A COMPARISON OF HEALTH RISK ASSESSMENTS FOR THREE OGDEN MARTIN SYSTEMS, INC. RESOURCE RECOVERY FACILITIES USING ESTIMATED (PERMITTED) AND ACTUAL EMISSION LEVELS

JEFFREY L. HAHN AND DONNA S. SOFAER
Ogden Martin Systems, Inc.
Fairfield, New Jersey

ABSTRACT

Health Risk Assessments (HRA) for three Ogden Martin Systems, Inc. (OMS) resource recovery facilities have been based either on emissions estimated from databases available prior to construction, i.e., in the permitting phase of the project, or on actual emissions determined from compliance testing performed during and after startup of the facility. When estimated emissions were used for the initial HRA, e.g., Stanislaus, the HRA was then required to be re-evaluated based on actual emissions providing a direct comparison. For Tulsa, the comparison was between the existing facility, e.g., designed with good combustion practices and an efficient ESP, and the facility if additional air pollution control equipment was added as a result of a top-down BACT analysis. In the case of the Babylon facility, the permit required that the HRA be performed only after the facility was operating. The results of using estimated (permitted) versus actual emission levels in the three HRAs are presented.

INTRODUCTION

The permitting process for the Stanislaus County Resource Recovery Facility, located in Crows Landing, California, required an HRA based on emission levels estimated from similarly designed facilities that were in operation prior to issuance of the Authority to Construct, i.e., pre-1986. The emission levels also had to include a 5% off-line emission estimate using data from the old Toronto incinerator. The Walter B. Hall Resource Recovery Facility, located in Tulsa, OK was permitted on the basis of emissions estimated from data available prior to 1984. Subsequent to startup of this facility, and in conjunction with a request to adjust the permitted emission limits to correspond to actual results, the State of Oklahoma, Air Quality Service (OAQS) and U.S. EPA, Region VI, required that an HRA be done using actual emissions from performance testing completed from 1986 to 1988 for the existing facility. The HRA was to then compare these emissions and the associated health risk with reduced emissions from top-down BACT air pollution control equipment that could be retrofitted to the Tulsa facility. The Babylon Resource Recovery Facility, located in Babylon, New York, was permitted with the stipulation that once performance testing was completed, the actual emission levels be subjected to an HRA prior to issuance of the permit to operate. Table 1 displays the technical descriptions for these three facilities.

BACKGROUND

Stanislaus: The HRA for this facility was performed in 1986 by Radian Corporation, under contract to

TABLE 1 DESCRIPTIONS OF THREE OGDEN MARTIN SYSTEMS, INC. RESOURCE RECOVERY FACILITIES

Technical Data	Stanislaus County, CA	Tulsa, OK	Babylon, NY
Began Operations:	September 1988	March 1986	December 1988
System Design:			
Furnace:	MB	MB	MB
Process Units:	2	3	2
Total TPD(tonnes/day):	800 (725)	1125 (1020)	750 (680)
Steam Pressure, psig (kPa)	865 (5964)	630 (4344)	655 (4516)
Steam Temperature, °F (°C)	830 (443)	700 (371)	700 (371)
Energy Products (net):			
Electricity, MW:	15	---	14
Steam, lbs/hr (kg/hr):	---	24,000 (10,886)	---
Air Quality Controls:			
Acid Gas Removal:	DS	---	DS
Particulate Removal:	FF	ESP	FF
Nitrogen Oxide Control:	Exxon's Thermal DeNO$_x$	Automatic Combustion Control	Automatic Combustion Control

MB = Mass-burn
DS = Dry Flue Gas Scrubber
FF = Fabric Filter Baghouses

OMS and was based on estimated emissions shown in Table 2. These emission estimates were developed by OMS from a pre-1986 database of emissions from facilities with similar design features, e.g., Chicago Northwest, Westchester, Malmo, Sweden, and other mass-burn, waterwall facilities from the U.S., Japan, and Europe [1]. Table 3 presents the key assumptions made in evaluating the estimated human health risks for two scenarios, i.e., Case 1 (moderately conservative, and therefore more likely to occur) and Case 2 (more conservative and less likely to occur). Table 4 summarizes the cancer risk for the Case 1 and the Case 2 exposure scenarios from substances known or suspected to be carcinogenic including different assumptions for 2,3,7,8-TCDD toxic equivalents (TEFs), which are in California Department of Health Services (DHS) TEFs.

