

Comparison of HAP Emission Estimates Developed Using Top-Down and Bottom-Up Techniques for New Haven, Connecticut

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ABSTRACT

The U.S. EPA's Region 1 Office provided the City of New Haven, Connecticut with funding to prepare a city level emissions inventory of hazardous air pollutants (HAPs). The effort focused on estimation of emissions from stationary industrial point and area sources using locally derived activity data to the greatest extent possible. The paper presents the results of the bottom-up emissions inventory prepared by the city of New Haven, and compares those estimates to ones derived by scaling down county level emission estimates contained in EPA's national emissions inventory database to the city level. The results indicate that although a good correlation exists for some source categories, for some pollutants and source categories a substantial difference exists in the emission estimates prepared using these two techniques. Therefore, it is evident that the expenditure of time and effort to prepare local level bottom-up emissions inventories can yield important information to agencies considering local HAP mitigation programs.

INTRODUCTION

The location of the city of New Haven on Long Island Sound bounded by valley hills at the junction of two major New England interstate highways has led to the city's economic development but also contributed to a disproportionate air pollution burden. New Haven County falls within non-attainment areas for both ozone and PM-10, and based on the National Air Toxics Assessment information it also has the second greatest number of urban air toxic emissions in New England.

New Haven is the second largest city in Connecticut with a diverse population of 123,626. Although economically disadvantaged compared to the rest of the state, with 21% of its population living at or below the poverty level, the city has maintained some of its older industrial base as well as expanding its port activities. The sources of air toxics within the city of New Haven, reflecting both its industrial past and physical location, are a mixture of point, area and mobile sources.

In 2002, New Haven had completed a citywide inventory of greenhouse gas emissions as part of their commitment to take part in the Cities for Climate Protection campaign. EPA's Community Air Toxic Assessment funds enabled the city to expand their inventory and reduction plans to develop a comprehensive air quality and emissions reduction program. New Haven's Clean Air Initiative is coordinated by both the Board of Health and the Department of City Plan with strong support by the Connecticut Department of Environmental Protection (CT-DEP) with the goal to improve air quality by reducing exposure to air toxics and reducing the community's contribution to global climate change through an integrated approach. The first step in this project was to develop an air toxics emission inventory in order to identify priorities for emission reductions.

Description of New Haven’s HAP Emissions Inventory

New Haven used EPA’s draft version 2 and 3 of the 1999 national emissions inventory (NEI) as a starting point for its HAP inventory effort. For the point source portion of the inventory, New Haven retrieved and reviewed the point source information from the NEI, then supplemented this information with information from the 2000 toxics release inventory (TRI), and information from the CT-DEP’s periodic emissions inventory of ozone precursors¹. For area sources, New Haven calculated emissions using, in most cases, VOC emission factors from the Emission Inventory Improvement Program (EIIP)² and speciation profiles contained within EPA’s documentation reports for the 1999 NEI³ in conjunction with local activity data. Future inventory work will include extrapolation of local traffic count data into on-road HAP mobile source estimates, and use of the EPA’s draft Nonroad model to calculate VOC and PM emissions on a sub-county basis, from which HAP emissions can be calculated for this sector.

Point Source Comparisons

The point source section of the draft version 3 NEI contained HAP emission estimates for 30 facilities in New Haven. New Haven adjusted and supplemented the point source information in the NEI by using new emission estimates available in the 2000 Toxic’s Release Inventory (TRI), and by adding 12 facilities taken from the CT- DEP’s periodic inventory of ozone precursors.

New Haven desired to have the most current information available in its inventory, and therefore for sources that report to TRI, New Haven used emission estimates from the 2000 TRI data-set in lieu of the 1999 TRI emission estimates contained in the NEI. Table 1 compares the 1999 and 2000 TRI emission estimates for these sources. Replacing the 1999 NEI-TRI data with 2000 TRI data resulted in an addition of 23.7 tons per year (tpy) of HAPs to the point source inventory. The first four facilities listed in Table 1 are petroleum storage facilities. The next three are fabric coaters (SIC 2295), and the two facilities listed with SICs of 3429 produce metal hardware products.

