Penobscot Nation Air Emissions Inventory Development

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ABSTRACT

In 2003, MACTEC prepared a Level 1 air emissions inventory for the Penobscot Nation in Maine. The Penobscot Nation has been the regional model air program for the New England tribes and, as such, wanted to develop a model emissions inventory that can be used as a format for all the New England Tribes. In addition, the 2002 air emissions inventory can serve as an air emissions baseline for future development and air quality management planning. Criteria and hazardous air pollutant (HAP) emissions were quantified for calendar year 2002 and included emissions from both stationary (point and area) and mobile sources. Stationary sources within the Penobscot Nation include primarily combustion sources and biogenic sources. Mobile sources include privately owned vehicles belonging to residents of the Penobscot lands as well as service trucks, buses, and automobiles that visit the Penobscot Nation. In addition, the Penobscot conduct timber cutting activities and recreational activities such as camping and hunting on various tracts of land. Emission estimates were developed for the timber cutting equipment, campfires, roadway dust, and vehicle fuel combustion. Additional emission sources that were considered include household product usage and activities such as bonfires and lawn maintenance. Emissions were calculated for criteria pollutants and for HAP using varying methodologies. This paper presents the methodologies used to estimate emissions from the various source categories.

INTRODUCTION

An air pollutant emission inventory was developed for the Penobscot Nation in Maine. This inventory addresses both stationary (point and area) sources and mobile sources. Under ideal circumstances, all stationary sources would be considered point sources for the purposes of developing emission inventories. In reality, however, only sources emitting more than a specified cutoff level (the level is determined by the attainment status of the region and specific pollutant) are considered point sources [1]. Using these constraints, there are no point sources throughout the Penobscot territories.

The Penobscot own 4,866 acres of land as part of the Penobscot Reservation and lay claim to an additional 60,743 acres held in trust by the federal government. Emission sources within the Penobscot Nation were characterized as being stationary area sources or mobile sources. Most stationary source pollution within the Penobscot Nation is emitted by combustion sources and biogenic sources. Mobile pollution sources include cars, trucks, and the equipment used for logging on Penobscot Nation trust lands.

PENOBSCOT NATION AIR EMISSIONS INVENTORY

Overview

The Penobscot Nation has been a Federally recognized Tribe since 1980. Additional information on the background of the Penobscot can be found on the Tribe's website at http://www.penobscotnation.org. The Penobscot Reservation consists of several islands located in Penobscot County, Maine, totaling almost 4,900 acres. Indian Island is the largest and only inhabited island on the Penobscot Reservation and has an area of approximately 4,000 acres. Indian Island is home to the Penobscot Nation administrative offices, an elementary school, a community center, a bingo facility, one commercial building that is used for a packaging operation, and approximately 200 residences.

The Penobscot Nation also holds 60,743 acres of trust lands that are distributed over three counties. The Federal Government holds title to trust lands for the benefit of the Penobscot Nation, a Federally recognized tribe. The Alder Stream Township, located in Franklin County, is the largest of these parcels at 20,545 acres. This site is used for timber cutting and there are 43 campsites on the tract that have been assigned to Tribe members for recreational use. Mattamiscontis is the second largest tract of trust land at 18,786 acres and is also used for timber cutting. Argyle, Matagamon, Grindstone, Williamsburg Township, and T.3, R.1 are tracts of land containing 4,690, 6,466, 5,464, 4,232, and 560 acres, respectively. There are 68 camping sites distributed over these six tracts. In addition, the Tribe owns 53,277 acres of fee lands. The Tribe conducts timber cutting and other economic activities on these fee lands [2]. The fee lands include 10 separate tracts, located in 3 counties, ranging in size from 2 acres to over 24,000 acres.

The Penobscot Nation wishes to grow and develop its economy without adversely impacting air quality in the region. To guide future air quality management efforts and decisions, an air emissions inventory is necessary to identify sources and quantities of emissions within the Penobscot Nation's lands. The primary focus of this inventory is the sources of emissions located on Indian Island. The stationary sources of pollutants on Indian Island include fuel combustion in heating units for residential and municipal buildings, a wastewater treatment plant, recreational bonfires, biogenic emissions, and emissions from fuel storage tanks. Mobile sources include light-duty cars and trucks owned by Indian Island residents or visitors to Indian Island and medium- or heavy-duty vehicles such as delivery trucks, garbage trucks, and tour buses serving the bingo facility on Indian Island.

