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Safety Assessment of Heavy Metal in Tea Garden Soil: A Case Study of Specialized Tea Towns in Guangdong

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Abstract More than 20 soil samples were collected from tea gardens of specialized tea towns in Guangdong, including Fenglang Town and Fengshun Town in Meizhou City, Changshan Town in Lianjiang City, Fenghuang Town in Chaozhou City. Content of 6 types of heavy metal (Cr, Cu, Pb, As, Cd, Hg) in tea garden soil was measured. On the basis of these, the safety was assessed. Results show that the comprehensive pollution index of these 6 types of heavy metal is lower than 0.7. According to Soil Pollution Grading Standard formulated by China Green Food Development Center, the soil is not polluted by heavy metal and remains at safety level. It proves that overall soil condition of specialized tea gardens in Guangdong Province is not polluted by heavy metal.

Key words Guangdong, Specialized tea towns, Heavy metal, Safety assessment

1 Introduction

Tea garden soil is the material base for survival of tea trees, and soil safety exerts direct influence on tea quality. Production practice has manifested that soil is one of the important factors influencing tea quality[1]. In recent years, people care more about food safety, and the tea quality becomes a focus of attention. Since heavy metals will be mingled in the process of production and processing of tea trees, content of heavy metal becomes an essential indicator for assessing safety of tea quality. As a variety of acidophilous plant, tea tree will absorb certain amount of harmful metallic elements from soil in the growth period. If those harmful elements enter into human body, it will cause physical injury. Some research has indicated that lead in soil is the major source of lead in tea, and it will enter into plant through contaminated soil, and ultimately harm human health[2]. Through constant accumulation, heavy metals in soil will gradually enter into plant system, then enter into agricultural products through the food chain, and finally jeopardize human health, biological safety and sustainable development of economy[3].

Situated in southern subtropical zone, Guangdong Province has better climate, great temperature difference between day and night, plentiful rainfall, and long frost-free period. Acid soil in hilly and mountain areas is especially suitable for planting tea trees. Thus, Guangdong Province has gifted production advantages in morning tea business and counter-season tea. Superior natural resources provide favorable conditions for tea development. At present, Guangdong Province has more than 500 000 mu tea gardens, with total output of tea reaching 60 000 tons and output value about 1.5 billion yuan. Main planting areas are distributed in Meizhou, Chaozhou, Heyuan, Shaoguan and Qingyuan, etc. In recent years, tea production develops rapidly in Jiangmen, Zhanjiang and Zhaoqing. Some regions have set up specialized tea production towns, including Changshan Town of Lianjiang City in western Guangdong, Fenglang Town of Meizhou City, Fenghuang Town and Fubin Town in Chaoan County of Chaozhou City, and Shangguan Town and Kanghe Town of Heyuan City in eastern Guangdong Province. Present researches manifest that there is no report about safety assessment of tea garden soil, so the soil quality is still a blind area. As important carrier of tea production base, the productivity quality of soil and environmental quality directly influence growth of tea trees and output and quality of tea. Therefore, safety assessment of tea garden soil has become a problem to be urgently solved in the process of tea production in Guangdong Province. Taking typical specialized tea gardens in Guangdong Province as research object, we assessed safety condition of heavy metals in tea garden soil. It is believed that this study will be of great significance to sustainable use of tea gardens, sound development of tea industry, and improvement of tea quality and safety. In addition, it will provide scientific basis and technical support for developing organic tea, and promoting and safeguarding sustainable development of tea industry.

2 Materials and methods

2.1 Sampling place We collected samples from tea garden soil in Fenglang Town and Fengshun Town of Meizhou City, Changshan Town of Lianjiang City and Fenghuang Town of Chaozhou City in May of 2012. The detail is listed in Table 1.

2.2 Sampling methods Five-point sampling method was adopted. We removed residual branches and stone on soil surface, and collected samples at 0 – 20 cm depth. After collecting the soil samples, we separated large root system and gravel, placed soil

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samples indoor for air drying, and finally ground the soil for use[3].

Table 1 Soil samples under test

No.	Location	Altitude or fertility	Fertilizer application
1	Changshan Town	300 m	
2		420 m	
3		550 m	
4		750 m	
5		900 m	
6	Fenglang Town	grey-brown soil, moderate fertility	
7		Sandy soil, yellow soil	
8		Yellow soil, high fertility	
9		Sandy soil, grey-brown soil	
10		Yellow soil, high fertility	
11	Fenghuang Town	550	
12		690	No fertilizer
13		899	
14		1050	
15		550	
16	Matu Town of Fengshun County	413	
17		520	
18		562	
19		585	
20		605	
21		684	
22		701	

2.3 Major reagents and instruments Acid digestion solution: nitric acid, perchloric acid, sulfuric acid and hydrochloric acid; alkaline solution: sodium hydroxide (NaOH), potassium hydroxide (KOH); standard stock solution for Cu, Pb, Cd, Cr, Hg and As. The above reagents are guaranteed (GR) reagents.

