi Town of Weixi Lisu people [EB/OL]. www.ynszxc.gov.cn. http://www.ynszxc.gov.cn/szxc/villagePage/vindex.aspx? departmentid =94939&classid =986937.
[4] Yezhi Town committee of the Communist Party of China, sponsored by Yezhi Town people's government. Human geography of Tongle Village in Yezhi Town of Weixi Lisu people [EB/OL]. www.ynszxc.gov.cn. http://www.ynszxc.gov.cn/szxc/villagePage/vindex.aspx? departmentid = 94903&classid = 986578.
[5] PENG YA, LUO LS. Study on the diversity of national culture in Hengduan Mountain District of Yunnan Province[J]. Resources Science, 2000, 22(5): 61. (in Chinese).
[6] Autonomous County Compiling Committee of Weixi Lisu People. Autonomous County of Weixi Lisu People 1978 –2005[M]. The Nationalities Publishing House of Yunnan, 2009: 33. (in Chinese).
[7] Autonomous County Compiling Committee of Weixi Lisu People. Autonomous County of Weixi Lisu People 1978 –2005[M]. The Nationalities Publishing House of Yunnan, 2009: 38. (in Chinese).
[8] Autonomous County Compiling Committee of Weixi Lisu People. Autonomous County of Weixi Lisu People [M]. The Nationalities Publishing House of Yunnan, 1999: 236. (in Chinese).
[9] Autonomous County Compiling Committee of Weixi Lisu People. Autonomous County of Weixi Lisu People [M]. The Nationalities Publishing House of Yunnan, 1999: 150. (in Chinese).
[10] Culture center of Diqing Tibetan Autonomous Prefecture, Intangible cultural heritage protection center of Diqing Tibetan Autonomous Prefecture, Intangible cultural heritage protection catalogue of Diqing Tibetan Autonomous Prefecture(volume one)[M]. The Nationalities Publishing House of Yunnan, 2010 –08:84. (in Chinese).
[11] LI YY. Lisu traditional culture which should face modern development[J]. Journal of Yunnan Nationalities University:Social Sciences, 1998(4):36 –37. (in Chinese).
[12] CUN RH. Preliminary study on the traditional forest resources management of Lisu people in the Gaoligong Mountain[J]. Journal of Beijing Forestry University: Social Science, 2002(9):45. (in Chinese).