Assessment of Benzo(a)pyrene Air Emissions In the Great Lakes Region

A report of the
Great Lakes Regional Toxic Air Emissions Inventory
Steering Committee

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Acronyms

B(a)p – Benzo(a)pyrene
FCCU – Fluidized Catalytic Cracking Unit
FIRE – Factor Information REtrieval System
HAPs – Hazardous Air Pollutants
IADN – Integrated Atmospheric Deposition Network
IDEM – Indiana Department of Environmental Management
IEPA – Illinois Environmental Protection Agency
L&E – Locating and Estimating
MARAMA – Mid-Atlantic Regional Air Management Association
MDEQ – Michigan Department of Environmental Quality
MPCA – Minnesota Pollution Control Agency
NEI – National Emissions Inventory
NYSDEC – New York State Department of Environmental Conservation
OEPA – Ohio Environmental Protection Agency
OMOE – Ontario Ministry of Environment
PAH – Polycyclic Aromatic Hydrocarbon
POM – Polycyclic Organic Matter
PDEP – Pennsylvania Department of Environmental Protection
RAPIDS – Regional Air Pollution Inventory Development System
SCC – Source Classification Code
TEF – Toxic Equivalency Factor
U.S. EPA – Environmental Protection Agency
WDNR – Wisconsin Department of Natural Resources

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About This Report

This report was compiled in 2006-2007 by the Steering Committee of the Great Lakes Toxic Air Emissions Inventory project. Those contributing to the preparation of the report and the underlying data include: Jon Dettling (Great Lakes Commission); Orlando Cabrera-Rivera (Wisconsin DNR); Karen Gee and John Hulsberg (Pennsylvania DEP); Cong Doan and Peter Wong (Ontario MOE); Tom Velalis (Ohio EPA); Carlos Mancilla (New York State DEC); Chun Yi Wu (Minnesota PCA); Dennis McGeen, Allan Ostrander and Jim Lax (Michigan DEQ); Jon Bates (Indiana DEM); and Buzz Asselmeier (Illinois EPA). Especial thanks go to Suzanne King and Steven Rosenthal of the U.S. EPA Air and Radiation Division (Region 5) and Tom Tseng of Environment Canada. Funding was provided by U.S. EPA's Air and Radiation Division. The report was published in March 2007 by the Great Lakes Commission, located in Ann Arbor, Michigan, and is available online at www.glc.org/air/.

Overview

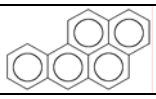
Benzo(a)pyrene is a persistent toxic substance whose presence in the environment is of concern due to impacts on wildlife and human health. In 1997, it was listed as one of twelve "Level I Substances" under the U.S.-Canada Binational Toxics Strategy. The two nations have committed to pursuing benzo(a)pyrene emission reduction strategies and tracking the progress of these efforts. Emissions inventories are valuable ways of identifying high-emitting sectors, determining the relative benefit of various emission reduction strategies, and—to a limited extent—for tracking trends. The eight U.S Great Lakes states and the Canadian province of Ontario have been collaborating on a regional toxic air emissions inventory for the past 15 years. Following the publication of the 2002 inventory, these states and province conducted a specific assessment of the benzo(a)pyrene emissions within the inventory, including the coverage of sources, estimation methods, available emission factors, errors and inconsistencies. Updates were made to the data to produce a regional inventory with greater accuracy, consistency and comprehensiveness. This report details the emissions inventory assessment process, presents the revisions to the 2002 regional benzo(a)pyrene emissions inventory, and offers recommendations for further correcting gaps in the emissions estimation for a variety of emission sources.

Introduction

Benzo(a)pyrene is a persistent toxic substance that has raised concerns for human and wildlife health due to its presence at high concentrations in the waters and sediments of the Great Lakes – St. Lawrence River system. It is one of twelve Level I Substances to have been identified and targeted for reduction efforts under the Great Lakes Binational Toxics Strategy.[1] A member of a group of chemicals known as polycyclic aromatic hydrocarbons (PAHs), benzo(a)pyrene is comprised of five joined benzene rings. As with other PAHs, it is emitted to the environment primarily from combustion processes. Although less persistent than many halogenated toxic substances, benzo(a)pyrene persists long enough in the atmosphere to be transported efficiently on a regional scale (e.g., 1000 km)[2] and once deposited to water bodies and sediments, can be retained in those compartments for a period of several years before being degraded. Because of its moderate persistence, there is hope that reduced emission rates will result in reduced environmental levels within a relatively short timeframe.

Benzo(a)pyrene is listed as a probable human carcinogen (category 2B) by the U.S. EPA, based largely on data from animal studies.[3] Evidence of cancer in humans is substantial for mixtures of PAHs, but adequate work has not been done to establish cancer risks for individual PAH compounds such as benzo(a)pyrene.[3, 4] Information on the human toxicity of benzo(a)pyrene following oral exposure is not sufficient to derive a reference dose.[4] While not the most abundant PAH in most emission streams or environmental samples, benzo(a)pyrene is generally regarded as a principal contributor to the overall environmental and human health risk from PAH contamination. For example, applying a set of toxic equivalency factors (TEFs),[5] Petry et al. estimated that the contribution of benzo(a)pyrene to the total PAH toxicity in 6 occupational and 2 ambient air environments ranged from 27-67%.[6]

Table 1: Chemical characteristics of benzo(a)pyrene

Chemical profile of benzo(a)pyrene	
Chemical Abstract Service (CAS) number	50-32-8
Chemical structure	
Chemical formula	$C_{20}H_{12}$
Molecular weight	252.30
Melting point	175° C[7]
Boiling point	>360° C
Log K_{OW}	6.04[7]
Log K_{OA}	10.77
Degradation rate in air (half life)	5 to 170 hours[7, 8]
Degradation rate in water (half life)	940 to 1700 hours[7, 8]
Degradation rate in sediments (half life)	4700 to 55,000 hours[7, 8]

Benzo(a)pyrene in the Great Lakes environment

Benzo(a)pyrene concentrations have been well documented in the air, water and sediments of the Great Lakes basin. Being among the chemicals monitored by the Integrated Atmospheric Deposition Network (IADN), the record of benzo(a)pyrene within the region's air and precipitation is quite good. Measurements have been taken every 12th day in air and as 28-day composites in

precipitation at as many as 15 sites dating as far back as 1991. Results from an urban monitoring station in Chicago suggest a very strong urban-rural gradient, with air and precipitation concentrations at this station being 1-2 orders of magnitude higher than at other IADN stations. A significant long-term trend is not apparent in the IADN results for benzo(a)pyrene, with the exception of decreasing trend in precipitation from Chicago.[9, 10] Annual IADN atmospheric loadings (wet and dry deposition) to the Great Lakes from 1992-2000 were calculated to range from roughly 5 to 25 ng/m^2-day, with deposition to Lakes Erie and Ontario generally being higher than for the other lakes and Lake Superior receiving the lowest deposition rate.[11]

Being a chemical of moderately-high environmental persistence and moderately hydrophobic, benzo(a)pyrene may cause health impairments or ecological harm due to its partitioning to sediments and subsequent accumulation in the food chain. Sediment concentrations within the Great Lakes region are fairly well characterized, although many measurements are within highly impacted areas. In a sediment survey published in 2005 of 38 lakes across the U.S., it was found that concentrations of PAH were increasing in nearly all lakes over time.[12] It was also found that of those lakes in densely populated urban areas, approximately 50% exceeded the probable effect concentration for benzo(a)pyrene (1450 ng/g[13]). It is clear that many locations around the region have concentrations near or above this level.[7, 12, 14-20] In addition, concentrations at many more locations are above the threshold effect concentration of 150 ng/g.[13]

In addition to sediments, soils are also an important reservoir for benzo(a)pyrene. A worldwide survey of soil concentrations in temperate regions showed benzo(a)pyrene concentrations ranging from 2 to 6461 ng/g, with urban soil concentrations being generally higher than forested, which were slightly higher than grasslands and arable soils.[21] A set of paired sediment and nearby soil samples in upstate New York showed relatively higher concentrations in soil samples compared to sediment.[22]

A comparative risk assessment using various methodologies showed that exposure through consumption of plant and animal products are the primary human exposure route to benzo(a)pyrene, with inhalation contributing significantly to cancer risk in several cases where relatively high cancer slope factors for inhalation were used.[23] Depending on the methodology used, cancer risk for the general population from benzo(a)pyrene and/or total PAH compounds may be as high as one in ten thousand.[23, 24]

The Great Lakes Regional Toxic Air Emissions Inventory

The Great Lakes Regional Toxic Air Emissions Inventory[25] is a unique program, developed by the eight Great Lakes states and the Province of Ontario during the two decades since the signing if the Great Lakes Toxic Substance Control Agreement of 1986.[26] This effort has included the development and refinement of an agreed upon regional Protocol,[27] design and implementation of project software, creation of an internet data access tool, and production of triennial regional inventories for 1993, 1996, 1999 and 2002, with intervening updates for 1997, 1998 and 2001 data years. The project locates and estimates emissions from significant sources of more than 200 toxic air pollutant compounds and groupings.

The Great Lakes Regional Toxic Air Emissions Inventory is compiled to achieve numerous state and regional goals and objectives including:

- providing an information base to assist other efforts targeted at quantifying and reducing atmospheric inputs of toxic substances to the Great Lakes;
- assisting state-based compliance, enforcement, pollution prevention, rule-making and permitting activities;
- preparing reports to legislature, policy makers, other interested groups and the public;
- data exchange with the U.S. EPA's National Emissions Inventory (NEI) and other national or regional initiatives;
- supporting efforts to model air quality and chemical fate/exposure;
- and many others

A Steering Committee, comprised of one or several members from each of the participating state or provincial air quality control agencies, leads development of inventories and provides expertise for quality assurance of state and provincial data. Each participating jurisdiction benefits through the Committee's shared expertise, tools for state and provincial inventory development, capacity building and shared data dissemination tools. Within the project, each state develops inventories according to their state requirements. If not for this project, the state and provincial inventories across the Great Lakes basin would be largely incompatible. This project addresses the need for a regional inventory by bringing Great Lakes states and provinces together to develop a consistent and comprehensive basin-wide inventory of all toxic air emissions.

The main project objective is to present researchers, policymakers and other interested stakeholders with detailed, accurate, consistent and up-to-date regional data on the sources and emission levels of toxic air pollutants for the Great Lakes region. These data provide the foundation for a better understanding of the patterns and impacts of multi-media human and wildlife exposures and provide information supporting the reduction of adverse affects to the environment and human health. The project aims to provide decision makers with easy access to inventory information through dissemination on the Internet and through printed materials. There remain numerous challenges that must be addressed to achieve the goals of the project. These include the continued improvement of emission estimation techniques and consistency among state as well as outreach to user groups to facilitate incorporation of inventory data into regional scientific and policy efforts.

Assessment Methodology

This report presents the results of an assessment conducted to improve the comprehensiveness, accuracy and consistency of the emissions inventory data for benzo(a)pyrene for the Great Lakes region. First, several quality assurance checks were run on the pre-existing data to identify abnormalities in the data for individual jurisdictions, source types, and industrial facilities within the region. Where errors or discrepancies were uncovered, corrections were identified and implemented. Where additional, unreported sources were identified, emission estimates were generated and included in the inventory.

Second, benzo(a)pyrene emissions for each source classification code (SCC) in the 2002 inventory were compared to those with available emission factors from U.S. EPA's Factor Information Retrieval (FIRE) database, the 2002 U.S. EPA's National Emissions Inventory (NEI) documentation, and other available sources. A record was made of SCCs that were associated benzo(a)pyrene emissions in the inventory but for which emission factors are not available in FIRE or the NEI documentation. Participating states and provinces were asked to examine and justify the

inclusion of emissions from such SCCs. Similarly, cases where emission factors exist but where an individual state or province did not report benzo(a)pyrene emissions were also recorded and participating states/provinces were asked to either include these sources or justify their exclusion.

