ENVIRONMENTAL POLLUTION FROM SOLID WASTES

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SUMMARY

Research completed under the CRP during the past two years has encompassed several related aspects of environmental problems associated with solid wastes: assessment of major sources of toxic elements in a variety of solid waste forms, their leachability by simulated groundwater or rain/acid rain and the determination of the contribution of hospital incinerator to atmospheric releases. The summary of the findings of these investigations are given in this report.

Unexpected high levels of cadmium have been found in many solid wastes. Leaching tests indicate that, in some cases, over 70% of this can be leached out into the nearby waterways. Combustibility tests indicated that 35 to 45% of it is emitted to the atmosphere during burning. This explains the increased levels of cadmium in air particulates sampled downwind from waste incinerators. Plastic items in municipal and hospital wastes were particularly elevated in Cd, Cl, Cr, Ba and Zn. Up to 1300 µg/g of Cd was found in some domestic items. By inference, Pb also is found in some common plastics but the current studies did not permit Pb determination in solid wastes, but only in aerosols.

EXPERIMENTAL

Methods used have included a combination of instrumental neutron activation analysis (INAA), Photonuclear activation analysis (PNAA) and Particle induced X-ray

emission analysis (PIXE). The accuracy of the assays were checked using a number of SRM materials.

The aerosol samples were collected using a Sierra Hi-Vol impactor modified to collected only two fractions one above and another below the 2 microns particle size.

Multivariate correlation analysis, i.e., factor analysis was done using STATGRAPHICS software.

With respect to the leaching studies, two types of leachings were used: (a) 18 hr leaching at pH 5, and (b) sequential extraction procedure to identify five fractions viz. readily soluble, carbonate bound, Fe/Mn oxides bound, organic/sulphide bound and residual.

RESULTS AND DISCUSSION.

Elemental Concentration of Solid Wastes

The total elemental concentration of solid wastes are given in Table 1. The incinerator ashes show significant levels of toxic elements. The municipal refuse incinerator ash (MSW), in particular, contains high levels of Cd, As, Hg and Se.

Leaching of elements

Table 2 shows the extent of leaching of elements from solid wastes. The 18 hr acid leach test essentially represents the first two fractions of the sequential extraction procedure. It, therefore, represents the easily soluble and hence, probably bioavailable fraction. This is a significant fraction and hence poses a serious environmental and health hazard.

Aerosol Studies

Table 3 gives the elemental concentration in airborne particulates along with that of hospital incinerator ash. It is noted that, from this data, Ag, Cd, Cl, Cr, Sb and Zn can be identified as marker elements in the hospital incinerator ash. This is confirmed by Factor

analysis of aerosol emission data shown in Table 4. Hospital emissions were signalled in both the fine and coarse particle fractions by factor analysis. There was a strong dependence at Site 1 with south winds which agrees with the direction from which the hospital incinerator stack relative to the air sampler.

Table 5 shows the source contribution to total inorganic aerosol. This data was derived from chemical element balance calculations. The relatively large hospital contributions (22 and 36%) are due to the location of the sampling sites which had been chosen in preferred downwind directions and close to the emission stacks. Also discernable, while not prominent, was a so called 'sulphate' factor strongly associated with S, As and some Zn which could be long range transport of acidic components from the U.S. Northeast as well as from some Canadian Sulphide smelters at 300 KM distance from Toronto.

Following preliminary experiments, plastics in the hospital waste was further studied as the source of toxic elements. It was found that some of the plastic items e.g. surgical drape contain high concentrations of Cd. Pigments and plastic stabilisers are also other probable sources of Cd (Tables 6 and 7). Table 8 lists the results of experiments to investigate the extent of loss of elements to the air as a result of combustion of plastic items.

