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Original Research Paper

Influence of Sewage Irrigation on the Heavy Metal Content of Soil and Crops

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ABSTRACT

The paper deals with irrigation tests on farmlands by using different water-quality sewages, and researches on the distribution characteristics of various heavy metals (Pb, Cu, Zn and Cd) in soil on vertical direction after irrigation by different sewages, and the regularities of distribution of various heavy metals in different parts of wheat and corn. The results show that the contents of various heavy metals in soils of different irrigation areas are successively as follows: the industrial sewage irrigation area > the mixed sewage irrigation area > the domestic sewage irrigation area > the reclaimed water irrigation area. In different irrigation areas, the regularities of distribution of the contents of various heavy metals in wheat and corn are as follows: the content in the reclaimed water irrigation area is less, next is in the domestic sewage irrigation area, the contents in the mixed sewage irrigation area and the industrial sewage irrigation area are more. For the roots, stems and grains of wheat and corn in different irrigation areas, the contents of various heavy metals in them are increasing continuously with the increase of heavy metals in soil; and for the same irrigation area, the contents of heavy metals in the roots, stems and grains of wheat are higher than contents of Pb and Cd in grains of corn, which have exceeded National Food Safety Standards.

INTRODUCTION

As a country with scarce water resources, China has been listed as one of the world's 13 water-poor countries; meanwhile, water pollution in China is severe as well. With the rapid development of national economy and the growth in the living standard, many more water resources are required, and agricultural irrigation water is used constantly as industrial water and urban domestic water, making water shortage in agriculture more and more severe, in particular to north Region, where water resources have almost been depleted to a critical state. As water resource shortage and water-environment degradation are important factors to restrict China's economic and social development, it has been the critical solution to water shortage by developing and utilizing non-traditional water resources while saving water (Zheng Guo-zhang 2008). With the development of cities, urban domestic sewage has a larger output with stable water volume, forming a reliable water supply. A widely used practice, domestically and internationally, proves that utilizing domestic sewage and organic industrial sewage that have been treated properly to irrigate farmlands may not only ease the situation of agricultural water resource shortage and solve the problem of urban sewage drainage to a certain degree, but also utilize abundant nutrient substances in sewage to increase soil fertility and crop output (Impelitteri et al. 2003, Li et al. 2009, Sastre et al. 2004). The feasibility of sewage irrigation has been verified in some parts of China. Sewage irrigation may be taken as a measure for developing agricultural production and alleviating environmental pollution (Luan Wen-lou et al. 2009). However, supposing sewage irrigation does not have a reasonable system and sewage has a worse quality as well as prolonged life span of sewage irrigation, soil and underground water will be polluted, thus leading to environmental degradation, crop output reduction, crop pollution and food quality reduction. In such a way, human health will be directly threatened (Wang Chao et al. 2009).

North China plain is an important region for producing crops, cotton and cooking oil of China, but also a new region with rapid economic growth. However, it is has also one of the serious water shortage areas in China, so there are more sewage irrigation areas. In order to discuss the influence of different irrigation water quality on crops and soil, we made researches on irrigation test with different water quality in several irrigation areas of a city.

OVERVIEW OF THE RESEARCH AREA

The research area is located in sewage irrigation district of the main urban area of a city, and the sewage used for farmland irrigation can be classified into domestic sewage, industrial sewage and blended sewage. The discharge amount of the three types of sewage is large, and the temporal distribution is relatively stable, while the water quality has obvious differences. According to the types of sewage, the farmlands which regularly utilize some types of sewage for irrigation in a long term, can be divided into the domestic sewage irrigation area, industrial sewage irrigation area and the mixed sewage irrigation area. In addition, based on the research requirements, the reclaimed water irrigation area is chosen as well. This time, the selected domestic sewage irrigation area is about 8 hm^2, the mixed sewage irrigation area is about 33 hm^2, the industrial sewage irrigation area is about 13 hm^2, and the reclaimed water irrigation area is about 10 hm^2. The main crops in these irrigation areas are wheat and corn, and the time for using sewage irrigation in each irrigation district has exceeded ten years.

Sewage mainly comes from domestic water, industrial water and rainwater from road and solid waste. Through sampling inspection, the contents of heavy metals in various types of sewage are as given in Table 1.

SAMPLE COLLECTION

The point distributing and sampling in all the irrigation areas are in quincunx (5 points for each irrigation district). Soil samples and crop samples were taken. There are 60 soil samples taken in the depth of 0~20, 20~50 and 50~80cm. Crop samples and soil samples were taken from the same location. Twenty five wheat samples and 25 corn samples were taken respectively for each point including their roots, stems and grains. Atomic absorption spectrophotometer was used to measure the contents of Pb, Cu, Zn and Cd of the samples.