Tulsa: This facility was permitted during 1981–84 using limited data available at that time from a few similar mass burn facilities, but was mainly based on data estimates from U.S. EPA AP-42. No formal HRA was required at the time of permitting. However, OMS requested adjustments in the permitted emission limits to allow closer agreement with actual stack testing results based on the operation of a modern mass burn, resource recovery facility with good combustion practices. In 1987–88, OMS was required by OAQS and the U.S. EPA Region VI to perform a top-down BACT re-analysis for those pollutants for which an adjustment was requested including a HRA. The HRA was performed by Roy F. Weston, Inc., Seattle, WA, under contract to Ogden Martin Systems of Tulsa, Inc.

Babylon: The original New York State Department of Environmental Conservation (NYSDEC) air permit for this facility stipulated that once the facility was built and performance testing was completed, an HRA using actual emission results be conducted. The HRA for this facility was done by Health Risk Associates, Berkeley, CA under contract to Ogden Martin Systems of Babylon, Inc. after initial performance stack test results became available from OMS.

All three HRAs had their protocols approved by the appropriate state and Federal agencies prior to the inclusion of the source test results and completion of the HRAs.

RESULTS

Stanislaus: Table 5 provides the actual annual average emissions based on stack testing. Two subsequent quarterly dioxin tests replicate the initial dioxin results and are also shown in Table 5. Table 6 updates the cancer risk by various pathways for the Case 1 and Case 2 scenarios using these actual emissions. The total cancer risk based on actual emission levels is 14 to 24 times lower than originally estimated.

Tulsa: Table 7 demonstrates that the cancer risk predicted, using tested emissions from the Walter B. Hall facility as it is currently designed, is on the same order of magnitude as the cancer risk estimated for this facility if additional air pollution control equipment were retrofitted, i.e., adding Thermal DeNO$_x$ and dry scrubbers/fabric filters while removing the ESPs. The emission estimates for the retrofitted air pollution control equipment case were developed by Roy F. Weston from their worldwide database and actual operating data from other OMS facilities.

Babylon: Pursuant to permit requirements, a comprehensive health risk assessment was undertaken for exposure to the actual stack emissions from the Babylon Resource Recovery Facility. Over 20 emissions were considered including dioxins, lead, arsenic, mercury, and cadmium. An important finding was that the maximum average ground level air concentrations of all emissions were very much lower than existing levels present in suburban settings. For example, the maximum average ground level concentration estimated for arsenic was more than 500 times lower than measured levels in suburban samples in New York, and the maximum average air level for mercury was 6 times lower than typical urban levels. The air concentration of dioxins was estimated to be about 33 times lower than existing levels measured in air samples from West Babylon. Thus, even at the maximum point for ground level concentrations, the emissions would not make a significant impact on existing levels.

Upper limit estimates of cancer risk were calculated for those substances which have been found to cause cancer in animals or humans. The first stage of this assessment was to estimate the extent of potential human exposure to emissions. This meant estimating the extent of exposure for a hypothetical person assuming that the person was born at the point of maximum annual average ground level concentrations of emissions, and spent 24 hr a day there for a lifetime. All pathways of exposure were considered, including inhalation of air, contact with dust and soil, inhalation of resuspended dust and soil, consuming vegetables from a home garden, and fish consumption from a local lake.

Tables 8 through 11 present the details on the calculation of the estimate of cancer risk. Tables 12 and 13 present the comparisons between existing background levels of various pollutants and their modeled concentrations. Finally, in Tables 14 and 15, safety

TABLE 2 SUMMARY OF ESTIMATED EMISSIONS FOR THE STANISLAUS COUNTY RESOURCE RECOVERY FACILITY

Pollutant	Estimated Annual Average[a] Emissions (g/s)
Antimony (Sb)	6.80E-04
Arsenic (As)	1.10E-04
Beryllium (Be)	2.70E-06
Cadmium (Cd)	7.20E-04
Chromium (Cr)	4.5E-03
Copper (Cu)	1.70E-03
Lead (Pb)	1.70E-02
Manganese (Mn)	1.60E-03
Mercury (Hg)	9.6E-03
Hydrogen Fluoride (HF)	5.2E-02
Nickel (Ni)	3.70E-03
Selenium (Se)	1.80E-05
Tin (Sn)	3.10E-03
Vanadium (V)	1.20E-04
Zinc (Zn)	3.90E-02
Hydrogen Chloride (HCl)	2.6
Polychlorinated Biphenyls (PCB)	1.0E-05
Polycyclic Aromatic Hydrocarbons (PAH)	4.5E-04
TCDD (Case 1)[b]	6.1E-07
TCDD (Case 2)	1.72E-06

[a]Emissions are based on 8016 hours of operation per year.
[b]California DHS TEFs.

