Evaluation of Air Toxics Concentrations and Emissions for the San Juan, Puerto Rico MSA

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ABSTRACT

Air toxics pollution continues to be a pervasive problem in many cities around the U.S. Acute and chronic exposure to certain pollutants can lead to cancer and/or noncancer effects. Over the last several years, efforts have been made by federal, state, local, and tribal agencies to reduce air toxics emissions and concentrations, thereby reducing associated risk. Understanding the relationship between emissions and concentrations, and integrating meteorological data can be useful in developing strategies for reducing air toxic pollution.

An evaluation of air toxics emissions and concentrations was conducted for two monitoring sites in the San Juan, Puerto Rico (PR) Metropolitan Statistical Areas (MSA) that participated in the 2005 Urban Air Toxics Monitoring Program (UATMP). The U.S. Environmental Protection Agency (EPA) sponsors the UATMP to obtain air toxics measurements data to characterize the composition and magnitude of pollution across the United States. Air toxics monitoring data from the same sampling day were reviewed at these two sites to determine if there is a significant difference in concentrations from the upwind and downwind locations. Air toxics pollutants analyzed include volatile organic compounds (VOCs) and carbonyls. An evaluation of emission sources from the 2002 National Emissions Inventory (NEI) potentially affecting downwind concentrations is also presented. The NEI is also managed by U.S. EPA, and contains emissions information from stationary (point and area nonpoint) and mobile (onroad and nonroad) sources. Data from the National Weather Service (NWS) and the National Oceanic and Atmospheric Administration (NOAA) are used to identify predominant daily wind flow and for the construction of back trajectories.

INTRODUCTION

Air toxics pollution continues to be a pervasive problem in many cities around the U.S. Acute and chronic exposure to specific hazardous air pollutants (HAPs) can lead to cancer and/or noncancer effects. Since the passage of the 1990 Clean Air Act Amendments (CAAA),[1] EPA has spent considerable time and resources in establishing federal regulations, primarily through maximum achievable control technology (MACT) standards, to reduce emissions of HAPs. Ambient monitoring data can help identify specific emission sources affecting an area's air quality.

San Juan, PR is a medium-sized city with over 4 million residents within the MSA.[2] In February 2006, EPA released the results of its national-scale air toxics assessment (NATA), and modeled theoretical cancer and noncancer risks were estimated at the census tract-level.[3] Many census tracts within the San Juan, PR MSA exhibited cancer risks greater than 25 in-a-million. For example, the highest cancer risk in the country due to dichloromethane exposure (71 in-a-million) was calculated for a census tract within this MSA (census tract ID 72017590300). Additionally, cumulative census tract-level cancer risks (multiple HAPs) from mobile sources were among the highest in the country, as high as 107 in-a-million for onroad sources and 197 in-a-million for nonroad sources.

Two monitoring sites were sited within the San Juan MSA to evaluate air quality and to identify emission sources affecting the air quality. Two questions were developed to guide this evaluation: 1) How do ambient monitoring concentrations vary within the San Juan MSA?

2) What emission sources/sinks are affecting concentrations/levels?

The integration of ambient monitoring concentrations, emissions data, and meteorological measurements are used to answer these questions.

METHODOLOGY

Sites of Interest

EPA sponsors numerous ambient monitoring programs, including the UATMP, a network designed to characterize the composition and magnitude of urban air pollution through extensive ambient monitoring efforts.[4] Hundreds of monitoring sites have participated in this program since its inception in 1987. Each UATMP site must follow a rigorous EPA-approved quality assurance project plan (QAPP) to ensure that the data is sufficient for robust statistical analysis.

Table 1 presents the two monitoring sites in the San Juan, PR MSA that sampled during the 2005 program year. The Barceloneta monitoring site (BAPR) is on the western side of the MSA, and is less than 30 miles due west of the San Juan site (SJPR) monitoring site. While the BAPR monitoring site participated in the UATMP previously from 2001 to 2003, the SJPR monitoring site began in 2005. Other site characteristics in Table 1 are land use types, location setting, and daily traffic passing by the monitor. The locations of these sites are plotted in Figure 1, along with major roadways and point source emission locations, as reported in EPA's 2002 National Emissions Inventory (NEI).[5] It's interesting to note that the census tract containing the BAPR monitoring site is the same census tract that modeled the highest cancer risk for dichloromethane.