Finally, a small set of source categories (SCCs) were identified for closer attention. These included SCCs that were recognized as a major potential contributors to regional benzo(a)pyrene emissions and that showed significant variability in the presence and magnitude of emission estimates. The Steering Committee examined these SCCs and developed a consensus on estimation methodology and use of appropriate emission factors. Among the source categories that were closely examined are residential wood burning, coke ovens, metal production, open burning, crematories, and mobile sources. Observations regarding each of these sources are described in the Conclusions section.

The modifications to the regional benzo(a)pyrene emissions will be available as a downloadable database through the project website, www.glc.org/air.

Original 2002 Bezno(a)pyrene Emissions Data

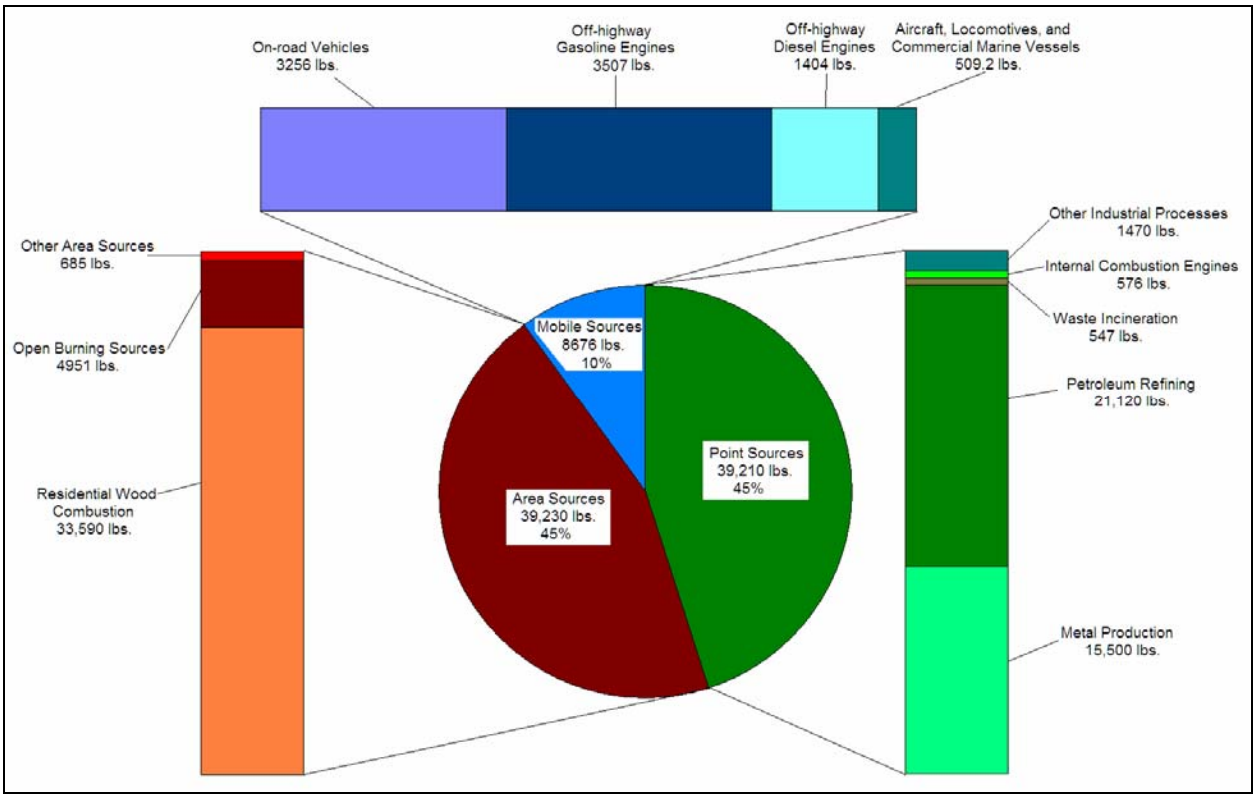
Prior to this reassessment, the original 2002 regional inventory included 87,120 pounds of benzo(a)pyrene emissions. Total emissions for individual states ranged over nearly a factor of ten. Nearly equal amounts of emissions were estimated for point and area sources, which together comprised 90% of the total emissions. Emissions from on-road and non-road mobile sources made up the remaining 10% of emissions. The total original 2002 emission estimates classified by source type and by state or province are shown in Table 2.

Table 2: Original 2002 regional benzo(a)pyrene emission estimates (lbs) by source type and state/province

	Area	Point	Mobile	Non-road	Total
Illinois	1151	3414	354.3	218.1	**5137**
Indiana	1535	5048	250.2	144.5	**6977**
Michigan	1152	7228	390.7	391.5	**9163**
Minnesota	4555	100.3	0	199.9	**4855**
New York	20,810	250.5	1163	230.8	**22,460**
Ohio	1483	15,070	373.9	3606	**20,530**
Ontario	3853	6162	233.4	149.4	**10,400**
Pennsylvania	2162	1921	303.2	267.9	**4654**
Wisconsin	2523	20	187.4	213.2	**2944**
Total	**39,230**	**39,210**	**3256**	**5422**	**87,120**

While emission estimates were made for 697 SCCs, the highest ten of these accounted for nearly 86% of the total emissions. The 400 SCCs with the lowest estimated emissions accounted for less than 0.5% of the total emissions. Among the top categories in the original data, both point sources (fluidized catalytic cracker units, steel production, coke processing, etc.) and area sources (wood fireplaces, wood stoves, open burning, etc.) were prevalent. The emissions by source category are shown in Figure 1.

Figure 1: Regional emissions of benzo(a)pyrene by source category: original 2002 inventory data



Data Assessment and Modifications

Assessment Summary

The emissions estimates were compared based on SCC to the emission factors available through the U.S. EPA's FIRE and NEI documentation to identify emissions from sources for which factors are not available in those data sources. Also included in this analysis was a table of factors compiled by the regional project Steering Committee that attributes FIRE emission factors to similar source categories for which factors do not exist. It should be noted that some source types are not present within some states or provinces. As a result, there are likely to be many cases where this is the reason for emissions not being reported for a given source type within a certain state or province.

With only a few exceptions, the area source emissions that lacked a corresponding emission factor were relatively small in magnitude, together comprising only 0.4% of the overall estimated emissions, with the great majority of that coming from an estimate of scrap tire burning in Pennsylvania. In contrast, the point source emissions lacking emission factors are more substantial, totaling 7,543 pounds, or nearly 9% of the total estimated emissions. As with area sources, the majority of the point source emissions identified from this analysis are from a small number of source types, including steel production, paper and wood processing, incineration and refineries.

The emissions data were also compared to the available emission factors to identify existing sources for which there is a corresponding benzo(a)pyrene emission factor in one or more of the above mentioned sources, but for which no benzo(a)pyrene emissions were included in the report.

For each of the instances identified, the participating state and provincial agencies were asked to assess their data to determine if addition emission estimates should be included or if existing ones should be removed or revised.

Summary of Modifications

As shown in Table 3, the assessment resulted in an overall decrease of 32% of the original estimate of regional benzo(a)pyrene emissions. This change is due to a combination of decreases and increases to estimated values from a wide variety of source categories within each jurisdiction. A summary of the major changes from each jurisdiction is provided in Appendix B. Beyond the significance of the substantially decreased total emission estimate, the assessment resulted in important improvements in the consistency and comprehensiveness of the regional benzo(a)pyrene inventory. In spite of these improvements, the assessment also revealed several areas where uncertainties and inconsistencies remain. These will be discussed further in the Conclusions section below.

Metal production, originally among the several highest categories, saw an increase of 33% from the original estimate, becoming the largest source category in the final emissions inventory. In contrast, petroleum refining, also among the highest categories in the original inventory, saw a decrease of nearly 70% from the original estimate. As described in Appendix B, this was due to updating the emission factors and control efficiencies used for fluidized catalytic cracking units (FCCUs) based on information from several sources. This category remains a substantial contributor in the final inventory, contributing about 11% of the total emission estimate. Waste disposal processes saw significant increases in the final inventory. Waste incineration increased by 69% to over 900 pounds of emissions. Among other point source processes, internal combustion engine also saw a significant increase of about 75%, raising the regional emissions from this category to approximately 1000 pounds.

Table 3: Summary of Emissions by Source Classification Pre- and Post-Assessment

		Pre-Assessment Inventory		Post-Assessment Inventory		
	Category	Emissions (lbs)	Percent of Total	Emissions (lbs)	Percent of Total	Percent Change
Point Sources	Metal Production	15,500	17.8%	19,430	32.9%	25.4%
	Petroleum Refining	21,120	24.2%	6615	11.2%	-68.7%
	Waste Incineration	547	0.6%	922	1.6%	68.6%
	Internal Combustion Engines	576	0.7%	1006	1.7%	74.7%
	External Combustion Boilers	95.27	0.1%	99.4	0.2%	4.3%
	Other Industrial Processes	1375	1.6%	192	0.3%	-86.0%
Area Sources	Residential Wood Burning	33,590	38.5%	16,720	28.3%	-50.2%
	Open Burning Sources	4951	5.7%	7,848	13.3%	58.5%
	Stationary Fuel Combustion	231.4	0.3%	36.97	0.1%	-84.0%
	Other Area Sources	494.9	0.6%	681.2	1.2%	37.6%
Mobile Sources	On-road Vehicles	3256	3.7%	3409	5.8%	4.7%
	Off-highway Gasoline Engines	3507	4.0%	1633	2.8%	-53.4%
	Off-highway Diesel Engines	1404	1.6%	71.26	0.1%	-94.9%
	Other Non-road Vehicles	509.2	0.6%	429.6	0.7%	-15.6%
	Total	**87,157**		**59,087**		**-32.2%**

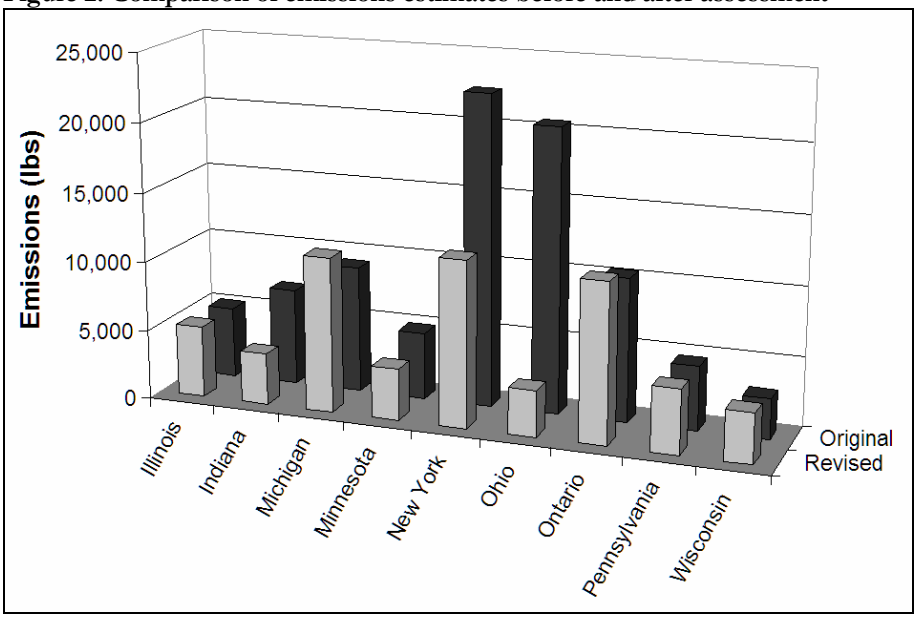
Residential wood combustion was the largest source category in the original inventory and despite an overall decrease of 50% in this source category, it remained the second highest category in the final inventory. Decreases in this category were due largely to a substantial decrease in the estimate from New York, which was offset to some degree by the inclusion of emissions data for this category for Pennsylvania and increases in estimates from several states, including Wisconsin and Michigan.

