Comparing the health impact of waste management options in New York City

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Scope of study

- **Compare inhalation health risks of landfill disposal and waste-to-energy (WTE) treatment of MSW in NYC**
  - 1 million tons of MSW in 1 year
  - Site hypothetical WTE facility in Greenpoint, Brooklyn
  - Landfill in Pennsylvania

Option A: Landfill disposal

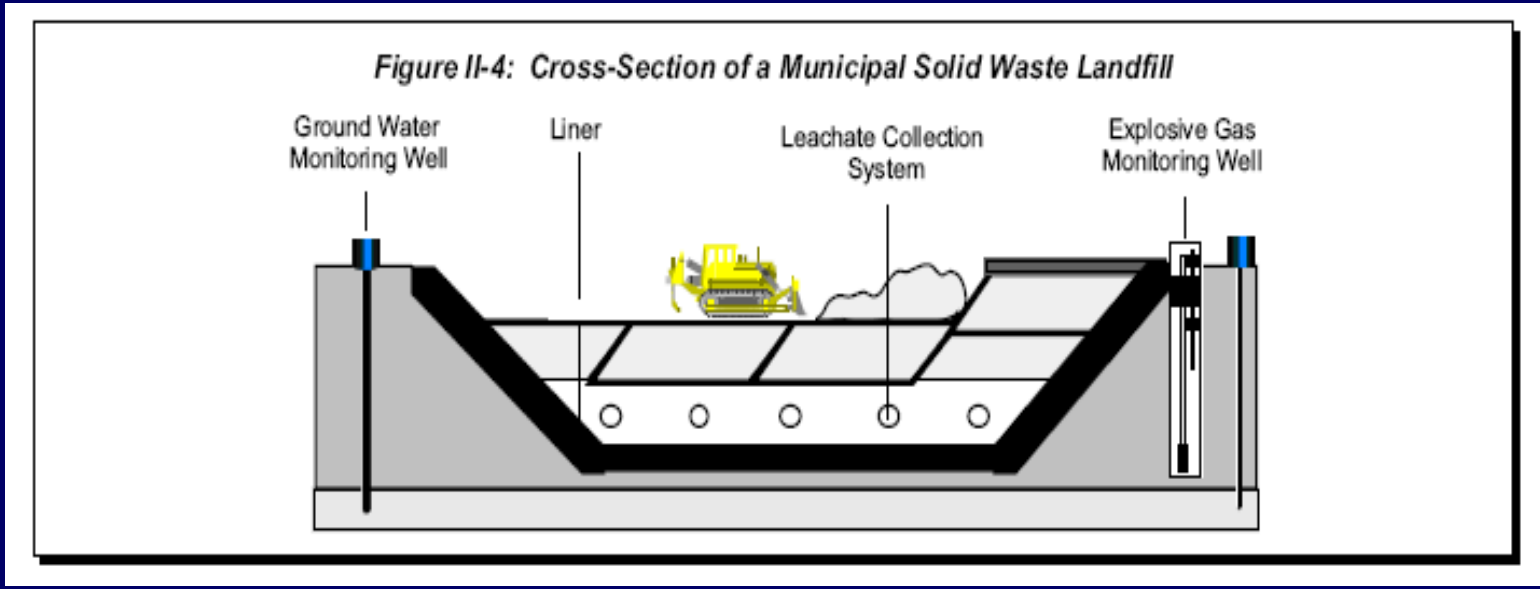
MSW to WTS to Pennsylvania landfill

Considers:

- Truck emissions (over 387 km)
- WTS emissions (from NY DOS study)
- Landfill emissions (from Manca et al, 1997)