Pollutants of Interest

Urban air pollution typically contains hundreds of components, including, but not limited to, VOCs, carbonyl compounds, metals, inorganic acids, and particulate matter. Both monitoring sites measured for the same set of pollutants, VOCs and Carbonyl compounds, for a total of 70 pollutants. Forty of these pollutants are HAPs and are presented in Table 2. All measurements consisted of 24-hour integrated canisters (TO-15) for VOCs and DNPH cartridges (TO-11A) for carbonyl compounds.[6,7] For this study, the individual xylene compound species (*o*-, *m*-, *p*-) are summed together as "total xylenes."

Meteorological Data

Meteorological surface observations were retrieved from the National Weather Service (NWS)[8] station located at Luis Munoz Marin International Airport, approximately 10 miles east-northeast (ENE) of the SJPR monitoring site. Hourly surface observations of temperature, pressure, moisture, and wind information (speed and direction) were integrated into 24-hour averages to match the sample duration of the canister and cartridge; annual and sample day averages are presented in Table 3. Although a mountain ridge runs through this MSA, its alignment is east-west; thus, the observations taken at this NWS station are assumed to be representative of the conditions at both the BAPR and SJPR monitoring sites (also aligned east-west).

Gridded meteorological data and the model used for back trajectory analyses were prepared and developed by the National Oceanic and Atmospheric Administration (NOAA). The model used is the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT).[9] Back trajectories were computed 24 hours prior to the sampling day (to match the 24-hour collection period of the sample), and composite back trajectory maps were constructed for sampling days using GIS software, as illustrated in Figures 2 and 3. The value of the composite back trajectory maps is the determination of an airshed domain for air originating 24 hours prior to a sampling day.

Finally, the daily average wind direction for each sampling day was classified into one of the 16point

compass regimes and is used in conjunction with the concentration data.

RESULTS

Concentration Data

Sampling Detects

For 2005, sampling was conducted from February 27th through December 30th, yielding a maximum potential of 51 sampling days under the 1-in-6 day sampling schedule. The BAPR monitoring site yielded valid samples for carbonyls and VOCs on 49 and 48 days, respectively, resulting in 96 percent and 94 percent completeness. The relatively few invalidated samples were due to field error or damage in transit. Conversely, carbonyl and VOC sampling at SJPR were valid on 40 sampling days, resulting in 78 percent completeness. A large number of invalidated samples occurred from September through December due to instrument error. Despite the invalidated samples, concurrent sampling between the two sites occurred on 38 sampling days.

Twenty-six of the 40 HAPs recorded at least 1 detect during the study period. Ten HAPs were detected on more than 75 percent of the 38 concurrent sampling days (> 28 days), while 8 HAPs were detected on less than 25 percent of the 38 concurrent sampling days (< 10 days). It's important to note that although acetonitrile was detected on 4 sampling days, the concentrations were not considered in this study due to potential cross-contamination from the TO-11A sampling methodology.

Daily Averages

Daily average concentrations are presented for each site in Tables 4 (BAPR) and 5 (SJPR) in total, and by wind regime. More than 75 percent of the concurrent samplings days were when the winds were of some easterly component (northeast to southeast). This observation is consistent with the composite back trajectories constructed for each site (Figures 2 and 3). Among the HAPs, the top five pollutants (minimum 28 detects) at BAPR by daily mass concentration average and confidence interval (using Student's *t*-test at $\alpha = 0.05$) were:

Dichloromethane, 6.45 ± 2.35 µg/m^3;
Total xylenes, 5.25 ± 0.72 µg/m^3;
Toluene, 3.90 ± 0.54 µg/m^3;
Chloromethane, 2.45 ± 0.19 µg/m^3; and
Acetaldehyde, 1.39 ± 0.23 µg/m^3.

Dichloromethane and chloromethane are only emitted by stationary sources, whereas total xylenes, toluene, and acetaldehyde are emitted by both stationary and mobile sources. At SJPR, the top five pollutants (minimum 28 detects) by daily mass concentration and confidence interval were:

Total xylenes, 10.35 ± 1.36 µg/m^3;
Toluene, 8.37 ± 1.77 µg/m^3;
Acetaldehyde, 6.31 ± 2.27 µg/m^3;
Formaldehyde, 2.22 ± 0.25 µg/m^3; and
Benzene, 2.13 ± 0.27 µg/m^3.