In contrast to residential wood combustion, open burning increased substantially to 7848 pounds, representing a 58.5% increase over the original figure. This increase was due mainly to the inclusion of additional sources (from Michigan, Minnesota, Ontario and Wisconsin) for which emission estimation was refined and updated after compilation the original inventory. Other substantial changes in area source categories included: stationary source fuel combustion, which underwent an 84% decrease to 37 pounds; and commercial cooking, which increased by more than three-fold to 333 pounds due to the inclusion of this category by Michigan, New York and Wisconsin.

On-road vehicle emissions increased by 5% due to the inclusion of emissions from Minnesota, which were previously omitted, as described in Appendix B. Non-road engine emissions decreased substantially across all categories due to corrections to significant overestimates in Ohio's data for these categories. Total regional non-road emission estimations decreased from 5422 pounds to 2127 pounds.

Emissions for each jurisdiction changed by more than 20% from the original estimate, with the exception of Illinois, whose emission estimate increased by less than 1% as a result of the assessment. While benzo(a)pyrene emission estimates increased for Michigan, Ontario, Pennsylvania and Wisconsin, they decreased for Indiana, Minnesota, Ohio and New York. A comparison of benzo(a)pyrene emissions for the nine participating jurisdictions before and after the assessment is shown in Figure 2.

Figure 2: Comparison of emissions estimates before and after assessment



Revised 2002 Benzo(a)pyrene Emissions Data

The revised inventory includes a total of 59,087 pounds of benzo(a)pyrene emissions. Point and area sources contributed similar magnitudes on a regional basis, accounting for 48% and 43% of the total emissions, respectively. Mobile sources contributed the remaining 9% of regional emissions.

Point sources contributed a total of 28,263 pounds of benzo(a)pyrene emissions. The most prominent point source category in the final inventory is metal production, which contributed 33% of the total regional emissions and 69% of the point source emissions. Petroleum refineries contributed 11% of the regional total. Waste disposal, waste incineration and internal combustion engines each contributed 1-3% to the regional total. All other point source categories were relatively insignificant, combining for less than 0.5% of the total emissions. Point source emissions varied considerably among the states and province, with total point source emissions ranging from 20 pounds to more than 7,000 pounds. Reasons for this difference include the variability of facility locations (some states or province having a higher density of large emitters), differences in how inventories are compiled (including varying classifications of certain source types among point and area sources) and differences in reporting thresholds.

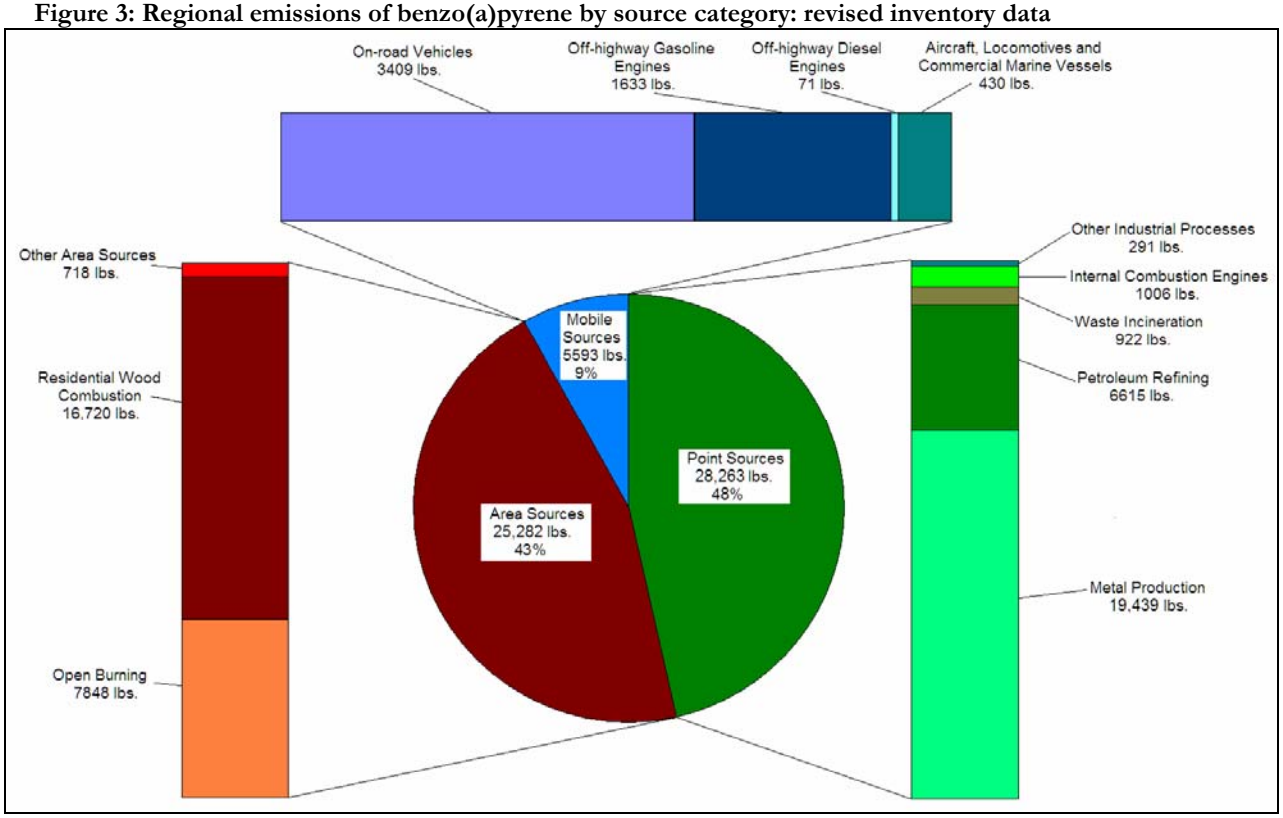
The total benzo(a)pyrene emissions from area sources in the revised 2002 inventory are 25,282 pounds. Residential wood combustion was the most significant area source category, contributing 28% of the total regional emissions from all sources. Open burning sources, including burning of household waste, forest fire and prescribed burning, accounted for 13% of the regional total. Among other significant are sources were commercial cooking and "accidental releases" (in this case a scrap tire fire in Pennsylvania, see Appendix B and page 15), each contributing more than 300 pounds, or about 0.5% of the total.

Mobile sources contributed a total of 5543 pounds to the regional benzo(a)pyrene inventory. On-road mobile sources contributed more than 60% of that amount, although only 5.4% of the total regional emissions. 2-stroke gasoline engines were by far the largest contributor of off-highway vehicles and engines. Aircraft, locomotives and commercial marine vessels contributed a combined 430 pounds, or 0.7% of the total regional emissions. Within both on-road and off-road mobile sources, gasoline engines contributed far more emissions than diesel engines (see Appendix A).

Table 4: Revised 2002 regional benzo(a)pyrene emission estimates (lbs) by source type and state/province

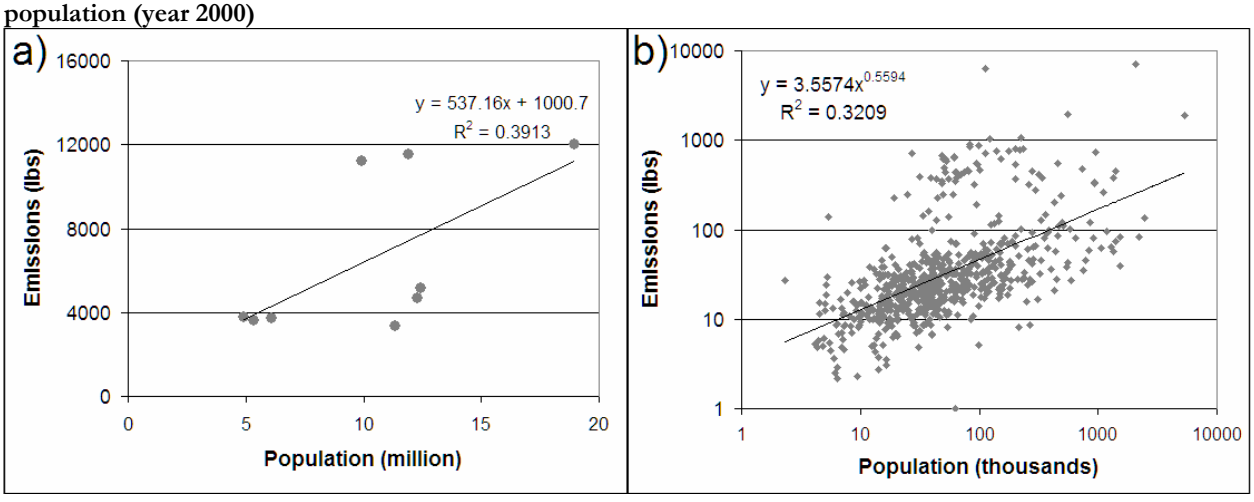
	Area	Point	Mobile	Non-road	Total
Illinois	1166	3416	354	219	**5155**
Indiana	1535	1802	250	146	**3733**
Michigan	3213	7231	391	394	**11,229**
Minnesota	3294	100	153	202	**3748**
New York	4226	6416	1163	231	**12,036**
Ohio	1483	1197	374	307	**3361**
Ontario	4996	6162	233	151	**11,542**
Pennsylvania	2162	1919	303	269	**4653**
Wisconsin	3207	20.48	187	215	**3629**
Total	**25,282**	**28,263**	**3,408**	**2,134**	**59,087**

Figure 3: Regional emissions of benzo(a)pyrene by source category: revised inventory data



The benzo(a)pyrene emissions estimates vary by more nearly four-fold among the nine jurisdictions included in this analysis, from a low of 3361 pounds, to a high of 12,036 pounds. Figure 4 shows the correlation of the 2002 benzo(a)pyrene emission estimate for each of the nine jurisdictions to the year 2000 population and the correlation to population at the county level. Monitoring data from the IADN network have shown a strong positive correlation between observed PAH concentrations and population density[10, 28] and a similar relationship is seen here.

Figure 4: Correlation of benzo(a)pyrene emissions by state/province (a) and county (b; U.S. only) to population (year 2000)



The relationship suggests that population differences may explain around one third the differences among jurisdictions. While a correlation with population is to be expected, for some sources the relationship to population is a complex one and not to be considered the only driving force. For example, wood burning and residential waste burning activities are among categories for which emissions will only increase with population to a certain point and then show a negative correlation with population, as these activities are far less common in urban settings. The correlation of emissions with population indicates that the intake fraction[29] of benzo(a)pyrene emissions within the region is likely higher than it would be if emissions were evenly distributed.

Prominent Source Categories

Fireplaces and Woodstoves

In the initial 2002 regional emissions inventory, residential wood combustion was the single largest category of benzo(a)pyrene sources within the region. In the revised inventory, the total emissions from this category decreased to 16,720 pounds or 28.3% of the revised total, as shown in Table 7.

The Mid-Atlantic Regional Air Management Association (MARAMA) released a report in 2006 containing an extensive review and calculation of residential wood combustion emissions from that region.[30] Two of the MARAMA states, Pennsylvania and New York are part of the Great Lakes regional project and have used the MARAMA numbers to replace their original 2002 benzo(a)pyrene data in this report. The report also contained information not previously available, including emission factors for standard fireplaces (i.e., without inserts), which allowed several states to include emissions for these sources.