Table 1 Comparison of 1999 and 2000 TRI data for sources in New Haven.

| Name | SIC | 1999 Total HAPs (tpy) | 2000 Total HAPs (tpy) | Net Change (tpy) |
|-----------------------------------|-------------------------------------|-----------------------|-----------------------|------------------|
| Amerada Hess Corp. | 5171 | 2.83 | 4.13 | 1.30 |
| Getty Terminals | 5171 | 1.05 | 1.50 | 0.45 |
| Gulf Oil Terminal | 5171 | 16.8 | 18.4 | 1.60 |
| Motiva Enterprises, LLC | 4226 | not in 1999 NEI | 6.03 | 6.03 |
| Von roll Isola USA, Inc. | 2295 2672 2851 | 20.1 | 13.6 | - 6.50 |
| Saint Gobain Performance Plastics | 2672 2295 2822 3069 | 46.8 | 51.3 | 4.50 |

| | | | | |
|----------------------------------|-------------|-----------------|--------------|-------------|
| Uretex, Inc. | 2295 | 12.3 | 25.3 | 13.0 |
| H.B. Ives Co. (copper emissions) | 3429 | not in 1999 NEI | 3.03 | 3.03 |
| Sargent Manufacturing | 3429 | 0.01 | 0.52 | 0.51 |
| H Krevit & Company | 2819 | 0.22 | 0.004 | - 0.216 |
| Total | | 100.1 | 123.8 | 23.7 |

The CT-DEP's emissions inventory of ozone precursors contains VOC emission estimates for 12 sources that are not listed in HAP portion of the 1999 NEI. New Haven used the VOC emissions from CT-DEP, and EPA's "Speciate⁴" database to develop the HAP emission estimates shown in Table 2. This added 40.5 tpy of total HAPs to the point source inventory from a diverse group of sources.

Table 2 HAP emissions derived from CT-DEP's ozone inventory.

| Name | SIC | VOC Emissions (tpy) | Total HAP Emissions (tpy) |
|-------------------------------------|------------|----------------------------|----------------------------------|
| Yale University Central Power Plant | 8221 | 18.5 | 7.2 |
| H.B. Ives Co. | 3429 | 12.3 | 8.7 |
| U.S. Repeating Arms | 3949 | 7.5 | 1.0 |
| Simkins Industries | 2631 | 1.1 | 1.1 |
| Williams Energy Ventures (Forbes) | 4226 | 27.7 | 5.9 |
| Williams Energy Ventures (Waterf.) | 4226 | 33.3 | 7.1 |
| Electrix, Inc. | 3646 | 3.0 | 1.7 |
| G&O Manufacturing | 3585 | 19.6 | 2.7 |
| Knights of Columbus | 8641 | 3.8 | 3.3 |
| Milford Barrel Company | 5085 | 2.8 | 0.4 |
| Sylvan Cleaners | 7215 | 0.8 | 0.8 |
| Conn Classic Cleaners | 7215 | 0.6 | 0.6 |
| Total | | 131.0 | 40.5 |

Total HAP emissions from point sources in New Haven equal 168.5 tons per year after addition of these 12 sources to the inventory and incorporating the 2000 TRI data.

Area Source Comparisons

Gasoline distribution

New Haven's inventory effort included HAP emission estimates for tank truck unloading (stage

1), automobile refueling (stage 2), underground tank breathing, and losses from tank trucks in transit. New Haven was unable to obtain current actual gasoline sales data from all individual gasoline stations in the city, and so based its estimate on the average of two surrogate methods. The first consisted of use of a survey of gasoline consumption by municipality conducted by the Connecticut Office of Policy and Management in 1990. New Haven scaled the 1990 gasoline consumption data to 2000 using the 16.9% statewide change in VMT that occurred over this time-frame. This produced a gasoline consumption estimate of 38,354,500 gallons. The second method involved apportioning current statewide gasoline consumption data from the state's Department of Revenue Services to New Haven using data kept by the Connecticut Department of Consumer Protection on the number of gasoline nozzles at each service station in the state. This technique yielded a gasoline consumption estimate of 56,197,300 gallons. New Haven used the average of these two estimates (47,275,900) in its emission calculations.

