Bull. Environ. Contam. Toxicol. (1985) 35:38–43

Bulletin of Environmental Contamination and Toxicology

Heavy Metal Concentrations in Municipal Wastewater Treatment Plant Sludge

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Heavy metals are used widely as part of construction materials, in agriculture, transportation, and in the processing of many industrial and commercial materials. When uncontrolled, they may be introduced by a variety of pathways as environmental contaminants. They may be found in significant quantities in municipal wastewater treatment plant influents as a result of contributions by industry (Nemerow 1978; Water Pollution Control Federation 1981), residential users (Ridgley and Galvin 1982), and urban runoff (Murphy and Carleo 1978; Brown and Lester 1979). Many heavy metals are removed during the treatment of wastewater and, thus, concentrate in the sludges generated by these processes. While metals in trace concentrations may not be harmful to aquatic or terrestrial life, elevated concentrations may be toxic. Therefore, where elevated concentrations of metals are found in municipal treatment plant sludges, options for disposal of these sludges may be limited by statute or regulation (JRB Associates 1981; Lester et al. 1983):

(a) land spreading of sludge may be restricted because toxic pollutants can result in uptake into crops and, subsequently, into the human food chain;
(b) land spreading may be restricted due to the potential for surface or groundwater contamination;
(c) storage of sludge on land may be restricted for the reasons presented in (a) and (b) preceding;
(d) sludge may not be permitted in conventional landfills due to the potential contamination of groundwater by leachate;
(e) the sale of sludge as a soil conditioner may be restricted due to contamination by toxics; or
(f) unknown environmental effects of toxics in municipal sludges have led some state agencies to restrict land disposal of these sludges.

Municipal sludge heavy metal concentrations are dependent upon influent concentrations and efficiency of removal by treatment plant processes, and may vary significantly if the characteristics of a municipality's industrial mix changes, or if major industries institute wastewater pretreatment programs (Koch et al. 1982).

Therefore, sludge heavy metal concentrations may vary considerably from plant to plant (Minear et al. 1981; Mumma et al. 1984).

Legislative mandate contained in the U.S. Clean Water Act and its implementing regulations has required municipal wastewater treatment plants to develop programs to monitor and control industrial discharges to publicly owned treatment works (POTWs). As part of such programs, treatment plant final sludges have been analyzed for priority pollutant heavy metals, and other metals which may be problematic to a specific municipal system. Priority pollutants are metals, organics and miscellaneous compounds specifically regulated by the U.S. Environmental Protection Agency under the Clean Water Act Amendments of 1977. This paper reports the results of the determination of heavy metal concentrations in final sludges from 11 municipal wastewater treatment plants in New York State. These analyses were performed during the period of 1982 to 1983.

MATERIALS AND METHODS

Samples of final sludge were collected from each treatment plant, placed in 1 qt. glass jars with Teflon caps, and stored refrigerated until analysis. Metals were determined by flame atomic absorption spectrophotometry using a Varian Model 575 Atomic Absorption Spectrophotometer after wet ashing the sludge samples with nitric acid. Mercury was determined by cold vapor flameless atomic absorption (APHA 1980).

RESULTS AND DISCUSSION

Table 1 presents heavy metal concentrations in municipal secondary sludges. Generally, values are the mean of two samples collected in consecutive 24 hour periods. Concentration of metals are not consistent from one POTW to another. This variation in values is usually attributable to industrial discharges. Such is the case in Geneva where iron and copper concentrations were related to the discharge from a metal finishing process. Markedly different heavy metal concentrations were observed in sludges from different POTWs.

Table 2 lists the results of sludge analyses from three plants where the wastewater receives only primary treatment. The Port Chester POTW contains significantly lower contributions of metals than were detected in the other two primary plants.

Table 1. Heavy metals in municipal secondary sludge (values in mg/kg dry weight).

Metal	Schenectady	Geneva	Dunkirk	Poughkeepsie	Herkimer Co.	Jamestown	Peekskill[a]	Yonkers[a]
Al	NA	NA	4559	NA	NA	12584	NA	NA
Ag*	49	22	ND	21	9.2	NA	54	0.62
As*	1.4	NA	ND	0.691	4.6	NA	2.3	0.03
B	NA	NA	NA	NA	NA	NA	ND	5.5
Ba	6.8	NA	NA	230	NA	NA	NA	NA
Be*	ND	NA	NA	0.25	NA	NA	ND	ND
Cd*	10	2.55	ND	3.97	6.4	14.6	9.6	0.15
Co	NA	NA	NA	5.33	NA	NA	NA	NA
Cr(total)*	86	82.7	3628	81	179	93	85	1.6
Cr(VI)	10	ND	ND	ND	NA	11.8	ND	ND
Cu*	855	5732	4.15	358	464	8763	1700	17.9
Fe	NA	16497	NA	5260	NA	NA	13200	147
Hg*	0.91	6.79	9.81	0.246	3.22	NA	4.1	0.07
Mn	NA	NA	NA	NA	NA	870	NA	NA
Ni*	52	26	930	33.2	56.7	150	170	1.5
Pb*	282	285	139.6	155	147	472	340	6.1
Sb*	494	NA	1303	17.4	NA	303	360	NA
Se*	ND	NA	0.99	390	NA	NA	1.2	0.07
Sn	NA	NA	NA	25.4	NA	NA	NA	NA
Tl*	ND	NA	NA	4.99	NA	NA	ND	0.13
Zn*	753	710	624	371	612	42.5	1000	16.4