RESULTS AND ANALYSIS

The vertical distribution of heavy metals in soil: As given in Table 2, the contents of various heavy metals in soils of different irrigation areas are successively as follows: the industrial sewage irrigation area > the mixed sewage irrigation area > the domestic sewage irrigation area > the reclaimed water irrigation area. The mean values of all the heavy metals in soil conform to the water quality of irrigation water resources. This shows that sewage quality has a direct influence on soil.

As given in Table 2, the content of the same heavy metal in different depths of soil is different, this is divided into the following three kinds of situations: (1) The regularities of distribution of the contents of Pb, Cu, Zn in the depths of 0~20cm and 20~50cm of soil is as follows from high to low: the mixed sewage irrigation area > the industrial sewage irrigation area > the domestic sewage irrigation area > the reclaimed water irrigation area. (2) The regularities of distribution of the contents of Pb, Cu, Zn in the depth of 50~80cm of soil is as follows from high to low: the industrial sewage irrigation area > the mixed sewage irrigation area > the domestic sewage irrigation area > the reclaimed water irrigation area. (3) The contents of Cd in different depths of soil do not have obvious regularity.

The distribution of heavy metals in soil layers with various depths in the same irrigation district is as follows: (1) The accumulation tendency of heavy metals is in the following order from high to low: Pb, Zn, Cu and Cd; (2) In the irrigation areas of recycled water, blended sewage and domestic sewage, the heavy metal contents in soil layers with different depths have a vertical distribution tendency, and the ones in soil with a depth of 0~20cm are more than those in soil with depths of 20~50cm and 50~80cm, indicating surface accumulation (except Pb in the irrigation district of domestic sewage). In the irrigation areas of industrial sewage, the heavy metal contents in soil layers with a depth of 50~80cm are more than those in soil with depths of 20~50cm and 0~20cm. This indicates that bottom accumulation appears in heavy metals.

By comparing the contents of heavy metal in soil with soil environment standard values in GB15618 -1995 (Table 3), when the pH value of soil is more than 7.5, all heavy metal contents in various irrigation areas fail to exceed the standards of second-class soil. The secondary standards are limited values for soil to guarantee agricultural production and to maintain human health. However, with continual sewage irrigation, the contents of heavy metals in soil will accumulate and increase. Therefore, high attention must be paid to such phenomenon, and effective measures must be taken to protect soil from being polluted.

The content distribution of heavy metals in roots, stems and grains of crop in different irrigation areas: When the heavy metal pollutants from different water quality penetrate into soil, crops may absorb them by root metabolism. Some pollutants within root cells are kept inside roots, while others move with bioplasm to nearby cells, transported to ducts across root pericycles through the transportation among cells, and finally move toward the over-ground part with crop transpiration and accumulate inside crop stems, leaves, seeds and fruits (Tables 4 and 5).

Because the water quality differs in all irrigation areas, the contents of heavy metals in different types of soil are

Table 1: The content of heavy metals in different types of sewage mg/L.

Category of sewage	Pb	Cu	Zn	Cd
Domestic Sewage	0.0510	0.0375	0.1130	0.0060
Mixed Sewage	0.0600	0.0480	0.2899	0.0100
Industrial Sewage	0.1400	0.1030	0.4780	0.0400

Table 2: The contents of various heavy metals in different depths of soil of irrigation areas.

Irrigation Districts	Soil Thickness cm	Content of heavy metals (mg/kg)			
		Pb	Cu	Zn	Cd
Irrigation District of Recycled Water	0~20	84.47	21.55	34.30	0.44
	20~50	66.33	16.25	28.32	0.31
	50~80	48.14	12.54	27.38	0.43
	Average	66.31	16.78	30.00	0.39
Irrigation District of Domestic Sewage	0~20	73.67	23.27	35.31	0.27
	20~50	81.34	18.46	30.52	0.27
	50~80	53.25	17.62	28.65	0.24
	Average	69.42	19.78	31.49	0.26
Irrigation District of Blended Sewage	0~20	90.00	28.57	50.15	0.75
	20~50	76.79	23.32	40.19	0.31
	50~80	77.75	24.83	41.73	0.42
	Average	81.51	25.57	44.02	0.49
Irrigation District of Industrial Sewage	0~20	87.43	25.30	39.37	0.31
	20~50	71.67	21.83	35.32	0.37
	50~80	95.89	29.05	46.65	0.38
	Average	85.00	25.39	40.45	0.35

Table 3: Standard values of soil environment mg/kg at different pH values.

Item	First-class soil	Second-class soil			Third-class soil
	Natural Background	< 6.5	6.5~7.5	> 7.5	> 6.5
Pb ≤	35	250	300	350	400
Cu ≤	35	50	100	100	400
Zn ≤	100	200	250	300	500
Cd ≤	0.2	0.3	0.3	0.6	1

Table 4: The content distribution of heavy metals in roots, stems and grains of wheat in different irrigation areas mg/kg.