All five of these HAPs are emitted by both stationary and mobile sources. Concentrations measured at the SJPR monitoring site are generally higher than the BAPR monitoring site, and for some pollutants are significantly higher (e.g., total xylenes). HAP concentrations tended to be higher for certain wind regions than others (although no statistical significance can be applied). For example, at SJPR, the total HAP concentrations

were highest when the winds were from the ESE (78 μg/m^3), SE (66 μg/m^3), N (65 μg/m^3), and NE (64 μg/m^3) and lowest when the winds were from the SSW (41 μg/m^3) and SSE (44 μg/m^3).

Emissions Data

Dichloromethane

According to the 2002 point sources NEI, dichloromethane is emitted primarily from refuse systems, plastic foam production, and pharmaceuticals production. For the San Juan, PR, MSA, the total dichloromethane emissions are 962 tons per year (tpy) as presented in Table 6. The top three emitting source categories are: pharmaceutical production (537 tpy); commercial solvent usage (252 tpy); and architectural surface coating (106 tpy). Based on this emissions breakdown, over 55% of the dichloromethane point source emissions in the San Juan, PR MSA are from pharmaceutical production. The remaining 45% are from area nonpoint sources, where the emissions are more ubiquitous and spread out at the county-level. Figure 4 is an emission source location map of all dichloromethane point sources, as reported in the 2002 NEI. Nearby and to the east of the BAPR monitoring site are four pharmaceutical plants: Abbott Healthcare (327 tpy), Bristol-Myers Squibb (14 tpy), Schering Plough (6 tpy), and Pfizer (4 tpy). The dichloromethane concentrations measured at BAPR appear to be influenced by the emissions as the wind passes over these pharmaceutical plants. At SJPR, there does not appear to be any significant source of dichloromethane.

This trend matches well with the 1999 NATA results for the census tracts housing these sites. The cancer risk due to dichloromethane exposure in the BAPR census tract was 71 in-a-million compared to less than 1 in-a-million in the SJPR monitoring site.

Chloromethane

According to the 2002 NEI, chloromethane is emitted primarily from prescribed burnings, forest and wildfires, and agricultural rangeland burnings. For the San Juan, PR MSA, the total chloromethane emissions are 24 tpy as presented in Table 6. The top emitting source categories are from prescribed burnings (14 tpy) and architectural surface coatings (9 tpy). The area near the BAPR monitoring site is more rural and agricultural than the SJPR monitoring site, and the practice of open burning may be captured by the BAPR monitoring site.

Acetaldehyde, Benzene, Formaldehyde, Toluene, and Total Xylenes

According to the 2002 NEI, acetaldehyde, benzene, formaldehyde, toluene, and total xylenes are primarily emitted from mobile sources, forest and wildfires, and prescribed burnings. For the San Juan, PR MSA, the total emissions for these HAPs are 15,476 tpy and are presented in Table 7. The top emitting source categories are from mobile sources (13,225 tpy) and prescribed burnings (554 tpy). Mobile sources account for 85% of the emissions for these specific HAPs, and appear to be the major influence on these HAP concentrations at BAPR and SJPR, as both monitoring sites are surrounded by major roadways. As illustrated in Figure 5, mobile source emissions upwind of SJPR are more than double of those upwind of BAPR (4,426 tpy vs. 1,758 tpy), which is a similar pattern to the mass concentration differences at each site (i.e., more than double).

Upwind vs. Downwind Analysis

The SJPR and BAPR monitoring sites are aligned east-west (E-W) to one another. Thus, winds coming from the east or west can be used for an upwind-downwind analysis. Under an east wind, the SJPR monitoring site is designated as upwind and the BAPR monitoring site is designated as downwind. Conversely, under a west wind, the BAPR monitoring site is designated as upwind and the SJPR monitoring site is designated as downwind. Under this analysis, we are expanding the alignment to include winds from the east-northeast to

west-southwest (ENE-WSW) and east-southeast to west-northwest (ESE-WNW) to account for wind variability.