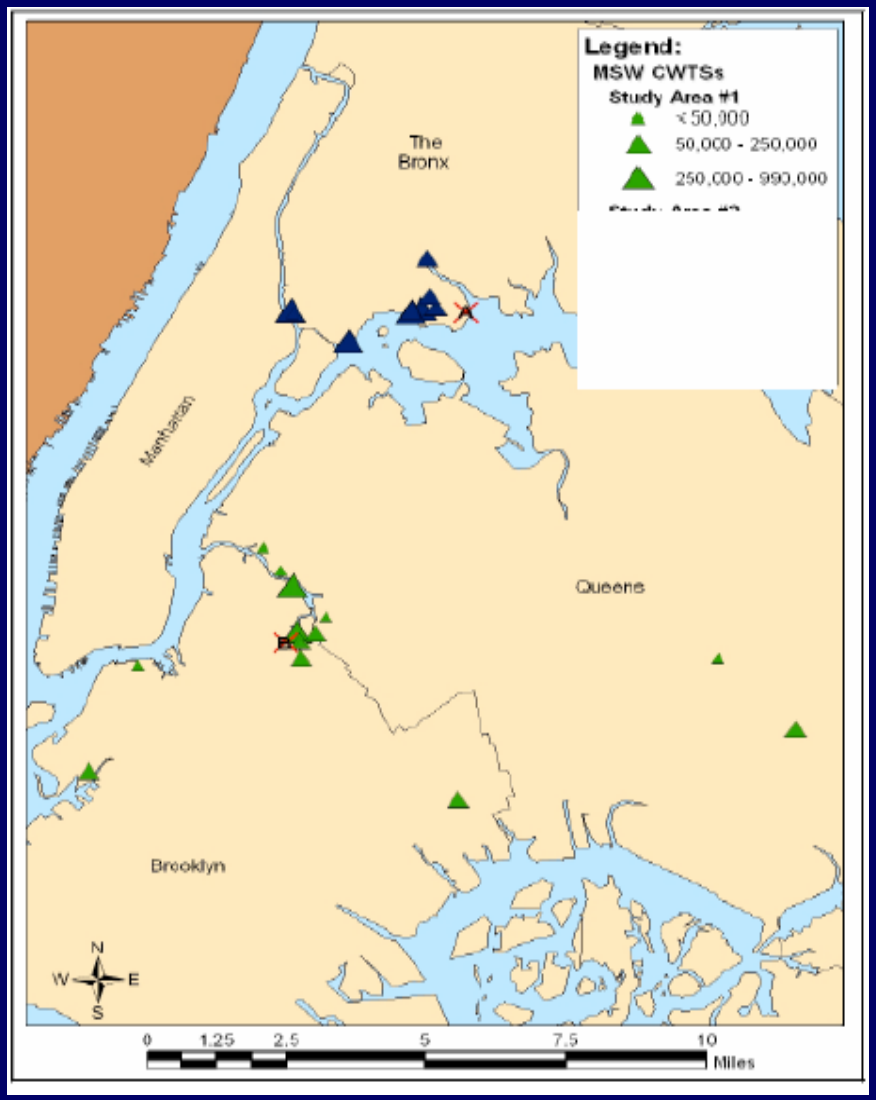
Landfill Overview

- Dominant method of MSW disposal in U.S.
- Difficult to characterize and quantify emissions



