THE HEAVY METAL CONTENT OF MSW INCINERATOR ASH FROM THE CITY OF PHILADELPHIA, DUMPED IN GONAIVES, HAITI.

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Background

In October 1987, the Haitian Department of Commerce gave it's permission for the import of "fertilizers" to the operators of the boat the "Khian Sea". Unbeknownst to the Haitians, the cargo actually contained 13,764 tonnes of toxic ash, originating from a municipal waste incinerator operated by the city of Philadelphia (1). When the Haitian government became aware of the real contents of the ship it ordered it to retrieve the ash from the beach on which it had been dumped. Instead, however, the "Khian Sea" fled, leaving between 2,000 and 4,500 tonnes of toxic ash on the beach at Gonaives (2).

Five years later, in October 1993, the operators of the "Khian Sea" were convicted of dumping their cargo of toxic ash somewhere in the Indian Ocean. The operators were neither charged or convicted of anything in relation to the dumping of the ash in Haiti (3).

At the time the City, E.P.A. and the Pennsylvania Department of Environmental resources found the ash to be "non-hazardous" (4). While ash from municipal solid waste incinerators is legally classed as "non-hazardous" (5), it often contains hazardous constituents. On October 5, 1987, the E.P.A. issued a report about the then planned export of Philadelphia's ash to Panama. The report, "Flash Report: Philadelphia Incinerator Ash Exports for Panamanian Road Projects, Potential Environmental Damage in the Making" by John C. Martin states with respect to heavy metals:

"Samples of the ash have been shown to contain levels of lead, cadmium, and benzene which occasionally exceed hazardous waste thresholds, as well as a wide array of heavy metals and toxic chemicals. Significant amounts of these substances in the ash will very likely reach wetlands and aquatic environments, possibly damaging or killing aquatic life and entering the human food chain..."

"E.P.A. Region (iii) and the City of Philadelphia conducted numerous tests during 1984-1986 to determine the levels of metals and chemicals in the ash. These tests showed that one sample of the ash contained cadmium and benzene in excess of thresholds for hazardous waste, and another sample contained hazardous levels of lead. All of these samples showed the presence of heavy metals and toxic chemicals in varying amounts."

Thus it does seem that a characterisation of the waste as "non-hazardous", does not capture the true nature of the waste.

Investigators have reported that at least 1,000 tonnes of the Philadelphia ash still remain on the beach at Gonaives, but that the ocean and rainfall are slowly washing it away. People living near to the ash storage dump (30m long) have reported that their animals are dying following exposure to the dumped material.

The following report contains the findings of recent analysis (December 1994) of the Philadelphia incinerator ash, including that piled on the beach and that stored in a concrete containment box (15ft by 15ft), uphill from the dump site. Soil samples taken at different depths and distances from these sites were also collected and analysed, as was drinking water taken from a house close to the containment area.

Materials and Methods

Eight samples were taken, in accordance with the EPA's regulation FH846 for the sampling of Resource Conservation and Recovery Act (RCRA) wastes (chapter nine), from the following sites:

1. Incinerator ash, transported from the dumpsite to the containment area. Covered with 5cm of soil.

2. Soil from the rain water runway system, near to the containment area.

3. Incinerator ash taken from the dumpsite, location one.

4. Incinerator ash taken from the dumpsite, location two.

5. Soil, (25cm deep), collected 1.25m away from the dumpsite.

6. Soil, (50cm deep), collected 1.50m away from the dumpsite.

7. Sand, possibly brought by the "Khian Sea", to cover up the incinerator ash.

8. Drinking water, taken from a house close to the containment area.

0.5g of each of the solid samples was transferred to a 120ml teflon vessel fitted with a screw cap and a pressure relief valve. To this, 10ml of deionised water was added, followed by 7.5ml of concentrated hydrochloric acid and 2.5ml of concentrated nitric acid. The vessel was sealed, placed on a rotating table in a microwave (model MDS-200, CEM Corp.), and allowed to digest for one hour at full power (630W). After cooling to ambient temperature, the digest was transferred to a 50ml volumetric flask, diluted with deionised water and mixed. All samples were prepared in duplicate. Also prepared was a Certified Reference Material, of similar nature to the samples being analysed, BCR-143 (trace elements in a sewage sludge amended soil), certified by the Commission of the European Communities, and a sample blank to monitor the possibility of contamination. The sample of drinking water was preserved with 5% concentrated nitric acid and allowed to stand for 24 hours prior to analysis.