An inventory was also developed for emissions originating from the Penobscot trust lands. Stationary sources include campfires and biogenic sources such as trees and vegetation. Mobile sources include cars and trucks used to reach the campsites and timber cutting equipment.

The remaining sections in this report present a description of the inventory of criteria and HAP emissions by source category. Separate discussions are presented for the stationary area and mobile source emissions from Indian Island and from the Penobscot Nation trust lands.

Emissions From Indian Island

Comfort Heating

The Penobscot Reservation consists of 4,866 acres of islands in the Penobscot River. Indian Island is the largest of these and the only inhabited island. Indian Island houses Penobscot tribal

buildings and over 500 Penobscot. Most Penobscot activities are centered on Indian Island, and a variety of stationary and mobile sources of air pollution are present on Indian Island.

Stationary sources of air pollutants on Indian Island include heating units, the wastewater treatment plant, fuel storage tanks, bonfires, and biogenic sources. Comfort heating accounts for most of the anthropogenic stationary source pollution on Indian Island. Although there is one manufacturing facility on the island, the Olamon Industries facility, there were no industrial pollutant emissions in 2002. In prior years, Olamon Industries manufactured cassette tapes using an injection molding process. In 2002, the facility was used only as a packaging operation and the only pollutants emitted resulted from the combustion of fossil fuels in heating units.

Most homes and buildings on the Island use No. 2 distillate heating oil as the primary fuel for comfort heating during the winter. Some tribal buildings use propane as either the primary or an emergency fuel source, and approximately 10 percent of the homes on the Island stock wood to supply fireplaces and to conduct outdoor burning. Fuel use across the Island was quantified for each fuel type, and pollutant emissions were calculated using the AP-42 emission factors published by the US EPA [3, 4, 5].

Fuel usage amounts for the nonresidential buildings were obtained from the fuel suppliers by the Penobscot Air Programs Office. Kerosene and heating oil use in public buildings was provided by RH Foster Fuels and propane use was provided by Amerigas [6, 7]. Fuel use for 48 residential homes was also provided by the Penobscot Air Programs Office [8].

Wood is not used as a primary source of heat, but fireplaces are used by some residents as a supplemental heat source. Wood is also used for ceremonial or recreational outdoor burning in bonfires by some Island residents. Annual wood use was estimated from the number of wood piles and from personal communication with Island residents [9]. Approximately 10 percent of the 200 homes on Indian Island had woodpiles, and on average each woodpile contained three cords of wood. It was assumed that half of the wood was burned in fireplaces and that half was burned in bonfires. Using a weight of 1.2 tons/cord of wood [10], approximately 36 tons of wood were burned in fireplaces each year.

Pollutant emissions from heating units were determined by multiplying the annual fuel consumption by the appropriate AP-42 emission factor [3, 4, 5]. Emission factors for heating oil and propane differ depending on the size of the combustion unit, as measured by a unit's heating capacity. It was assumed that residences used heating units rated at less than 0.3 MMBtu/hr while tribal buildings used units with ratings between 0.3 and 10 MMBtu/hr. In AP-42, no HAP emission factors were reported for propane (LPG) and polycyclic organic matter (POM) was the only HAP reported for fireplace wood burning [11].

Wastewater Treatment

There is a wastewater treatment plant on Indian Island. All wastewater entering the plant is domestic. The plant consists of an oxidation ditch system followed by circular clarifiers and a chlorine contact tank and has an average flow of 0.0704 million gallons per day [12]. Pollutant emissions from the wastewater treatment plant were estimated from emission factors published by the EPA [13].

Fuel Storage

Heating oil and kerosene burned for fuel are stored in tanks on Indian Island. Pollutants are emitted into the surrounding atmosphere when the tanks are refilled (also known as working losses) and

through breathing loss. In above-ground storage tanks, breathing losses are a more significant source of pollutant emissions than working losses. Emissions from these tanks were modeled using an EPA computer program.

Heating oil is dispensed to homes on Indian Island from small above-ground storage tanks. It was assumed that each home had an individual tank and that there were a total of 200 small residential tanks located on the island. Average annual fuel oil use for a residence was 465 gallons [8]. The residential tanks were modeled assuming an above-ground horizontal tank with a diameter of 3.5 ft and a length of 5.5 ft (capacity 400 gallons).

