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Study on soil heavy metals contamination of a lead refinery

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Abstract The contents of Pb, Cd, Cr, As, and Hg was investigated in the neighboring areas of a lead smelting enterprise and the metals contamination of soil was evaluated with the methodologies of the single factor index and Nemerow integrated index. It is found that the content of heavy metals in the neighboring areas has no obvious difference from the reference points. And the soil contamination of heavy metals varies by elements, the contamination index follows the pollution order: Cd>Hg>Cr>As>Pb. The pollution degree of Cd is at high level and Hg at low level, but Cr and As reached the warning level. Therefore, the lead smelting enterprises should not only control lead but also other heavy metals as Cd.

Key words lead refinery; soil; heavy metal

1 Introduction

As one of the major sources of heavy metals contamination, lead refinery industry releases dusts containing heavy metals during the production, which entered into the soil. The heavy metals remained in soil are not easily decomposed. Instead, they aggregate and finally cause the soil pollution which has a big impact on the farmland yield and quality with the potential possibility to harm the well-being of human beings through food chain (Xie et al., 2011).

This paper chose a lead refinery in South China as study objective. The enterprise has been in operation since 2008 with advanced technology and fine management and there are no other pollution sources around. The heavy metals (Pb, Cd, Cr, As, and Hg) in the soil around the lead refinery was examined with the aim to provide reference to environment protection (Zhang, 2001).

2 Samples collection

19 locations along the axis of major and second windward were chosen around the lead refinery enterprise and 4 locations from the residential areas and 1 location from upper windward, totally 24 locations are picked. In 10 locations, the samples were got from the soil section plan at 0–2, 2–20, 20–40, 40–60 cm; in other locations, the samples were from the soil section plane at 0–2 and 2–20 cm, so there are totally 68 samples. The positional relationship between the samples and the lead refinery is shown in Fig. 1.

The soil sampling and analysis methodology followed the instruction after the Technical Specification for Soil Environmental Monitoring (HJ/T166-2004) and by the “snake-like” approach. The soil samples were dried in natural wind and then griddled by 2 mm ×2 mm grid to remove debris, roots and small stones. After that, the samples were equally divided into four parts, griddled again by 100 mesh sieve, and waited for Ph tests or instrumental analysis (Institute of Soil Science, 2003).

3 Results and discussions

3.1 Assessment criteria

The assessment is done based on the second criteria of Soil Environment Quality Standard (GB15618-1995) (Table 1).