CONCLUSIONS

It is not enough to treat the solid wastes by incineration to protect the environment from such wastes. These contain high concentrations of toxic elements which are labile and can contribute significantly to air and water pollution. It is important to take adequate steps to contain emissions from the solid wastes during incineration and then to protect the ashes during storage from leaching by rain or ground water. Otherwise, the time and money spent on treatment facilities would be nullified.

TABLE 1. TOTAL ELEMENT CONCENTRATIONS* IN SOLID WASTES

Element (μg/g)	Refuse inc. ash	Coal fly ash	Hospital inc. ash	Sewage sludge	Sewage inc. ash
Ag	88.5 (1.4)	0.9 (0.1)	85.1 (1.5)	32.6 (0.9)	66.6 (1.3)
Al (mg/g)	59.7 (0.8)	118.2 (1.0)	158.0 (1.5)	28.4 (0.3)	55.9 (0.5)
As	105.7 (4.9)	149.8 (6.3)	6.5 (0.4)	6.6 (0.3)	8.8 (0.6)
Ba	85.5 (8.3)	1663 (85)	3592 (49)	752 (77)	1867 (89)
Br	572 (11)	13.0 (0.5)	297 (4)	13.1 (0.7)	3.5 (0.2)
Ca (mg/g)	80.9 (0.8)	35.9 (0.3)	82.8 (0.8)	32.7 (0.6)	65.3 (0.7)
Cd	563.3 (51.2)	16.8 (1.6)	20.9 (2.0)	68.9 (6.3)	36.6 (3.4)
Co	31.4 (1.0)	38.3 (1.3)	48.2 (1.5)	8.5 (0.5)	15.5 (0.7)
Cr	380.0 (7.0)	152.5 (4.5)	416.6 (8.0)	697.4(10.1)	1252 (21)
Fe (%)	3.5 (0.1)	11.7 (0.2)	0.86(0.2)	9.3 (0.2)	18.5 (0.3)
Hg	7.5 (0.3)	1.3 (0.2)	3.0 (0.2)	4.0 (0.3)	1.8 (0.2)
La	21.5 (1.0)	68.7 (1.0)	37.3 (1.4)	57.6 (1.5)	103.6 (4.7)
Sb	1164 (20)	9.0 (1.5)	79.4 (4.6)	94.2 (4.0)	152.7 (8.2)
Sc	8.7 (0.1)	30.8 (0.3)	13.4 (0.2)	28.2 (0.3)	64.2 (0.5)
Se	49.1 (1.0)	15.3 (0.6)	13.4 (0.6)	27.8 (0.9)	32.0 (1.3)
Sm	2.7 (0.1)	14.6 (0.1)	5.7 (0.1)	7.0 (0.1)	15.7 (0.1)
Ta	5.4 (0.2)	2.4 (0.2)	3.5 (0.2)	22.3 (0.5)	50.3 (0.8)
V	118.8 (2.1)	213.9 (3.8)	126.1 (3.1)	431.4 (3.0)	683.4 (3.7)
W	8.5 (0.3)	6.3 (0.3)	10.5 (0.4)	8.9 (0.2)	16.9 (0.3)
Zn (mg/g)	26.9 (0.6)	0.16(0.01)	6.09 (0.14)	2.85(0.07)	4.74(0.11)

* Mean (SD); n= 3.