From EPA http://www.epa.gov/epaoswer/general/orientat/rom2.pdf

Option B: WTE treatment



MSW to WTE facility to landfill

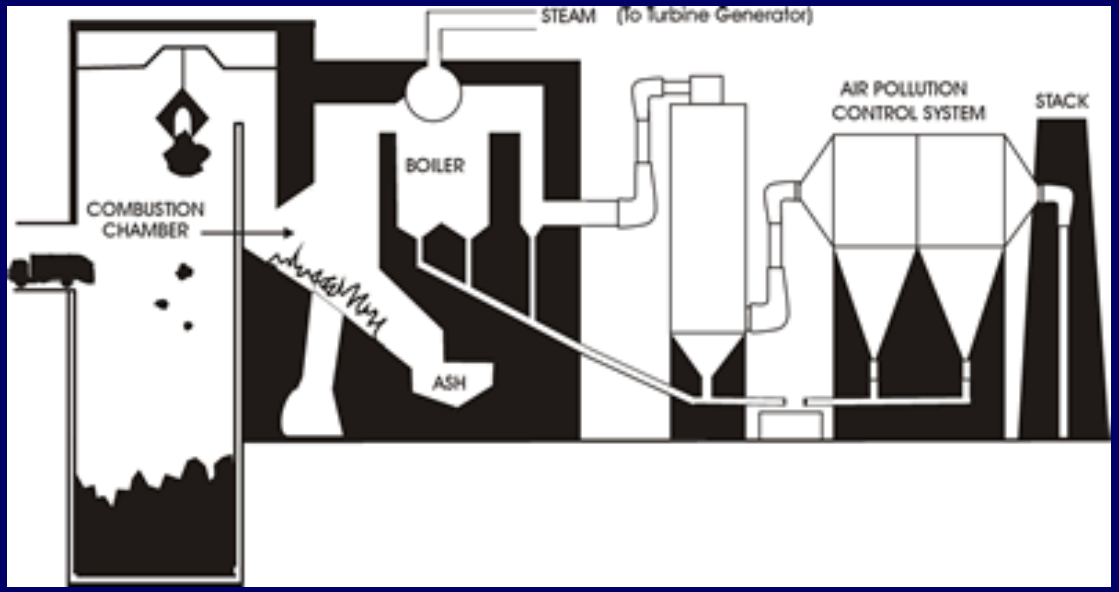
Considers:

- WTE emissions (Calculated)
- Truck transport of WTE ash to landfill (over 387 km)
- Landfill emissions from WTE ash* (from Manca et al 1997)

*Assumes same emissions as untreated MSW, 80% reduction in volume

WTE Combustor Overview

- Up to 90% reduction in volume of waste
- Requires disposal of ash



From EIA
http://www.eia.doe.gov/kids/energyfacts/saving/recycling/solidwaste/wastetoenergy.html

Methods: In Brief

- **WTS emissions**
  - Risk values from NYC Department of Sanitation study
- ***Truck emissions****
  - Simple box model equation
- **Landfill emissions for untreated MSW and WTE ash**
  - Risk values from Manca et al 1997
- ***WTE emissions****
  - Gaussian dispersion using Excel

*Calculated values

Data Sources

- **Health data**

  -Integrated Risk Information Systems (IRIS); Cal Office of Environmental and Health Hazard Assessment (OEHHA); US EPA, HEAST tables

- **Emission data**

  -WTE: Covanta energy; colleagues at the Earth Engineering Center; EPA

  -Landfill: Manca et al, 1997; US EPA

- **Environmental data**

  -National Climatic Data Center (NCDC), National Oceanic Atmospheric Association (NOAA), National Renewable Energy Laboratory (NREL)

- **Population data**

  - U.S. Census 2000

Truck Emissions

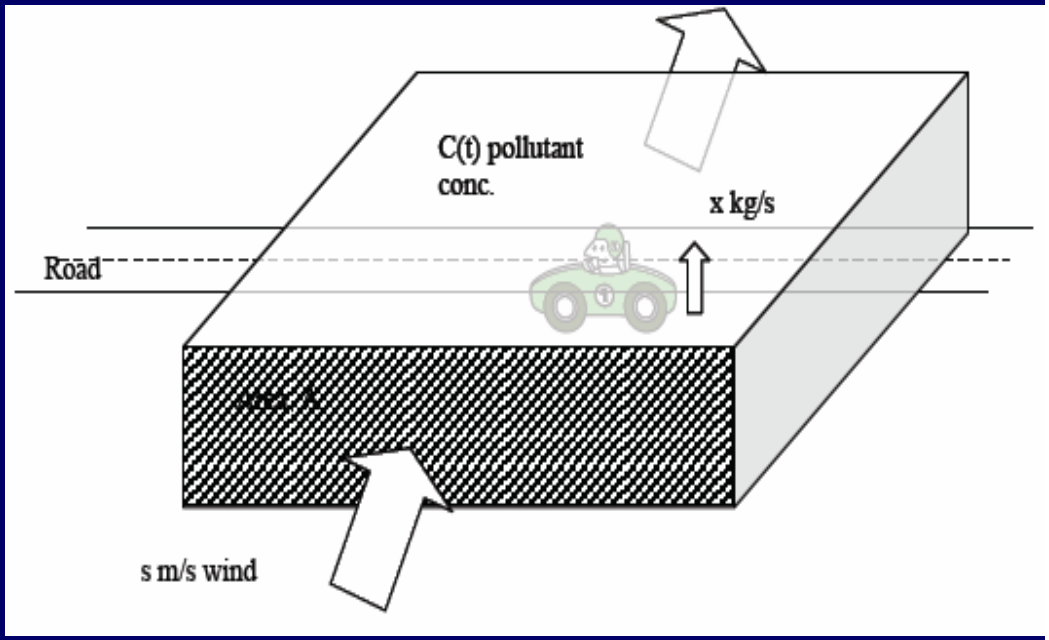
Compound	EPA Emission standard for new trucks, 1998 (g/bhp-hr)	EPA Emission standard for new trucks, 2004 (g/bhp-hr)
NOx	4	2
PM	0.1	0.01

