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Cancer Risk Assessment for the Inhalation of Metals from Municipal Solid Waste Incinerators Impacting Chicago

William H. Hallenbeck, Sheila P. Breen, and Gary R. Brenniman

University of Illinois at Chicago, School of Public Health, MC 922, Division of Environmental and Occupational Health Sciences, Chicago, Illinois 60680, USA

The emissions of two municipal solid waste (MSW) incinerators impact the air quality of Chicago. The Northwest Waste-to-Energy Facility in Chicago is a mass burn MSW incinerator (site-erected, water wall, four furnaces, 1600 tpd capacity) which generates steam for industrial-commercial purposes. One of the furnaces is used as a maintenance/emergency backup which reduces the processing capacity to 1200 tpd. The plant presently processes less than 800 tpd and operates 24 hours/day, 7 days/week, and a minimum of 30 weeks/year. Air pollution control is by electrostatic precipitators (ESP). No changes in pollution control have been made since 1970 (Rood 1988; IDENR 1988; DSS 1992). Emissions from MSW combustors like the Northwest Facility with ESP control technology include particulates (with associated metals and organics), acid gases (SO_2 and HCl), NO_x, CO, hydrocarbons, dioxins (PCDD) and furans (PCDF).

The East Chicago Municipal Waste Incinerator in Indiana also impacts Chicago's air shed. This mass burn continuous feed incinerator commenced operation in 1971 and serves the East Chicago region. The incinerator consists of two refractory wall combustor units with a capacity of 250 tpd each and operates 24 hours/day, 5 days/week, and 48 weeks/year. It is estimated that this incinerator burns 59,800 tons of waste/year (Summerhays 1989; USEPA 1989). Air pollution control is by venturi scrubbers (spray chamber with a plate-type scrubbing tower). These scrubbers are assumed to be 80% efficient for particulates (USEPA 1987a).

Particulates emission rates for these two incinerators and meteorological data were used to determine annual average air concentrations for four carcinogenic metals (arsenic, beryllium, cadmium, and chromium VI) throughout the city of Chicago. These metal concentrations were used

Send reprint requests to W. Hallenbeck at address above.

to evaluate the inhalation cancer risks for the 1990 City of Chicago population of 2,783,726 people.

MATERIALS AND METHODS

The chemical speciation of metal emissions from MSW incinerators is unresolved. It is likely that emitted metals are in the form of chlorides and oxides. Hexavalent chromium is the recognized carcinogenic form of chromium. The ratio of chromium VI to total chromium in MSW emissions ranges from 0.007 to 0.1 (Levin 1991). For a worst case analysis, ten percent of the chromium emitted from the incinerators was assumed to be hexavalent. At this time, any valence state of arsenic, beryllium, and cadmium are assumed to be carcinogenic.

Metal emission rate data were not available for the Northwest incinerator. Assuming metals are primarily deposited on particulates, metal emission rates can be estimated from the measured annual particulate emission rate, published metal emission factors, and operating time data. The Northwest incinerator emitted 283 tons of total particulate in 1989. Metal emission factors for the Northwest Facility (estimated) and the East Chicago Incinerator (estimated for beryllium) are shown in Table 1.

Table 1. Metal emission factors

Metal	Northwest Incinerator (μg metal/g of controlled particulates emitted)[a]	East Chicago Incinerator (μg metal/g of controlled particulates emitted)
Arsenic	335	200[b]
Beryllium	0.091	11.9[a]
Cadmium	686	1500[b]
Chromium	9476	105[b]

[a] USEPA 1987b,c (estimated metal emission factors from similar incinerators)
[b] Greenberg 1978 (measured metal emission factors)

The measured annual particulate emission rate, measured metal emission factors (arsenic, cadmium, and chromium), and operating time data were available for the East Chicago Incinerator. The East Chicago Incinerator emitted 72 tons of total particulate in 1989. Measured emission factors (arsenic, cadmium, and chromium) for this

facility are shown in Table 1. The emission factor for beryllium was estimated from a similar incinerator.

Since the incinerators are point sources in an urban setting, the USEPA's Industrial Source Complex Long Term (ISCLT) Dispersion Model was used to analyze metal emission rate and meteorological data for 1989 to determine annual average air concentrations of metals throughout the city of Chicago. Surface meteorological data were from Chicago's O'Hare International Airport. The Airport is about ten miles northwest of the Northwest Facility. Peoria Airport mixing height data were used since these data were unavailable from O'Hare International Airport. Peoria mixing height data were acceptable since the ISCLT Model is relatively insensitive to changes in mixing height. Lake Michigan wind effects and any atmospheric reactions of the metals were not included in the model.