TABLE 2. PERCENT OF ELEMENTS LEACHED* FROM VARIOUS SOLID WASTES

Element	Refuse inc. ash	Coal fly ash	Hospital inc. ash	Sewage sludge	Sewage inc. ash
Ag	6.3	9.1	3.5	1.5	1.9
Al	4.8	1.1	12.4	0.7	0.7
As	20.3	32.7	12.6	17.0	11.5
Ba	12.2	8.0	4.3	15.4	8.5
Br	75.9	44.6	79.8	11.5	20.0
Ca	20.0	22.0	22.5	10.6	4.3
Cd	76.4	36.9	46.4	34.3	14.2
Co	11.3	4.7	2.9	12.9	9.0
Cr	3.8	4.4	1.1	1.6	1.2
Fe	5.8	1.5	16.3	1.4	0.3
Hg	6.7	15.3	13.3	12.5	23.1
La	14.0	4.5	10.2	4.0	1.2
Sb	0.3	27.8	2.0	2.0	1.7
Sc	2.9	1.6	0.6	0.3	0.1
Se	17.5	22.9	19.4	16.2	4.2
Sm	1.9	7.9	0.2	0.4	1.2
Ta	5.6	8.3	14.3	4.0	1.0
V	7.6	6.3	5.2	3.6	1.6
W	4.7	6.3	14.3	2.2	5.3
Zn	52.8	18.8	13.8	12.3	1.1

TABLE 3. ELEMENTAL CONCENTRATIONS IN AIRBORNE PARTICULATE MATTER (1a) (ng/m³) AND IN ASH SAMPLES (1b) FROM HOSPITAL AND MUNICIPAL INCINERATORS (ppm)

Element	Site 1 1a	Site 2 1a	Suburban 1a	Hospital Inc. Ash (1b)	Municipal Inc. Ash (1b)
Ag*	5.3	4.2	0.56	160	85
Al	2460	1680	600	40200	10900
As	12.4	9.3	5.3	98	40
Br	27	42	70	180	120
Ca	4905	803	2150	25500	43000
Cd*	8.2	6.0	–	680	42
Ce	2.7	1.8	–	34	78
Cl*	4300	7800	2340	99000	8000
Co	1.12	1.82	0.45	18	35
Cr*	32.0	27	7.5	2422	1330
Cs	>2.7	2.8	–	3	0.76
Cu	2370	1829	740	2.2	–
Fe	1640	1230	640	36500	52000
Hf	>0.42	–	–	2.6	6.8
I	1.4	>0.8	3.2	6.8	25
K	550	1100	–	32050	–
La	1.2	2.4	1.5	13	34
Mn	115	278	34	1260	4300
Na	625	1890	1520	18200	14500
Ni	23	26	–	–	–
Pb	*210*	*330*	–	–	–
Sb*	6.4	4.9	1.4	750	270
Sc	0.37	0.38	–	5.6	10.4

TABLE 3. (continued)

Element	Site 1 1a	Site 2 1a	Suburban 1a	Hospital Inc. Ash (1b)	Municipal Inc. Ash (1b)
Se	2.27	2.90	3.3	66	3.4
Ti	150	230	64	21000	32000
V	16.8	91.8	5.9	15.4	135
W	0.75	>0.43	–	12.4	16
Zn*	434	330	108	18000	10800

* Hospital incinerator marker elements

+ solid samples were not analyzed by PIXE

Note: Site 1 – near Western Hospital, 1989 summer, this work
Site 2 – near Mt. Sinai Hospital, 1989 winter, this work
Suburban – Port Credit, Ontario, 1985, Pringle
Hospital Incinerator Ash, 1989, this work
Municipal Incinerator Ash. USA, 1978, Greenberg

TABLE 4. ROTATED FACTOR PATTERN (HOSP. SITE 1)

F1 (Soil)	F2(Hosp.)	F3(Cement)	F4(Vehicle)	F5(sulphate)
Sc (0.96)	Cd (0.93)	Ca (0.99)	Br (0.97)	S (0.96)
Al (0.93)	Cl (0.92)	SW*(0.93)	Pb (0.84)	As (0.82)
La (0.80)	Ag (0.86)	Si (0.76)	Mn (0.72)	Zn (0.39)
Sm (0.72)	Sb (0.62)	Fe (0.58)		
Fe (0.65)	Zn (0.38)			
	SO (0.82)			

*SW = southwest wind; SO = south wind direction

Hospital emission marker elements: Cd, Cl, Ag, Sb (Cr) (As)

ROTATED FACTOR PATTERN (HOSP. SITE 2; FINE)