Following preparation, the samples were analysed by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES), using a Varian Liberty-100 spectrometer. The calibration standards were prepared from analytical grade metal nitrate stock solutions (1000mg/l) and matrix matched to the samples. The validity of the calibration was checked by preparing quality control standards, independently from the calibration standards, at both 20% and 80% of the calibration range ie. at 2.0mg/l and 8.0mg/l. All samples producing emission intensities greater than the top standard of 10mg/l were diluted, in duplicate, accordingly. The spectrometer was recalibrated after every 20 samples, to compensate for any drop in sensitivity. All other instrument quality control procedures (6) were adhered to.

Results

Sample no.	Description
H4001	Incinerator ash, transported from the dump site to the containment area, covered with 5cm soil.
H4003	Soil, from the rain-water runway system, near to the containment area.
H4006	Incinerator ash taken from dump site (location 1).
H4007	Incinerator ash taken from dump site (location 2).
H4008	Soil (25cm deep), collected 1.25m away from dump site.
H4009	Soil (50cm deep), collected 1.50m away from dump site.
H4010	Sand, possibly brought by the "Khian Sea", to cover up the incinerator ash.
H4011	Drinking water, taken from a house close to the containment area.

All results are expressed as mg/kg dry wt (except H4011 mg/l).

	H4001	H4003	H4006	H4007	H4008	H4009	H4010	H4011
Cr	79.5	114.6	101.7	108.2	74.9	40.6	2.0	0.01
Zn	2550.3	75.0	2597.3	2339.3	4146.5	100.9	5.9	0.01
Cu	1315.4	50.4	1124.2	1091.7	2594.0	68.7	11.8	<0.01
Pb	1352.0	23.6	1068.5	1093.8	1312.7	29.4	n/d	<0.03
Ni	77.3	100.7	74.4	95.7	104.9	26.6	n/d	<0.01
Cd	14.4	7.5	12.0	12.9	19.5	n/d	n/d	<0.01
Mn	759.9	1312.5	896.8	756.1	764.3	312.5	2.0	0.03
Co	11.0	21.4	14.2	10.8	12.0	8.4	n/d	<0.01
Hg	0.8	n/d	0.4	0.3	0.4	n/d	n/d	<0.001
As	3.3	3.3	5.4	6.8	1.6	n/d	n/d	<0.01
Sb	42.0	n/d	22.5	41.0	15.9	n/d	n/d	<0.01

n/d= none / detected

Discussion

The results show great similarities exist between the levels of heavy metals found in the ash itself and those present in the soil taken at the shallower depth of 25cm. Indeed six of the eleven metals analysed are present at a higher concentration in the soil than they are in the ash, indicating that there is leaching into the soil. The levels of metals found in the ash are comparable with data from other sources, in that levels of Cu Zn and Pb are greater than Ni and Cr, which in turn are greater than Cd and Hg. Sawhney and Fink (1991) collected samples of MSW incinerator ash from six Connecticut towns between 1988 and 1989 and their findings show the levels of heavy metals present to be comparable to those found in the Philadelphia ash (7).

An interesting study was carried by Williams (1988) on animal and human disease around a site with two incinerators, one chemical and the other municipal, in Bonnybridge, Scotland. The investigation was initiated after a report on the death of 51 cattle (between 1977 and 1980), grazing on a field adjacent to the dump site, where the waste from both of these incinerators was piled. Analysis of the area gave the following results:

	Cr	Cd	Pb	Ni	Cu
Incinerator ash.	832	3.5	244	61.1	333
Soil,6m away from dump site.	138	1.7	55.3	30.9	28.1
Grass.	<5	<1	<10	<5	<7

All results expressed as mg/kg dry wt.

The paper stated that it could not " be concluded from these results that the polluted soils (or vegetation) contributed to the death of the cattle ", but it did indicate that further toxicological investigation was required before this possibility could be ruled out. The paper also covered the incidence of cancers of the hematopoietic and lymphatic tissues. These cancers were chosen because they have been associated with occupational exposure to chemicals (8,9), and have a latency period which can be as low as 5 years. Interpretation of the results was difficult due to the relatively small numbers involved, however, differences between the number of cases of leukemia and Hodgkin's during the period 1976-1979 and 1980-1984 in zones closest to the incinerator dump sites was consistent with environmental contamination, " but of course did not prove causality."(10) Also a shift was seen towards the younger ages in these zones," again indicative of environmental pollution".