Fuel storage tanks were also used to supply heating oil and kerosene to tribal buildings. Fuel demand at individual tribal buildings ranged from 1,000 to 20,300 gallons per year. Tanks supplying tribal buildings could be grouped into two different size categories. Seven tribal buildings and the church (eight buildings total) had fuel consumptions of less than 5,500 gallons per year. These tanks were labeled "small municipal tanks" and were modeled by assuming an above-ground horizontal storage tank with a diameter of 8 ft and a length of 16 ft (capacity 6,000 gallons). Three tribal buildings consumed greater than 9,000 gallons per year of fuel oil or kerosene. Storage tank emissions from these locations were modeled assuming a buried horizontal storage tank with a diameter of 8 ft and a length of 26 ft (capacity 10,000 gallons); these tanks were labeled "large municipal tanks."

Emissions from fuel storage tanks were estimated using the computer program TANKS [14]. User input included tank sizes, volumes, and number of turnovers. TANKS calculated annual throughput by multiplying working volume by the number of turnovers. The number of turnovers had to be a whole number. The number of turnovers was set to 1 for small municipal tanks and 2 for large municipal tanks and for residential fuel storage tanks. TANKS calculations incorporated meteorological data from Portland, ME

Bonfires

Bonfires are stationary sources of air pollutants on Indian Island. Bonfires are of ceremonial importance to the Penobscot and several bonfires occur throughout the year. The total pollutant emissions from bonfires on Indian Island were calculated from available information.

Wood use was estimated from the amount of wood stored on Indian Island. Approximately 10 percent of the 200 homes had woodpiles in their yards. Island residents who had these woodpiles estimated that they burned 3 cords of wood each year [9]. It was estimated that one half of the wood was burned in fireplaces and the other half in bonfires on Indian Island. Calculations showed that 60 cords of wood were burned on the island, and that bonfires consumed half of that total. Using a weight of 1.2 tons for a standard cord of wood [10], the total weight of wood burned each year was estimated as 36 tons

Emissions from wood burning were estimated by multiplying the total amount of wood burned annually by AP-42 emission factors. In all cases, it was assumed that there were no emission controls in place and the emission factors available for wood burning in fireplaces would also apply to bonfires. The EPA has developed emission factors for wood burning in fireplaces [5]. Emission factors were presented for criteria pollutants, POM, and aldehydes.

Biogenic Sources

There are only 200 houses located on the 4,000 acre Indian Island and much of the rest of the island is tree covered. The primary varieties of trees present are fir, maple, beech, and cedar [15].

Biogenic emissions of VOC and NO_X were calculated for Penobscot County using the EPA-issued BEIS software, version 2.3 [16].

The BEIS program is designed to calculate biogenic emissions for each county within the United States. User inputs include the state, county, and temperature of the region. Emission factors have been developed for a wide variety of plant cover seen throughout the United States [17]. BEIS draws off of a database that includes the foliar density of each plant species in each county and uses that data to calculate VOC and NO_X emitted by the biogenic sources throughout the county (pollutant emissions are expressed in kg/hr). The Penobscot Reservation covers 4,866 acres, 0.493 percent of the land area of Penobscot County [2]. The total emissions for Penobscot County were multiplied by 0.493 percent to obtain VOC and NO_X emissions for the Penobscot Reservation.

Version 2.3 of the BEIS software does not generate HAP species, but recent research has developed some speciation of VOC. Three different HAPs are produced by biogenic sources; these pollutants are methanol, acetaldehyde and formaldehyde. Methanol represents 12 percent of the total VOC produced by biogenic sources and acetaldehyde and formaldehyde each represent between 0.3 percent and 2 percent of the total VOC flux from biogenic sources. The median value of 1.15 percent was assumed to apply here [18]. The estimated VOC emissions were multiplied by these percentages to determine the HAP emissions.

Household Products

In 2000, 562 members of the Penobscot Nation lived on Indian Island [19]. It was assumed that the 2002 population was also 562. Island residents use a variety of cleaning materials and other household products that emit VOC. The VOC emissions from these products were evaluated.

Emissions from household products were calculated using AP-42 emission factors [20]. The per capita VOC emissions have been quantified for cleansers and other products in use around the home. Total VOC emissions from household goods were determined by multiplying Indian Island's population by the AP-42 emission factor. AP-42 does not provide speciated emission factors for HAPs, however, because the products are intended for household use, the percentage of VOC that are considered to be hazardous are expected to be low.