Adapted from DeAngelo, 2004

Methods: Calculating Truck Emissions

Truck emissions

- Simple box model equation
- Assumptions



WTE Combustor Emissions

Compound	Emission factor [a] (kg/Mg MSW fired)	Emission rate of hypothetical WTE combustor [b] (ug/s)
Dioxin/ Furan (TEQ)	4.72 E-10	1.50 E-02
Mercury	7.86 E-05	2.50 E+03
Cadmium	1.19 E-05	3.79 E+02
Lead	1.70 E-04	5.41 E+03
Particulate Matter	2.53 E-02	8.05 E+05
HCl	9.55 E-02	3.04 E+06
SO2	1.46 E-01	4.65 E+06
NOx	2.00	6.36 E+07
Total	2.27	7.21 E+07

[a] DATA SOURCE: EPA Docket A-90-45, Performance Data for Large MWC at MACT (Year 2000)

[b] Per 1 million tons, see Appendix A for calculation

WTE Combustor Parameters

Parameter	Value
WTE facility:	
Stack height, m	85.34
Stack internal diameter, m	2.13
Stack exit temperature, K	410 [3, 70]
Exit velocity, m/s	6.10
Effective stack height, m	247
Study Population:	
NYC population density, per $100m^2$	1.02E-02 [52]
Meteorology:	
Wind speed, m/s	3.02 [30]
Wind direction	NE [30]
Stability class	C (urban)
Average temperature, K	295 [33]
Grid size, m^2	100

Except where noted, values were obtained from correspondence with Mr. Hanwei Zhang or Mr. Masato Nakamura of the Earth Engineering Center at Columbia University, 50

Methods: Calculating WTE Emissions

- **Gaussian dispersion model**

$$c = \frac{q}{2\pi u \sigma_z \sigma_y} \exp\left(-\frac{y^2}{2\sigma_y^2}\right)\left[\exp\left(-\frac{(z-h)^2}{2\sigma_z^2}\right) - \exp\left(-\frac{(z+h)^2}{2\sigma_z^2}\right)\right]$$