The emission assessment resulted in better consistency across the region for this source category. Emissions were added for the only state previously lacking these emissions and a significant reduction was made in the original estimate of the only state with a substantially higher estimate than others. As a result of these changes, the total emissions from residential wood combustion decreased substantially (about 50%). However, residential wood combustion remained among the largest source categories in the final inventory. In future years, it will be important to continue to increase the accuracy and consistency of emission estimates for this source category. Uncertainties may still exist in estimates of wood burned, the magnitude and variability of emissions and distribution of burning among various stove types. Accounting for the impact of the rapidly-proliferating outdoor wood boilers will also be important.[31]

While promoting use of new, EPA-certified fireplaces and woodstoves is one of the primary benzo(a)pyrene reduction efforts taking place at the state, provincial and federal levels, there are inconsistencies among the emission factors used for these sources regarding the reductions that would be achieved by such efforts. In some cases, reviews of available information have resulted in a set of emission factors in which the certified units are assumed to emit *more* benzo(a)pyrene than non-certified units. Perhaps the best side-by-side comparison was done by Environment Canada and the Hearth Products Association of Canada and showed that certified stoves emit 2-10 times less than non-certified units, although the ranges overlap somewhat, especially if different types of wood are used.[32] Other compilations of information on the topic which are the basis for most emission estimates have recommended factors based on a consensus of multiple studies and show either a marginally smaller benzo(a)pyrene emission rate for certified units or show a higher emission rate. Emission factors from three sources are shown in Table 5. If conclusive evidence has, in fact, shown

that certified stoves emit substantially less benzo(a)pyrene, this information should be communicated to those publishing emission factors to ensure the difference is adequately reflected.

Table 5: Emission factors for benzo(a)pyrene from certified and non-certified woodstoves and fireplaces

Wood Burning Unit Type	SCC	Emission Factor (lb/ton wood)		
		MARAMA[30]	NEI 2002[33]	EC-HPAC[32]*
Fireplaces and woodstoves with conventional inserts	2104008002 & 2104008010	1.68×10^{-3}	2.48×10^{-3}	1.02×10^{-3} (maple) to 1.04×10^{-3} (spruce)
Fireplaces and woodstoves with EPA-certified non-catalytic inserts	2104008003 & 2104008050	2.18×10^{-3}	2.42×10^{-3}	1.2×10^{-4} (maple) to 7.6×10^{-4} (spruce)
Fireplaces and woodstoves with EPA-certified catalytic inserts	2104008004 & 2104008030	3.94×10^{-3}	2.05×10^{-3}	

*Calculated here by averaging three runs; maple and spruce results are shown separately

FCCUs

Fluidized-bed catalytic cracking units (FCCUs) were a very significant contributor to overall benzo(a)pyrene emissions in the original inventory, accounting for 21,030 pounds, or about 24% of the original total. All of the FCCU benzo(a)pyrene emissions in the original inventory were from just four states: Indiana (650 lbs), Michigan (4501 lbs), Ohio (13,960 lbs), and Pennsylvania (1920 lbs) No other state or province showed emission estimates for this source category, although Minnesota and Ontario each reported 30-40 pounds of benzo(a)pyrene emissions from unclassified petroleum industry processes (SCC 30699999). In the revised inventory, emissions from this source category decreased significantly to 6521 pounds, or about 11% of all emissions. The decrease is due to the adoption on lower emission factors representing control technologies on the FCCU process in Ohio and Indiana.

FCCUs are used within the petroleum refining process to catalytically break heavy-weight hydrocarbons into lighter weight compounds for use in automotive gasoline, heating fuels and other end products. During the cracking process, reaction products such as coke accumulate on the catalyst, slowing the reaction process. To restore catalytic function, the catalyst is "regenerated" by burning off the accumulated coke. It is this regeneration step within an FCCU that is associated with PAH emissions.[34] There is evidence that modern technologies employed in this process have significantly reduced emissions compared to past levels. While in the past many FCCUs have operated under a system of incomplete combustion—in which carbon monoxide, PAH and other byproducts are produced in large amounts—most FCCUs now operate under conditions in which near complete combustion is achieved, significantly decreasing emissions of benzo(a)pyrene and other PAH.[34] A comparison of some emission factors for controlled and uncontrolled emissions from FCCU is discussed in Appendix B show that a several orders-of-magnitude reduction in emissions is achieved.

Several of the states with high emissions from FCCU sources in the original inventory examined the rationale for these estimates, which resulted in substantial decreases in FCCU benzo(a)pyrene emissions in the final inventory. In several cases, it was found that controlled emission factors or

control efficiencies were not being correctly applied to such sources. When these control factors were correctly applied, the emissions for many of these facilities decreased substantially, as seen in the large decreases in this source category for Ohio and Indiana. Illinois had previously omitted emissions from this category entirely based on evidence that they were substantially smaller than previously thought. In the revised inventory, FCCU benzo(a)pyrene emissions from Illinois are included at an amount of less than 1 pound. Michigan and Pennsylvania account for the vast majority of the 6521 pounds shown in the revised inventory. Further investigation is needed to determine the accuracy of the FCCU benzo(a)pyrene emission estimates in these states.

Metal Production

Among industrial facilities, metal production was the activity which results in the greatest regional contribution to benzo(a)pyrene activity based on the revised 2002 inventory. The inventory shows 33% of all emissions coming from metal production processes. The majority of the metal production emissions included in this inventory is from coke oven processes (see Table 8). Other metal production sectors found to be emitting benzo(a)pyrene include aluminum ore reduction cells and electric arc furnaces.

"Coke oven gas," is a chemical mixture identified as a distinct hazardous air pollutant within the Clean Air Act.[35] It is well established that benzo(a)pyrene is a constituent of coke oven gasses[36, 37] and the EPA's residual risk assessment for this source category indicated that benzo(a)pyrene is one of a number of constituents of coke oven gas that can have adverse health effects.[38] While some coke oven sources report emissions as individual compounds, others only report the coke oven gas chemical mixture. Benzo(a)pyrene emissions reported as part of this chemical mixture are not accounted for in the inventory numbers presented here.

Coke oven gas (and benzo(a)pyrene) emissions are currently regulated under National Emissions Standards for Hazardous Air Pollutants (NESHAP) under section 112d of the Clean Air Act. These regulations require specific work practices and equipment for charging, topside lids, and doors. These regulations have been in place since October 1993.[39] EPA recently finalized residual risk rules under section 112f of the Clean Air Act for these emission points.[40] In April, 2003 EPA issued a final NESHAP for pushing, quenching and battery stacks.[41] Primary Aluminum emissions have been regulated under EPA's NESHAP program since October, 1997.[42] These rules result in reduced benz(a)pyrene emissions from coke ovens and aluminum plants.

A more detailed analysis of the inventory would need to be performed to determine the completeness and accuracy of the emission estimates from this sector, and further measures need to be taken by states to ensure that all emission points and coke oven pollutants are consistently addressed in future inventories.

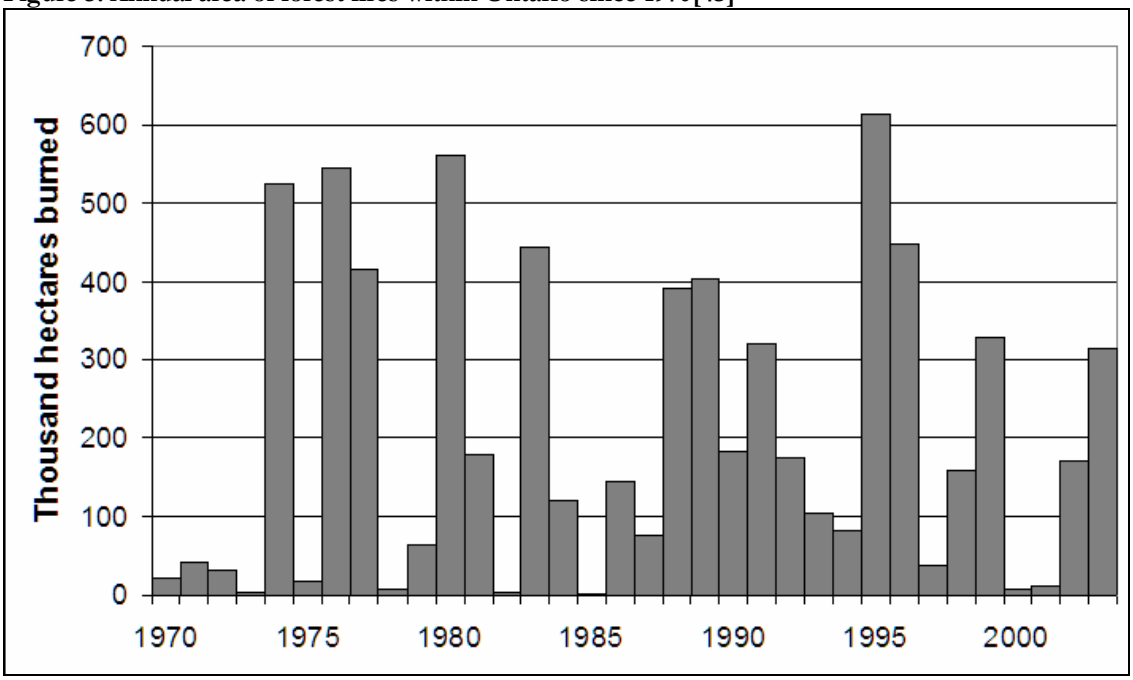
Open Burning

While of lesser significance in the original dataset, open burning emissions of benzo(a)pyrene increased substantially as part of the assessment and represent about 13% of the emissions in the final dataset. While prescribed burning emissions saw the addition of emission estimates for two states and recalculations for two others, the overall change in magnitude was relatively small. In contrast, emissions of benzo(a)pyrene from wildfires increased several-fold, particularly due to the addition of an estimate of these emissions from Ontario and Minnesota. Household waste burning

emissions were added for two states in addition to the four that had included this source category originally, resulting in a near doubling the total emission estimate from this source type.

These open-burning sources as a group clearly represent a significant source of benzo(a)pyrene emission on a regional scale. They also represent an area of remaining uncertainty and inconsistency within the inventory. Following the assessment, household waste burning, wildfires and prescribed burning were included in the benzo(a)pyrene inventory for six, six and five of the nine states/provinces, respectively. While in some cases the absence of estimates are due to restrictions on these activities, such as a ban on prescribed burning in New York in others, there are information gaps or lack of confidence in methodologies that prevent the inclusion of these emissions. For the estimates that are included, open burning remains a category of substantial uncertainty from both a standpoint of quantifying the activity of these sources and quantifying appropriate emission factors. In addition, forest fires, a significant component of the open burning emissions, can vary considerably from year to year. For example, Figure 5 shows the total area of forest fires within the province of Ontario for each year from 1970-2003. There is clearly substantial variation among years, with the 2002 area burned being 84% of the average value over this period.

Figure 5: Annual area of forest fires within Ontario since 1970[43]



Mobile Sources (on-road and off-road)

Mobile sources contributed, in total, about 9% to the final inventory. Both within the on-road and off-road sectors, gasoline engine emissions were of greater significance than diesel. Generally, the confidence in the emission estimates from these categories of sources is greater than for many of the other major source types (e.g., residential wood combustion or open burning). It can therefore be said that mobile sources are an important contributor to regional benzo(a)pyrene emissions, but very likely not a dominant source. Mobile sources are, however, a source category for which activity levels are likely to continue increasing with time, suggesting their percent contribution may grow, especially if other categories' emissions are successfully reduced.

Scrap Tire Fires

The inventory included a single instance of a scrap tire fire, an August 2002 fire in Edwardsville, Pennsylvania in which approximately 150,000 tires burned. This event is classified under "Accidental Releases" in Table 20 and resulted in an estimated 348 pounds of benzo(a)pyrene emissions, or about 0.55% of the total regional emissions. As an isolated event, the emissions from such a source are not highly significant at the regional level. However, on a local scale, a release of this magnitude could be highly significant for impacts on local receptors. It is not certain how many events of this type occur within the region on an annual basis and what total number or weight of tires burns in such fires. It is possible that if well quantified, these events would be an important contributor to the benzo(a)pyrene emissions inventory. Determining with greater accuracy the number of events, their size and location would allow for a better assessment of their contribution of regional emissions.