Instruments used include novAA400 atomic absorption spectrophotometry (equipped with Pb, Cu, Cd, and Cr hollow – cathode lamps) made by Analytik Jena AG and AFS – 9700 atomic fluorescence spectrometer made by Beijing Kchuang Haiguang Instrument Co., Ltd.

2.4 Methods for measuring content of heavy metals Cd adopts hydrochloric acid – nitric acid – perchloric acid digestion method; As adopts nitric acid – hydrochloric acid – perchloric acid digestion method; Hg adopts nitric acid – permanganic acid digestion method; Cu and Pb adopts hydrochloric acid – nitric acid – hydrofluoric acid – perchloric acid wet digestion method, and ICP – AES measurement; Cr adopts sulfuric acid – nitric acid – hydrofluoric acid digestion method. After digestion, we measured content of heavy metals in soil samples using the above stated instruments[4].

2.5 Assessment methods for heavy metal pollution of tea garden soil For the nonce, assessment methods for heavy metals in tea garden soil both at home and abroad mainly include single factor pollution index method and Nemerow synthetic pollution index method[5-7].

Single factor pollution index method: $Pi = Ci/Cs$, where Pi signifies pollution index of the contaminant i in the samples, Ci stands for measured value of contaminant i in the samples, and Si refers to standard value of contaminant i in the samples.

Nemerow synthetic pollution index method:

$$p = \sqrt{\frac{p_{max}^2 + p_{ave}^2}{2}}$$

where P is the pollution index of soil (*i. e.* Newmerow pollution index), P_{max} means the maximum value of single pollution index of soil contaminants, and P_{ave} is the average value of single pollution index of soil contaminants. China Green Food Development Center has formulated soil pollution grading standard, as listed in Table 2.

Table 2 Grading standard for heavy metal pollution of soil

Grade	Synthetic pollution index	Pollution intensity
1	$P \leqslant 0.7$	Safe
2	$0.7 < P \leqslant 1.0$	Warning
3	$1.0 < P \leqslant 1.5$	Mild pollution
4	$1.5 < P \leqslant 2.0$	Medium pollution
5	$2.0 < P \leqslant 3.0$	Heavy pollution
6	$P > 3.0$	Severe pollution

3 Results and analyses

3.1 Analysis on heavy metal content in tea garden soil sampled in different location Table 3 indicates that most 6 types of heavy metals have not exceeded specified standard in tea garden soil sampled in different location, only Cr with sample number 17, 19 and 20 exceeds the standard. On the whole, the quality of tea garden soil reaches Grade 2 of national standard. In tea garden soil, content of heavy metals is Cr > Pb > Cu > As > Hg > Cd.

Relative content of Cr is higher, and the average value is up to 68.4 mg/kg, possibly because of some agricultural pollution sources, such as application of fertilizer. Average content of Pb is 26.6 mg/kg at medium level. Excessive application of nitrogen fertilizer will lead to soil acidification. Since Pb is vulnerable to be converted into soluble state, its biological effectiveness will rise accordingly[3]. Also, it will increase crops' absorption of Pb. Besides, Pb content is soil of tea gardens along roadsides with motor vehicles driving. Thus, tea gardens should be far away from areas with motor vehicles running as much as possible. Average content of Hg is about 0.072 mg/kg. Generally, the Hg content in soil is greatly influenced by human activities, indicating that human activities are relatively weak in sampling areas.

In sum, heavy metals are relatively less in soil of specialized tea towns, and the soil is relatively clean.

3.2 Assessment of heavy metal pollution of tea garden soil We take NY 5020 – 2001 *Standard for Soil Environmental Quality of Pollution-free Tea Garden* as the standard for assessing soil environmental quality, and take the synthetic pollution index as assessment indicator. From the single factor pollution index (Table 4), it can be known that samples 17, 19 and 20 have Cr pollution index greater than 1, exceeding the specified standard, and other heavy metals in tea garden soil do not exceed standard. The pollution index of 6 types of heavy metals is Cr > Hg > Cd > As > Pb > Cu, and the average pollution index falls in the range of 0.085 – 0.457.