Where,

c = concentration, ug/m^3

u = wind speed, m/s

sigma values represent diffusion along the appropriate axes

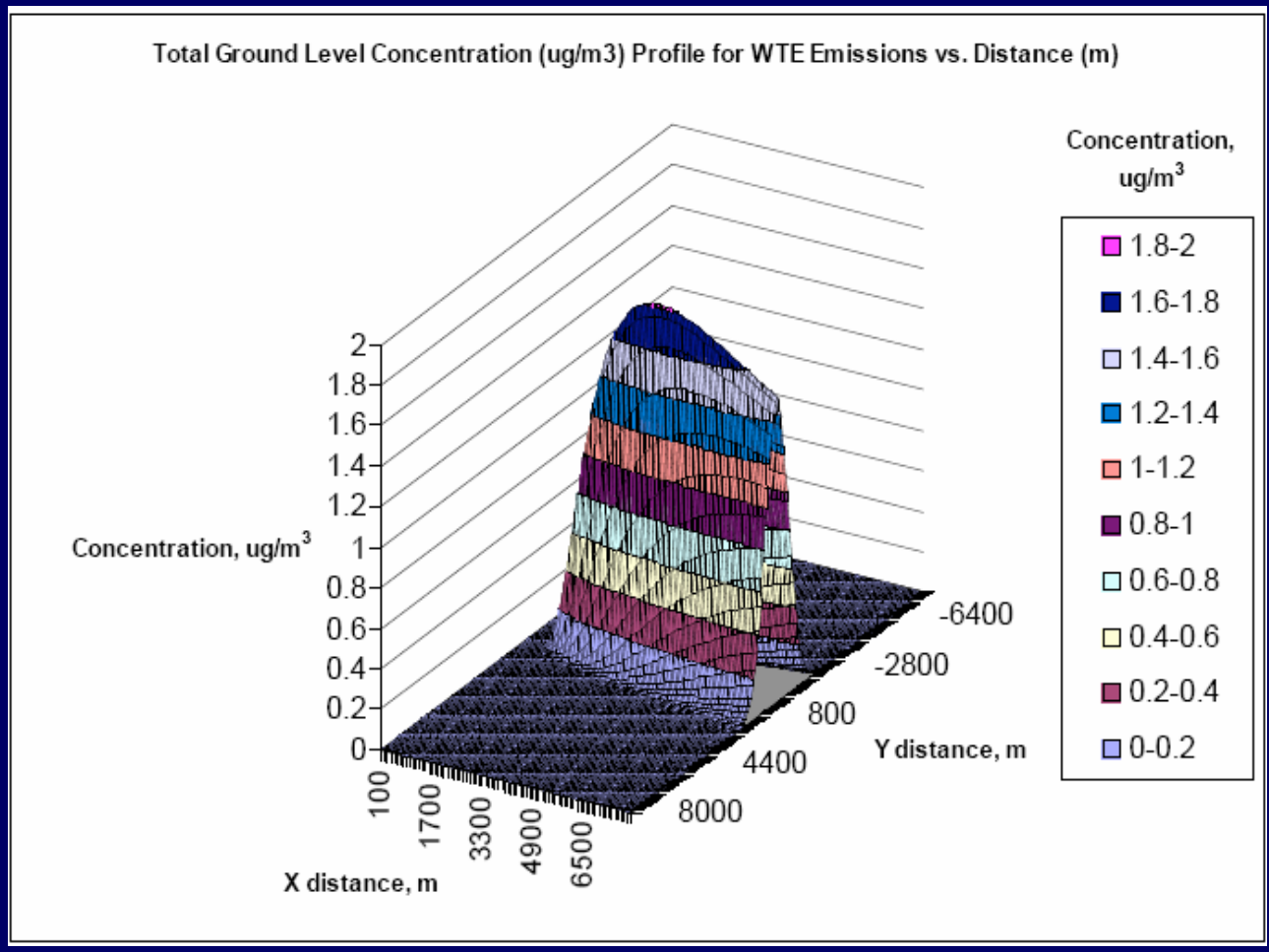
y = horizontal distance off plume axis

z = height, m

Assumptions

- evenly distributed population
- 100 m^2 grids
- total area= 64 km2

Model Output



Health Risk Equations

Individual non-cancer risk:

- Individual non-cancer risk= Pollutant concentration (ug/ m^3) / non-cancer risk value (ug/ m^3)

Population non-cancer risk:

- Population non-cancer risk= individual non-cancer risk x affected population

Individual cancer risk:

- Individual cancer risk= Pollutant concentration (ug/ m^3) / cancer unit risk value (m^3/ug)

Population cancer risk:

- Population cancer risk= individual cancer risk x affected population

Exposed population for WTE combustor:

- Exposed NYC population = 101.94 people/$100m^2$ x 11660 $100m^2$ exposed grid cells = 1188647.8= 1188648 exposed people