The average daily winds never originated from the WSW, W, or WNW on sampling days as presented in Tables 4 and 5. The concentrations measured from the ENE, E, and ESE wind regimes are grouped into an "Easterly" wind regime for a total of 28 days (of the 38 concurrent sampling days). Concentration differences between the SJPR and BAPR monitoring sites are presented in Table 8, and statistically significant differences are denoted in bold. Two HAPs measured downwind concentrations that significantly increased from their upwind concentrations (positive effect):

Dichloromethane (6.18 ± 2.96 $\mu g/m^3$) and
Chloromethane (0.36 ± 0.26 $\mu g/m^3$).

Conversely, 12 HAPs measured downwind concentrations that significantly decreased from their upwind concentrations (negative effect). The top five HAP differences are:

Total xylenes (-4.96 ± 1.41 $\mu g/m^3$);
Toluene (-4.68 ± 2.23 $\mu g/m^3$);
Acetaldehyde (-4.39 ± 2.35 $\mu g/m^3$);
Formaldehyde (-1.52 ± 2.96 $\mu g/m^3$); and
Benzene (-0.96 ± 0.27 $\mu g/m^3$).

It's interesting to note that these five HAPs were also the five highest in mass concentration at SJPR. In the following sections, the emission sources/sinks affecting downwind concentrations are discussed.

Positive Downwind Effects

The significant increase in dichloromethane downwind points to the influence of the four nearby pharmaceutical plants identified earlier. As the wind passes over these plants, the dichloromethane concentrations increase.

For the chloromethane increase, emissions from open burning immediately to the east of BAPR may have been captured at the monitoring site.

Negative Downwind Effects

The significant decreases in concentration for a number of HAPs suggest the effects of VOC and carbonyl sinks reducing ambient concentrations. Three likely scenarios for the negative downwind concentration effect as the wind passes from the SJPR monitoring site towards the BAPR monitoring site are presented:

1) *Photochemical production of ozone*. Ozone is formed from the reactions of VOCs and carbonyl compounds with oxides of nitrogen in the presence of sunlight, thus acting as a sink. To corroborate this suggestion an upwind and downwind analysis of ozone concentrations would be optimal. Unfortunately, this cannot be performed, as only one ozone monitor in Puerto Rico operated in 2005. This monitor (AQS Site ID 72-033-0008) was situated 3 miles to the east of the SJPR monitoring site.

2) *Atmospheric dispersion*. As the air flows easterly, the pollutants captured at the SJPR monitoring site may be dispersed and mixed rapidly in the vertical and horizontal atmosphere prior to reaching the BAPR monitoring site.

3) *Orographic Lifting*. As the air flows easterly, an air parcel containing pollutants measured at the SJPR monitoring site may experience orographic lifting over the mountainous terrain, thereby passing over the BAPR monitoring site as the air parcel is lowered.

CONCLUSIONS

An evaluation of air toxics concentrations and emissions was conducted at two monitoring sites in the San Juan, PR MSA. These two monitoring sites, BAPR and SJPR, are aligned east-west to one another, and the predominant wind flow experienced across the MSA is easterly. Two questions were used to guide this evaluations:

How do ambient monitoring concentrations vary within the San Juan MSA? With the exception of a couple of HAPs, concentrations were greater at the SJPR monitoring site than the BAPR monitoring site, and in some cases significantly greater. Both monitoring sites are situated near major roadways, and the HAPs with the highest mass concentrations reflect the influence of these roadways. The intensity of mobile source emissions affecting the SJPR site is more than double the BAPR site, and the ambient concentrations at each site match that trend. Additionally, the area around the BAPR site is more rural than the SJPR site, and concentration intensity and composition reflect that.

What emission sources are affecting downwind concentrations? At BAPR, the close proximity of four pharmaceutical plants emitting dichloromethane is evident, as the air moves easterly across the MSA. At SJPR, the effect of mobile source emissions east of this monitoring site is also evident. Concentrations appear to decrease for most HAPs as the air moves easterly towards the BAPR monitoring site. Photochemical production of ozone, atmospheric dispersion, and orographic lifting are potential scenarios for the decreasing concentrations downwind.