New Haven used information available in the Emission Inventory Improvement Program (EIIP) guideline series, the State of Connecticut's 1996 Periodic Emissions Inventory, and EPA's non-point source documentation for the 1999 National Emissions Inventory (NEI) for HAPs to estimate emissions from gasoline distribution. The results of New Haven's stage 2 calculations are shown in Table 3 below.

The emission estimates prepared by New Haven were then compared to EPA's emission estimates for New Haven county as reported in version 2 of the 1999 NEI, and also compared to approximations of New Haven city level emissions obtained by apportioning the county level NEI emissions to the city level using gasoline consumption as a surrogate. Use of the gasoline consumption surrogate yielded an apportioning ratio of 13.1%. The comparison is made to version 2 of the NEI because New Haven used the version 2 area source documentation to calculate its emissions.

A comparison to NEI stage 1 emissions has not been made because the 1999 NEI for HAPs, version 2, does not offer a good means of comparison to New Haven's stage 1 emission estimate. The NEI stage 1 emission estimates actually include emissions from filling tanker trucks at bulk terminals and bulk plants with emissions from filling tanks at gasoline service stations. New Haven's stage 1 emission estimates only account for true stage 1 emissions (i.e., emissions from filling underground tanks at gasoline stations). Additionally, version 2 of the NEI mis-allocates stage 1 emissions geographically by apportioning emissions via use of the ratio of county employment for the bulk terminal industry sector⁵. This method does not properly allocate stage 1 emissions from gasoline stations in the NEI, as many counties are shown to have zero stage 1 emissions despite having numerous gasoline stations. The NEI does not contain emission estimates for underground tank breathing or tank trucks in transit. Therefore, Table 3 only shows a comparison of NEI and city prepared HAP emission estimates for stage 2 operations.

The correlation between the two city level estimates is quite good for all pollutants except hexane and MTBE. This is probably an artifact of different assumptions made in the split between summertime reformulated gasoline and wintertime oxygenated fuel use in the state made by New Haven and in the NEI. The speciation profiles for the other 6 HAPs shown in Table 3 are the same for both fuel types, therefore such assumptions would not affect them.

Table 3 Comparison of stage 2 emission estimates.

| HAP | City's Estimate (tons/year) | NEI <u>County</u> Estimate (tons/year) | NEI City Estimate (using surrogates) (tons/year) |
|-----|--------------------------------|---|--|
|-----|--------------------------------|---|--|

| | | | |
|------------------------|-------|------|-------|
| 2,2,4-Trimethylpentane | 0.40 | 2.80 | 0.36 |
| Benzene | 0.31 | 2.62 | 0.34 |
| Ethyl benzene | 0.056 | .368 | 0.048 |
| Hexane | 4.34 | 5.59 | 0.73 |
| MTBE | 5.8 | 9.53 | 1.25 |
| POM as 16-PAH | 0.28 | 1.84 | 0.24 |
| Toluene | 0.62 | 4.49 | 0.59 |
| Xylene | 0.23 | 1.69 | 0.22 |

Aircraft Refueling

New Haven estimated emissions from aircraft refueling at its Tweed-New Haven airport. A contact at the airport provided the amount of aviation gasoline and Jet-A fuel used at the facility. New Haven used VOC emission factors from EPA's AP-42 emission factor document⁶ and the lead speciation profile from the NEI area source guidance to determine that 0.140 lbs of lead are emitted from aircraft refueling in New Haven. The EPA's NEI indicates that 0.308 lbs of lead are emitted in New Haven county. Connecticut's 1999 periodic emissions inventory⁷ lists the number of landing and takeoffs (LTOs) for each airport in New Haven county, from which it was determined that 14.8 percent of the LTO's in New Haven county occur at New Haven's (city) Tweed airport. If LTO's are used to apportion county level lead emissions in the NEI, approximately 0.046 lbs of lead would be expected in the city of New Haven as shown in Table 4.

