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Research on Soil Heavy Metal Accumulation and Chemical Environmental Quality Evaluation Based on Environment Law

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In this paper, it gives research on annual net flux and accumulative amount of the soil heavy mental in the Pearl River Basin on the basis of giving full consideration to environment law, by adopting such methods as theoretical calculation and field test and based on input/output flux model of soil chemical quality evaluation, and it gives heavy metal content warning and rating to paddy field, dry land and orchard in the Pearl River Basin based on heavy metal chemical evaluation warning method. The research conclusion indicates that: the main heavy metal pollution elements of paddy field and dry land in the Pearl River Basin are Cd, Ni and Hg; heavy metal pollution elements of orchard soil are As, Cr and Ni. Soil of the paddy field, dry land and orchard surrounding Guangzhou city is polluted more seriously; soil of the paddy field and dry land surrounding Jiangmen city and Zhongshan city is given severe pollution warning; soil of the paddy field, dry land and orchard surrounding Zhuhai and Zhaoqing is polluted slightly. Soil quality can be evaluated better by utilizing the input/output flux model for soil chemical quality evaluation proposed in this paper.

1. Introduction

The Pearl River Basin is located in the southern part of China, and it is sub-tropical hot and humid climate. Soil of the Pearl River Basin is mainly used for forest, plough, water area and urban residential land, etc. Human activity causes serious pollution to the soil, and it has bad influence on growth of agricultural product and living environment of the human, which all do not satisfy with provisions of the environment law.

Soil quality is the important basis for promotion of crop yield and sustainable development of ecological environment. The chemical environmental evaluation of soil quality advocated by environment law is the research hotspot in recent years, and the research directions mainly include influence of soil elements (heavy metal element or beneficial element) in agricultural field (Nagaraju and Karimulla, 2002; Sterckeman et al., 2002; Gałuszka, 2007), soil quality management (Ande and Onajobi, 2009; Mariano et al., 2009), soil quality evaluation and soil remediation(Ávilachávez and Trejo, 2010), relation between soil environment and human health (Nwachukwu and Pulford, 2010; Patel et al., 2005), etc. The soil quality evaluation methods in environment law mainly include soil dynamics algorithm, relative mass method, Craig method and comprehensive evaluation method (Stewart et al., 2011; Li et al., 2010; Wilson et al., 2010; Ducsay et al., 2009; Karimi et al., 2013; Wei and Yang, 2010; Chakraborty et al., 2010; Krishna et al., 2010), etc.

In this paper, it gives research on annual net flux and accumulative amount of the soil heavy mental in the Pearl River Basin on the basis of giving full consideration to environment law, by adopting such methods as theoretical calculation and field test and based on input/output flux model of soil chemical quality evaluation, and it gives heavy metal content warning and rating to paddy field, dry land and orchard in the Pearl River Basin based on heavy metal chemical evaluation warning method. The research conclusion indicates that soil quality can be evaluated better by utilizing the input/output flux model for soil chemical quality evaluation proposed in this paper.

2. Flux model and input flux calculation

Expression of flux model is as follows:

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$$\frac{dC_s}{d_t} = \sum_i \frac{dC_{si}}{d_t} - \sum_j \frac{dC_{sj}}{d_t} \tag{1}$$

C_s refers to content of the corresponding heavy metal element in soil; i and j refer to input and output modes. Invasion routes of the heavy metal in soil mainly include atmospheric deposition, chemical fertilizer and irrigation water, etc, and transfer ways of heavy metal element are harvest of crops in surface soil and volatilization of heavy metal element, etc. Such eight elements as arsenic, mercury, copper, zinc, nickel and chromium widely distributed in soil can be selected, and soil heavy metal content can be calculated by adopting geochemical element flux method. Soil in the Pearl River Basin is mainly used for production and living via river water irrigation, and annual input Q_i of the heavy metal element in soil can be expressed as:

$$Q_i = C_i \times V_i \tag{2}$$

C_i refers to irrigation coefficient; V_i refers to irrigation water capacity. Formula 2 can be used in calculating soil heavy metal input flux of Guangzhou, Dongguan, Huizhou, Jiangmen and Zhuhai in the Pearl River Basin, as shown in table 1.