REFERENCES

1. U.S. EPA. Clean Air Act Amendments. OAQPS. Internet address: http://www.epa.gov/air/oaq_caa.html/

2. U.S. Census Bureau. Metropolitan and Micropolitan Statistical Areas, 2003. Internet address: http://www.census.gov/population/www/estimates/metroarea.html

3. U.S. EPA. The National-Scale Air Toxics Assessment. Internet address: http://www.epa.gov/ttn/atw/nata/

4. U.S. EPA. Urban Air Toxics Monitoring Program. Internet address: http://www.epa.gov/ttn/amtic/uatm.html

5. U.S. EPA. 2002 National Emissions Inventory (NEI) Data and Documentation. Data retrieved from ftp://ftp.epa.gov/EmisInventory/2002finalnei/

6. U.S. EPA. Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition, TO-15: Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS). Office of Research and Development. EPA/625/R-96/010b. January, 1999. Internet address: http://www.epa.gov/ttn/amtic/files/ambient/airtox/to-15r.pdf

2 U.S. EPA. Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air, Second Edition, TO-11A: Determination of Formaldehyde in Ambient Air Using Adsorbent Cartridge Followed by High Performance Liquid Chromatography (HPLC). Office of Research and Development. EPA/625/R-96/010b. January, 1999. Internet address:http://www.epa.gov/ttn/amtic/files/ambient/airtox/to-11ar.pdf

3 National Climatic Data Center (NCDC). World's Largest Archive of Climate Data. Unedited Local Climatological Data Set purchased. Internet address: http://www.ncdc.noaa.gov/oa/ncdc.html

4 Draxler, R.R. and Rolph, G.D., HYSPLIT (Hybrid Single-Particle Lagrangian Integrated Trajectory) Model access via NOAA ARL READY Website (http://www.arl.noaa.gov/ready/hysplit4.html). NOAA Air

Resources Laboratory. Silver Spring, MD.

KEYWORDS

Hazardous Air Pollutants (HAPs) Intra-MSA Comparison Air Toxics Upwind/Downwind Analysis Back Trajectories Ambient Air Monitoring Emissions Inventory National Emissions Inventory (NEI) Urban Air Toxics Monitoring Program (UATMP) Data Analysis Puerto Rico

Table 1. Site Information

Site	Location	AQS Site ID	Census Tract ID	Latitude (degrees)	Longitude (degrees)	Elevation (meters)	Traffic Estimate[1]	Land Use	Locat Settin
BAPR	Barceloneta, PR	72-017-0003	72017590300	18.436111	-66.580556	0	10	Residential	Rural
SJPR	San Juan, PR	72-021-0006	72021030103	18.416667	-66.150833	24	250	Industrial	Subu

[1] Traffic estimate is in terms of vehicles passing daily by the monitor.

Table 2. Pollutant Information – VOC and Carbonyl HAPs **Table 3.** Average Meteorological Parameters for Monitoring Sites in Puerto Rico **Table 4.** BAPR HAP Concentrations

Pollutant	TO-15	TO11A	Stationary Source HAP	Mobile Source HAP
Acetaldehyde		X	X	X
Acetonitrile	X		X	
Acrylonitrile	X		X	
Acrolein	X		X	X
Benzene	X		X	X
Bromomethane	X		X	
Butadiene, 1,3-	X		X	X
Carbon Tetrachloride	X		X	
Chlorobenzene	X		X	
Chloroethane	X		X	
Chloroform	X		X	
Chloromethane	X		X	
Chloroprene	X		X	
Dibromomethane, 1,2-	X		X	
Dichlorobenzene, p-	X		X	
Dichloroethane, 1,1-	X		X	
Dichloroethane, 1,2-	X		X	
Dichloroethene, 1,1-	X		X	
Dichloromethane	X		X	
Dichloropropane, 1,2-	X		X	
Dichloropropene, cis-1,3-	X		X	
Dichloropropene, trans1,3-	X		X	
Ethyl Acrylate	X		X	
Ethylbenzene	X		X	X
Formaldehyde		X	X	X
Hexachlorobutadiene	X		X	
Methyl Ethyl Ketone	X		X	X
Methyl Isobutyl Ketone	X		X	