TABLE 3 KEY ASSUMPTIONS FOR CALCULATING HUMAN EXPOSURE, STANISLAUS HEALTH RISK ASSESSMENT

Variable	Case 1	Case 2
Dioxin/Furan toxic equivalent weighting scheme:	DHS	DHS
Deposition velocity:	1.0 cm/s	1.0 cm/s
Carcinogenicity of Cr, Cd, and Ni by ingestion:	yes	yes
Dose adjustment for gastrointestinal absorption of carcinogenic metals:	Absorption factors applied	Complete absorption through the GI tract
GI tract absorption of dioxins and furans from environmental matrices:	15% of the conc. on fly ash. 50% of conc. absorbed in crops, 100% from milk, meat, fish.	25% of the conc. from fly ash. All others same as Case 1
Exposure Period:	30 years	70 years
Pathway Assumptions:		
Plant:		
Consumption of locally grown produce:	15%	20%
Root uptake of dioxins/furans:	1%	10%
Soil:		
Consumption rate:	4.2E-04 kg/day	2.4E-04 kg/day
Dairy/Beef:		
Root uptake of TCDD in grass:	1%	10%

TABLE 4 CASE 1 AND CASE 2 CANCER RISK DETERMINED BY USING ESTIMATED EMISSIONS DEVELOPED PRIOR TO STARTUP OF THE STANISLAUS COUNTY RESOURCE RECOVERY FACILITY

Chemical	Soil	Plant	Dairy	Fish	Dermal	Milk	Inhal	Total
Case 1								
As	5.36E-09	3.41E-08	0.00E+00	6.01E-11	1.13E-10	---	5.48E-09	
Be	4.27E-11	2.71E-10	0.00E+00	1.43E-13	8.97E-13	---	4.36E-11	
Cd	9.34E-10	5.93E-09	0.00E+00	9.42E-11	3.27E-10	---	1.59E-08	
Cr	6.60E-08	4.19E-07	0.00E+00	4.44E-10	1.26E-08	---	6.13E-07	
Ni	1.38E-09	8.78E-08	0.00E+00	1.88E-12	2.91E-10	---	1.41E-08	
PAH	8.41E-09	5.34E-08	2.15E-08	1.13E-07	3.54E-10	---	1.72E-08	
PCB	1.41E-10	8.96E-10	3.60E-10	4.74E-10	2.97E-12	---	1.44E-10	
TCCD1	2.15E-08	3.93E-07	8.62E-08	2.93E-08	3.01E-09	5.13E-07	2.53E-07	
Case 1	1.04E-07	9.16E-07	1.08E-07	1.44E-07	1.87E-08	5.13E-07	9.19E-07	2.72E-06
Case 2								
As	1.87E-08	1.11E-07	0.00E+00	2.75E-10	6.13E-10	---	1.28E-08	
Be	1.33E-10	8.80E-10	0.00E+00	6.58E-13	4.88E-12	---	1.02E-10	
Cd	4.84E-08	3.21E-07	0.00E+00	7.20E-09	1.78E-09	---	3.72E-08	
Cr	1.87E-08	1.24E-05	0.00E+00	1.85E-08	6.85E-08	---	1.43E-08	
Ni	4.30E-08	2.85E-07	0.00E+00	8.53E-11	1.58E-09	---	3.29E-08	
PAH	5.23E-08	3.47E-07	8.97E-08	5.19E-07	1.92E-09	---	4.01E-08	
PCB	4.39E-10	2.91E-09	1.52E-09	4.22E-09	1.81E-11	---	3.38E-10	
TCCD2	1.35E-07	2.00E-05	1.05E-06	1.93E-07	1.97E-08	6.45E-06	1.66E-08	
Case 2	2.16E-06	3.34E-05	1.14E-06	7.42E-07	9.42E-08	6.45E-08	3.22E-08	4.72E-05