Mobile sources

Mobile sources contribute significantly to anthropogenic pollutant emissions on Indian Island. These mobile sources include cars and trucks owned by Island residents, diesel buses that deliver tourists to the Penobscot High Stakes Bingo Hall located on Indian Island, and lawn maintenance equipment (e.g., lawnmowers, leafblowers and snowblowers). Lawn maintenance equipment is used at individual homes, and emissions from these items are estimated using off-road emission factors. Emissions from cars and buses are represented by on-road emission factors. Emissions from idling buses were also examined, as diesel-fueled buses frequently remain in idle in the parking lot for several hours each time bingo games are held.

On-road Mobile Sources

Two pollutant categories were examined. Because no manufacturing occurred on Indian Island during 2002, there should have been no industrial traffic at the time. Most traffic on the Island would have consisted of cars, trucks, and service vehicles. Intermittently, several large diesel-fueled buses arrive on Indian Island to deliver tourists to the Bingo Palace. These buses travel some distance on

Indian Island, and then remain in the parking lot in idle for several hours. It was assumed that the average national emission factors generated by MOBILE 6 [21] would provide a reasonable estimate of emissions from moving vehicles on Indian Island. Emissions from idling buses were calculated and added into the totals.

Annual pollutant emissions from vehicles traveling on the Island were obtained by multiplying emission factors by the miles traveled for each car by the annual vehicle count. Annual distance traveled on the Island was estimated by multiplying traffic counts by an average distance traveled. Penobscot officials set up a traffic counter at the bridge that provides the only access onto the Island and collected 117 days of traffic count data [22]. There are approximately 7 miles of road on Indian Island and most buildings on the Island lie within 3 miles of the bridge. It was therefore assumed that a car crossing the bridge would travel an average of 3 miles on the Island. The number of annual bridge crossings was estimated by multiplying the average daily number of bridge crossings by the number of days in a year.

Vehicle pollutant emissions were estimated using emission factors generated by the EPA computer program MOBILE 6. MOBILE 6 generates emission factors in units of grams (g) or milligrams (mg) pollutant per mile traveled [23]. Because all of the roads on Indian Island are small and have a low speed limit, the average speed on the Island was assumed to be 25 miles per hour. The average speed was input into the MOBILE 6 model to assure that the appropriate emission factors were generated.

MOBILE 6 produces emission factors for the average vehicle composition within the United States. This average composition includes approximately 12 percent heavy-duty vehicles. The number of heavy-duty vehicles traversing Indian Island may be less than the national average. However, it was assumed that with the combination of service trucks (such as garbage trucks) and tour buses, the national average was appropriate.

Emissions from diesel-fueled buses were also calculated using MOBILE 6 emission factors. The Bingo Hall operates 14 days per year. On those days, approximately 28 buses bring tourists onto the Island and they normally idle for several hours while the bingo games are in session [24]. In the case of buses, the Nation was interested both in the pollutants emitted by buses in motion (which are included in total mobile emissions estimates for the Island) and in the pollutants emitted by idling buses. The emission factors for idling buses were obtained by generating a MOBILE 6 emission factor for city buses traveling at 2.5 miles/hour and multiplying this factor by an average speed of 2.5 miles/hour [25]. The resulting emission factor has units of grams per hour (or mg per hour) and is multiplied by the hours spent at idle to obtain the total emissions for that time period.

Off-road Mobile Sources

Most off-road mobile sources in use on Indian Island fall within the category of lawn and garden equipment. This category of equipment includes lawnmowers, leafblowers, and snowblowers, along with other equipment used to maintain residents' homes and property. Because no specific information was available about equipment in use, it was assumed that every home on Indian Island made use of a lawnmower, leafblower, and snowblower. Although the actual composition of equipment used may differ, this should provide a reasonable estimate of emissions from off-road mobile sources on Indian Island.

Pollutant emissions from lawn maintenance equipment such as lawnmowers, leafblowers, and snowblowers were calculated using emission factors from the EPA Nonroad Engine and Vehicle

Emission Study (NEVES) Report [26]. The 1991 NEVES emission factors were chosen over more recently published factors because no information was available on the age of lawn equipment on Indian Island or on any emissions controls that might be in place on the engines. This document tabulates average horsepower ratings, load factor estimates, and emission factors for off-road vehicles and equipment. Horsepower estimates and load factor estimates were obtained from Inventory A of the NEVES report. The values in Inventory A were calculated from a series of emissions tests conducted by the EPA. These values were multiplied by the average emission factor (in grams/hp-hr) and the number of hours each piece of equipment was used annually to give the mass of pollutant produced over the course of a year. The Air Programs Officer provided an estimate on the amount of snow Indian Island received each year, and this information was used to develop estimates of annual use of snowblowers [27]. Annual equipment hours were estimated by making the following assumptions: lawnmowers operated 3 months out of the year for 2 hours/month, leafblowers operated 2 months out of the year for 2 hours/month, and snowblowers operated 4 months out of the year for 2 hours/month.