Table 3 Content of heavy metals in soil samples

No.	Content of heavy metals in soil // mg/kg					
	Hg	As	Pb	Cd	Cr	Cu
1	0.016	2.30	12.20	0.18	11.27	15.00
2	0.012	1.10	8.90	0.06	9.38	10.40
3	0.005	0.80	9.80	0.05	11.44	7.50
4	0.018	2.80	10.90	0.28	20.55	12.30
5	0.026	3.70	15.70	0.10	15.30	9.80
6	0.109	9.90	23.50	0.11	34.31	7.80
7	0.075	8.90	12.10	0.03	20.03	5.90
8	0.169	6.50	9.70	0.03	18.97	6.80
9	0.103	6.70	27.90	0.04	17.38	5.40
10	0.153	10.10	20.15	0.09	22.08	9.45
11	0.07	7.26	27.1	0.03	78.6	11.8
12	0.05	2.68	32	0.04	55.4	6.1
13	0.08	4.14	31.8	0.04	61.2	4.4
14	0.06	2.38	60.6	0.08	41.7	7.6
15	0.15	5.7	30.9	0.07	106	42.4
16	0.05	4.09	39.6	0.07	52.3	18
17	0.1	14.8	36.8	0.03	230.7	24.5
18	0.04	15	38.7	0.07	88	18.4
19	0.09	24.3	33.3	0.04	210.6	17.8
20	0.1	7.5	35.6	0.06	168.8	15.6
21	0.05	15.6	34.3	0.03	126.2	15.3
22	0.06	4.5	32.7	0.04	104.3	8

Table 4 Assessment of heavy metal pollution of tea garden soil

No.	Single factor pollution index						Nemerow synthetic pollution index	
	Cu	Pb	Cd	Cr	Hg	As		
1	0.1	0.05	0.6	0.08	0.05	0.06	0.117	0.098
2	0.069	0.04	0.2	0.06	0.04	0.03	0.055	
3	0.05	0.04	0.17	0.08	0.02	0.02	0.046	
4	0.082	0.04	0.93	0.14	0.06	0.07	0.164	
5	0.065	0.06	0.33	0.1	0.09	0.09	0.109	
6	0.052	0.09	0.37	0.23	0.36	0.25	0.237	0.197
7	0.039	0.05	0.1	0.13	0.25	0.22	0.183	
8	0.045	0.04	0.1	0.13	0.56	0.16	0.168	
9	0.036	0.11	0.13	0.12	0.34	0.17	0.16	
10	0.063	0.08	0.3	0.15	0.51	0.25	0.239	
11	0.079	0.11	0.1	0.52	0.23	0.18	0.193	0.169
12	0.041	0.13	0.13	0.37	0.17	0.07	0.117	
13	0.029	0.13	0.13	0.41	0.27	0.1	0.146	
14	0.051	0.24	0.27	0.28	0.2	0.06	0.136	
15	0.283	0.12	0.23	0.71	0.5	0.14	0.255	
16	0.12	0.16	0.23	0.35	0.17	0.1	0.151	0.317
17	0.163	0.15	0.1	1.54	0.33	0.37	0.408	
18	0.123	0.15	0.23	0.59	0.13	0.37	0.325	
19	0.119	0.13	0.13	1.4	0.3	0.61	0.534	
20	0.104	0.14	0.2	1.13	0.33	0.19	0.28	
21	0.102	0.14	0.1	0.84	0.17	0.39	0.344	
22	0.053	0.13	0.13	0.7	0.2	0.11	0.175	

Nemerow synthetic pollution index not only reflects pollution intensity of soil, but also highlights impact of high content pollutant on soil environmental quality[3]. From Table 3, we can know that the synthetic pollution index of all soil samples collected in this study is lower than 0.70, and remains the safe pollution intensity. The synthetic pollution index of Fenglang Town, Changshan Town, Fenghuang Town and Fengshun Town is 0.098, 0.197, 0.169 and 0.317 respectively. According to *Soil Pollution Grading Standard* formulated by China Green Food Development Center, it falls within the range of safe level (as listed in Table 2), indicating the general soil condition is excellent.

4 Conclusions

Among all human factors, industry, agriculture and transportation are major ones giving rise to heavy metal pollution of soil. Tea garden soil in Guangdong Province is deep and fertile, has appropriate acidity, and excellent environment, so it is extremely suitable for growth of tea trees. Through this study, it is found that most heavy metals in tea garden soil of Guangdong Province do not exceed the standard, except individual heavy metal in specific area. In general, the quality of tea garden soil reaches Grade 2 of national standard. As to single factor pollution index and Nemerow synthetic pollution index, the average pollution index of 6 types of heavy metals is in the range of 0.085 – 0.457; the synthetic pollution index is lower than 0.70. According to *Soil Pollution Grading Standard* formulated by China Green Food Development Center, the soil is not polluted by heavy metal and remains at safety level.

This study firstly assesses safety for heavy metals of soil environment in specialized tea towns of Guangdong Province. In future, we will undertake the safety assessment of soil environment in specialized tea towns of Guangdong Province. It is believed that these study results will promote sustainable development of local tea industry.

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