TABLE 5 EMISSIONS PREDICTED FROM ACTUAL TEST RESULTS OF THE STANISLAUS COUNTY RESOURCE RECOVERY FACILITY

Pollutant	Actual Annual Average Emissions[a] (g/s)	Percent of Original Estimate (%)
Arsenic (As)	5.26E-05	48%
Beryllium (Be)	2.04E-08	1%
Cadmium (Cd)	8.25E-05	12%
Chromium (Cr)	4.68E-04	10%
Nickel (Ni)	9.68E-04	26%
Polychlorinated Biphenyls (PCB)	6.79E-06	68%
Polycyclic Aromatic Hydrocarbons (PAH)	1.16E-04	26%
TCDD (Case 1: December 1988)[b]	1.65E-08	3%
(Case 1: Spring 1989)[b]	<4.16E-08	7%
(Case 1: Summer 1989)[b]	<0.85E-08	1%
TCDD (Case 2)	9.59E-08	1%

[a]Emissions are based on 8016 hours of operation per year.
[b]California DHS TEFs.

TABLE 6 CASE 1 AND CASE 2 CANCER RISK DETERMINED BY USING ESTIMATED EMISSIONS FROM ACTUAL STACK TESTING OF STANISLAUS COUNTY RESOURCE RECOVERY FACILITY

Chemical	Soil	Plant	Dairy	Fish	Dermal	Milk	Inhal	Total
Case 1								
As	2.6E-09	1.6E-08	0.0E+00	2.9E-11	5.4E-11	---	2.6E-09	
Be	3.2E-13	2.0E-12	0.0E+00	1.1E-15	6.8E-15	---	3.3E-13	
Cd	1.1E-10	6.8E-10	0.0E+00	1.1E-11	3.7E-11	---	1.8E-09	
Cr	6.9E-09	4.4E-08	0.0E+00	4.6E-11	1.3E-09	---	6.4E-08	
Ni	3.6E-10	2.3E-09	0.0E+00	4.9E-13	7.6E-11	---	3.7E-09	
PAH	2.2E-09	1.4E-08	5.6E-09	2.9E-08	9.2E-11	---	4.5E-09	
PCB	9.6E-11	6.1E-10	2.4E-10	3.2E-10	2.0E-12	---	9.8E-11	
TCCD1	5.8E-10	1.1E-08	2.3E-09	7.9E-10	8.1E-11	1.4E-08	6.8E-09	
Case 1	1.3E-08	8.8E-08	8.1E-09	3.0E-08	1.7E-09	1.4E-08	8.3E-08	2.4E-07
Case 2								
As	8.9E-09	5.3E-08	0.0E+00	1.3E-10	2.9E-10	---	6.1E-09	
Be	1.0E-12	6.6E-12	0.0E+00	5.0E-15	3.7E-14	---	7.7E-13	
Cd	5.5E-09	3.7E-08	0.0E+00	8.2E-10	2.0E-10	---	4.3E-09	
Cr	1.9E-07	1.3E-06	0.0E+00	1.9E-09	7.1E-09	---	1.5E-07	
Ni	1.1E-08	7.5E-08	0.0E+00	2.2E-11	4.1E-10	---	8.6E-09	
PAH	1.4E-08	9.0E-08	2.3E-08	1.3E-07	5.0E-10	---	1.0E-08	
PCB	3.0E-10	2.0E-09	1.0E-09	2.9E-09	1.1E-11	---	2.3E-10	
TCCD2	1.3E-09	1.9E-07	1.0E-08	1.9E-09	1.9E-10	6.2E-08	1.6E-08	
Case 2	2.4E-07	1.7E-06	3.4E-08	1.4E-07	8.7E-09	6.2E-08	1.9E-07	2.4E-06

TABLE 7 COMPARISON OF CANCER RISKS ASSOCIATED WITH EXISTING DESIGN AND RETROFIT OF THE WALTER B. HALL RESOURCE RECOVERY FACILITY