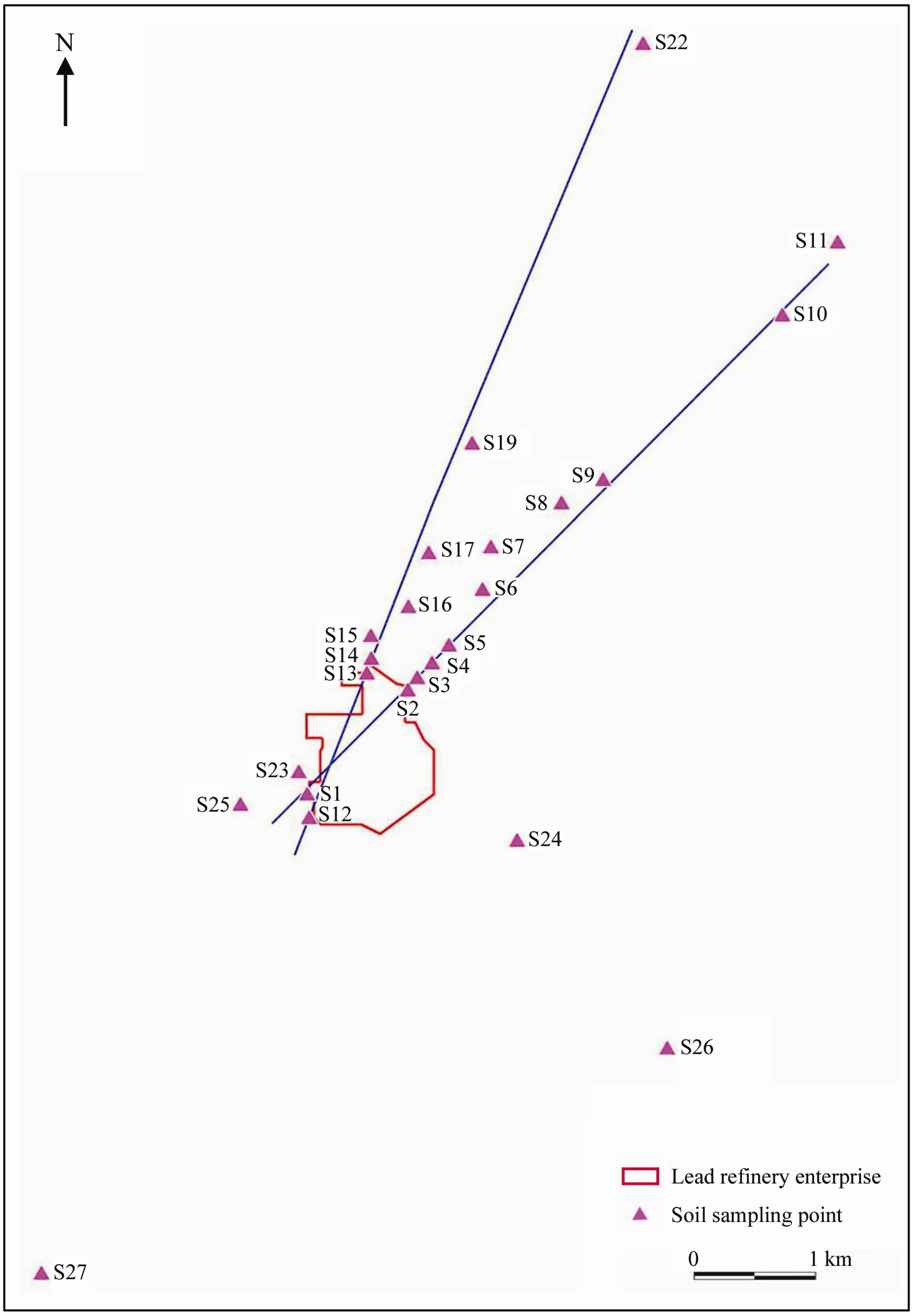

Fig. 1. Map of positional relationships between the samples and the lead refinery.

Table 1 Soil environment quality standard (mg/kg)

Item	pH	Pb	Cd	Cr	As	Hg
				Dry land	Dry land	
Standard (max)	< 6.5	250	0.30	150	40	0.30
	6.5−7.5	300	0.30	200	30	0.50
	> 7.5	350	0.60	250	25	1.0

3.2 Assessment methodology

Single and integrated pollution index were used for the assessment of pollution situation in the areas of lead refinery enterprise.

(1) Single pollution index

The pollution index is calculated by the comparison of actual content of heavy metals in soil and the assessment standard:

$$P_i = \frac{C_i}{C_{0i}}$$

where, P_i is the single pollution index for heavy metal I; C_i is the actual value of heavy metal I (mg/kg); C_{0i} is the reference value of Environmental Quality Standard for Soils (mg/kg).

(2) Nemerow Integrated Index

In order to obtain different impacts from all heavy metals and identify the impact from heavy metals of the highest pollution, the Nemerow Integrated Index was used. The calculation is as follows:

$$P_z = \left\{\left[(C_i/C_{0i})^2_{\max} + (C_i/C_{0i})^2_{ave}\right]/2\right\}^{1/2}$$

$$P_{\text{integrated}} = \left\{\left[(C_i/C_{0i})^2_{\max} + (C_i/C_{0i})^2_{ave}\right]/2\right\}^{1/2}$$

Where, P_z is the Nemerow Integrated Index; $(C_i/C_{0i})_{\max}$ is the max value of single pollution index for each heavy metal; $(C_i/C_{0i})_{ave}$ is the average of single pollution index for each heavy metal.

According to the Guidance of Soil Environmental Quality Situation Assessment for Green-food Production Area (beta version) issued by China Green Food Development Center in 1994, the pollution situation indicated by Nemerow Integrated Index are categorized by three levels (Table 2).

Table 2 Levels of soil pollution

Grade	P_z	Pollution Grade	Level of pollution
1	P_z≤0.7	Security	Clean
2	0.7<P_z≤1.0	Warning	Clean
3	1.0<P_z≤2.0	Lightly polluted	Soil are slightly polluted, the crops start to be polluted
4	2.0<P_z≤3.0	Medium polluted	All crops are polluted
5	P_z>3.0	Heavily polluted	All crops are heavily polluted

3.3 Assessment results and analysis

The soil pollution results are listed in Table 3.