NA = not analyzed
ND = not detected
[a] = sludge is anaerobically digested
* = priority pollutant metal

Table 3. Reported Concentrations of Metals in Municipal Sludges values as mg/kg dry weight. (x = mean, N = number of plants sampled).

	Furr et al. 1976		Mumm et al. 1983			This Study		
Metal	x	Range	x	Range	N	x	Range	N
Al	18,300.	8,100-51,200	15,800.	4,100-31,000	24	8,572.	4,559-12,584	2
Ag	--	--	--	--	--	22.	0.13-54	9
As	12.7	3.0-30.	8.4	1.6-109	24	2.7	0.007-9.9	7
B	37.	16-90	16.8	5.9-48.3	24		5.5	1
Ba	621.	272-1,066	700.	216-2,797	22	8.0	2.25-230	3
Be	a	--	--	--	--	--	0.25	1
Cd	104.	6.8-443.7	39.	2.0-410	24	6.3	0.04-14.6	9
Co	9.6	3.7-17.6	6.5	1.8-46.1	24	--	5.33	1
Cr	2,226.	169-14,000	1,307.	38-15,167	24	414.	0.36-3,628	11
Cu	1,346.	458-2,890	1,507.	117-13,380	24	1,667.	0.03-8,763	11
Fe	31,000.	8,800-82,800	13,850.	3,300-53,000	24	5,835.	51.5-16,497	7
Hg	8.6	3.4-18.	6.2	2.4-14.8	23	171.5	0.006-1,690	10
Mn	188.	32-527	179.	34.1-814	24	318.	0.6-870	3
Ni	236.[b]	36.4-562	71.	13.1-358	24	140.	0.18-930	11
Pb	1,849	136-7,627	143.	20-340	24	190.	2.1-472	11
Sb	10.6	2.6-44.4	6.8	1.6-49.9	24	49.5	17.4-1,303	5
Se	3.1[b]	1.7-8.7	4.4	1.2-8.4	24	79.	0.07-390	5
Sn	216.	111-492	--	--	--	--	25.4	1
Tl	--	--	--	--	--	26.	0.13-89	4
Zn	2,132.	560-6,890	1,186.	223-7,068	24	450.	4.4-1,000	11

[a] - Ba was not detected in any of 15 samples; detection limits ranged from 4-15 ppm.

[b] - mean of 15 cities; all other values, mean of 16 cities.

Values in both primary and secondary sludges (as presented in Tables 1 and 2) varied sufficiently that no categorization of the sludge can be made based upon sludge metal concentrations based and the extent of treatment.

In some municipal systems, domestic contributions of specific heavy metals may be significant. Table 3 presents a summary of reported concentrations of heavy metals in three previous studies.

Table 2. Heavy metals in municipal primary sludges (values in mg/kg dry weight).

Metal	Mamaroneck	Port Chester	Blind Brook
Ag	29	0.13	14
As	9.9	0.007	LT2.52
B	NA	NA	LT860
Ba	LT89	2.25	NA
Be	LT8.9	LT0.008	LT3.4
Cd	LT8.9	0.04	9.8
Cr(total)	147	0.36	176
Cr(VI)	LT0.44	LT0.0003	LT16
Cu	290	0.03	153
Fe	1350	51.5	4340
Hg	LT0.22	0.006	1690
Mn	83	0.6	NA
Ni	97	0.18	24
Pb	165	2.1	94
Sb	LT155	LT0.14	NA
Se	LT2.2	LT0.002	4.6
Tl	89	LT0.08	11
Zn	426	4.4	392

LT = less than analytical detection limits
NA = not analyzed

The ranges and means of heavy metal concentrations as reported by Furr et al. (1976) and Mumma et al. (1983) are comparable to those presented herein, although all are characterized by wide ranges in values. This variability in reported values is probably due to differences in local industrial contributions to each treatment plant.

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Received July 29, 1984; accepted August 28, 1984.