Conclusions

The revised 2002 Great Lakes regional emissions inventory shows that the categories of residential wood burning, metal production, petroleum refining and open burning contribute more than 85% of the total regional emissions. The revised estimate of total regional 2002 emissions is a 32% decrease from the original 2002 estimate. In many cases, changes within a certain source category or within a certain state or province were even more substantial than the change in the overall estimate implies. The resulting revised inventory provides the best information base to date on benzo(a)pyrene emissions in the Great Lakes region and can serve as an important tool for scientific analysis of the fate and impacts of this chemical and for state, provincial and federal policy makers to use in targeting emission reduction strategies. At the same time, there remain considerable uncertainties in estimates for some categories and the potential that important categories are not currently being inventoried. Discussed below are some important areas of uncertainty and un-inventoried sources, the effect of reporting thresholds on the inventory, a qualitative assessment of changes in emissions over time and recommendations for future work.

Areas of Uncertainty

Although the revised inventory represents an important step forward, there remain many uncertainties in the inventory that require further investigation. These include uncertainties in emissions from highly variable sources, uncertainties in control effectiveness, and lack of emission factors and/or activity data.

Emissions from highly variable sources

Several of the most highly emitting area sources are ones in which high variability among millions of small sources leads to considerable uncertainty in current emission estimates. For example, burning of residential waste commonly occurs in rural areas in 50-gallon drums. The burning conditions in these drums (moisture, temperature, oxygenation, etc.), as well as the waste content, can vary over a wide range. To get a truly accurate estimate of emissions, it is necessary not only to characterize the variation in emissions over the full range of conditions, but to also characterize the prevalence of each set of conditions among burning events. Similar problems exist with other sources, including fireplaces, forest fires, prescribed burning, and commercial cooking. There are other, currently unquantified sources, such as outdoor wood-fired boilers and agricultural plastic burning, for which this type of uncertainty is also an important factor.

Uncertainties in control effectiveness

For several types of sources, there is a challenge in determining to what extent control measures that are in place are affecting emissions. For example, many municipalities or counties have bans on burning of household waste. However, within rural locations it is very difficult to enforce such regulations or to evaluate how effective they are. The actual emissions from a county with a ban on waste burning is likely somewhere between the level that would be predicted without such a ban and that resulting from assuming no burning at all. In addition, some control measures of this type can be local phenomena, posing a challenge to accurately capture at the level of the state, province or region. For example, New York has a ban on prescribed burning and so shows no emissions for this category. Within other states, localities might either have a ban on such burning or simply do not practice it. However, these variations can be difficult to quantify.

Lack of emission factors and activity data

There are several cases in which likely sources of benzo(a)pyrene exist but are currently not quantified within the emissions inventory because there is inadequate information on the emissions and activity levels from these sources or their prevalence. Outdoor wood-fired boilers are an increasingly prevalent method for heating homes, particularly in the Great Lakes region.[31] However, there is not adequate available information on the emissions of benzo(a)pyrene from these units or the amount of wood being burned in them. Burning of agricultural wastes and plastics is a prevalent activity in agricultural regions that certainly emits benzo(a)pyrene. Quantifying how much is emitted from such sources is not possible, however, due to a lack of information on the emissions from these events, emission factors, and characterization of their occurrence.

Scrap tire fires could be substantial sources of benzo(a)pyrene, but it can be difficult to collect thorough information on the incidence of such fires and the amount of tires burned. Efforts to reduce tire stockpiles have been successful over the past decade,[44] suggesting the magnitude of this source category is diminishing. Coal-tar sealcoat (used on asphalt surfaces) and creosote-treated wood may represent sources of evaporative emissions but have not been well studied or characterized as of yet. Studies on creosote emissions from treated wood indicate that while emissions of total PAH are substantial, heavier PAH compounds such as benzo(a)pyrene represent a very small portion of those emissions.[45] In contrast to creosote, the percent contribution of heavy PAH compounds in coal-tar sealcoat is substantial.[46] Methodologies are not yet available to inventory either of these categories at the regional level.

Reporting thresholds

The participating states and the Province of Ontario have different reporting requirements and thresholds on benzo(a)pyrene. Many of the states (including Illinois, Minnesota, Michigan and New York) do not have a reporting threshold specific to benzo(a)pyrene, other states and Ontario do. Ontario requires facilities to report benzo(a)pyrene (and 16 other individual PAH species) if the combined total emission of these 17 PAH species is equal to or greater than 50 kg. Wisconsin has had a benzo(a)pyrene reporting threshold of 12 pounds in 2002, but will be applying a much lower threshold for the 2005 inventory and beyond (0.8 lbs). This lower threshold should cause more facilities to report emissions and should therefore result in a more complete inventory of benzo(a)pyrene emissions than would have been obtained under the prior threshold. As part of the present assessment, the Wisconsin DNR calculated emissions for facilities that were below the benzo(a)pyrene reporting threshold, but which were required to report for other emissions. The result of these calculations was a very modest increase to the emissions estimate. The differences in

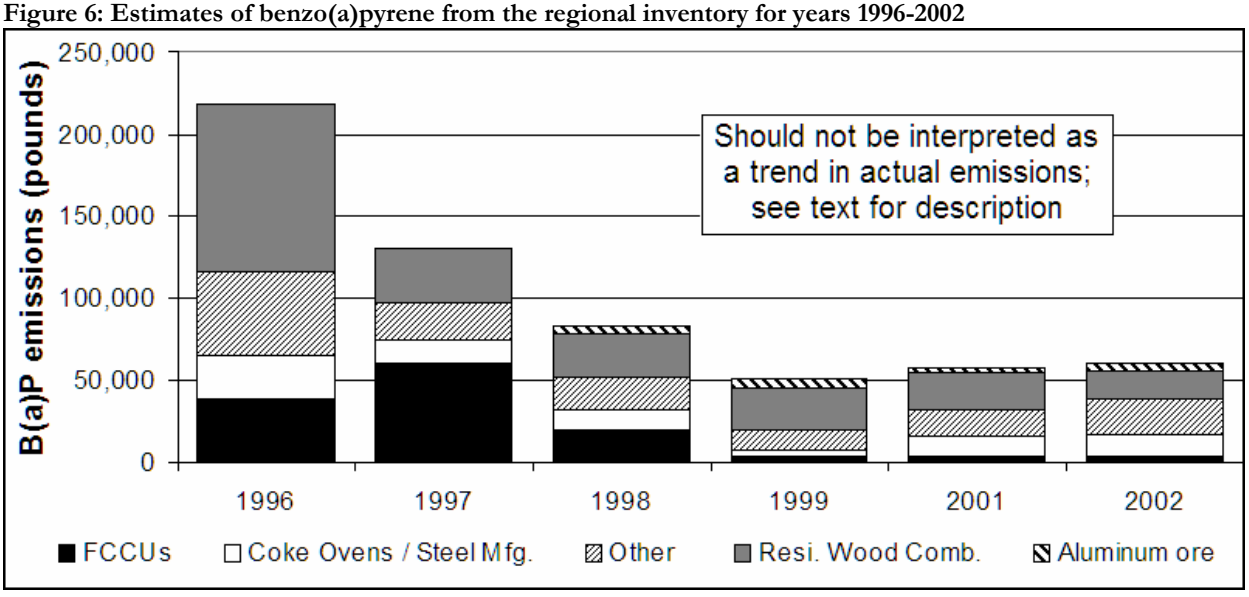
these reporting requirements may result in systematic disparities in the amount of benzo(a)pyrene emissions reported by facilities from various jurisdictions.

Assessing emission changes over time

While the Great Lakes Toxic Air Emissions Inventory project has now produced inventories for many years, it is inadvisable to compare the emissions data from one year to another with the intent of determining a trend in overall emissions. Over time, changes are made in emission estimation methodologies and to important reference data, such as emission factors. An emphasis has consistently been placed on improving the comprehensiveness and accuracy of the inventory data, with the accepted consequence that interannual comparability is lost.

Figure 6 shows the estimate of benzo(a)pyrene emissions for the regional inventory since 1996. While there is an apparent trend in the estimated total, it would be inappropriate to interpret this as a decrease of similar magnitude in actual emissions. It is necessary to look more closely at underlying information to determine if the decrease is one in actual emissions, or is an artifact of efforts to improve the emission estimate. The largest decrease over this period was a significant drop in residential wood combustion emissions. This decrease is due to the implementation of a revised set of emission factors for this category that was released by the EPA following the publication of the 1996 dataset.[47] It is therefore this change in reference data that is responsible for this apparent large change in estimated emissions. Other changes, such as the gradual decline in emissions from FCCUs are possibly quite real, as control technologies for this source type were required during the 1990s. However, the timing of this decline may be different from what is shown in the dataset, as some industrial sources or state agencies may have continued using the uncontrolled emission factor to produce their emission estimates, even after these controls were in place.

Figure 6: Estimates of benzo(a)pyrene from the regional inventory for years 1996-2002



Although it is difficult to quantify the decline in actual benzo(a)pyrene emissions, there is significant information available about the primary sources to make a *qualitative* assessment of changes in emission levels for the region. Table 6 summarizes what is known regarding the likely changes in regional emissions from primary source types for the period 1990-2006. As can be seen from the information in the table, it is very likely that the overall benzo(a)pyrene air emissions within the

Great Lakes region have decreased substantially over the past 15 years. While it is not possible based on current information to reliably estimate the percentage of this reduction, the large decreases in the metal production and petroleum refining categories suggest it is likely to be by a factor of 2 or more, based on the currently available information.

This assessment of trends takes account only of those sources that are currently identified and sufficiently characterized to offer a rough estimate of their overall magnitude. There may be other significant sources of benzo(a)pyrene not considered here that would affect the trend in regional emissions, several of which are mentioned in Table 6. For example, there has been suggestion that asphalt surfaces may present a major source to concentrations in urbanized areas.[48] While coal-tar sealcoat has been identified as a potentially large contributor to waterborne releases of benzo(a)pyrene through runoff,[46] measurements of atmospheric releases have not been made. Given that measurements of air and precipitation concentrations within the Great Lakes region have not substantially declined over the past 15 years[9, 10] and concentrations in lake sediments across the U.S. appear to be increasing,[12] there is a reason to suspect that un-inventoried sources may be significant. Alternately, it may be that regional emissions have declined but concentrations in the environment are significantly effected by releases from elsewhere in North America. Modeling of emissions and concentrations on a regional and continental scale is needed to better characterize the influence of regional versus continental emissions.