Irrigation Districts	Position	Pb	Cd	Cu	Zn
Irrigation District of Recycled Water	Wheat Root	13.08	0.5	15.38	50.5
	Wheat Stem	2.31	0	1.27	7.19
	Wheat Grain	1.33	0	5.18	28.62
Irrigation District of Domestic Sewage	Wheat Root	13.08	0.38	21.8	46.81
	Wheat Stem	6.92	0.12	3.42	13.04
	Wheat Grain	3.33	0.08	6.3	32.32
Irrigation District of Blended Sewage	Wheat Root	12.31	0.5	10.27	97.31
	Wheat Stem	6.92	0.12	5.54	12.04
	Wheat Grain	1.66	0	4.45	30.8
Irrigation District of Industrial Sewage	Wheat Root	13.85	0.88	10.69	77.92
	Wheat Stem	7.69	0.12	5.12	24.08
	Wheat Grain	1.33	0	6.67	35.37

different. Planting various crops in various irrigation areas enables heavy metal contents in soil to change. Endocrine of rhizosphere soil of different crops influences various heavy metals in the surrounding environment differently, thereby, changes the ability of heavy metals to transfer towards inside plants.

As given in Tables 4 and 5, heavy metal contents of wheat and corn roots, stems and leaves in various irrigation areas increase with those in soil. In wheat and corn stems, roots and grains, the heavy metal contents differ. Most of the heavy metals first transfer and accumulate inside wheat and corn root systems, then stems and grains. Generally speaking, organs with exuberant metabolism have a large quantity of accumulation, while organs storing nutrition have a small quantity of accumulation; therefore, the heavy metal contents of crop roots are higher than those of stems and grains (Cheng Hong-yan et al. 2012). This phenomenon reveals that root system of crops may be taken as a filter to prevent heavy metals from further transferring into stems and grains, thereby reducing their toxic effect.

Table 5: The content distribution of heavy metal in corn roots, stems and grains of different irrigation areas mg/kg.

Irrigation Districts	Position	Pb	Cd	Cu	Zn
Irrigation District of Recycled Water	Corn Root	5	1	2.5	20.28
	Corn Stem	3.34	0.83	4.9	43.35
	Corn Grain	5.33	0.67	1.67	37.03
Irrigation District of Domestic Sewage	Corn Root	8.67	1.17	11.47	34.13
	Corn Stem	5.33	1	2.92	25.27
	Corn Grain	2.67	0.58	1.67	24.5
Irrigation District of Blended Sewage	Corn Root	6	1.08	5	25.87
	Corn Stem	4.33	0.92	6.88	28.83
	Corn Grain	1.67	0.5	1.57	23.18
Irrigation District of Industrial Sewage	Corn Root	5	0.92	2.5	28.92
	Corn Stem	5	0.75	4.9	14.63
	Corn Grain	3.33	0.58	1.67	28.77

In the same irrigation district, the heavy metal contents of wheat roots, stems and grains are higher than those of corn roots, stems and grains. Wheat and corn have different root system, and endocrine of rhizosphere soil of different crops has different influences on heavy metals in the surrounding environment; what is more, the growing period of wheat is longer than that of corn, so the heavy metal contents of wheat are higher than those of corn in roots, stems and grains.

According to the provision of GB2762-2012 National Food Safety Standards, pollutant quantity in food should be limited, lead content in crops shall be ≤ 0.2mg/kg, and cadmium content shall be ≤ 0.1mg/kg. As given in Tables 4 and 5, the Pb and Cd contents in grains of wheat and corn have exceeded the sanitary standards for food, yet without any symptom showing that the grains are hurt by heavy metal. Besides, it also shows that heavy metal pollution in soil has affected human health in a concealed way.

CONCLUSION

For the regions lack of water resources, utilizing sewage to irrigate farmlands can solve some problems of agricultural water shortage, yet if sewage irrigation is conducted with water not treated, soil will be polluted, and pollutants will accumulate within crops. Experimental data of this show that the wheat and corn planted in sewage irrigation area have been polluted by heavy metals, and heavy metal contents in wheat and corn grains have exceeded National Food Safety Standards.

In the aspect of utilizing sewage irrigation, we should take action according to practical conditions, while learning advanced experience at home and abroad. And various sewage irrigation modes shall be put forward according to soil types and crop species, so as to rationally utilize sewage irrigation and alleviate its harms to soil and crops. Only in this way, can sewage for irrigation be a new water resource for the sustainable development of agriculture. China is a country with a severe lack of water, so sewage irrigation plays a significant part in alleviating freshwater resource shortage. Meanwhile, real-time monitoring should be conducted for sewage irrigation. The negative effects caused by sewage irrigation can not be ignored. Positive and effective countermeasures and scientific attitudes should be taken to guide sewage irrigation to a higher level.

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