

Ultrafine particle emissions from waste transportation averted as a result of WTE: A case study of the New York metropolitan area

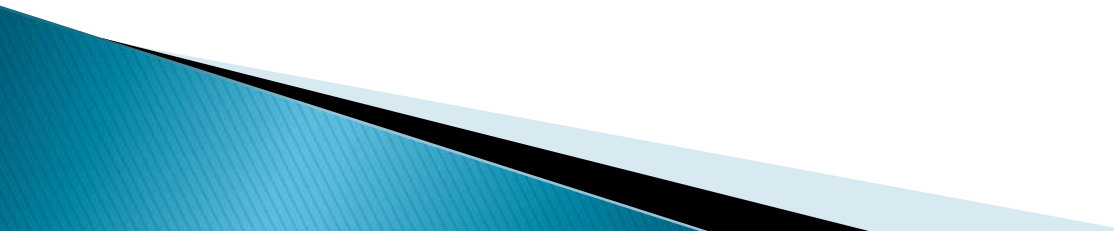
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What are ultrafine particles (UFPs)?

- ▶ UFP diameter < 100 nm (nanoparticles)
 - ▶ Produced mainly by combustion reactions
 - Natural
 - Anthropogenic
 - ▶ Large in number, small in mass
 - ▶ Potential adverse health effects
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Chemical composition of UFP emitted from diesel motor vehicles

Chemical Constituent	Source	Variability
Hydrocarbons ($>C_{19}$)	Unburned fuel	High concentration under idling conditions
Hydrocarbons ($>C_{35}$)	Unburned lubricating oil	High concentration during deceleration
Sulfate	Sulfur present in fuel	High concentration under high engine load conditions
Metallic ash	Metal compounds in fuel/oil; engine wear	N/A

Waste-to-energy (WTE) facilities as an alternative to landfills

- ▶ WTE facilities combust municipal solid waste (MSW) to produce energy
 - Alternative energy source
 - Alternative means of handling waste
 - ▶ Landfills dispose of waste by burial
 - ▶ Vehicles are needed to collect and transport waste to either WTE facilities or landfills
 - Collection vehicles (usu. 12-ton) collect waste and take them to WTE facilities or transfer stations
 - Larger diesel trucks (usu. 20-ton) take waste from transfer stations to landfills
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Objective

- ▶ Waste-to-energy facilities have been shown to save UFP emissions as compared to other fuel-burning processes¹
- ▶ Hypothesis: UFP emissions from motor vehicles are saved by using WTE facilities instead of landfills
 - Different transportation routes
- ▶ Hypothesis confirmed by the rough calculations from this study

1: Yinon, L. Ultrafine particle emissions: Comparison of waste-to-energy with coal- and biomass-fired power plants. M.S. Thesis, Columbia University, New York, 2010 (advisors: V. F. McNeill and N. J. Themelis)

Mobile sources associated with WTE facilities and landfills

- ▶ Two types of vehicles
 - Garbage trucks (can hold 12 tons MSW)
 - Transfer trailers (20 tons MSW)
- ▶ Diesel
- ▶ Heavy duty vehicles (HDVs)

Size range measured (nm)	HDV (10^{14} particles km^{-1} vehicles $^{-1}$)
18–100	1.7–10.5
30–100	3.19

Ultrafine particle emissions from HDVs²

2: Morawska, L., Ristovski, Z., Jayaratne, E.R., Keogh, D.U., Ling, X., 2008. Ambient nano and ultrafine particles from motor vehicles emissions: Characteristics, ambient processing and implications on human exposure. Atmos. Environ. 42, 8113–8138.

Possible waste transport pathways

Waste-to-energy pathway

Residential areas

Residential MSW collected by garbage trucks

WTE facility

MSW dropped off

MSW combusted to produce energy

Landfill pathway

Residential areas

Residential MSW collected by garbage trucks

Transfer station

MSW dropped off

MSW repackaged into larger transfer trailers

Landfill

MSW dropped off

MSW treated and stored

Case study: New York City

- ▶ Urban environment
 - ▶ >12,000 tpd of residential MSW
 - ▶ NY Department of Sanitation
 - Fleet of 2,230 collection vehicles
 - ▶ >20 waste transfer stations
 - ▶ Landfills in PA, OH, VA take NYC waste
 - ▶ WTE facilities in NY and NJ
 - ▶ GOAL: Estimate/compare UFP vehicular number emissions from WTE and landfill pathways handling NYC MSW
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Assumptions