Landfill Health Risk Values

Landfill Chemical	LECR	LECR/1mt*	ER	ER/1mt*
Atmospheric emissions				
Carcinogenic air emissions				
1,1-Dichloroethane	1.2E-04	1.8E-05		
Vinyl chloride	6.5E-05	9.8E-05		
Bromodichloromethane	3.3E-05	5.0E-06		
1,1-Dichloroethylene	1.8E-05	2.7E-06		
1,1,2,2-Tetrachloroethane	9.9E-06	1.5E-06		
Methylene chloride	5.2E-06	7.9E-07		
Trichloroethylene	2.6E-06	3.9E-07		
1,2-Dichlorothane	1.3E-06	2.0E-07		
1,1,2-Trichloroethane	1.0E-06	1.5E-07		
Chloroethane	6.8E-07	1.0E-07		
Benzene	2.2E-06	3.3E-07		
Total Carcinogen	2.6E-04	3.9E-05		
Systemic air emissions				
Methyl mercaptan			2.5	0.4
Ethyl mercaptan			1.6	0.2
Hydrogen sulfide			0.1	0.0
Total Systemic			4.2	0.6
Particulate Bound metal emissions				
Fe			56	8.5
Zn			14	2.1
Pb			1.6	0.2
Total Metal			71.6	10.8
Leachate emissions				
Carcinogenic leachate emissions				
1,1-Dichloroethane	9.3E-06	1.4E-06		
Vinyl chloride	1.9E-06	2.9E-07		
Total leachate	1.1E-05	1.7E-06		
Total	2.7E-04	4.1E-05	75.8	11.5

LECR= Lifetime Excess Cancer Risk
ER=Exposure ratio (Threshold= 0.1)
*mt= million ton (Calculated by dividing original value by 6.6 million tons of MSW to yield risk per 1 million ton of MSW)

WTS Health Risk Values

Air Pollutant	Acute Non Cancer Risk		Chronic Non Cancer Risk		Cancer Risk	
Carcinogens						
Benzene					Total Cancer Risk	1.34E-07
Formaldehyde						
1,3 Butadiene						
Acetaldehyde					Cancer Risk Threshold	1.0E-06
Benzo(a)pyrene						
Non-carcinogens						
Propylene	Total Acute Hazard Index	2.83E-01 (Threshold= 1.00E+00)	Total Chronic Hazard Index	1.72E-01 (Threshold= 1.00E+00)		
Acrolein						
Toluene						
Xylenes						
Anthracene						
Benzo(a)anthracene						
Chrysene						
Napthalene						
Pyrene						
Phenanthrene						
Dibenz (a,h) anthracene						

From NYC DOS FEIS of SWMP, April 2005.

Health Effects Data: WTE Combustor & Truck Transport

Emission source	Compound	Non-cancer health value (ug/m^3)	Inhalation Unit Cancer Risk Factor (m^3/ug)
WTE combustion	Dioxin (TEQ)	4.50E-05 [7]	3.30 E-11 [61]
	Mercury	3.00E-01 [62]	NA
	Cadmium	1.00E-02 [7]	1.80 E-03 [62]
	Lead	1.50E+00 [56]	1.20 E-05 [6]
	PM	5.00E+01 [56]	ND
	HCl	9.00E+00 [7]	NA
	SO2	7.80E+01 [56]	NA
	NO2	1.00E+02 [56]	NA
Truck transportation	NO2	1.00E+02 [56]	NA
	Diesel Exhaust Emissions	5.00 E+00 [7]	3.0 E-04 [62]

NA= Not applicable; ND= No data

Truck Transport Health Risk Values

Waste Mgmt Option	Compound	Conc., ug/m3	Non-Cancer Risk		Cancer Risk	
			Individual HI	Population HI	Individual	Population
A	NOx*	2.57E-02	2.61E-04	5.58E+00	NA	NA
	PM**	1.28E-03	2.61E-04	5.58E+00	3.91E-07	8.38E-03
	Total	2.74E-02	5.22E-04	1.16E+01	3.91E-07	8.38E-03
B	NOx	5.22E-03	5.22E-05	1.12E+01	NA	NA
	PM	2.61E-04	5.22E-05	1.12E+01	7.82E-08	1.68E-03
	Total	5.47E-03	1.04E-04	2.24E+00	7.82E-08	1.68E-03
Ratio (Option A / Option B)			5.00E+00	5.00E+00	5.00E+00	5.00E+00