	Route of Exposure			
	Inhalation	Ingestion	Dermal	Total
Existing Facility				
Organics				
Dioxins/Furans (EPA Toxic Equiv.)	8.33E-08	1.05E-09	1.43E-11	8.44E-08
PCBs	7.27E-09	1.21E-10	3.82E-12	7.40E-09
PAHs (carcinogenic)	1.23E-09	1.92E-11	2.14E-16	1.25E-09
Aldehydes	2.18E-08			2.18E-08
Inorganics				
Arsenic	2.78E-07	8.15E-10		2.79E-07
Beryllium	1.13E-10			1.13E-10
Cadmium	1.75E-08			1.75E-08
Chromium (VI)	2.58E-07			2.58E-07
Nickel	1.26E-08			1.26E-08
Total	6.80E-07	2.00E-09	1.81E-11	6.82E-07
Retrofit: Spray Dryer, Fabric Filter, Thermal DeNO$_x$				
Organics				
Dioxins/Furans (EPA Toxic Equiv.)	1.35E-08	2.63E-09	3.58E-11	1.62E-08
PCBs	8.44E-09	2.17E-09	6.83E-11	1.07E-08
PAHs (carcinogenic)	1.42E-09	3.43E-10	5.35E-16	1.77E-09
Aldehydes	2.53E-08			3.53E-08
Inorganics				
Arsenic	3.23E-09	1.46E-10		3.38E-09
Beryllium	9.15E-12			9.15E-12
Cadmium	2.03E-08			2.03E-08
Chromium (VI)	2.99E-07			2.99E-07
Nickel	1.47E-08			1.47E-06
Total	3.86E-07	5.28E-09	1.04E-10	3.91E-07

TABLE 8 CALCULATION OF 2,3,7,8-TCDD TOXIC EQUIVALENTS FOR ACTUAL EMISSIONS OF DIOXINS AND FURANS FROM THE BABYLON RESOURCE RECOVERY FACILITY USING EADON AND U.S. EPA WEIGHTING FACTORS

Compound	Emission Rate[a] µg/sec	Eadon Factors[b]	Eadon Toxic Equivs. µg/sec	U.S. EPA Factors	U.S. EPA Toxic Equivs. µg/sec
2,3,7,8-TCDD[c]	7.03E-04	1	7.03E-04	1	7.03E-04
other TCDD	1.61E-02	0.01	1.61E-04	0.01	1.61E-04
2,3,7,8-PCDD	1.64E-03	1	1.64E-03	0.5	8.20E-04
other PCDD	4.22E-02	0.01	4.22E-04	0.005	2.11E-04
2,3,7,8-HxCDD	1.61E-02	0.03	4.83E-04	0.04	6.44E-04
other HxCDD	7.52E-02	0.0003	2.62E-05	0.0004	3.01E-05
2,3,7,8-HpCDD	5.58E-02	0.001	5.58E-05	0.001	5.58E-05
other HpCDD	8.42E-02	0.00001	8.42E-07	0.00001	8.42E-07
2,3,7,8-TCDF[d]	2.18E-02	0.33	7.19E-03	0.1	2.18E-03
other TCDF	7.70E-02	0.003	2.31E-04	0.001	7.70E-05
2,3,7,8-PCDF	8.56E-03	0.33	2.82E-03	0.1	8.56E-04
other PCDF	7.08E-02	0.003	2.12E-04	0.001	7.08E-05
2,3,7,8-HxCDF	2.40E-02	0.01	2.40E-04	0.01	2.40E-04
other HxCDF	3.20E-02	0.0001	3.20E-06	0.0001	3.20E-06
2,3,7,8-HpCDF	2.89E-02	0.001	2.89E-05	0.001	2.89E-05
other HpCDF	1.30E-02	0.00001	1.30E-07	0.00001	1.30E-07
total 2,3,7,8-TCDD equivalent			0.0142		0.0061

(a) Emission rates supplied by Ogden Martin Systems based on stack flue gas testing. Emission rates were adjusted for upset conditions.

(b) Eadon toxicity factors used are as revised in 1988.

(c) Since no 2,3,7,8-TCDD was detected, the detection limit value was used.

(d) U.S. EPA Toxic Equivalents derived from maximum possible concentrations of 2,3,7,8-TCDF, i.e., actual value is lower.