Emissions factors in the NEVES document include values for hydrocarbons emitted by "exhaust," "crank," "refueling," and "evaporation." These values were combined to obtain a single emission factor for hydrocarbons. It was assumed that this hydrocarbon emission factor provided the best measure of VOC emitted by off-road equipment. HAPs for these mobile sources were obtained by multiplying the total VOC emissions by the weight percentages of each HAP [28].

Penobscot Nation Trust Lands

In addition to Indian Island and other islands forming the Penobscot Reservation, the Penobscot Nation makes use of 60,742 acres of trust lands in parcels scattered throughout Penobscot, Piscataquis, and Franklin Counties. Trust lands are tracts of land held in trust for the Penobscot Nation by the federal government. The Nation has exclusive rights to develop the resources on these lands. The Penobscot Nation trust lands are an important economic resource. The Nation logs several of these tracts of land. Areas within the trust lands not actively used for logging are assigned to different members of the Penobscot Nation and used for camping and other recreational activities. The roads running through trust lands are largely unpaved roads. Pollutant emissions within the trust lands result from fuel consumption, use of the unpaved roads, campfires, and biogenic sources.

Stationary Sources

Pollutants are emitted from two stationary sources located throughout Penobscot Nation trust lands. These sources are campfires and biogenic emission sources.

- Campfires

There are campsites scattered throughout Penobscot Nation trust lands and campsites are assigned to Penobscots. When camping, members of the tribe typically burn wood for heat and to cook food. The contribution of campfires to the overall pollutant emissions on the trust lands was evaluated.

An estimate of wood use in campfires was established through the questioning of island residents [9]. Penobscots who camped frequently stated that they burned approximately one cord of wood each year in campfires. It was assumed that on average, one cord of wood would be burned at each campsite each year. Using a weight of 1.2 tons for a standard cord of wood [5], the emissions from wood burning were estimated by multiplying the total weight of wood burned annually by AP-42 emission factors.

In all cases, it was assumed that the emission factors available for wood burning in fireplaces would also apply to campfires [11]. This appeared reasonable as fireplaces do not contain emissions controls.

Emissions were calculated for criteria pollutants and polycyclic organic matter (POM). Although reference 4 includes an emission factor for aldehydes, the EPA deems the emission factor nonrepresentative, and thus, aldehydes are not included in the emission calculations.

- Biogenic Sources

The Penobscot Trust lands are covered in dense forest containing primarily fir, maple, beech, and cedar [15]. The forests themselves are a significant source of area emissions throughout the Penobscot Nation trust lands. In this heavily forested region, biogenic VOC emissions are significantly greater than those resulting from any other source on Penobscot lands.

The Penobscot Nation's trust lands lie within three counties of Maine. The Alder Stream Township, 20,545 acres of forest and streams, is located in Franklin County. The Nation holds trust rights to several plots of land spread throughout Penobscot County, covering a total of 35,965 acres. Trust lands also include the Williamsburg Township, 4,232 acres of forested land located in Piscataquis County. Biogenic emissions of VOC and NO_X were calculated for each of the three counties in which trust lands are located using the EPA-issued BEIS software, version 2.3 [16].

The BEIS program calculates biogenic emissions for each county within the United States. User inputs include the state, county, and temperature of the region. Emission factors have been developed for a wide variety of plant cover seen throughout the United States [17]. BEIS draws off of a database that includes the foliar density of each plant species in each county and uses that data to calculate VOC and NO_X emitted by the biogenic sources throughout the county (pollutant emissions are expressed in kg/hr). No data on HAPs are calculated by version 2.3 of the BEIS model, but recent research has developed HAP speciation values. Three different HAPs are produced by biogenic sources; these pollutants are methanol, acetaldehyde, and formaldehyde. Methanol represents 12 percent of total VOC produced by biogenic sources and acetaldehyde and formaldehyde each represent between 0.3 percent and 2 percent of the total VOC flux from biogenic sources [18].