Table 4 Comparison of lead emission estimates for New Haven.

| HAP | City's Estimate (lbs./year) | NEI County Estimate (lbs./year) | NEI City Estimate (using surrogates) (lbs./year) |
|------------|---------------------------------------|---|---|
| lead | 0.140 | 0.308 | 0.046 |

Automobile Refinishing

New Haven estimated emissions from automobile refinishers by obtaining employment data via a telephone survey, and combining that activity information with a state-specific per-employee VOC emission factor developed by the CT-DEP⁸. New Haven then used the speciation profile available in the 1999 NEI area source documentation to develop its HAP emission estimates. Table 5 shows the results of their calculations, and comparisons to the county-wide HAP estimates in the version 2 NEI and to an estimate of emissions for New Haven made by apportioning the NEI county level emissions to the city level using employment data as a surrogate. Connecticut DEP's 1999 periodic emissions inventory indicates that there were 632 employees in New Haven county in this industry, while New Haven's (city) telephone survey found 52 employees. This produces a county to city apportioning ratio of 0.082.

Table 5 Comparison of HAP emission estimates for automobile refinishers

| HAP | City's Estimate (tons/year) | NEI County Estimate (tons/year) | NEI City Estimate (using surrogates) (tons/year) |
|---------------------------------------|---------------------------------------|---|---|
| Butyl cellosolve | 0.222 | 3.48 | 0.285 |
| Cellosolve | 0.018 | 0.418 | 0.0343 |
| Ethylene glycol | 0.0178 | 0.279 | 0.0229 |
| Diethylene glycol monoethyl ether | 0.0089 | 0.139 | 0.0114 |
| Diethylene glycol monomethyl ether | 0.00890 | 0.139 | 0.0114 |
| Diethylene Glycol Monobutyl ether | 0.0412 | 0.645 | 0.0529 |
| Cellosolve Acetate | 0.0267 | 0.418 | 0.0343 |
| Methyl Ethyl Ketone | 1.29 | 20.2 | 1.66 |
| Methyl Isobutyl Ketone | 0.344 | 5.38 | 0.441 |
| Toluene | 1.44 | 22.6 | 1.85 |
| Xylene | 2.86 | 44.7 | 3.67 |

Architectural Surface Coating

New Haven's HAP emission estimation methodology exactly matches the population based method used to develop the NEI emission estimates for this sector. Accordingly, the emission estimates one gets by apportioning NEI county data to the city level using population as a surrogate matches the emission estimates in New Haven's HAP inventory.

Traffic Markings

New Haven estimated the amount of HAP emissions from traffic markings by obtaining local activity data from the two entities responsible for this in New Haven, and by obtaining the material safety data sheets (MSDS) from these entities for the products applied. The Connecticut Department of Transportation and the New Haven Traffic & Parking Department supplied information on the amounts of paints applied, and the MSDS sheets for these products. Both organizations use paints that combine quick setting epoxies with water based paints. The only HAP identified from the MSDS sheets was methyl alcohol, and New Haven estimates that 0.811 tons/year of it are emitted from traffic marking activity. The NEI emission estimates for New Haven county do not include an emission estimate for methyl alcohol for this sector, but rather include HAP emission estimates for 13 HAPs typically associated with solvent based paints. The use of combination epoxy and water-based paint mixtures in New Haven rather than solvent based paints makes the NEI's HAP emission estimates for this sector

invalid.

Dry Cleaners

New Haven determined the number of dry cleaning facilities in the city using the yellow pages and information maintained by the Connecticut Economic Resource Center, then used information from the CT-DEP and a regional industry association to estimate perchloroethylene (perc) emissions from dry cleaners. CT-DEP's information consisted of a state-wide survey of perc usage by dry cleaners conducted in the early 1990s. New Haven adjusted this estimate upward to account for population growth, then reduced the perc consumption levels to account for EPA's MACT standard for this industry, and also for a state perc regulation. The Northeast Fabricare Association provided New Haven with the number of dry cleaners in the state (482). New Haven used the ratio of dry cleaners within New Haven (26) to the total number of dry cleaners in the state as a means of apportioning estimated statewide perc consumption levels to the city level. This produced a perc emission estimate of 17.9 tons per year. The NEI county level emission estimate is 51.3 tons per year, which if apportioned to the city level using a population ratio (15.2%) yields 7.80 tons per year.