TABLE 9 ESTIMATING THE MAXIMUM ANNUAL AVERAGE AMBIENT GROUND LEVEL CONCENTRATION (GLC) OF 2,3,7,8-TCDD EQUIVALENTS AND THE MAXIMUM ANNUAL DEPOSITION RATE FOR RESIDENTIAL AREAS USING CONVERSION FACTORS SUPPLIED BY SIGMA RESEARCH CORPORATION FROM DISPERSION AND DEPOSITION MODELING

Dioxin emission rate:	
Eadon equivalents	0.0142 μg/sec
U.S. EPA equivalents	0.0061 μg/sec
Adjustment multiple for upset conditions[a]:	1.02
Adjusted dioxin emission rate:	
Eadon equivalents	0.0145 μg/sec
U.S. EPA equivalents	0.0062 μg/sec
Conversion factor[b] for maximum annual average residential area GLC (g/sec to $\mu g/m^3$):	0.11667
Maximum annual average GLC	
Eadon weightings	1.69E-09 $\mu g/m^3$
U.S. EPA weightings	7.24E-10 $\mu g/m^3$
Conversion factor[b] for maximum annual average residential area deposition rate (g/sec to $g/m^2/yr$)	0.01934
Maximum annual average deposition, Eadon	2.81E-10 $g/m^2/yr$
Maximum daily average deposition, Eadon	7.69E-13 $g/m^2/yr$
Maximum annual deposition, U.S. EPA	1.20E-10 $g/m^2/yr$
Maximum daily deposition, U.S. EPA	3.29E-13 $g/m^2/yr$

(a) The adjustment factor of 1.02 takes into account possible increased long term average emissions due to startup, shutdown, and upset conditions.

(b) Dispersion and deposition conversion factors used throughout the document were averages of 1974-78 yearly estimates.

TABLE 10 ESTIMATION OF LIFETIME DOSE OF DIOXIN EQUIVALENTS FROM ALL PATHWAYS FOR A PERSON LOCATED FOR A CASE 2 LIFETIME AT THE POINT OF MAXIMUM GROUND LEVEL AIR CONCENTRATION AND MAXIMUM DEPOSITION RATE OF 2,3,7,8-TCDD EQUIVALENTS

	g/kg/day
Inhalation dose rate	1.91E-16
Dose rate from home vegetable consumption	8.50E-17
Dose rate from soil consumption	1.80E-17
Dose rate from skin contact	7.28E-18
Dose rate from dust ingestion	3.60E-18
Dose rate from inhaling dust and resuspended soil[a]	3.60E-19
Dose rate from shellfish consumption	3.46E-17
Dose rate from fish consumption	2.52E-16
Averaged contribution from breast milk	1.58E-16
Total	7.49E-16
Cancer potency for ingestion rate in mg/kg/day	1.56E+05
Adjustment for gastrointestinal absorption[b]	0.55
Cancer potency for absorbed dose in mg/kg/day	2.84E+05
Lifetime cancer risk[c] from dioxin equivalents per million people exposed at the maximum level	0.213

(a) Dust and soil inhalation were estimated as 2% of soil ingestion.

(b) The cancer potency value was adjusted by the estimate of 0.55 gastrointestinal absorption for the rodents in the bioassay.

(c) The lifetime cancer risk estimate makes the assumption that permanent 24-hr location at the point of maximum ground level concentration was involved for a 70-year lifetime, and that exposure occurred from air, 1 year of breast milk feeding, soil, dust, vegetable, fish and shellfish consumption and from skin contact.

TABLE 11 LIFETIME CANCER RISKS PER MILLION FOR A PERSON RESIDENT FOR 70 YEARS AT THE POINT OF MAXIMUM ANNUAL AVERAGE GROUND LEVEL CONCENTRATIONS OF EMISSIONS DUE TO EXPOSURE TO CARCINOGENIC EMISSIONS[a]

From dioxin and furan emissions, all pathways[b]			0.213
From heavy metals			
antimony		0.0034	
arsenic	inhalation	0.0231	
	ingestion	0.0087	
beryllium		0.0082	
cadmium		0.0048	
chromium VI		0.000005	
nickel		0.0040	
			0.052
From other trace organics by inhalation			
selected PAHs		0.041	
PCBs		0.008	
formaldehyde		0.031	
			0.080
From other trace organics, other pathways[c]			0.033
Total cancer lifetime risks from all emissions, per million			0.38

(a) The estimates incorporate adjustment of emission data for startup, shutdown, and upset conditions.

(b) Value used to calculate 2,3,7,8-TCDF toxic equivalencies is maximum possible concentration, i.e., actual value is lower.

(c) The non-inhalation pathways of exposure to organics (other than dioxins and furans) were included by adding 50% to the exposure rate from inhalation of PAHs and formaldehyde, and 150% to the inhalation dose of PCBs.

