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Field Survey of Cd and Pb Contents in Spring Wheat *(Triticum aestivum L.)* Grain Grown in Baiyin City, Gansu Province, People's Republic of China

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Cadmium (Cd) and lead (Pb) have long been recognized as toxic elements and non-essential minerals to crops. Our understanding of their importance as environmental contaminants increases when relationships were identified between the lowering, damage and alteration of animal or human physiological functions and the selected metals contents in crops (Kobayashi, 1978; Silbergeld, 1991; Gupta, et al., 1995). It is also been found that the soil polluted by heavy metals can produce farm products containing high levels of heavy metals harmful to life (Kloke, 1984; Adriano, 1986; Xian, 1989; Levy, et al., 1992; Dudka, et al., 1994).

Baiyin city is a major non-ferrous metals mining and smelting base built in the 1950s and is currently focusing on the production of zinc and lead. Improvement in effluent treatment over the past decade has significantly reduced the release of metals into the streams and waterways. However, measurable concentrations of Cd and Pb are still found in our field investigation.

The area studied is situated in the semi-arid region of Northwest China with a surface area of about 501 km^2 divided into two basins by the watershed, i.e., Dongdagou stream basin and Xidagou stream basin, both of which accept domestic wastewater and industrial sewage. Due to the shortage of irrigation water and under the direction of the wastewater land treatment policy, it has a long history of using the industrial and domestic wastewater to irrigate or partially irrigate croplands.

Studies on the contamination of Cd and Pb in soils and plants have so far been restricted to highly industrialized regions, and the availability of quantitative data is limited on the fate of these pollutants in soil-crop system of industrializing regions (Ramachandran et al., 1998), especially in calcareous soil region. Spring

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wheat *(Triticum aestivum L.)* is in the area studied an important crop whose quality bears a great influence on the health of human beings who consume it. In view of the toxicity of the selected metals to human health through the food chain, it is necessary to record and evaluate the impact of nonferrous metals mining and smelting activities on crops to ensure public health. This work is the first study on contents of heavy metals in spring wheat grown in calcareous soil in Baiyin City. In this study the contamination of selected metals in grain was recorded and evaluated.

MATERIALS AND METHODS

Spring wheat grain samples, each weighing about 1 kilogram, were collected at its mature period. The locations of sampling sites are shown in Fig. 1. Sites Al- A10 are located adjacent to the Dongdagou stream, which is exposed to the wastewater discharged from all nonferrous metals mining and smelting plants, several other factories, and partial city dweller daily life. The stream water here can easily be used for arable irrigation. Sites Bl-B4 are situated where the cropland can use the water from the Yellow River for irrigation. Sites Dl-D6 are found near the Xidagou stream receiving the sewage from one copper processing plant and several other factories and partial city dwelling. Sites of series C, E and F are at such croplands farther from the streams or the metal contaminating sources.

The glassware and Teflon pressure bomb were washed with detergent solution, rinsed with tap water followed by distilled water, and soaked in 1:1 (vol./vol.) HNO_3 solution for at least 48 h. before use. They were then rinsed with distilled water and de-mineralized water and oven-dried at 60 °C .

The grain samples were washed with tap water and distilled water followed by de-mineralized water, and then air-dried. The digesting of air-dried grain samples was carried out by using nitric acid bomb digestion. A 5.0g sample was dissolved in concentrated HNO_3 for 24 hours, then the mixture was heated to the boiling point on an electric plate heater until the formation of nitrous fumes stopped. Next, the mixture was boiled until the digesting solution became a faint yellow sticky piece. The remaining digest was diluted with 10% (vol. /vol.) HNO_3 solution to 10 ml in a test tube for determination.

For the last two decades, inductively coupled plasma spectroscopy (ICP) has been widely used to determine the concentration of heavy metals in environmental samples because of its high sensitivity and freedom from interference of associated major elements (Soltanpour et al., 1982; Chappelka, et al., 1991; Levy, et al., 1992; Stilwell, et al., 1997; Schuhmacher, et al., 1997). In this study the