Graphic Arts

New Haven estimated HAP emissions from the graphic arts sector using the first alternative method recommended by the EIIP area source guideline series. This method involves the use of ink sales data as a means of gauging ink use in an area. New Haven obtained information about the dollar value of printing ink sales for New Haven county from the Printing Industries of America, Inc. New Haven then used information from the U.S. Census's Manufacturing-Industry Series reports to translate the monies spent on various types of graphic arts inks to quantities of ink used. This county level information was then apportioned to the city level using the city to county employment ratio, which was 33.9% for this industry. New Haven used the speciation profile from the NEI's area source documentation to calculate HAP emissions, which are shown in Table 6. Table 6 also shows the county level HAP estimates from the NEI, and estimated NEI city level emissions developed by apportioning the county level estimates to the city level using employment in the graphic arts industry as a surrogate. Data from draft version 3 of the NEI was used in this comparison, rather than version 2 of the NEI, because the version 2 NEI emission estimates for graphic arts contain an error whereby the tons of VOC were incorrectly converted to tons of HAPs. This error was corrected in the draft version 3 NEI.

The large discrepancies seen in Table 6 for dibutyl phthalate and toluene diisocyanate are due to emission factor differences. New Haven used the emission factors contained in the NEI area source documentation. The emission factors in the raw data files for draft version 3 of the NEI match those referenced in the area source documentation for the other 4 pollutants, but differ for dibutyl phthalate and diisocyanate.

The substantially larger emission estimates found by New Haven for the remaining 4 pollutants shown in Table 6 occur due to different activity level assumptions. In the NEI, national emissions were apportioned to counties using employment as a surrogate. However, the NEI assumed New Haven county's employment was only 523; the U.S. Census Bureau's year 2000 County Business Patterns report indicates 2,953 people are employed in this industry in New Haven county.

Table 6 Comparison of graphic arts emission estimates.

| HAP | City's Estimate (tons/year) | NEI County Estimate (tons/year) | NEI City Estimate (using surrogates) (tons/year) |
|------------------------|---------------------------------------|---|---|
| Toluene | 73.7 | 33.9 | 11.5 |
| Dibutyl Phthalate | 113.7 | 0.157 | 0.0532 |
| Toluene Diisocyanate | 0.341 | 5.23 | 1.77 |
| Methyl Carbitol | 0.455 | 0.209 | 0.0709 |
| Methyl Ethyl Ketone | 617 | 284 | 96.3 |
| Methyl Isobutyl Ketone | 168 | 77.3 | 26.2 |

Residential heating with natural gas

New Haven obtained consumption data from the Southern Connecticut Gas company, then used HAP speciation data from the NEI's area source inventory documentation to calculate the HAP emission estimates shown in Table 7. Table 7 also shows the county level HAP estimates from the NEI, and estimated NEI city level emissions developed by apportioning the county level emissions using the ratio of city to county gas consumption rates. The apportioning ratio so derived was 24.5%.

Table 7 Comparison of HAP emission estimates from residential gas combustion

| HAP | City's Estimate (lbs./year) | NEI County Estimate (lbs./year) | NEI City Estimate (using surrogates) (lbs./year) |
|--------------|---------------------------------------|---|---|
| Acetaldehyde | 0.0339 | 0.184 | 0.0458 |
| Benzene | 5.48 | 29.6 | 7.37 |
| Formaldehyde | 196 | 1,058 | 263 |
| Fluoranthene | 0.00783 | 0.0424 | 0.0106 |
| Fluorene | 0.00731 | 0.0396 | 0.00986 |
| Naphthalene | 1.59 | 8.6 | 2.14 |
| Phenanthrene | 0.0444 | 0.24 | 0.0598 |
| Pyrene | 0.0131 | 0.071 | 0.0177 |