Table 6: Causes for change in emissions of benzo(a)pyrene in the Great Lakes region for the period 1990 - 2006

Category	1990 Order of Magnitude	Change	Explanation
Mobile sources	10^4 pounds	Decrease by 30-50%	A gradual increase in vehicle miles traveled (VMT) has been offset by improved controls on automotive and diesel engine emissions. A U.S. national study using U.S. EPA's MOBILE6 software has estimated a decrease in mobile source benzo(a)pyrene emissions of 50% from the period 1990-2002, despite a 30% decrease in VMT during this period.[49] It is reasonable to assume these changes are representative of the Great Lakes states and of Canada.
Metal production	10^5 pounds	Decrease by at least 90%	EPA estimates that emissions from coke ovens decreased by 94% based on the 1993 MACT rule for this source. This estimate does not account for the closing of 1/3 of the ovens operating when this rule was enacted, which would result in even greater reductions.[50] EPA estimates POM (including benzo(a)pyrene) emissions will be reduced from 50 to 90% a result of the Primary Aluminum NESHAP.[51]
Petroleum Refining	10^5 pounds	Decrease by at least 99%	The 1995 MACT rule for petroleum refineries required controls on FCCU emissions. FIRE shows a 10^4 difference between the controlled and uncontrolled emissions from these sources.[52]
Residential Wood Combustion	10^4 pounds	Uncertain	National wood consumption decreased by about 30% over this period.[53] Certified woodstoves have been gradually phased in, although they currently represent only a small (<10%) portion of the overall woodstove population. There is contradicting information regarding the impact of certified stoves on benzo(a)pyrene, with some sources suggesting they greatly decrease emissions and others suggesting they result in an increase.[30] Finally, outdoor wood boilers have been gaining in popularity within the region in recent years and are likely to emit substantially higher amounts of toxic compounds than other wood burning devices.[31]
Open Burning	10^4 pounds	Negligible change	There is no expectation of a substantial change in emissions from forest fires, burning of yard waste, or burning of household waste during this period.
Other Sources	Uncertain	Uncertain	It is difficult to estimate the 1990 or present-day benzo(a)pyrene emissions for several potentially important source categories, including agricultural burning, use of creosote as a wood preservative, coal-tar sealcoat (for asphalt surfaces), structural fires and tire fires. The Rubber Manufacturer's Association estimates a decrease of more than 80% in the amount of scrap tires stockpiled in the U.S. since 1990.[44]

Recommendations for Future Work

Compared to the original 2002 benzo(a)pyrene emissions data, that of previous years within the regional inventory project, and that available elsewhere, the revised 2002 benzo(a)pyrene emissions information presented here for the Great Lakes region is a significant improvement. For many source categories, errors were corrected, previously omitted sources were included, and consistency among jurisdictions was significantly improved. While the overall estimate changed by a significant 30% based on this reassessment, the changes within specific categories were even more substantial. The inventory information here represents the most reliable source to date on benzo(a)pyrene air emissions within the Great Lakes region.

While the resulting set of emissions information is a considerable improvement in terms of quality and consistency, there are still several areas where improvements in data quality and consistency can be made. Future inventory production efforts should focus on maintaining the improvements made here in future datasets, continuing to improve consistency in estimation methodology and reference data among jurisdictions and improvement or inclusion of estimation methodologies and/or emission factors for additional source types. Such improvements in the inventory quality require better communication among inventory preparers, policy developers and the scientific community.

To verify the results of the emissions inventory, comparison of the major source categories identified in this report with receptor modeling results is needed. Multi-medial models can be developed and employed to determine the fate of benzo(a)pyrene releases within the Great Lakes environment and the relative influence of sources beyond the region. To better understand the human and environmental health risks posed by benzo(a)pyrene in the Great Lakes region, the emissions data presented here can be employed in multi-media exposure and risk assessments. Combined with an understanding of the impacts of benzo(a)pyrene emissions, this updated inventory can support an assessment of whether further emission reductions are needed to protect human and wildlife health. If such reductions are deemed important, this inventory data can provide an important tool for identifying important sources and help assess the effectiveness of certain emission reduction strategies.

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Appendix A: Detailed Summary of Revised 2002 Benzo(a)Pyrene Inventory

Table 7: Emissions from fireplaces and woodstoves in the revised 2002 inventory

Category	Residential Woodstoves and Fireplaces	2002 benzo(a)pyrene emissions				16,720 lbs		Percent of regional emissions			28.3%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
2104008000	Total woodstoves and fireplaces		1525				1483		436.1		3916
2104008001	Fireplaces - general			343.2	510.0	1415		275.4	141.3	519.7	3063
2104008002	Fireplaces- catalytic non EPA certified	481.3			226.4			202.0			909.7
2104008003	Fireplaces- non Catalytic EPA certified	29.10			27.91			44.65			101.7
2104008004	Fireplaces- catalytic EPA certified	9.946			0.4595			30.69			41.09
2104008010	Woodstoves - general	491.1		1150	1099					1349	4089
2104008030	Catalytic woodstoves - general	25.15			32.67			81.0	262.2	23.02	749.1
2104008050	Non-catalytic woodstoves - general	11.98			106.9			103.6	347.6	662.7	1664
2104008051	Non-catalytic woodstoves - conventional							3392	1367		6454
2104008052	Non-catalytic woodstoves – low emitting					943.4					943.4
2104008070	Wood burning equipment - outdoor					124.1					124.1
	Total	1049	1525	1493	2003	2483	1483	4129	2554	2554	16,720

Table 8: Emissions from metal production the revised 2002 inventory

Category	Metal Production	2002 benzo(a)pyrene emissions				19,430 lbs		Percent of regional emissions			32.9%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
30300101	Aluminum ore – reduction cell (prebaked)		1415			2475					3890
30300102	Aluminum ore – reduction cell (Soderberg)					2227					2227
30300302	By-product coke manufacturing – oven charging	1447	3.3	2350			893.1				4694
30300303	By-product coke manufacturing – oven pushing	97.28	24.92								122.2
30300304	By-product coke manufacturing – quenching	84.56	136.4				141.8				362.8
30300308	By-product coke manufacturing – oven/door leaks	180.0	164.1	130.5			49.61				524.3
30300314	By-product coke manufacturing – topside leaks		4.1								4.1
30300399	By-product coke manufacturing – not classified		0.15			454.6	22.93				477.6
30300702	Ferroalloy – electric Arc Furnace	845.5				200					1045
30300819	Iron production – sinter process	0.006356								0.18	0.1864
30300999	Steel manufacturing – not classified							6083			6083
	Total	2655	1748	2480	0	5356	1107	6083	0	0.18	19,430

Table 9: Emissions from open burning sources in the revised 2002 inventory

Category	Open Burning Sources	2002 benzo(a)pyrene emissions				7848 lbs		Percent of regional emissions			13.3%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
2610030000	Household waste burning	42.76		1574	953.0	1510			1770	488.3	6339
2810001000	Wildfires	2.330		39.81	157.3	52.18		656.3		65.31	973.2
2810015000	Prescribed burning – forest mgmt.	12.14	9.475	66.79	156.4			209.6		77.74	532.2
2810020000	Prescribed burning - rangeland				0.4836						0.4836
	Total	57.23	9.478	1681	1267	1562	0	865.9	1770	631.3	7848

Table 10: Emissions from petroleum refining in the revised 2002 inventory

Category	Petroleum Refining	2002 benzo(a)pyrene emissions				6615 lbs		Percent of regional emissions			11.2%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
3060010X	Petroleum industry: gas-fired process heaters	18.10	0.1301	3.035							21.27
30600201	Fluidized catalytic cracking unit	0.687	11.5	4501			85.98		1920		6521
30609903	Petroleum industry – natural gas incinerators		$1x10^{-8}$								$1x10^{-8}$
30699999	Petroleum industry – not classified				39.15			33.69			72.84
	Total	18.79	11.63	4504	39.15	0	85.98	33.69	01920	0	6615

Table 11: Emissions from on-road vehicles in the revised 2002 inventory

Category	On-road Vehicles	2002 benzo(a)pyrene emissions				3409 lbs		Percent of regional emissions			5.8%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
2201001XXX	Light-duty gasoline vehicles	84.88	80.87	96.75	32.58	106.0	125.9	77.64	72.29	62.54	739.4
2201020XXX	Light-duty gasoline trucks – class I	69.20	39.32	78.52	23.63	128.5	62.75	46.24	58.13	30.39	536.6
2201040XXX	Light-duty gasoline trucks – class II	30.41	20.72	40.20	11.59	74.90	26.17	34.40	31.70	10.32	280.4
2201070XXX	Heavy-duty gasoline vehicles	63.89	37.56	68.72	34.41	680.7	56.75	19.87	54.78	29.48	1046
2201080XXX	Motorcycles	3.007	1.199	3.572	1.246	2.171	1.766	0.8536	2.725	0.9423	17.48
2230001XXX	Light-duty diesel vehicles	1.866	1.860	4.655	0.4272	4.585	2.409	5.414	1.422	1.080	23.72
2230060XXX	Light-duty diesel trucks	2.939	1.689	4.132	1.819	28.07	2.504	8.878	3.323	1.213	54.57
223007XXXX	Heavy-duty diesel vehicles	98.15	66.98	94.18	47.35	137.8	95.70	40.14	78.82	51.45	710.5
	Total	354.3	250.2	390.7	153.0	1162	373.9	233.4	303.2	187	3409

Table 12: Emissions from internal combustion engines in the revised 2002 inventory

Category	Internal Combustion Engines	2002 benzo(a)pyrene emissions				1006 lbs		Percent of regional emissions			1.7%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
20100XXX	Internal combustion engines - electric generation (various fuels)	287.8	0.003164	0.01962	0.0719	25.50	0.07608				313.4
20200XXX	Internal combustion engines - industrial use (various fuels)	52.92	0.01789	195.3	0.2087	443.8	0.02487			0.000008	692.3
20300XXX	Internal combustion engines - commercial/institutional use (various fuels)	0.07899	0.000698	0.009869	0.04184	0.002542	0.00107				0.1350
	Total	340.8	0.02176	195.3	0.3224	469.3	0.1020	0	0	0.000008	1006

Table 13: Emissions from off-highway 2-stroke gasoline engines in the revised 2002 inventory

Category	Off-highway 2-stroke Gasoline Engines	2002 benzo(a)pyrene emissions				1279 lbs		Percent of regional emissions			2.2%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
22600010XX	Off-highway 2-stroke gasoline engines - recreational	25.22	14.75	90.21	48.91	71.74	29.31	18.51	31.75	54.48	384.9
22600020XX	Off-highway 2-stroke gasoline engines - construction and mining	4.034	3.111	6.508	2.111	5.254	6.722	3.785	3.666	2.868	38.06
22600030XX	Off-highway 2-stroke gasoline engines - industrial	0.04476	0.02996	0.04148	0.01932	0.04227	0.04856	0.09686	0.04151	0.02662	0.3913
22600040XX	Off-highway 2-stroke gasoline engines - lawn and garden	46.39	23.38	37.80	14.13	48.58	51.48	21.70	44.30	17.68	305.4
22600050XX	Off-highway 2-stroke gasoline engines - agricultural	0.1976	0.1070	0.05786	0.1645	0.03718	0.08849	0.02552	0.03487	0.07994	0.7929
22600060XX	Off-highway 2-stroke gasoline engines - commercial	3.396	1.320	2.192	1.470	6.018	2.732	4.474	2.761	1.316	25.68
2260007005	Off-highway 2-stroke gasoline engines - agricultural	0.0040	0.0543	0.8739	0.3485	0.2858	0.1870	2.108	0.4775	0.8097	5.148
228200501X	Recreational boats: 2-stroke gasoline	53.78	30.95	114.7	75.71		52.92	47.53	45.91	97.11	518.6
	Total	133.1	73.70	235.4	142.9	132.0	143.5	98.23	128.9	174.4	1279

Table 14: Emissions from non-point, stationary source fuel combustion in the revised 2002 inventory

Category	Non-point, Stationary Source Fuel Combustion	2002 benzo(a)pyrene emissions				36.97 lbs		Percent of regional emissions			<0.1%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
210100XXXX	Electric utility fuel combustion					0.01799					0.1799
21020XXXXX	Industrial fuel combustion (various fuels)			0.1318	3.063	0.06717	0.1848				3.447
21030XXXXX	Commercial/institutional fuel combustion (various fuels)		0.2055	0.2526	2.032	11.32	0.1753			0.005204	13.99
210400XXXX	Residential Fuel Combustion (non-wood)	15.84	0.3043	1.771	0.1786	0.4512	0.4206	0.3684		0.1801	19.51
	Total	15.84	0.5099	2.155	5.274	11.86	0.7807	0.3684		0.1854	36.97

Table 15: Emissions from off-road 4-stroke gasoline engines in the revised 2002 inventory