- ▶ UFP emissions $\propto$ distance travelled by vehicles
 - HDVs: 1 to 10×10^{14} particles km^{-1} vehicles $^{-1}$
- ▶ Waste produced $\propto$ population
- ▶ Residential areas (for curbside collection) are restricted to one address per borough
 - Represents the “average” by population density
- ▶ One transfer station serves an entire borough
- ▶ One landfill serves New York City
- ▶ WTE facilities near the city (collectively) have the capacity to handle all MSW produced by the city

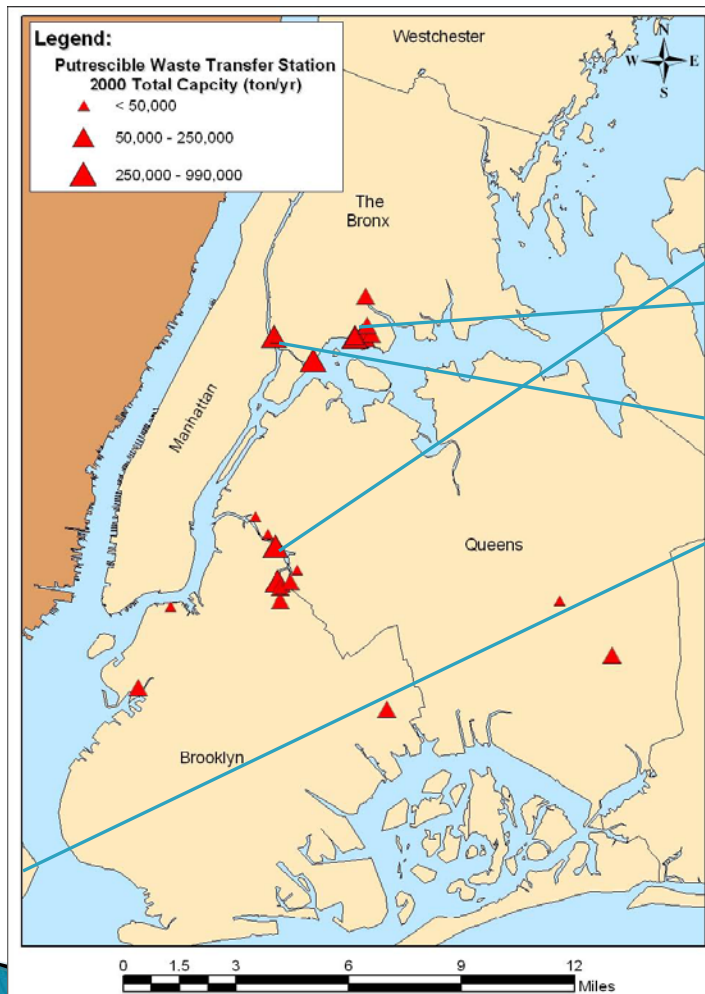
Residential points of interest



Borough	Address
Bronx	E 182 St & Crotona Ave
Brooklyn	Eastern Pkwy & Bedford Ave
Manhattan	E 82 St & 5 th Ave
Queens	Junction Blvd & Corona Ave
Staten Island	Clove Rd & Victory Blvd

Used ArcGIS 10 from ESRI, population density maps of NYC, and Google Earth

Transfer stations (TS)



Name	Borough(s) served
Hi-Tech Resource Recovery Inc.	Brooklyn, Manhattan
Tri-State Transfer & Associates	Queens
Harlem River Yard	Bronx
Staten Island Transfer Station	Staten Island

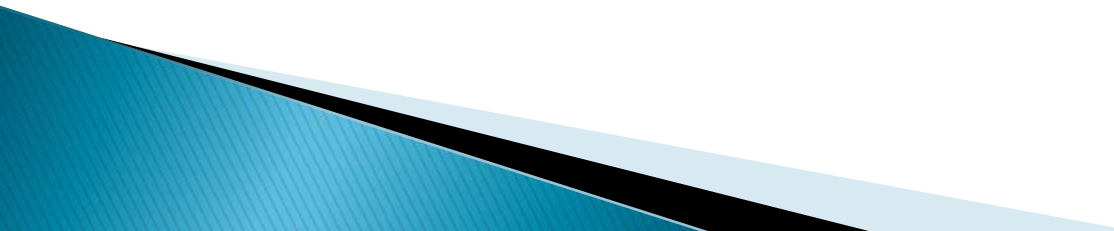
De Angelo, M. Siting of Waste-to-Energy Facilities in New York City Using GIS Technology. M.S. thesis Columbia University, New York, 2004 (advisor: N. J. Themelis).