Table 1: Heavy metal input flux of 5 cities in the Pearl River Basin

City	As	Cd	Cu	Hg	Cr	Ni	Pb	Zn
Guangzhou	2.66	0.51	10.79	0.05	17.69	11.88	3.87	266.07
Dongguan	1.11	0.50	3.22	0.02	6.19	12.93	1.50	47.84
Huizhou	2.55	0.41	105.65	0.04	9.42	5.33	8.76	182.34
Jiangmen	3.21	0.54	15.05	0.02	20.12	15.43	12.98	411.37
Zhuhai	1.56	0.17	12.43	0.01	12.35	8.77	7.03	185.78

When using chemical fertilizer for the crops in surface soil, content of the heavy metal in chemical fertilizer input in soil yearly shall be given statistics, with expression as follows:

$$Q_i = C_i \times W_i \tag{3}$$

W_i refers to annual average use of chemical fertilizer. Figure 1 shows statistics of the content of each heavy metal element in soil for input of the heavy metals in soil by using chemical fertilizer as to the various cities in the Pearl River Basin, of which 1-6 of the horizontal axis represent Foshan, Guangzhou, Dongguan, Huizhou, Jiangmen and Zhuhai respectively, and vertical axis represents content of each element. It can be seen from the figure that: Ni, As and Zn contents are relatively high in each city, and Hg and Pb contents are relatively low. For great use of the chemical fertilizer, soil of the aforementioned cities is polluted by heavy metal to different extents.

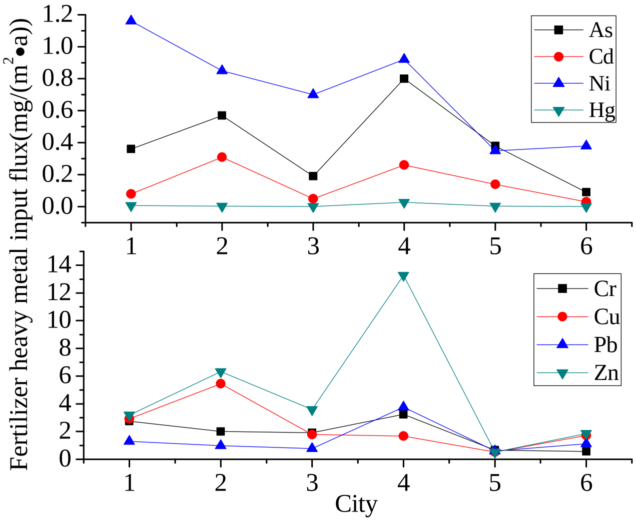

Figure 1: Heavy metal input flux from chemical fertilizer of 6 cities in the Pearl River Basin

Atmospheric deposition is also the way for soil heavy metal input, and expression of the atmospheric heavy metal deposition flux is as follows:

$$Q_{\text{deposition}} = \sum_{i=1}^{4} C_{ij\text{dry}} \times W_{ij\text{wet}} \times \text{A} + \sum_{i=1}^{4} C_{ij\text{wet}} \times W_{ij\text{dry}} \times \text{A} \tag{4}$$

C_{ij} refers to dry and wet element content in different quarter, A refers to conversion ratio, and W_{ij} refers to deposition quality. Table 2 shows the maximum value, average value, variable coefficient and standard deviation of annual atmospheric dry deposition flux and annual water flux of the different cities in the Pearl River Basin. It can be seen from the table that: annual atmospheric deposition fluxes of the various cities show little difference, the variable coefficients are all less than 1, and the standard deviations are also in allowable scope.

Table 2: Basic statistic parameters of atmospheric bulk dust/fall flux in the Pearl River Basin

City	Maximum	Average	Standard Deviation	Coefficient of Variation	Maximum	Average	Standard Deviation	Coefficient of Variation
Shenzhen	134.5	80.3	46.7	0.52	1733.4	1366.8	302.7	0.21
Foshan	254.2	89.3	86.1	0.98	1292	960	530.5	0.66
Guangzhou	365	90.7	68.4	0.65	1583	1123.2	272	0.25
Dongguan	240.3	97.6	65.2	0.75	1656.2	1354.7	188.6	0.22
Zhaoqing	195.6	78.3	54.8	0.69	1332.4	1010.5	200.2	0.15
Huizhou	320.4	128.7	93.5	0.68	1610.7	1423.4	222.8	0.17
Zhongshan	88	46.3	35.5	0.76	1580.4	1129.3	399.5	0.37
Jiangmen	83.3	32	17.8	0.47	1588.9	1337.8	282.9	0.3
Zhuhai	41.2	25.1	9.6	0.41	1594.3	1390	331.5	0.17

3. Soil heavy metal output statistics

Transfer and output ways of the heavy metal in soil are mainly agricultural product harvest, irrigation and drainage, surface water leaching and transpiration, etc. Heavy metal transfer amount in irrigation and drainage is calculated as follows:

$$Q_i = C_i \times V_i \times (1-\delta) \tag{5}$$

δ refers to water consumption rate. Table 3 shows transfer amount of soil heavy metal in the Pearl River Basin for irrigation and drainage.