Annual average ground level metal concentration isopleths were constructed for the city of Chicago. Because the emission factor for beryllium was very small, the model was unable to calculate concentrations of beryllium from the Northwest incinerator.

Three levels of analysis were used: Level I, II, III. In Level I analysis, worst case annual average air concentrations were assigned to each of the 77 community areas in Chicago. If a community area was located between two isopleths, the concentration of the higher isopleth was assigned to the population of the community area. If a community area crossed an isopleth, the highest concentration of the higher interval was assigned to the community area. If a community area crossed two or more isopleths, the highest concentration of the highest interval was assigned to the population of the community area. Due to the number of excess cancer cases predicted from Level I analysis of chromium VI, more refined Levels II and III analyses were carried out for chromium VI.

Level II analysis was based on isopleths and census tracts within community areas. Due to the large number of census tracts in Chicago, only the census tracts in the five community areas which contributed the highest number of excess cases in Level I analysis were analyzed in more detail. If a census tract was located between two isopleths, the concentration of the higher isopleth was assigned to the population of the census tract. If a census tract crossed an isopleth, the highest concentration of the higher interval was assigned to the community area. If a census tract crossed two or more isopleths, the highest concentration of the highest interval was assigned to the population of the census tract.

Level III analysis was based on concentrations within census tracts and was performed for the two community areas which contributed the highest number of excess cases in Levels I and II analyses. An attempt was made to match each census tract's center coordinates with the concentration coordinates generated by the ISCLT Model. Many census tract center coordinates did not match the model concentration coordinates since the model's cartesian coordinates were at half mile intervals. In this case, center concentrations were calculated by averaging the concentrations from surrounding coordinates.

USEPA cancer risk factors for the four metals (Table 2, USEPA 1990) and 1990 census data were used to calculate theoretical excess cancer cases for each community area. USEPA risk factors are upper bound (95%) and assume 70 years of exposure. Clearly, the predicted excess cases will be an overestimate since it is very unlikely that the incinerators will operate for 70 years. Excess cases were calculated by multiplying the population of a selected geographic area by the metal concentration and by the risk factor for the metal. Although all the risk factors were based on epidemiology studies which involved the inhalation of metals, none of the unit risk factors were chemically speciated or defined by size distributions.

Table 2. USEPA cancer risk factors for the inhalation of arsenic, beryllium, cadmium, and chromium VI

Metal	Risk factor $(\mu g/m^3)^{-1}$
Arsenic	0.0043
Beryllium	0.0024
Cadmium	0.0018
Chromium VI	0.012

RESULTS AND DISCUSSION

The results of Level I analysis for four metals and Levels II and III analyses for chromium VI are shown in Table 3,4 and 5, respectively. Table 3 shows that even under the worst case conditions of Level I analysis:

- Only 12 excess cases of cancer are generated by 70 years of exposure to incinerator metal emissions.
- The contribution of theoretical excess cases in Chicago from the East Chicago incinerator is negligible.

- Chromium VI is the metal of primary concern.

Table 3. Level I analysis: Theoretical excess cancer cases generated in Chicago from 70 years of exposure to selected metal emissions from two incinerators

Metal	Northwest Incinerator	East Chicago Incinerator
Arsenic	1.3	0.05
Beryllium	a	0.0001
Cadmium	1.1	0.09
Chromium VI	10	0.005
total	12	0.1

[a] Because the emission factor for beryllium was very small, the ISCLT model was unable to calculate concentrations for beryllium.

Table 4. Level II analysis for chromium VI: Theoretical excess cancer cases due to chromium VI for the five most impacted Chicago community areas

Community area number	Level I analysis (by community area)	Level II analysis (by census tract)
19	0.6	0.3
22	0.5	0.2
23	1.6	0.9
24	0.5	0.25
25	2.7	1
total	6	3

Table 5. Level III analysis for chromium VI: theoretical excess cancer cases due to chromium VI for the two most impacted Chicago community areas

Community area number	Level I analysis	Level II analysis	Level III analysis
23	1.6	0.9	0.4
25	2.7	1	0.5
total	4	2	1

Table 4 shows that a more refined Level II analysis reduced the total predicted cases by a factor of about two in the five most impacted community areas. Table 5 shows that the most refined Level III analysis reduced the total predicted cases by a factor of about four (compared to Level I analysis) in the two most impacted community areas. Within the limitations of this study, the health impact on Chicago due to carcinogenic metal emissions from the Northwest Facility and the East Chicago Incinerator appears to be very small.

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