Residential heating with oil

New Haven estimated the amount of oil used by this source category by surveying ten local oil distributors to gauge the amount of oil used in a year by an average household, and then estimated that 39% of New Haven households use oil based on information provided by the Independent Connecticut Petroleum Association. New Haven then used the speciation profile from the NEI area source guidance

document to calculate emission estimates for 26 HAPs. Table 8 shows the results for 8 of these HAPs; these are the same 8 HAPs emitted by natural gas combustion. Table 8 also shows the county level HAP estimates from the NEI, and estimated NEI city level emissions developed by apportioning the county level estimates using oil consumption rates as a surrogate. The apportioning factor so derived was 14.0%.

Table 8 indicates that the NEI derived city estimates are much lower than the estimates obtained by New Haven. This is due to a lower oil consumption estimate in the NEI. The NEI assumed that the oil consumption for New Haven county was equivalent to 2.359 trillion BTUs. However, CT-DEP's 1999 periodic inventory report indicates an oil consumption rate equivalent to 18.24 trillion BTUs.

Table 8 Comparison of HAP emission estimates from residential oil combustion

| HAP | City's Estimate (lbs./year) | NEI County Estimate (lbs./year) | NEI City Estimate (using surrogates) (lbs./year) |
|--------------|---------------------------------------|---|---|
| Acetaldehyde | 89.6 | 82.6 | 11.6 |
| Benzene | 3.84 | 3.53 | 0.50 |
| Formaldehyde | 614 | 566 | 79.2 |
| Fluoranthene | 0.0896 | 0.0814 | 0.0114 |
| Fluorene | 0.0819 | 0.075 | 0.011 |
| Naphthalene | 20.7 | 19.02 | 2.66 |
| Phenanthrene | 0.192 | 0.177 | 0.0248 |
| Pyrene | 0.0768 | 0.0716 | 0.010 |

Structure fires

Data from New Haven's Fire Department indicates that in 2000, 269 fires occurred in the city. New Haven used a fuel loading factor of 1.15 tons of material per fire burned developed by the California Air Resources Board, and the speciation profiles for four HAPs from the NEI area source guidance document. Table 9 compares the cities emission estimates to county level estimates from the NEI, and estimated city level emissions made by allocating the NEI county emissions to the city level based on population (15.2%).

Table 9 Comparison of HAP emission estimates from structure fires

| HAP | City's Estimate (lbs./year) | NEI County Estimate (lbs./year) | NEI City Estimate (using surrogates) (lbs./year) |
|--------------|---------------------------------------|---|---|
| Acrolein | 1,364 | 7,773 | 1,181 |
| Formaldehyde | 315 | 1,801 | 274 |

| | | | |
|-------------------|--------|--------|-------|
| Hydrochloric Acid | 4,674 | 26,612 | 4,045 |
| Hydrogen Cyanide | 10,978 | 62,492 | 9,499 |

CONCLUSIONS

Although the U.S. EPA's national emissions inventory can form a good starting point to local level HAP inventory efforts, in some instances EPA's national emission estimates, when allocated to a smaller geographic area such as New Haven, produces inaccurate results. This is not unexpected, as EPA's national emission's inventory's primary purpose is to provide estimates at the national level. Significant improvement can be made by collecting local data and calculating HAP emissions using readily available emission estimation tools.

New Haven was able to expand upon the universe of point sources found in the NEI by speciating the VOC emission estimates that the CT-DEP previously determined for 12 sources. This added 40.5 tons of total HAPs to the inventory. For area sources, New Haven would have erred if it had apportioned NEI county level emissions data to the city for the traffic markings, stage 1 gasoline tank filling, graphic arts, dry cleaning, and residential oil heating categories. However, doing so for the stage 2, aircraft refueling, automobile refinishing, architectural surface coating, structure fires, and residential gas combustion categories would have produced reasonable results.

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KEYWORDS

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