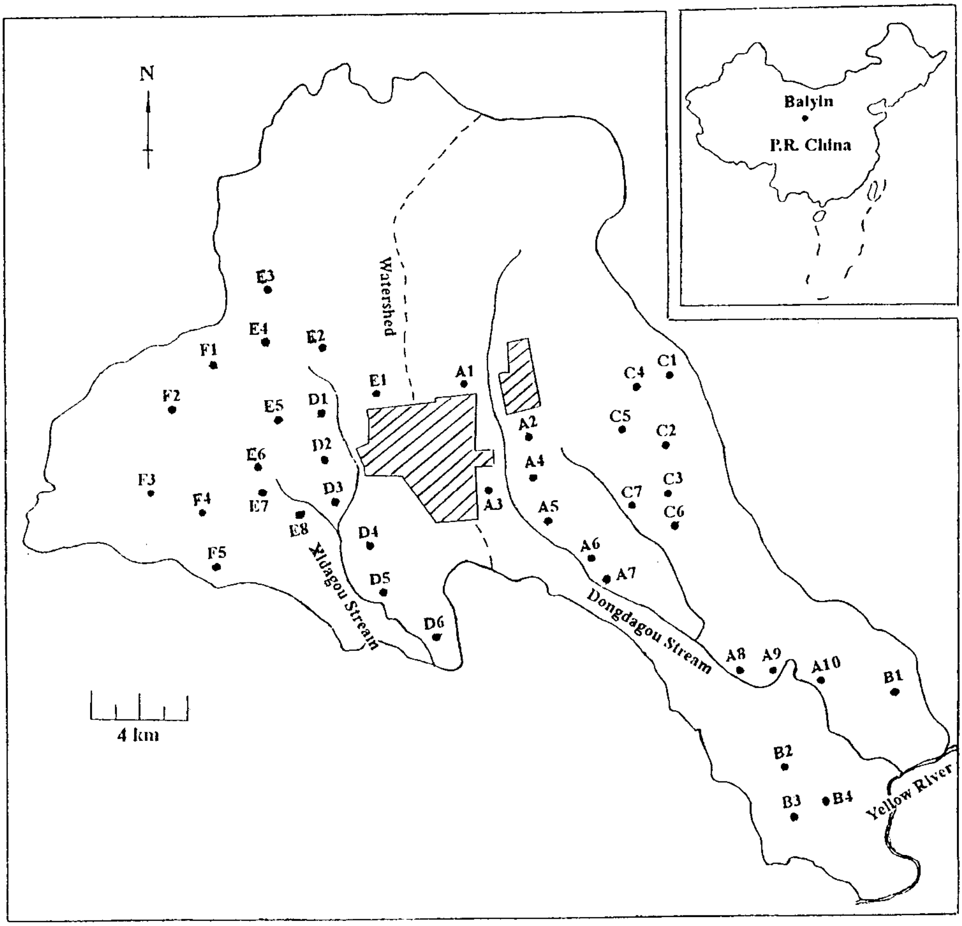

Figure 1. Map showing the location of the 6 series of sampling sites
Built-up

concentration of selected metals was determined by using ICP. The instrument was calibrated with standard solutions using the concentration mode. Analytical precision of the method was improved by including several duplicate samples (10% of total). Reproducibility was within ±5%.

RESULTS AND DISCUSSION

The concentration, arithmetic means, standard deviations and ranges of cadmium and lead in 40 spring wheat grain samples of the 6 series from the two basins are listed in Tables 1 and 2. The background values of wheat grain, the maximum safe intake levels and the hygienic standards for grains from literature are listed in Table 3.

Table 1. Concentration of Cadmium and Lead (mg kg^{-1} DW) in spring wheat grain

Dongdagou stream basin			Xidagou stream basin		
Sample No.	Cd	Pb	Sample No.	Cd	Pb
A1	0.04	0.51	D1	0.01	nd.
A2	0.65	18.49	D2	0.02	0.42
A3	0.07	0.67	D3	nd.	1.73
A4	0.51	0.72	D4	nd.	0.74
A5	1.19	0.30	D5	0.04	0.42
A6	0.59	0.31	D6	nd.	0.68
A7	0.28	0.52	E1	0.08	0.74
A8	0.23	0.69	E2	0.02	0.64
A9	0.60	0.76	E3	nd.	0.13
A10	0.50	1.70	E4	0.15	0.06
B1	0.05	nd.	E5	nd.	0.33
B2	nd.	0.09	E6	nd.	0.76
B3	0.04	0.52	E7	0.03	0.22
B4	nd.	0.69	E8	0.04	1.04
C1	0.03	0.55	F1	0.12	0.15
C2	0.01	0.55	F2	0.08	1.46
C3	0.00	0.42	F3	0.08	0.60
C4	0.07	0.28	F4	nd.	0.09
C5	nd.	0.31	F5	0.10	0.49
C6	0.05	0.18			
C7	0.14	0.31			

Detection limit: 0.01 ppm for Cd, 0.04 ppm for Pb. nd. – non detectable.