Landfills

- ▶ Fresh Kills landfill in NY closed in 2000
- ▶ NYC now uses landfills in PA, OH, and VA
- ▶ Landfills usu. within 200 miles of NYC
- ▶ **Keystone Sanitary Landfill**
 - 249 Dunham Drive, Dunmore, PA 18512-2686



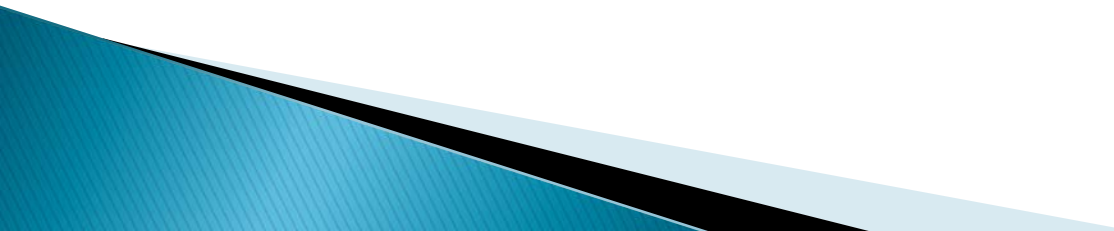
WTE facilities near New York City

- ▶ Essex County Resource Recovery Facility
 - ▶ Union County Resource Recovery Facility
 - ▶ Babylon Resource Recovery Facility
 - ▶ Hempstead Resource Recovery Facility
 - ▶ Huntington Resource Recovery Facility
 - ▶ MacArthur WTE Facility
 - ▶ Wheelabrator Westchester L.P.
 - ▶ **Total capacity: about 11,000 tpd**
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Population and waste statistics of New York City

Borough	2009 Population ³	Percentage of Total NYC Population	Approximate Daily Waste Produced (tpd)
New York City	8,391,881	100.0%	12,000
Bronx	1,397,287	16.7%	2,000
Brooklyn	2,567,098	30.6%	3,670
Manhattan	1,629,054	19.4%	2,330
Queens	2,306,712	27.5%	3,300
Staten Island	491,730	5.9%	700

3: 2000 Census; Census Bureau Current Estimates Program



Daily distance: landfill pathway

Borough	Estimated waste produced (tpd)	Distance from residential address to TS (miles)	Distance from TS to landfill (miles)	Total truck miles per day (miles/day)
Bronx	2,000	5.5	122	13,120
Brooklyn	3,670	4.1	119	23,090
Manhattan	2,330	7.7	119	15,360
Queens	3,300	8.2	124	22,720
Staten Island	700	8.7	132	5,130
Total	12,000	34.2	616	79,420

Residential to TS: 12-ton trucks; TS to landfill: 20-ton trucks

Daily distance: WTE pathway

Borough	Estimated waste produced (tpd)	Average distance from residential area to WTE facilities (miles)	Total truck miles travelled per day (miles/day)
Bronx	2,000	35.8	5,970
Brooklyn	3,670	35.3	10,800
Manhattan	2,330	35.6	6,910
Queens	3,300	32.5	8,940
Staten Island	700	42.5	2,480
Total	12,000	181.7	35,100

Residential to WTE: 12-ton trucks

UFP number emissions: difference between landfill and WTE pathways

Pathway	Distance travelled per year (km/yr)	UFP emissions (lower bound) [particles/yr]	UFP emissions (upper bound) [particles/yr]
Landfill	3.83×10^7	3.83×10^{21}	3.83×10^{22}
WTE facility	1.69×10^7	1.69×10^{21}	1.69×10^{22}
Difference	2.14×10^7	2.14×10^{21}	2.14×10^{22}

Conclusion

- ▶ UFP number emissions averted by using WTE facilities instead of a landfill to handle NYC MSW = $2.14 \text{ to } 21.4 \times 10^{21}$ particles/year
- ▶ Compare to 1.8×10^{16} UFP particles per year from WTE facilities serving the United States (Yinon)
- ▶ Vehicular emissions due to landfill activity greatly outnumber the combined plant and vehicular emissions from WTE activity

Thanks to...

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- ▶ The McNeill Group
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- ▶ WTERT
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WTERT

Waste-to-Energy Research and Technology Council

Advancing Sustainable Waste Management

Appendix: Distance difference between landfill and WTE pathways

Pathway	Distance travelled per day (miles/day)	Distance travelled per day (km/day)	Distance travelled per year (km/yr)
Landfill	79,420	1.28×10^5	3.83×10^7
WTE facility	35,100	5.65×10^4	1.69×10^7
Difference	44,320	7.13×10^4	2.14×10^7