Table 3: Heavy metal output flux of irrigation in the Pearl River Basin

City	As	Cd	Cu	Hg	Cr	Ni	Pb	Zn
Guangzhou	2.53	0.10	49.22	0.03	5.77	2.54	1.80	127.65
Dongguan	0.09	0.46	2.63	0	2.67	11.60	1.82	95.25
Huizhou	1.49	0.41	43.54	0.02	7.57	5.32	8.49	44.18
Zhaoqing	0.71	0.1	4.46	0.04	4.26	7.55	3.12	69.16
Jiangmen	2.1	0.15	6.03	0.03	7.42	5.49	2.90	183.8
Zhuhai	0.54	0.05	2.21	0	3.02	1.85	0.80	101.23

Crop is also the important way for soil heavy metal transfer. When the heavy metal content in soil is out of limit, crop can be seriously polluted by the heavy metal and cannot be eaten, then the peasant shall suffer great economic loss, and output of grain, fruits and vegetables shall reduce in large area. Thus, the evaluation on heavy metal output of crops in surface soil has great importance, and the calculation formula is basically same as the formula 5. Figure 2 shows curve of the heavy metal content detected in vegetables in the various cities in the Pearl River Basin, and the horizontal axis represents Guangzhou, Huizhou, Zhaoqing, Dongguan, Foshan, Jiangmen and Zhuhai respectively. Table 4 shows heavy metal content in the banana planted.

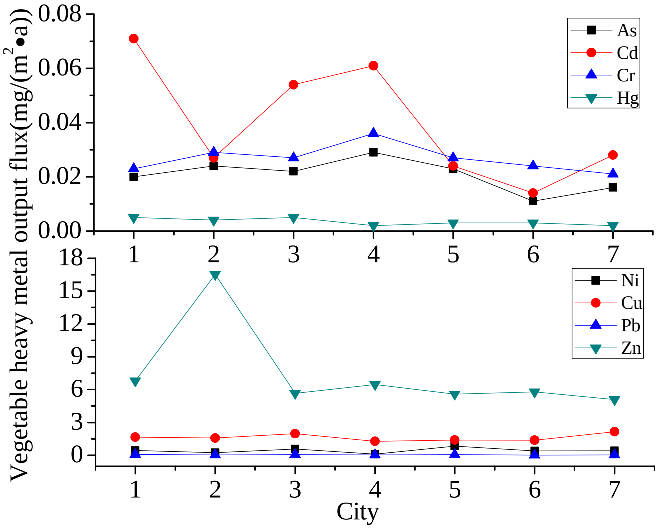

Figure 2: Vegetable heavy metal output flux in the Pearl River Basin

Table 4: Banana heavy metal output flux in the Pearl River Basin

City	As	Cd	Cu	Hg	Cr	Ni	Pb	Zn
Foshan	0.009	0.013	4.065	0.004	0.019	0.123	0.004	6.703
Guangzhou	0.012	0.002	3.995	0.005	0.005	0.059	0.010	6.132
Dongguan	0.041	0.009	3.503	0.015	0.254	0.734	0.414	6.315
Jiangmen	0.005	0.003	2.838	0.004	0.019	0.320	0.003	5.575
Zhuhai	0.004	0.004	7.500	0.009	0.004	0.157	0.006	5.181

4. Soil chemical environmental quality evaluation

Table 5 and Figure 3 show heavy metal accumulation rates in the soil of paddy field and orchard in the cities in the Pearl River Basin respectively.

Generally speaking, soil chemical environmental quality can be evaluated as favorable, mild warning, medium warning and severe warning. One or several heavy metal elements in soil can be selected as evaluation factor, and the soil could be deemed as no pollution when the evaluation factor is less than 5% of the specified value, it shall be given mild warning when the evaluation factor is between 5% and 30% of the specified value, it shall be given medium warning when the evaluation factor is between 30% and 60% of the specified value, and it shall be given severe warning when the evaluation factor exceeds 90% of the specified value.