By examining the database used by the BEIS program, it was possible to determine what area in each county was covered by forest, water, and farmland/other [15]. Most of the land tracts in the Penobscot nation consisted of forest and streams but contained no farmland. For most of the locations examined, the land area that was covered by forest and water was calculated. The land area held by the Penobscot nation was expressed as a percentage of total land area in the county and emissions were calculated using that percentage. For other locations, farmland/other represented less than 5 percent of the total county area. In these cases, it was assumed that the tract of land was representative of the county, and emissions were calculated from a simple percentage of total area.

Mobile Sources

- Logging Operations

The trust land areas of Alder Stream and Mattamiscontis are actively logged at this time. The Penobscot Nation provided information on equipment used, number of units of each type of equipment, the number of hours per day each would be operational, and number of months throughout the year that logging occurred [29]. This information was used to calculate annual equipment hours of operation at each location. The Nation also provided maps of each location showing roads and the distance that would be traveled along each road [30]. The maps were used to estimate the distance traveled by a particular piece of equipment during the course of a year's logging.

Pollutant emissions from diesel-powered heavy equipment were calculated using the emission factors incorporated into EPA's NONROADS model. Emission factors for heavy equipment were taken from EPA Report NR-009A [31]. Emission factors were presented for hydrocarbons, CO, NO_X, particulate matter, and SO_2. It was assumed that hydrocarbons equaled VOC. HAP emission factors were developed by multiplying the VOC (hydrocarbon) emission factors by the relative weight percents of HAPs [these percentages are presented in reference 28 and were developed from information available in reference 26]. Emission factors for off-road sources are given in units of grams/hp-hr. To estimate total emissions, these emission factors are multiplied by the hours the equipment is in use per year by the average horsepower ratings of that equipment by a vehicle loading factor. Average horsepower estimates for heavy equipment were obtained from the 1991 EPA Nonroad Vehicle Engine Study (NEVES) [26] and were compared to manufacturer's websites [32]. The 1991 horsepower values were no longer applicable to skidders and slashers, but seemed reasonable in other cases. Horsepower ratings for skidders and slashers were estimated using the average of manufacturers' values. Load factor estimates were obtained from EPA Report No. NR-005A [33].

Load factors and horsepower ratings were listed for a variety of vehicle types. Not every vehicle used in logging was listed in the EPA tables, and in those cases, factors from the closest analog were used. It was assumed that log trucks could be represented by off-highway trucks and that snowplows could be represented by the category tractors/loaders/backhoes. The load factors and horsepower ratings from those pieces of equipment were used to estimate emissions from log trucks and snowplows. The load factors used for skidders and slashers were those for the category "forest equipment." In NR-005A, emission factors vary with horsepower rating. The appropriate emission factor was selected for each piece of equipment [33].

Pollutant emissions from chainsaws were calculated as described in the NEVES study [26]. Although the emission factors for spark ignition engines (such as chainsaws and other gasoline-powered, off-road engines) that are used in the NONROADS model have been published [35], they were not used in this case. The newer emission factors incorporate the age of equipment and emissions controls. Because the data were not available, the 1991 emission factors were more applicable to the Penobscot study. The horsepower ratings, emission factors, and load factors used were those for chainsaws used in commercial logging. Horsepower estimates were compared to those for late-model chainsaws and the values were reasonable [32].

- Recreational Traffic

In addition to the mobile sources used for logging, there are mobile sources associated with recreational activities in the Penobscot Nation trust lands. Cars and trucks traveling to campsites distributed through the trust lands emit pollutants from fuel combustion and kick up dirt (or particulate matter pollution) from unpaved roads. Although there is some limited use of snowmobiles and all-terrain vehicles (ATVs), very few members of the Penobscot Nation own these vehicles and they are not discussed further here. Pollutant emissions from individual vehicles were calculated using emission factors generated by MOBILE 6 [21]. The average speed on the trust lands was assumed to be 25 miles per hour. Although MOBILE 6 calculates emissions for on-road mobile sources, it was assumed that MOBILE 6 emission factors would provide a reasonable estimate of emissions from fuel combustion. Because these vehicles were operating off road, there should be particulate matter kicked up from the unpaved road that is not accounted for in the MOBILE 6 output. Particulate emissions from the roads were calculated based on AP-42 unpaved road emission factors [35].