Methyl Methacrylate	X		X	
Methyl tert-Butyl Ether	X		X	X
Propionaldehyde		X	X	X
Styrene	X		X	X
Tetrachloroethane, 1,1,2,2	X		X	
Tetrachloroethylene	X		X	
Toluene	X		X	X
Trichloroethane, 1,1,1-	X		X	
Trichloroethane, 1,1,2-	X		X	
Trichloroethylene	X		X	
Vinyl Chloride	X		X	
Xylenes (total)	X		X	X
	37	3	40	12

Site	Weather Station	Type	Average Maximum Temperature (°F)	Average Temperature (°F)	Average Dew Point Temperature (°F)	Average Wet Bulb Temperature (°F)	Average Relative Humidity (%)	Average Sea Level Pressure (mb)	Average u-component wind (m/s)
	Luiz Munoz	All 2005	85.87 ± 0.41	80.02 ± 0.33	72.06 ± 0.38	74.57 ± 0.32	77.50 ± 0.59	1014.49 ± 0.21	-3.86 ± 0
BAPR	Marin Int. Airport	Sample Day	87.49 ± 0.80	81.13 ± 0.73	73.15 ± 0.74	75.59 ± 0.64	77.55 ± 1.28	1014.40 ± 0.53	-3.99 ± 0
SJPR	(WBAN 11641)	Sample Day	87.33 ± 0.85	80.98 ± 0.77	73.09 ± 0.73	75.51 ± 0.65	77.78 ± 1.33	1014.45 ± 0.52	-3.89 ± 0

Pollutant	# Detects	Daily Average (µg/m3)	N (µg/m3)	NE (µg/m3)	ENE (µg/m3)	E (µg/m3)	ESE (µg/m3)	SE (µg/
Acetaldehyde	39	1.39 ± 0.23	2.34	1.10 ± 0.29	1.26 ± 0.24	1.53 ± 0.44	4.25	1.81 ± 0
Acrolein	2	0.57 ± 0.54	ND	ND	0.57 ± 0.54	ND	ND	ND
Benzene	38	1.14 ± 0.12	1.76	0.84 ± 0.38	1.07 ± 0.13	1.18 ± 0.35	0.96	1.61 ± 0
Bromomethane	15	0.06 ± 0.01	ND	0.08	0.06 ± 0.01	0.06 ± 0.02	ND	0.04
Butadiene, 1,3	23	0.18 ± 0.04	ND	0.15 ± 0.04	0.17 ± 0.03	0.20 ± 0.11	ND	0.33
Carbon Tetrachloride	38	0.64 ± 0.04	0.63	0.72 ± 0.04	0.64 ± 0.06	0.68 ± 0.07	0.57	0.63 ± 0
Chloroethane	10	0.04 ± 0.01	ND	ND	0.05 ± 0.03	0.03	ND	0.03
Chloroform	10	0.17 ± 0.03	ND	ND	0.19 ± 0.06	0.14 ± 0.01	ND	ND
Chloromethane	38	2.45 ± 0.19	2.29	2.68 ± 0.83	2.45 ± 0.31	2.43 ± 0.3	2.5	2.25 ± 0
Dichlorobenzene, *p*-	21	0.62 ± 0.14	ND	0.28 ± 0.14	0.74 ± 0.19	0.43 ± 0.11	ND	0.75 ± 0
Dichloroethane, 1,2	1	0.12	ND	ND	0.12	ND	ND	ND
Dichloromethane	32	6.45 ± 2.35	3.44	1.58 ± 0.64	4.93 ± 1.83	14.16 ± 8.62	2.47	3.86 ± 1
Ethylbenzene	38	0.71 ± 0.08	1.35	0.54 ± 0.27	0.65 ± 0.09	0.73 ± 0.22	1.04	0.93 ± 0
Formaldehyde	39	0.69 ± 0.10	1.22	0.64 ± 0.16	0.61 ± 0.08	0.69 ± 0.17	2.12	0.81 ± 0
Hexachlorobutadiene	2	0.11	ND	ND	ND	0.11	ND	ND
Methyl Ethyl Ketone	9	2.29 ± 1.24	ND	1.21	1.78 ± 0.59	4.79 ± 3.62	ND	ND
Methyl Isobutyl Ketone	3	0.22 ± 0.06	ND	ND	0.18 ± 0.03	0.29	ND	ND
Methyl *tert*-Butyl Ether	4	0.42 ± 0.10	ND	ND	0.47	0.50	0.25	ND
Propionaldehyde	34	0.06 ± 0.03	0.11	0.04 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.58	0.05
Styrene	26	0.19 ± 0.03	0.3	0.13 ± 0.05	0.20 ± 0.05	0.18 ± 0.04	0.17	0.26
Tetrachloroethylene	4	0.61 ± 0.81	ND	ND	0.79 ± 1.00	ND	ND	ND
Toluene	38	3.90 ± 0.54	9.65	2.60 ± 1.09	3.48 ± 0.5	4.31 ± 1.59	3.39	5.26 ± 1
Trichloroethane, 1,1,1	20	0.13 ± 0.01	ND	0.11	0.13 ± 0.02	0.14 ± 0.02	ND	0.16