The single pollution index in Table 3 shows that heavy metal content in 13 samples are higher than the standard value, among which, 7 are located in major windward direction (SW-NE), 4 in the second windward direction (SSW-NNE), 2 in residential areas. S6, S11 and S16 have more than 3 index higher than standard respectively. S19 and S22 have 2 index higher than standard. And the rest 8 locations have 1 index higher than standard. The most far-away location with higher index (S23) is 5540 m away from the border of the refinery and 6390 m from the pollution source. The nearest location with higher index (S1) is 80 m away from the border of the refinery and 280 m from the pollution center. S16 has the highest index of Cd with 3.38 times higher than the standard.

In terms of the single pollution index of Table 3, all others are less than 1.0 except the index of Pb ranging from 0.04–0.27. The index of Cd ranges from 0.30 to 4.38, with the index of 15 samples higher than 1.0, accounting for 22.1% of the total samples. Cr index ranges from 0.25 to 1.11, with 2 samples exceeding 1.0, taking up 2.9% of the total samples. The index of Hg are between 0.008 and 2.77, with 3 samples higher than 1.0, accounting for 4.4% of the total samples. The index of As ranges 0.0003–1.05, with only 1 sample higher than 1.0, accounting for 1.5%.

In terms of the integrated index of Table 3, 31 samples out of 68, about 45.6% of the samples are higher than the security level 0.7, among which index of 17 samples are between 0.7 and 1, which is of warning level, accounting for 25.0%; 8 samples are between 1.0 and 2.0, slightly polluted level, accounting for 11.8%; 5 samples are between 2.0 and 3.0, medium polluted level, accounting for 7.4%; 1 sample is higher than 3.0, heavily polluted level, accounting for 1.5%.

From the integrated index of Table 3, the contamination index follows the pollution order: Cd>Hg>Cr>As>Pb.

4 Conclusion and suggestion

(1) The heavy metal content around the lead refinery has no obvious difference from the reference value as the enterprise chosen is relatively newly built with good technology and management.

(2) The soil contamination of heavy metals varies by the elements. The contamination index follows the pollution order: Cd>Hg>Cr>As>Pb. The pollution degree of Cd is at high level and Hg low level, while Cr and As reached the warning level. Therefore, the lead smelting enterprises should take measures to control not only lead pollution but also the other heavy metals like Cd.

Table 3 Pollution index of heavy metals in soil (single pollution index and integrated index)