Table 5: Accumulation rate of paddy soil heavy metals in the Pearl River Basin

City	As	Cd	Cu	Hg	Cr	Ni	Pb	Zn
Shenzhen	0.007	0.002	0.058	0.0003	0.059	0.019	0.068	0.0602
Foshan	0.012	0.003	0.170	0.0003	0.105	0.040	0.186	1.190
Guangzhou	0.015	0.005	0.040	0.0002	0.090	0.059	0.249	1.650
Dongguan	0.010	0.003	0.117	0.0001	0.068	0.032	0.121	2.171
Huizhou	0.010	0.001	0.180	0.0003	0.024	0.009	0.010	0.781
Zhongshan	0.005	0.002	0.060	0.0002	0.005	0.005	0.069	0.552
Jiangmen	0.010	0.004	0.100	0.0002	0.035	0.030	0.102	1.180
Zhuhai	0.009	0.003	0.067	0.0002	0.016	0.021	0.080	0.756

According to the aforementioned statistical results of the heavy metals in soil, the following conclusions can be obtained: medium warning is given to As, Cu and Zn elements in the paddy field soil in the Pearl River Basin, and severe warning is given to Cd, Hg and Ni elements. Paddy field in Jiangmen, Zhongshan and Guangzhou is seriously polluted by heavy metal, and it belongs to severe warning; while paddy field in Zhaoqing, Zhuhai and Huizhou is slightly polluted.

Dry land soil is not polluted by Cu, Cr and Pb elements, slightly polluted by As and Zn elements, and seriously polluted by Cd, Hg and Ni elements. Simultaneously, dry lands in Guangzhou, Zhongshan and Jiangmen are also seriously polluted, while such lands in Zhuhai and Zhaoqing are slightly polluted.
There is no Cr and Pb pollution in orchard, and it suffers mild pollution of Cu and Hg elements and severe pollution of Cr, As and Ni elements. Soil of the orchard surrounding Zhuhai, Foshan and Zhaoqing basically suffers no pollution or mild pollution, and Guangzhou and Huizhou suffer more serious pollution.

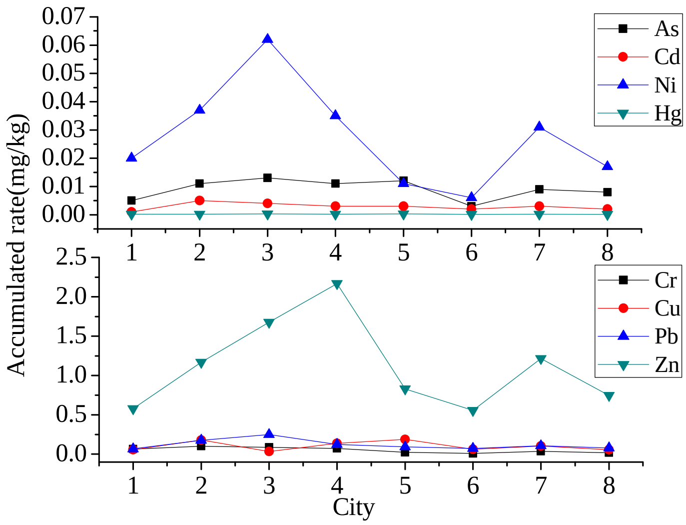

Figure 3: Accumulation rates of orchard soil heavy metals in the Pearl River Basin

4. Conclusions

In this paper, it gives research on annual net flux and accumulative amount of the soil heavy mental in the Pearl River Basin on the basis of giving full consideration to environment law, by adopting such methods as theoretical calculation and field test and based on input/output flux model of soil chemical quality evaluation, and it gives heavy metal content warning and rating to paddy field, dry land and orchard in the Pearl River Basin based on heavy metal chemical evaluation warning method. The research conclusions are as follows:
(1) The main heavy metal pollution elements of paddy field and dry land in the Pearl River Basin are Cd, Ni and Hg; heavy metal pollution elements of orchard soil are As, Cr and Ni.
(2) Soil of the paddy field, dry land and orchard surrounding Guangzhou city is polluted more seriously; soil of the paddy field and dry land surrounding Jiangmen city and Zhongshan city is given severe pollution warning; soil of the paddy field, dry land and orchard surrounding Zhuhai and Zhaoqing is polluted slightly. Soil quality can be evaluated better by utilizing the input/output flux model for soil chemical quality evaluation proposed in this paper, and it conforms to the requirements of environment law.

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