Category	Off-highway 4-stroke Gasoline Engines	2002 benzo(a)pyrene emissions				353.7 lbs		Percent of regional emissions			0.6%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
22650010XX	Off-highway 4-stroke gasoline engines - recreational	4.265	3.153	7.905	4.084	4.402	6.904	3.757	7.168	4.161	45.80
22650020XX	Off-highway 4-stroke gasoline engines - construction and mining	1.064	1.101	2.403	0.5567	2.588	2.447	0.996	0.9670	0.9472	13.07
22650030XX	Off-highway 4-stroke gasoline engines - industrial	1.514	0.9833	1.443	0.6540	2.655	1.642	1.008	1.405	0.8995	12.20
22650040XX	Off-highway 4-stroke gasoline engines - lawn and garden	23.09	11.43	19.62	7.822	38.77	25.40	11.99	23.41	9.573	171.1
22650050XX	Off-highway 4-stroke gasoline engines - agricultural	1.125	0.6082	0.3304	0.9361	0.3553	0.5036	0.288	0.1986	0.455	4.800
22650060XX	Off-highway 4-stroke gasoline engines - commercial	10.85	4.292	7.006	4.700	29.02	8.731	13.94	8.824	4.208	91.58
22650070XX	Off-highway 4-stroke gasoline engines - logging	0.00028	0.004705	0.06246	0.02514	0.04098	0.0135	0.016	0.03446	0.05841	0.2559
2265008005	Off-highway 4-stroke gasoline engines - airport ground support	0.03092	0.007723	0.0135	0.3532	0.07237	0.00834	0.096	0.1681	0.00256	0.7527
2265010010	Off-highway 4-stroke gasoline engines - oil field equipment	0.04354	0.0024	0.01366	0.00212	0.1509	0.1503		0.04333		0.4063
2282010005	Recreational boats: 4-stroke gasoline	1.250	1.564	2.666	1.760		2.222	1.202	1.085	1.957	13.71
	Total	43.23	23.15	41.46	20.89	78.05	48.02	33.29	43.303	22.26	353.7

Table 16: Emissions from off-highway diesel engines in the revised 2002 inventory

Category	Off-highway Diesel Engines	2002 benzo(a)pyrene emissions				71.26 lbs		Percent of regional emissions			0.1%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
2270001060	Off-highway diesel engines - recreational carts	0.005373	0.004416	0.00946	0.008809	0.0977	0.009401	0.00896	0.01190	0.00913	0.1560
22700020XX	Off-highway diesel engines - construction and mining	3.055	2.566	4.242	3.027	12.78	4.265	3.764	2.724	2.755	36.42
22700030XX	Off-highway diesel engines - industrial	0.4207	0.2586	0.3784	0.1765	1.967	0.4367	0.3439	0.4016	0.2282	4.383
22700040XX	Off-highway diesel engines - lawn and garden	0.1005	0.05181	0.07568	0.02642	0.7360	0.1129	0.02272	0.08808	0.03430	1.214
22700050XX	Off-highway diesel engines - agricultural	3.472	1.594	1.039	2.889	2.050	1.554	5.242	0.6126	1.413	18.45
22700060XX	Off-highway diesel engines - commercial	0.3446	0.1426	0.2183	0.1492	2.991	0.2772	0.2741	0.2802	0.1336	4.677
22700070XX	Off-highway diesel engines - logging	0.0001155	0.002138	0.02896	0.01164	0.04004	0.006267	0.0470	0.01594	0.02707	0.1521
2270008005	Off-highway diesel engines - airport ground support	0.03996	0.009878	0.01748	0.008088	0.1750	0.01083	0.1283	0.02164	0.003307	0.4112
2270009010	Off-highway diesel engines - underground mining	0.008429	0.0082				0.01067		0.06707		0.09437
22820200XX	Recreational boats: diesel	0.02059	0.02473	0.5288	0.02899		0.0430	0.007027	0.01787	0.0299	0.6710
	Total	7.467	4.662	6.538	6.325	20.84	6.726	9.838	4.241	4.633	71.26

Table 17: Emissions from other non-road vehicles in the revised 2002 inventory

Category	Other Non-road Vehicles	2002 benzo(a)pyrene emissions				429.6 lbs		Percent of regional emissions			0.7%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
22750XXXXX	Aircraft	1.819	21.29	62.49	25.98	0.000048	67.56	0.8993	57.57	10.70	248.3
228000XXXX	Commercial marine vessels	26.26	20.13	30.27	1.777		36.97	4.405	32.22	0.007548	152.0
228500XXXX	Railroads	6.868	3.097	1.138	4.204		4.346	3.901	2.566	3.117	29.24
	Total	34.95	44.51	93.90	31.96	0.000048	108.9	9.206	92.36	13.82	429.6

Table 18: Emissions from external combustion boilers in the revised 2002 inventory

Category	External Combustion Boilers	2002 benzo(a)pyrene emissions				99.40 lbs		Percent of regional emissions			0.2%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
1010XXXX	External combustion boilers - electric generation (various fuels)	0.2512	1.958	1.220	7.192	0.5149	2.091				13.23
1020XXXX	External combustion boilers - industrial use (various fuels)	22.29	11.64	1.579	37.83	4.986	0.1033			0.2412	78.67
1030XXXX	External combustion boilers - commercial/institutional use (various fuels)	0.4569	0.041167	0.05349	6.744	0.1379	0.02583			0.000596	7.460
1050XXXX	External combustion boilers - space heating (various fuels)	0.006342	0.001738	0.014		0.02287					0.04495
	Total	23.00	13.64	2.866	51.77	5.661	2.220			0.2418	99.40

Table 19: Emissions from other industrial processes in the revised 2002 inventory

Category	Other Industrial Processes	2002 benzo(a)pyrene emissions				1114 lbs		Percent of regional emissions			1.9%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
3019XXXX	Chemical manufacturing	0.001220	0.000113			0.000001		4.851			4.852
3029XXXX	Food and agriculture	0.003706	0.000241			0.000006					0.003952
3039XXXX	Primary metal production	0.6757	0.001913			0.000021		0.2426			0.9202
304XXXXX	Secondary metal production	0.2017	0.1629	0.1218		2.002				3.320	5.808
305XXXXX	Mineral Products	0.4759	8.410	1.397	0.8797	0.5477		0.1323		0.00126 3	11.84
307XXXXX	Pulp, paper and wood products	0.0004191	20		0.7498	0.000094		15.88		4.17	40.80
308900XX	Rubber and plastic products	0.0002780	2.68×10^{-6}		9.64×10^{-7}						0.000282
309XXXXX	Fabricated metal products	0.005133	0.000153			0.000008					0.005294
31299999	Machinery, miscellaneous		0.000006		0.000019						0.000025
31390003	Electrical equipment - natural gas process heaters	0.0000299	1.8×10^{-6}								0.000032
314XXXXX	Transportation equipment		1.87E-05								1.87E-05
31150210X and 2810060100	Crematories	89.95		0.000838	0.000334						89.95
39000XXX	In-process fuel use (390)		0.002758			0.08478				12.55	12.64
3999XXXX	Manufacturing, miscellaneous	0.001263				0.000395		24.04			24.04
40XXXXXX	Petroleum and solvent evap.	0.005128	0.000177			0.000086					0.00539
50XXXXXX	Waste disposal - incineration	287.5	0.05573	43.98	7.423	582.7	0.33		1.2	0.0119	923.2
&2620030000	Waste disposal: non-incineration	0.001012	0.000478	0	0.0002486	0.000638	0	0.3749	0	0	0.3773
	Unspecified				7.93×10^{-7}						7.93E-07
	Total	378.8	28.63	45.50	9.053	585.4	0.33	45.52	1.2	20.05	1114

Table 20: Emissions from other area sources in the revised 2002 inventory

Category	Other Area Sources	2002 benzo(a)pyrene emissions				681.2 lbs		Percent of regional emissions			1.2%
SCC	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total
23020XXXXX	Commercial cooking	44.71		35.99	18.80	169.0			43.30	21.25	333.1
2830000000	Accidental releases								348.1		348.1
	Total	44.71	0	35.99	18.80	169.0	0	0	391.4	21.25	681.2

Table 21: Revised 2002 benzo(a)pyrene emissions (lbs) by standard industrial classification*

SIC Code	Description	IL	IN	MI	MN	NY	OH	ON	PA	WI	Total	Percent of Total
3312	Blast furnaces and steel mills	1810	276.4	2480	0.000959	0.04584	1108	6083			11760	18.96%
3334	Primary aluminum		1415			5156	0.000774				6571	10.60%
2911	Petroleum refining	55.75	23	4506	39.15		85.99	33.69	0.00048		4743	7.65%
3321	Gray and ductile iron foundries	834.4	0.1631	0.1227	0.000473	0.001123	0.001434			0.00027	834.7	1.35%
4931	Electric and other services combined	146.2		0.04090	0.01023	417.7	0.5127				564.5	0.91%
4953	Refuse systems	8.870	0.00034	40.61	7.424	369.4	0.0033		3×10^{-7}		426.3	0.69%
4939	Combination utilities				5.98×10^{-6}	213.9					213.9	0.34%
4911	Electric services	105.6	1.959	59.97	0.7982	39.36	1.641			0.00071	209.4	0.34%
7261	Funeral service and crematories	200.9		4.0×10^{-6}	0.000334						200.9	0.32%
3339	Primary nonferrous metals	0.000233		0.000435		200.0		0.2426			200.2	0.32%
4922	Natural gas transmission	27.89	0.01396	112.4	0.01240	11.66	0.000016				151.9	0.24%
4925	Gas production and/or distribution	0.003497	56.42	0.00369	2.81×10^{-6}						56.43	0.09%
8062	Medical & surgical hospitals	55.46	0.000361	0.002396	0.07758	0.5699				8.0×10^{-7}	56.11	0.09%
8221	Colleges and universities	46.32	0.01370	3.314	0.04404	0.07132	0.3370				50.10	0.08%
5812	Eating places	44.71									44.71	0.07%
2611	Pulp mills			0.000886	9.652	1.412	0.000312	13.10		16.94	41.10	0.07%
3241	Cement, hydraulic	0.02108	8.411	1.345		0.5646		24.17			34.51	0.06%
4581	Airports, flying fields, & services	2.495	0.00004	0.000312	26.36						28.86	0.05%
6553	Cemetery subdividers and developers	24.59									24.59	0.04%
2491	Wood preserving	0.000217	20.00	0.000786				0.00441			20.01	0.03%
2621	Paper mills	3.121	0.000032	0.06739	13.67	0.01138	0.000433	2.778			19.65	0.03%
2493	Reconstituted wood products	0.000043		0.01374	18.41	0.001904					18.42	0.03%
Var.	Others, individually less than 0.3% (474 categories)	103.4	0.5095	24.64	15.23	4.808	0.07599	5.225	0.0	3.534	157.4	0.25%
	Total	**3470**	**1801.9**	**7228**	**130.8**	**6416**	**1196**	**6162**	**1920**	**20.47**	**26426**	**42.63%**

* 30,390 lbs of emissions (49.7%) within the dataset are not classified by SIC. Mobile sources and many area sources can not be attributed to and industrial category.

Appendix B: Corrections and Modifications by Jurisdiction

Each state or province used the assessment results to identify potential updates to their benzo(a)pyrene emissions data and made the appropriate corrections where possible. The results of each state's assessment and revisions are described below:

Illinois

Many of the point sources identified within Illinois as having available emission factors but lacking emissions data were determined to be situations in which specific emission units at sources existed but were not operating. In these cases, the emission data has been changed from a blank field to zero.