Members of the Penobscot Nation are assigned campsites across areas of the Nation's trust lands. There are 43 campsites located throughout the trust lands [36]. Far more information was available about Alder Stream, Mattamiscontis, and Mattagamon than the other plots, so emissions at these

locations were calculated first and used as a guide for calculating emissions at the other campsites. The Penobscot Nation provided maps and vehicle counts of Alder Stream, Mattamiscontis, and Mattagamon [22, 30].

The vehicle counts at were taken over the course of 2-week periods throughout the year. The weekly vehicle counts at each location were averaged and the annual vehicle count at each location was estimated by multiplying the average weekly vehicles by the approximate number of weeks per year the campsite was accessible. The vehicle counter registered every time a car entered or left the site. Average miles driven at each location were estimated from maps. Because the vehicle counter registered each vehicle within the site on both its entry and exit, distance traveled had to be adjusted accordingly.

Pollutant emissions from fuel combustion were estimated by multiplying the emission factor (in units of grams/mile or mg/mile) by the average miles traveled by the average vehicle counts at each location. Because the roads in these locations are unpaved, it was assumed that vehicles traveling to campsites would be light trucks. The emission factors used were those listed for light-duty gasoline trucks (or LGDT1) in the MOBILE 6 output.

Particulate emissions from the unpaved roads were estimated using the techniques described in AP-42, Section 13.2.2 [35].

CONCLUSIONS

Tables 1.1 through 1.4 located at the end of this paper present summaries of the criteria pollutant emissions and the primary HAP emissions (more than one ton) that were estimated to originate from within the Penobscot territories. As is evident from the information presented in the tables, the majority of emissions result from fuel combustion, mobile sources, and biogenic sources.

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TABLE 1.1 CRITERIA POLLUTANT EMISSIONS ON INDIAN ISLAND AND THE PENOBSCOT RESERVATION

Source	Emissions (ton/yr)[a]							
	VOC	**CO**	**Lead**	**NO_X**	**PM**	**PM10**	**PM2.5**	**SO_2**
Stationary Sources								
Heating Units	4.17	5.05	9.86×10^{-5}	1.71	7.07×10^{-1}	6.70×10^{-1}	6.60×10^{-1}	5.56
Wastewater Treatment	--	--	--	--	--	--	--	--
Bonfires	4.12	4.55	--	4.68×10^{-2}	6.23×10^{-1}	6.23×10^{-1}	6.23×10^{-1}	7.20×10^{-3}
Biogenic Emissions	66.1	--	--	1.27	--	--	--	--
Household Products	1.79	--	--	--	--	--	--	--
Fuel Storage Tanks	1.59×10^{-2}	--	--	--	--	--	--	--
Subtotal	76.2	9.60	9.86×10^{-5}	3.03	1.33	1.29	1.28	5.57
Mobile Sources								
Mobile Vehicles	4.44	59.3	--	6.47	1.77×10^{-1}	1.39×10^{-1}	7.94×10^{-2}	2.70×10^{-1}
Idling Buses	8.25×10^{-1}	7.15×10^{-2}	--	1.10×10^{-1}	8.10×10^{-3}	6.40×10^{-3}	3.64×10^{-3}	5.26×10^{-3}
Lawnmowers	8.50×10^{-1}	1.78	--	5.52×10^{-4}	1.47×10^{-2}	1.16×10^{-2}	6.60×10^{-3}	3.88×10^{-3}
Leafblowers	4.05×10^{-1}	1.20	--	8.46×10^{-4}	3.17×10^{-3}	2.51×10^{-3}	1.43×10^{-3}	1.80×10^{-3}
Snowblowers	1.65	3.42	--	1.07×10^{-3}	2.85×10^{-2}	2.25×10^{-2}	1.28×10^{-2}	7.55×10^{-3}
Subtotal	8.18	65.7	--	6.58	2.31×10^{-1}	1.82×10^{-1}	1.04×10^{-1}	2.79×10^{-1}
All Sources								
Total Emissions	84.4	75.3	9.86×10^{-5}	9.61	1.56	1.47	1.38	5.85

[a]All values are rounded to three significant figures.