*NOx health effects assumed to be from NO2

**PM health effects were assumed to be from diesel exhaust particles (DEP)

HI= Hazard Index (Threshold = 1.00E+00), NA= Not applicable

Population= 21,412

WTE Combustor Health Risk Values

Compound	Annual Average GLC (ug/m^3)	Non-Cancer Risk				Cancer Risk	
		Individual Non-Cancer Risk		Population risk		Individual risk	Population risk
Dioxin (TEQ)	1.90E-11	4.22E-07		5.02E-01		6.35E-08	7.54E-02
Mercury	3.16E-06	1.05E-05		1.25E+01		NA	NA
Cadmium	4.79E-07	4.79E-05		5.69E+01		2.01E-09	2.39E-03
Lead	6.84E-06	4.56E-06		5.42E+00		8.21E-11	9.76E-05
PM	1.02E-03	2.04E-05		2.42E+01		ND	ND
HCl	3.84E-03	4.27E-04		5.08E+02		NA	NA
SO2	5.88E-03	7.53E-05		8.96E+01		NA	NA
NO2*	4.03E-03	4.02E-05		4.78E+01		NA	NA
Totals	9.12E-02	Total HI	6.26E-04	Total HI	7.45E+02	6.55E-08	7.79E-02

GLC= Ground level concentration, HI=Hazard Index (Threshold=1.00E+00)
*NO2 concentration was calculated by multiplying the NOx concentration by 0.05 (27).
Population exposed= 1188648, See Appendix D for Calculation

Sources: Cal EPA, Cal OEHHA, US EPA, IRIS, HEAST Tables

Results Summary

- Option A (Landfill disposal) poses greater cancer and non-cancer risks than Option B (WTE treatment).

Option	Activity	Individual Non-cancer risk HI	Population Non-cancer risk HI	Individual Cancer risk	Population Cancer risk
A	MTS*	2.83E-01	ND	1.34E-07	ND
	Truck Transport	5.22E-04	1.16E+01	3.91E-07	8.38E-03
	Landfill**	1.15E+01	ND	4.09E-05	ND
	Total	1.18E+01	1.16E+01	4.14E-05	8.38E-03
B	WTE facility	6.26E-04	7.45E+02	6.55E-08	7.79E-02
	Truck Transport	1.03E-04	2.24E+00	7.82E-08	1.68E-03
	Landfill*	3.48E-01	ND	1.24E-06	ND
	Total	3.49E-01	7.47E+02	1.38E-06	7.96E-02
Ratio (Option A/Option B)		3.37E+01	ND	3.00E+01	ND

ND= No data

* Data from NYCDOS FEIS 2005 (39). Individual non cancer HI was calculated by taking the average of the acute and chronic HI ([2.83E-01+1.73E-01]/2)

** Data from Manca et al 1997 (29). For WTE, the risk values per 1 million ton of waste from Table 8 were multiplied by 0.2 to account for the 80% volume reduction of landfill waste after WTE treatment.

Discussion

- **Comparison with other study findings**

1. UK (2004) and Canadian (1999) studies

   -Landfill disposal and WTE treatment posed low health risks

   -Landfill disposal posed greater health risk than WTE treatment (100x)

2. Eschenroeder and von Stackelback (1999)

   -Landfill disposal posed greater health risk than WTE treament (100x)

3. Montgomery County, MD study by Rao et al. (2003)

   -Inhalation risk from WTE facility was similar to present findings

Summary and Conclusion

- **Provides rough estimation of health risks from landfill disposal and WTE treatment**
- **Landfill disposal may pose greater health risks than WTE treatment**
  - -Similar conclusions from other studies
  - -Suggests that simple approach to assessing health risks of waste management options may be feasible
- **Potential areas for future research**
  - - Validate and refine findings
  - -Compare results with other models
  - -Better characterization of LFG emissions from MSW and WTE leachate
  - -Look at socioeconomic and environmental justice impacts