TABLE 12 EMISSION RATES AND MAXIMUM ANNUAL AVERAGE GROUND LEVEL RESIDENTIAL AREA AIR CONCENTRATIONS (GLC) FOR METALS

Metal	Emission Rate[a] (g/sec)	Adjusted Emission Rate[b] (g/sec)	Maximum Average GLC[c] ($\mu g/m^3$)
Antimony	2.02E-04*	2.30E-04	2.69E-05
Arsenic	4.04E-05*	4.61E-05	5.37E-06
Beryllium	2.57E-05*	2.93E-05	3.42E-06
Cadmium	2.02E-05*	2.30E-05	2.69E-06
Total Chromium	4.04E-05*	4.61E-05	5.37E-06
Chromium VI[d]	2.83E-09	3.22E-09	3.76E-10
Cobalt	1.01E-04*	1.15E-04	1.34E-05
Copper	4.04E-05*	4.61E-05	5.37E-06
Lead	4.30E-05	4.90E-05	5.72E-06
Manganese	3.34E-06*	3.81E-06	4.44E-07
Mercury	1.27E-02	1.45E-02	1.69E-03
Nickel	1.01E-04*	1.15E-04	1.34E-05
Scandium[e]	2.40E-05	2.74E-05	3.19E-06
Selenium	2.02E-05	2.30E-05	2.69E-06
Vanadium	4.04E-04*	4.61E-04	5.37E-05
Zinc	1.19E-04	1.36E-04	1.58E-05

(a) Emission rates marked * were estimated at the detection limit since the metals were not detected.

(b) A multiple of 1.14 was used to adjust the emission rates for upset conditions (See Reference 4, Appendix 17).

(c) The maximum annual average ground level concentrations were estimated using a conversion factor for inorganics supplied by Sigma Research Corporation dispersion modeling analyses.

(d) Chromium VI was not measured and was estimated to be 0.007% of total chromium emissions (see Reference 4).

(e) Scandium emissions were not measured and were based on the estimate used in the Brooklyn Navy Yard Health Risk Assessment adjusted for facility size differences.

TABLE 13 COMPARISON OF MAXIMUM ANNUAL RESIDENTIAL AREA GROUND LEVEL AIR CONCENTRATIONS OF EMISSIONS WITH BACKGROUND LEVELS REPORTED FOR URBAN OR SUBURBAN AREAS IN THE UNITED STATES

Metal	Maximum Average GLC ($\mu g/m^3$)	Typical Background Level[a] (ng/m^3)	Location	Ratio Background to Emitted
Antimony	2.69E-05	32.0	Chicago	1191
Arsenic	5.37E-06	2.9	NY State suburban	540
Beryllium	3.42E-06	0.03	detection limit	9
Cadmium	2.69E-06	0.6	NY State suburban	223
Total Chromium	5.37E-06	5.3	NY State suburban	986
Cobalt	1.34E-05	0.9	detection limit	67
Copper	5.37E-06	106.1	NY State suburban	19746
Lead	5.72E-06	23.0	West Babylon, NY	4022
Manganese	4.44E-07	21.9	NY State suburban	49298
Mercury	1.69E-03	10.0	typical urban	6
Nickel	1.34E-05	3.9	NY State suburban	290
Selenium	2.69E-06	1.0	typical urban	372
Vanadium	5.37E-05	5.8	NY State suburban	108
Zinc	1.58E-05	35.8	NY State suburban	2262
Trace Organic emissions				
PCBs	3.80E-06	5.78	North Hempstead, NY	1523
PAHs (BaP only)	1.36E-06	0.361	NY State urban	266
		(pg/m^3)		
Dioxin equivs.[b]	7.24E-10	0.024	West Babylon, NY	33

(a) The background levels were derived from the tables in Appendix 9 of Reference 4.

(b) The dioxin equivalents used in this table are U.S. EPA toxic equivalents.