Table 2. The arithmetic mean, standard deviation, and range of Cd and Pb in spring wheat grain in series and basins

		Cadmium			Lead		
	N	AM	SD	Range	AM	SD	Range
Series							
A	10	0.47	0.34	0.04 – 1.19	2.47	5.64	0.30 – 18.49
B	4	0.04	0.01	0.04 – 0.05	0.44	0.31	0.09 – 0.69
C	7	0.05	0.05	0.00 – 0.14	0.37	0.14	0.18 – 0.55
D	6	0.02	0.02	0.01 – 0.04	0.80	0.54	0.42 – 1.73
E	8	0.06	0.05	0.02 – 0.15	0.49	0.35	0.06 – 1.04
F	5	0.09	0.02	0.08 – 0.12	0.56	0.55	0.09 – 1.46
Basins							
Dongdagou	21	0.29	0.33	0.00 – 1.19	1.48	4.13	0.09 – 18.49
Xidagou	19	0.07	0.07	0.03 – 0.15	0.48	0.41	0.06 – 1.04

N – Sample Size. AM - Arithmetic Mean. SD - Standard deviations.

Table 3. Concentrations of metals from the literature (mg kg^{-1} DW)

Element	Cd	Pb	Reference
Background value*	0.05	0.21	Chen H (1996)
Maximum safe intake level	0.1	0.3	FAO/WHO$
Hygienic standards for grain	0.1	1.0	NSBC#

* = the value indicates that in wheat grain in P. R. China.

$ = see: "*Trace elements in the terrestrial environment*", D. C. Adriano (1986), pp139, 251.

= National Standard Bureau of P. R. China (GBn 238-84, GB 2731-81).

The mean contents for cadmium were 0.29±0.33 mg kg^{-1} with a range of 0.00-1.19 mg kg^{-1} in Dongdagou stream basin (n=21) and 0.07±0.07 mg kg^{-1} with a range of 0.03-0.15 mg kg^{-1} in Xidagou stream basin (n=19). Some samples (14% in Dongdagou and 37% in Xidagou) have concentration below the detection limits. The average contents of Cd in whole region were higher than the background value of wheat grain (0.05mg kg^{-1} DW).

The mean contents for lead were 1.48± 4. 13 mg kg^{-1} with a range of 0.09-18.49 mg kg^{-1} in Dongdagou stream basin (n=21) and 0.48±0.41 mg kg^{-1} with a range of 0.06-1.04 mg kg^{-1} in Xidagou stream basin (n=19). Some samples (4.8% in Dongdagou and 5.3% in Xidagou) have concentration below the detection limits. The average contents of Pb in whole region were higher than the background value of wheat grain (0.21mg kg^{-1} DW).

The average concentration of Cd and Pb in Dongdagou stream basin was higher than the maximum safe intake levels (0.1 mg Cd kg^{-1} and 0.3 mg Pb kg^{-1}) and the hygienic standards for grains (0.1 mg Cd kg^{-1} and 1.0 mg Pb kg^{-1}). The average concentration of Cd and Pb in Xidagou basin was not higher than those values except the maximum safe intake level of Pb. These results suggest that the crops are not at risk from the arable irrigation of the Xidagou stream water.

It can also be seen that the concentration of Cd and Pb in grain samples of Series A was significantly higher than those of Series B and C. When the assayed values of the two elements of Series A and Series B and C were compared respectively, the average concentration of Cd and Pb from Series A (0.47 mg Cd kg^{-1} and 2.47 mg Pb kg^{-1}) was approximately 10 and 6 times higher than those from Series B and C.

The average concentration of Cd and Pb in the grain sample of Series A was 0.47 ±0.34 mg Cd kg^{-1} and 2.74±5.64 mg Pb kg^{-1}, with a range of 0.04-1.19 mg Cd

kg^{-1} and 0.30-18.49 mg Pb kg^{-1}, respectively. The average values were 4 and 2 times higher than the hygienic standards for grain, and 4 and 9 times higher than the maximum safe intake levels. The arithmetic means of selected metal contents in grain samples of Series B and C were lower than or had the same order with the hygienic standards for grains, and 4 and 9 times higher than the maximum safe intake levels. This result confirmed the contamination of these two metals in the agricultural ecosystem around the Dongdagou stream.

From this survey it can be clearly seen that the difference in contents of selected metals in wheat grains is related to the same metal concentration in the soil of the sampling sites. Therefore, cadmium and lead pollution is the result of industrial wastewater in arable irrigation. The metal concentration in soils is the main source to crop absorption although plants can take in some metals in the air through the leaves. This finding is in agreement with Chen, 1996.

The facts from this investigation strongly suggest that the continuous growth on those sites could elevate the metal contents in grain and bring adverse effects on the residents who mainly consume it. Therefore, restriction of the spring wheat consumption here and the establishment of a monitoring program should be considered in order to protect the residents from the potential of toxicity and to improve food safety. The relationships between heavy metal concentration in spring wheat, gray calcareous soil, and the interactions among the heavy metal pollutants are to be undertaken as a separate study.

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