Several years ago, IEPA received comments on benzo(a)pyrene emissions estimates being too large for fluid catalytic cracking units (FCCUs) at refineries and documentation of stack-test results was provided as evidence of considerably lower emissions.[54] Web FIRE has two b(a)p emission factors for this source type. One is uncontrolled and is 0.48 lb b(a)p/1000 barrels fresh feed. The other has a control type "incinerator" and is 0.0000311 lb b(a)p/1000 barrels. The letter sent to Illinois suggests an emission factor of 3.4e-7 lb b(a)p/1000 lb coke burned. This equates to about 7.5 e-5 lb b(a)p/1000 barrels, or about double the controlled emission factor in FIRE. In subsequent inventories, emission values for these sources were not provided to reflect the smaller emission rate. For this assessment, benzo(a)pyrene emissions for Illinois' FCCUs were estimated using the emission factor in a 1999 letter from Equilon Enterprises to the U.S. EPA.[54] The resulting state-wide total emissions from FCCUs are estimated to be 0.687 pounds.

In its initial inventory, IEPA also included many emission units that had benzo(a)pyrene emissions but for which there was no identified emission factor. These processes were determined to be similar to other processes which did have emission factors for benzo(a)pyrene and the emission estimates were retained. These processes are:

Oil combustion: 10500105, 10500205, 20300102, 30390004, 30490031
Natural gas combustion: 20300202, 30490031, 40290013
Process gas combustion: 30490034
Incineration: 50100505, 50200101, 50200504, 50300101
Asphaltic concrete: 30500201, 30500208

Area source emission updates were exclusively for residential fuel combustion emissions (coal, natural gas and fuel oil). These source categories did not have benzo(a)pyrene emissions calculated for them in the original inventory as an oversight, but have been included in this update. The total state-wide estimate for benzo(a)pyrene from these sources is 15.84 pounds.

Indiana

The primary revisions to the inventory were to point source estimates at primary aluminum and petroleum refinery plants. A voluntarily reported total for a tar products manufacturer was also identified, and subsequently revised by the source, as part of this assessment.

Benzo(a)pyrene estimates for primary aluminum potlines were revised using information from EPA's Locating and Estimating (L&E) document for air emissions of polycyclic organic matter (POM).[55] Estimates were recalculated using the average factor from Table 4.4.1-10 of this document. Emissions calculated for FCC Units at petroleum refineries were also investigated. The benzo(a)pyrene factor obtained from Table 4.5-1 of the L&E document was used to recalculate these estimates.[55]

A number of point source processes were flagged as lacking estimates where applicable FIRE emission factors were available. Estimates were made for most of these processes using similar factors and added to the inventory. A few estimates were not made due to either a lack of activity data or situations where controlled FIRE emission factors did not match the control configurations reported by the sources.

Estimates initially made for steel mill process gas combustion were removed because the mixture of the process gas is unknown, and there are no emission factors for the reported SCC within FIRE. It was also noted that a few estimates were made using revoked FIRE emission factors. These estimates have also been removed.

For area sources, the assessment identified a lack of emission estimates for residential and commercial fuel oil consumption. Estimates have been calculated for each county and included in the inventory. No other changes were made to area or mobile source benzo(a)pyrene estimates..

Michigan

Generally, the reasons for emissions that were flagged as missing for point sources were determined to be either very minute emission factors, zero throughput, or lack of emission factors. Those that were excluded due to their small size represent a total of 0.611 pounds and include some categories of distillate oil, natural gas and wood combustion. Point sources that were flagged as lacking emissions but having emission factors were primarily those for which the factor is in the "FIRE+" database. Source types for which this applies include some types of coal combustion, distillate oil combustion, natural gas combustion, in-process fuel use and coating ovens.

For area sources, the absence of benzo(a)pyrene emissions was generally due to lack of factors available, alternate SCCs being used for reporting, or (in the case of commercial and industrial area source fuel combustion) estimates of HAPs not being made due to staff time constraints. Among the six commercial and industrial area source fuel combustion SCCs omitted (2103002000, 2102002000, 2103006000, 2102006000, 2103004000, and 2102004000), activity data was available within Michigan for four. The emissions from these categories were added to the dataset and represent a total state-wide emission of about 0.4 pounds.

Several other area source categories were either adjusted or added. Human cremation was added, using an emission factor from the California Air Resources Board. The resulting state-wide emission is less than a thousandth of a pound. Using an emission factor published in the recent MARAMA report,[30] emissions for standard fireplaces (2104008001) were estimated, adding 343 pounds of benzo(a)pyrene emission to the residential wood combustion category. Several categories of commercial cooking were added, with a state-wide estimate of about 36 pounds of benzo(a)pyrene. Open burning of municipal solid waste was the most significant category added, totaling 1574

pounds of emissions. Other open burning sources added include wildfires and prescribed burning, with a total statewide emission of slightly more than a hundred pounds between the two.

Minnesota

The data assessment revealed that MPCA had not originally estimated benzo(a)pyrene emissions for any mobile sources. After further analysis, it was revealed that the reason for this is that an EPA document[56] from which the speciation factors were obtained listed benzo(a)pyrene, but gave the CAS number for benzo(*e*)pyrene. Representatives of the MPCA checked with the EPA to ensure that it was benzo(a)pyrene that was intended and corrected their data so that these mobile source emissions were classified as benzo(a)pyrene. Corrections resulted in additional 153 pounds of B(a)P emissions from 144 SCCs for a variety of vehicle types.

For forest wildfires and prescribed burning area sources, MPCA adopted EPA's final NEI estimates instead of the draft NEI estimates used in the initial inventory. As a result, 1,260 pounds of estimated benzo(a)pyrene emissions were removed from the database and one SCC was added. Benzo(a)pyrene emissions from human cremation were brought to Minnesota's attention during the regional assessment. MPCA used primarily factors from the NEI guidance documents which didn't have emissions for benzo(a)pyrene. However, an emission factor was found in FIRE for a point source crematory stack (SCC 31502101). This emission factor was obtained from emission testing of a propane fired incinerator at a crematorium in 1992 and included the use of wrapping material (4 pounds of cardboard and 2 pounds of wood). The inventory Steering Committee decided that the emission factor was appropriate to use. This action added a relatively insignificant 0.000334 pounds of benzo(a)pyrene emissions for Minnesota.

The final benzo(a)pyrene emission estimate for Minnesota is 3748 pounds in 2002. The present assessment reduced this number by about 100 pounds from the original estimate, while increasing the number of SCCs inventories from 270 to 416.

New York

New York had only one point source showing emissions for which an emission factor is not available (electrode manufacturing). It was determined that emissions for this source were based on source-specific stack testing. There were a large number of point sources identified in the assessment as lacking emissions, despite the availability of emission factors. These emissions were calculated and added to the repository. In all, 751 additional point source estimates were uploaded, totaling more than 6000 pounds of benzo(a)pyrene emissions.

The original estimate of residential wood combustion emissions for New York totaled over 20,000 pounds, which accounted for more than 20% of the original inventory and was 5-20 times higher than the estimates from all other jurisdictions for this category of sources. The reason for this large emission estimates appears to have been a significantly larger estimate from the U.S. Department of Energy of wood fuel used in New York compared to other states in the region. In 2006, MARAMA published a report including revised residential wood combustion methodologies and activity data for New York. Much of this was adopted by NYSDEC for purposed of this report, resulting in an 88% decrease in their estimate for this source category.

Ohio

The assessment showed that nonroad engine emission estimates in Ohio were unusually high compared to other states. In many cases, they were 1-2 orders of magnitude higher than all other states. These estimations were re-run and resulting in significant decreases in the nonroad emission estimates of benzo(a)pyrene for Ohio. In total, non-road emissions from Ohio were decreased by about 3300 pounds, or 92% of the original estimate.

In the initial data summary, Ohio showed very high emissions from several fluidized catalytic cracking units (FCCUs, SCC 30600201). Upon further examination, it was determined that these high emissions were due to an error in the emission estimation program in which a control device was not being properly assigned. For one facility, a controlled emission factor was present and was applied. For another, there was documentation of a device with 99.99% control efficiency and this factor was applied to the original, uncontrolled emission estimate. As a result of these changes, Ohio's emissions for FCCUs decreased from nearly 14,000 pounds to about 50 pounds.

OEPA did not calculate emissions for open burning of household waste due to the lack of what they saw as a reasonable methodology. Emission estimates remain absent for Ohio for several other categories for similar reasons. Because of the changes noted above, the estimate of benzo(a)pyrene emissions for Ohio decreased by more than 17,000 pounds as part of this assessment.

Ontario

The assessment showed that several Ontario point sources have potential to emit benzo(a)pyrene in view of the availability of emission estimation methodologies for these type of industries. This may be the case where facilities did not meet Ontario requirement to report benzo(a)pyrene. Ontario requires facilities to report benzo(a)pyrene (and 16 other individual PAH species) if the combined total emission of these 17 PAH species is equal to or greater than 50 kg.

For residential LPG combustion, there was no FIRE emission factor available. OMOE and several states (MI, WI, OH, and MN) used emission factor from the RAPIDS methodology for residential fuel combustion. This emission factor was derived from FIRE emission factor of natural gas (SCC 10300603).

In addressing to the lack of benzo(a)pyrene emissions from area source crematory category which had SCC 2810060100 and had no emission factors associated with, Ontario re-estimated total emission using alternative point source SCC 31502101. However, the resulted emission was insignificant (0.004 lb) and was not included in Ontario's inventory.

Forest wildfire is categorized as open source in Ontario. It was considered separately and not included in OMOE's anthropogenic inventory. Occurrence and magnitude of wildfires were varied significantly from year to year (6737 hectares in 2000, 10,731 in 2001 and 172,075 hectares in 2002). For the purpose of this benzo(a)pyrene assessment study, OMOE added emission from forest wildfires to the inventory. Benzo(a)pyrene emissions from forest wildfires were estimated to be 656 pounds and accounted for 6% of total benzo(a)pyrene emissions in Ontario of 11,542 pounds.

Pennsylvania

In the original inventory, Pennsylvania did not have any benzo(a)pyrene emissions for residential wood combustion, the largest overall category of sources. A discussed above for New York, the residential wood combustion inventory prepared for MARAMA was adopted for Pennsylvania in this report at well, resulting in a state-wide addition of 2554 pounds of benzo(a)pyrene emissions.

The emissions of 348 pounds from "accidental releases" (SCC 2830000000) were investigated and determined to be from an August 2002 scrap tire fire in Edwardsville, Pennsylvania in which approximately 150,000 tires burned.

Wisconsin

Area Sources: The categories of residential coal, wood and natural gas combustion were identified as having activity information, but no emissions or emissions equal to zero. Upon reviewing the categories with zero emissions, it was discovered that a number of emissions factors, less than 0.000001 in magnitude, were set to zero during the data conversion process. Correcting to these emission factors resulted in 0.00007 pounds of benzo(a)pyrene emissions. Emission estimates were revised for residential Natural Gas Combustion using an emission factor ($1.2x10^{-6}$ lb/mmcf) from Minnesota's methodology for Residential Fuel Combustion. The total emissions resulting from this update were 0.15 pounds of benzo(a)pyrene.

Conventional fireplaces were not estimated in the original regional inventory due to the lack of emission factors availability. It was then decided to adopt the emission factor used in the MARAMA report for conventional fireplaces (2104008001). Accounting for the conventional fireplace emissions resulted in an additional 520 pounds of benzo(a)pyrene to the residential wood combustion category.

Two other area source categories not included in the original 2002 regional inventory were Human Cremation and Commercial Cooking. For the cremation category, emission estimation of benzo(a)pyrene was conducted using an emission factor from the California Air Resources Board, and resulted in only 0.0005 pounds. Emissions from commercial cooking amounted to 21.24 pounds.

Point Sources: A number combustion processes from point sources in the original 2002 inventory lacked benzo(a)pyrene emissions because their emissions were below the state's 12 pound reporting threshold. The throughput and estimated emissions from these point sources was added to the Stationary Source Fuel Combustion category. It is of note that Wisconsin's benzo(a)pyrene reporting threshold for 2005 has been lowered to 0.808 pounds. This could potentially result in a more complete inventory of point sources for the 2005 regional inventory.