TABLE 14 COMPARISON OF MAXIMUM ANNUAL AVERAGE GROUND LEVEL AIR CONCENTRATIONS WITH TLVs AND THE INTERIM NEW YORK STATE GUIDELINES FOR THE CONTROL OF TOXIC AMBIENT AIR CONTAMINANTS

Metal	Maximum Average GLC ($\mu g/m^3$)	Workplace TLV (mg/m^3)	NY State AAL[a] ($\mu g/m^3$)	Safety Factors
Antimony	2.69E-05	0.5	1.67	62159
Arsenic	5.37E-06	0.2	0.67	124689
Beryllium	3.42E-06	0.002	0.007	2048
Cadmium	2.69E-06	0.05	0.167	62159
Chromium VI	3.76E-10	0.05	0.167	4.4E+08
Cobalt	1.34E-05	0.1	0.33	24566
Copper[b]	5.37E-06	0.2	20	3722070
Lead[c]	5.72E-06	0.15	0.5	87425
Manganese	4.44E-07	10	---	---
Mercury[d]	1.69E-03	0.05	0.16	95
Nickel	1.34E-05	1	3.3	245657
Scandium	3.19E-06	---	---	---
Selenium	2.69E-06	0.2	0.66	245657
Vanadium	5.37E-05	0.05	---	---
Zinc	1.58E-05	1	3.3	208498

(a) AALs are interim guidelines published by New York DEC.

(b) TLV reported is for copper fume while the AAL is for copper dust.

(c) Lead is assumed to be all lead arsenate since this form has the lowest AAL.

(d) The mercury TLV and AAL are for mercury vapor.

factors are presented for non-carcinogenic health effects.

CONCLUSIONS

When all three HRAs are compared for the cases where real emission data are used, i.e., the revised Stanislaus HRA, the existing facility HRA for Tulsa, and the operational HRA for Babylon, carcinogenic risk levels are insignificant based on governmental agency criteria for risk management. Some differences are apparent when "default" scenarios are required, i.e., constant deposition velocity; however, these differences disappear when more sophisticated modeling approaches are employed.

As emission databases for each type of resource recovery facility design are expanded, the large difference between estimated (or permitted) emission and the corresponding risk calculation and the actual risk calculation based on tested emissions will be dramatically narrowed. This will be especially true with the use of real data for upset and startup/shutdown factors as

TABLE 15 COMPARISON OF PROJECTED MAXIMUM AVERAGE EXPOSURE LEVELS FOR METALS WITH LEVELS OF EXPOSURE CAUSING EFFECTS IN HUMANS OR ANIMALS

Metal	Maximum Average GLC ($\mu g/m^3$)	Health Effect Level (mg/m^3)	Health Effects(a)	Ratio of Effect Level to Max GLC(b)
Antimony	2.69E-05	0.5	Lung radiographic changes	1.86E+07
Cobalt	1.34E-05	0.008	pulmonary function	5.96E+05
Copper	5.37E-06	0.075	mild nasal discomfort	1.40E+07
Lead(c)	5.72E-06	0.005	increased blood pressure	8.74E+05
Manganese	4.44E-07	0.39	pneumonia and bronchitis	8.78E+08
Mercury	1.69E-03	0.1	wt loss, tremors, insomnia	5.92E+04
Scandium	3.19E-06	0.56	reduced growth rate	1.75E+08
Selenium	2.69E-06	0.007	conjunctivitis	2.61E+06
Vanadium	5.37E-05	0.02	nose and throat irritation	3.72E+05
Zinc	1.58E-05	4	guinea pig lung function	2.53E+08

(a) Equivalent to safety factors.

(b) We were unable to find any health effect levels for compounds of some metals. Assumed no effect levels have been used as discussed in Appendix 9 of Reference 4.

(c) The air level given for lead is that which has been estimated could cause a 10 $\mu g/100$ ml increase in blood lead.

was done for the Babylon HRA using one year's worth of operational, e.g., opacity, data generated at the OMS facility in Marion County, Oregon and the U.S. EPA's startup/shutdown testing performed in 1987 at the same facility [5].

The use of expanded emission databases will continue to require regulatory understanding that not-to-exceed permit and contractual guarantees based on limited, i.e., short-term compliance testing, must give way to the use of annual average or "typical" emissions for input to HRAs. For example, the New York State DEC, in its Section 219 rulemaking for waste to energy plants recognizes and codifies this concept; there are four levels for dioxin emissions: *(a)* a level never to be exceeded; *(b)* a level to be designed that is near the lowest achievable level, i.e., a goal; *(c)* the upper boundary value of a 95% confidence interval of five years of testing every 9 months (a minimum of 12 tests), which becomes the permitted level; and *(d)* the actual mean level of dioxin emissions during the 5 years of testing. Thus, the difference between the never to exceed and/or upper bound limit level versus the mean value is the difference between the current concept of permitted levels versus typical levels for use as input in HRAs.

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