F1 (Oil/Coal)	F2(hospital)	F3(Vehicle)	F4(Soil)
S (0.93)	Cd (0.96)	Br (0.93)	Sc (0.88)
Se (0.89)	Cr (0.92)	Pb (0.51)	Al (0.76)
V (0.73)	Ag (0.82)	Sb (0.63)	Sm (0.74)
Fe (0.62)	Sb (0.69)		
Ni (0.42)	Cl (0.58)		

ROTATED FACTOR PATTERN (HOSP. SITE 2; COARSE)

F1 (Soil)	F2(Hospital)	F3(Salt)	F4(Vehicle)
Al (0.93)	Cd (0.84)	Cl (0.84)	Br(0.83)
La (0.87)	As (0.72)	Na (0.54)	
K (0.63)	Sb (0.67)	Ca (0.35)	
Pb (0.43)	Zn (0.39)		

Hospital marker elements: Cd (Cl) Ag, Cr, Sb, Zn (As)

TABLE 5. CHEMICAL ELEMENT BALANCE: SOURCE CONTRIBUTIONS (%)

Source	Site 1 (Summer)	Site 2 (fine) (Winter	Site 2 (coarse) (Winter)
Hospital incineration	22	36	6
Motor Vehicle	9	24	1.5
Wind-entrained soil/road dust	55	10	79
Cement from construction	12	n.a.	n.a.
Coal combustion/ secondary sulphate	2.3	30	n.a
De-icing salt	n.a.	n.a.	13.5

n.a. = not apportioned in C.E.B. as the source was not identified in F.A.

TABLE 6. TRACE ELEMENT CONTENT OF HOSPITAL DISPOSABLE PLASTIC ITEMS ($\mu g/g$)

	IV Container	Gloves	Pill Bottle	Medicine Applicator	Surgical Drape	Syringe
Ag	-	-	0.04	0.04	<0.01	0.06
As	0.01	-	0.08	0.14	0.46	0.22
Ba	-	-	-	-	31	19300
Br	0.14	0.30	0.05	0.08	2.9	0.11
Cd	0.62	-	0.13	0.28	6.1	-
Cl	-	3630	121	15	94	-
Cr	1.80	0.34	0.75	n.d.	1.0	11.5
Cu	n.d.	7.90	-	-	55	-
Fe	3.9	7.40	-	-	54	-
Ga	-	-	-	-	7.6	17.3
Hg	-	-	-	1.24	0.66	-
I	-	-	0.70	0.01	0.12	-
Sb	0.06	0.30	0.01	0.03	0.41	-
Ti	n.d.	-	2310	131	15200	-
W	0.01	-	-	-	0.03	0.3
Zn	13	47	6.3	15	0.85	3340

TABLE 7. TRACE ELEMENT CONTENT OF SOME DOMESTIC PLASTIC ITEMS (mg/g)

Soft drink bottle	(540 ppm Sb)
Freezer pouch	(150 ppm Sb)
Yellow food can cap	(1200 ppm Cd)*
Red Shaving cream cap	(1300 ppm Cd; 62 ppm Ag)*
Yellow marker cap	(650 ppm Cd)
Orange kitchen sieve	(930 ppm Cd)
Red deodorant cap	(720 ppm Cd; 2600 ppm Cr; 4200 ppm Ba)*
Yogurt cup	(280 ppm Cd)
White shopping bag	(2000 ppm Ba)
Yellow shopping bag	(2150 ppm Cr)
Needle syringe	(3300 ppm Zn; 20000 ppm Ba)

* Elevated Concentrations from Coloration Pigment and Plasticizer

TABLE 8. FATE OF ELEMENTS DURING PLASTIC COMBUSTION*

Element	% Lost in Combustion*
As	33-88
Br	40-92
Cd	36-46
Cl	62-95
Cr	8-51
Hg	75
Sb	33-61
Ti	9-29
Zn	6-31

* (lab burning up to 700-800°C based ranges for hospital plastic items studied)