The levels of heavy metals found in the soil samples were compared to those set as intervention and target levels in a soil protection policy document for the Netherlands (11). The soil taken 1.25m away from the dump site (H4008), contains levels of Zn, Pb, Cu and Cd which exceed maximum permissible limits; and target values for both Ni and Hg are also exceeded.This indicates that wherever such waste is dumped, the closely surrounding soil will be rendered unfit for consequent use should a time arise when the waste is removed. Also if this soil were to be categorised by a document published by the Department of the Environment on the redevelopment of contaminated land in the UK (12), it would be regarded as being contaminated with respect to Pb, and Ni, and heavily contaminated with respect to the levels of Zn, Cu and Cd present.

Of all of these levels, the amount of Cd present warrants the most concern. Transfer of Cd into the human food chain can be considerable compared to the other metals mentioned (13), and even though soil this close to the dump site is extremely unlikely to be used for grazing or crop cultivation, further leaching over time to a more widespread area, could make this transfer even more significant. Cd is of particular concern for a number of reasons, notably it's high toxicity, it's long body retention time and it's high mobility in the environment. Kloke (1984) has examined the mobility of a range of metals in the soil-plant system, and has deduced that Cd is one of the most bioavailable heavy metals along this pathway (14). The human diet, and in particular the vegetable/grain component represents a major source of Cd exposure (15). Thus the considerable mobility of Cd in the soil-plant system represents a potential hazard to human health when levels of Cd in soils are raised. Nriagu (1988) estimated that between 250,000 and 500,000 people globally have dietary exposures sufficiently high to lead to the onset of renal dysfunction,(16), the kidney being the main target organ of Cd toxicity (17). Leachability studies have shown that even in a lined landfill site, metals from MSW incinerator ash have the capability to leach into the surrounding environment (18), thus if the ash is merely dumped, and is close to either land set aside for crop production or grazing pasture the soil may be rendered unsuitable for these purposes, as well as posing a potential threat to both animal and human health.

The soil sample (H4008) also contains anomalously high levels of both Zn and Cu. Both of these, even though essential elements, can affect health if taken in quantities greater than the Recommended Dietary Allowances (RDAs). Most Cu deposited in the soil will be strongly adsorbed and remain in the upper few centimetres of soil, (19) bound to organic molecules; therefore the bioavailability of the Cu in the soil cannot be assessed based on the bioavailability information from drinking water or food studies. Further studies are required to assess the potential toxicity to people living near this site due to it's hazardous nature.(20) Further information is also required regarding the levels of Zn acceptable in soil. Even though Zn has been seen to accumulate in aquatic organisms, it has not been seen to concentrate itself in plants.(21) Reliable monitoring data for the levels of Zn in contaminated media at hazardous waste sites are needed so that the information obtained on levels of Zn in the environment can be used in combination with the known body burden of Zn to assess the potential risk of adverse health effects in populations living in the vicinity of hazardous waste sites.(22)

Lead was also found to be present at anomalously high levels. Plants and animals may both bioconcentrate Pb, although biomagnification has not been detected. Bioavailability of Pb in soils is limited because of the strong adsorption of Pb to the soil organic matter, however this availability can increase if the pH and the organic content of the soil are both reduced.(23) The presence of increased levels of Pb in food chain is of concern as Pb has been shown to effect every organ and/or system in the body of both humans and animals. The most sensitive target organs seem to be the nervous system (particularly in children), the hematopoietic and cardiovascular systems. The availability of lead compounds thus need to be further investigated.(24)

With respect to the other samples of soil taken, a decrease in the contamination by heavy metals is seen the further one travels away from the dump site. Further, the drinking water does not exceed EC Directive permitted concentration levels, or U.S. EPA guidelines. However even though leaching of the metals is not yet widespread, the possibility of human and animal exposure by direct inhalation of the ash carried through the air, cannot be excluded.A further study into the levels of heavy metals found in dust samples collected in the surrounding area could be of particular interest and importance.

Conclusion

The findings from this brief investigation do not concur with the City, E.P.A. and the Pennsylvania Department of Environmental Resources, which found this ash to be "non-hazardous". With respect to Cd, Pb, Cu and Zn, anomalously high levels are found to be leaching from the ash into surrounding soil, with the potential of contaminating a wider area. There is no doubt that emissions from MSW incinerators contain toxic pollutants some of which can be persistent and bioaccumulative,(25) and with this in mind the U.S. should assist and facilitate a plan between the City of Philadelphia and the Haitian Government to remove the toxic ash from Haiti.

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