TABLE 1.2 HAP EMISSIONS ON INDIAN ISLAND AND THE PENOBSCOT RESERVATION

Source	Emissions (ton/yr)[a]						
	Arsenic	**Cadmium**	**Formaldehyde**	**Manganese**	**Mercury**	**Methanol**	**Total HAPs**
Stationary Sources							
Heating Units	5.05	1.71	6.70×10^{-1}	5.56	4.17	--	18.5
Wastewater Treatment	--	--	--	--	--	--	1.50×10^{-3}
Bonfires	--	--	--	--	--		6.73×10^{-1}
Biogenic Emissions	--	--	7.60×10^{-1}	--	--	7.93	9.45
Household Products	--	--	--	--	--	--	0
Fuel Storage Tanks	--	--	--	--	--	--	0
Subtotal	5.05	1.71	1.43	5.56	4.17	7.93	28.7
Mobile Sources							
Mobile Vehicles	--	--	5.83×10^{-2}	--	--	--	2.49×10^{-1}
Idling Buses	--	--	6.74×10^{-4}	--	--	--	1.10×10^{-3}
Lawnmowers	--	--	1.08×10^{-5}	--	--	--	1.80×10^{-3}
Leafblowers	--	--	5.14×10^{-6}	--	--	--	8.58×10^{-4}
Snowblowers	--	--	2.09×10^{-5}	--	--	--	3.49×10^{-3}
Subtotal	--	--	5.90×10^{-2}	--	--	--	2.57×10^{-1}
All Sources							
Total Emissions	5.05	1.71	1.49	5.56	4.17	7.93	28.9

[a]All values are rounded to three significant figures.

TABLE 1.3 CRITERIA POLLUTANT EMISSIONS ON PENOBSCOT NATION TRUST LANDS

Source	Emissions (ton/yr)[a]						
	VOC	**CO**	**NO_X**	**PM**	**PM10**	**PM2.5**	**SO_2**
Stationary Sources							
Campfires	15.3	16.8	1.73E-01	2.30	2.30	2.30	$2.66x10^{-2}$
Biogenic Emissions	900	--	15.2	--	--	--	--
Subtotal	915	16.8	15.0	2.30	2.30	2.30	$2.66x10^{-2}$
Mobile Sources							
Alder Stream Logging Activities	7.52	22.8	12.9	$8.65x10^{-1}$	$6.83x10^{-1}$	$3.89x10^{-1}$	1.65
Mattamsicontis Logging Activities	11.9	35.5	15.4	1.14	$9.00x10^{-1}$	$5.13x10^{-1}$	1.97
Recreational Traffic – Roadway Dust Emissions	--	--	--	589	234	34.1	--
Recreational Traffic – Fuel Combustion Emissions	2.01	29.5	1.38	$2.40x10^{-2}$	$1.90x10^{-2}$	$1.08x10^{-2}$	8.72E-02
Subtotal	21.4	87.9	29.7	591	236	35.0	3.72
All Sources							
Total Emissions	937	105	44.7	593	238	37.3	3.74

[a]All values are rounded to three significant figures.

TABLE 1.4 HAZARDOUS AIR POLLUTANT EMISSIONS ON PENOBSCOT NATION TRUST LANDS

Source	Emissions (ton/yr)[a]							
	Acetaldehyde	**Formaldehyde**	**Hexane**	**Methanol**	**MTBE[b]**	**Toluene**	**Xylene**	**Total HAPs**
Stationary Sources								
Campfires	--	--	--	--	--	--	--	1.07×10^{-3}
Biogenic Emissions	10.3	10.3	--	108	--	--	--	129
Subtotal	10.3	10.3	--	108	--	--	--	129
Mobile Sources								
Alder Stream Logging Activities	8.86×10^{-2}	1.73×10^{-1}	9.37×10^{-2}	--	9.50×10^{-1}	6.49×10^{-1}	7.08×10^{-1}	3.06
Mattamsicontis Logging Activities	1.10×10^{-1}	2.13×10^{-1}	1.53×10^{-1}	--	1.56	1.06	1.15	4.87
Recreational Traffic – Roadway Dust Emissions	--	--	--	--	--	--	--	0
Recreational Traffic – Fuel Combustion Emissions	5.26×10^{-3}	1.52×10^{-2}	--	--	1.33×10^{-3}	--	--	7.83×10^{-2}
Subtotal	2.03×10^{-1}	4.01×10^{-1}	3.07×10^{-1}	--	1.95	1.71	1.86	8.00
All Sources								
Total Emissions	10.4	10.7	3.07×10^{-1}	108	1.95	1.71	1.86	137

[a]All values are rounded to three significant figures.

[b]MTBE = methyl tertiary butyl ether.

KEY WORDS

Air Emission Inventory, Penobscot Nation, Tribal Air Programs