Sample No.	Soil section plane (cm)	Pb	Cd	Cr	Hg	As	Integrated pollution index
S1	0–2	0.1324	1.0867	0.4787	0.1683	0.2235	0.8941
	2–20	0.1016	0.7567	0.5053	0.1300	0.2288	0.6771
	20–40	0.1132	0.6033	0.4873	0.1027	0.2180	0.5783
	40–60	0.1136	0.5567	0.5287	0.1090	0.2163	0.5544
S2	0–2	0.1344	0.5733	0.5200	0.1417	0.2150	0.5682
	2–20	0.1128	0.2967	0.5033	0.1430	0.2300	0.5052
	20–40	0.1368	0.4600	0.5353	0.1440	0.2270	0.5419
	40–60	0.1296	0.3367	0.5753	0.1217	0.2040	0.5498
S3	0–2	0.0952	0.4733	0.4927	0.0680	0.1275	0.4970
	2–20	0.0588	0.7067	0.3220	0.0333	0.0003	0.6015
	20–40	0.0624	0.6767	0.3787	0.0607	0.0146	0.5901
	40–60	0.0644	0.5633	0.4913	0.0570	0.0440	0.5298
S4	0–2	0.1260	0.4633	0.5073	0.1703	0.2345	0.5281
	2–20	0.1396	0.4633	0.5627	0.1460	0.2355	0.5595
S5	0–2	0.1268	0.5233	0.7000	0.1260	0.2458	0.6459
	2–20	0.1104	0.4133	0.5100	0.0973	0.1913	0.5121
S6	0–2	0.2748	3.5433	0.4953	0.2220	0.1030	2.5964
	2–20	0.1136	1.8700	0.5040	0.1107	0.0590	1.4192
	20–40	0.1040	1.0100	0.4920	0.0983	0.0520	0.8281
	40–60	0.0904	0.9000	0.4173	0.0177	0.0338	0.7422
S7	0–2	0.0800	0.5500	0.4653	0.0083	0.1175	0.5228
	2–20	0.1456	2.7833	0.5453	0.0603	0.1815	2.0604
S8	0–2	0.1092	2.7800	0.4547	0.0170	0.1955	2.0542
	2–20	0.0408	0.5000	0.5520	0.0083	0.0988	0.5219
S9	0–2	0.1096	0.3667	0.4587	0.0890	0.1700	0.4739
	2–20	0.0956	0.3233	0.5440	2.6367	0.1623	1.9627
S10	0–2	0.1828	2.8800	0.3727	0.1093	0.1928	2.1263
	2–20	0.1008	0.4433	0.4540	0.0563	0.1263	0.4702
S11	0–2	0.2220	2.6167	0.6267	0.1930	0.2278	1.9525
	2–20	0.1772	1.3400	0.6473	2.7733	0.2005	2.0879
S12	0–2	0.1244	0.5933	0.5327	0.2227	0.2218	0.5878
	2–20	0.1216	0.5067	0.5233	0.2573	0.2275	0.5483
	20–40	0.1220	0.4600	0.5273	0.2210	0.2600	0.5460
	40–60	0.1184	0.5100	0.5440	0.2297	0.2325	0.5581
S13	0–2	0.1200	0.6033	0.5400	0.2213	0.2525	0.5964
	2–20	0.0648	0.3533	0.5260	0.1937	0.0760	0.5096
	20–40	0.0788	0.3467	0.6800	0.2160	0.0905	0.6102
	40–60	0.0628	0.5533	0.4527	0.1847	0.0813	0.5353
S14	0–2	0.0960	0.5033	0.4140	0.1997	0.2335	0.5209
	2–20	0.0684	0.9267	0.3173	0.0083	0.0783	0.7545
	20–40	0.0612	0.4733	0.2460	0.0950	0.0199	0.4490
	40–60	0.0628	0.5233	0.3853	0.2133	0.0825	0.5135
S15	0–2	0.0940	0.5833	1.1067	0.1870	0.4925	0.9267
	2–20	0.1088	0.7333	0.5993	0.6733	0.3550	0.7182
S16	0–2	0.1032	1.4200	0.8267	0.7533	0.7400	1.1801
	2–20	0.1008	1.4167	0.8200	0.2823	1.0450	1.1705
S17	0–2	0.0708	0.8100	0.5373	0.2203	0.1545	0.7123
	2–20	0.0724	0.7633	0.5907	0.4033	0.1763	0.7014
	20–40	0.0700	0.8233	0.5580	0.3173	0.1915	0.7314
	40–60	0.0732	0.7500	0.6667	0.2037	0.1698	0.6838
S19	0–2	0.1756	4.3767	0.3340	0.1810	0.1128	3.1774
	2–20	0.0524	0.6767	1.0667	0.1420	0.0710	0.8774
S22	0–2	0.0500	0.9367	0.5867	0.1670	0.3775	0.8065
	2–20	0.0624	0.5133	0.7067	1.4733	0.3175	1.1801
	20–40	0.0508	1.1900	0.5613	0.1897	0.3225	0.9693
	40–60	0.0768	0.8067	0.5680	0.0937	0.1833	0.7058
S23	0–2	0.1216	0.9733	0.5033	0.3080	0.1840	0.8263
	2–20	0.1248	1.2533	0.4827	0.1587	0.2290	1.0051
S24	0–2	0.0848	1.5133	0.5187	0.2383	0.1788	1.1826
	2–20	0.0776	0.9967	0.4447	0.0610	0.1570	0.8188
S25	0–2	0.0888	0.8800	0.6293	0.1277	0.1850	0.7604
	2–20	0.0768	0.7933	0.6600	0.0843	0.1870	0.7034
S26	0–2	0.0828	0.4900	0.5047	0.3567	0.1630	0.5358
	2–20	0.1072	0.5467	0.6247	0.1300	0.2110	0.5975
S27	0–2	0.0823	0.8000	0.3900	0.0784	0.1000	0.6820
	2–20	0.0952	0.4633	0.5647	0.0927	0.0903	0.5386
	20–40	0.1040	0.4833	0.5387	0.1687	0.0838	0.5319
	40–60	0.1013	0.5100	0.4075	0.1650	0.1410	0.5124
Integrated pollution index		0.2076	3.1627	0.8702	1.9697	0.7517	

Note: The shadowed cells refer to the data which exceeded the environmental standard value.

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