Trichloroethylene	1	0.05	ND	ND	ND	0.05	ND	ND
Xylenes (total)	38	5.25 ± 0.72	12.24	4.1 ± 2.74	4.62 ± 0.68	5.19 ± 1.89	8.90	6.73 ± 2
		Total	35.33	16.80	25.21	37.86	27.20	25.51

ND = no detects

Table 5. SJPR HAP Concentrations

Pollutant	# Detects	Daily Average (µg/m3)	N (µg/m3)	NE (µg/m3)	ENE (µg/m3)	E (µg/m3)	ESE (µg/m3)	SE (µg/m
Acetaldehyde	39	6.31 ± 2.27	25.76	3.45 ± 1.21	5.43 ± 2.28	3.16 ± 1.27	32.43	15.48 ± 9
Acrolein	2	1.01 ± 0.51	ND	ND	1.01 ± 0.51	ND	ND	ND
Benzene	38	2.13 ± 0.27	1.76	2.96 ± 0.46	1.98 ± 0.40	2.32 ± 0.51	1.69	3.23 ± 0.7
Bromomethane	15	0.08 ± 0.01	ND	0.10	0.09 ± 0.03	0.08 ± 0.01	ND	0.04
Butadiene, 1,3	23	0.30 ± 0.06	ND	0.40 ± 0.22	0.27 ± 0.08	0.30 ± 0.13	ND	0.49
Carbon Tetrachloride	38	0.62 ± 0.05	0.57	0.68 ± 0.07	0.63 ± 0.08	0.64 ± 0.13	0.69	0.57 ± 0.0
Chloroethane	10	0.09 ± 0.05	ND	ND	0.11 ± 0.07	0.09 ± 0.10	ND	0.03
Chloroform	10	0.24 ± 0.04	ND	ND	0.27 ± 0.07	0.21 ± 0.04	ND	ND
Chloromethane	38	2.08 ± 0.18	1.80	2.12 ± 0.03	1.98 ± 0.29	2.31 ± 0.37	2.52	2.03 ± 0.5
Dichlorobenzene, *p*-	21	1.16 ± 0.35	ND	1.08 ± 0.08	1.23 ± 0.59	1.00 ± 0.37	ND	1.53 ± 0.2
Dichloroethane, 1,2	1	0.20	ND	ND	0.20	ND	ND	ND
Dichloromethane	32	0.91 ± 0.32	0.59	0.61 ± 0.16	0.91 ± 0.48	0.78 ± 0.31	0.69	0.89 ± 0.1
Ethylbenzene	38	1.38 ± 0.18	1.48	2.21 ± 0.66	1.29 ± 0.27	1.45 ± 0.33	1.56	1.74 ± 0.3
Formaldehyde	39	2.22 ± 0.25	0.88	2.58 ± 0.45	2.19 ± 0.32	2.38 ± 0.57	1.23	1.28 ± 0.4
Hexachlorobutadiene	2	0.16 ± 0.07	ND	ND	ND	0.21	ND	ND
Methyl Ethyl Ketone	9	2.95 ± 0.94	ND	4.16	2.55 ± 01.57	3.21 ± 0.53	ND	ND
Methyl Isobutyl Ketone	3	1.09 ± 0.83	ND	ND	1.31 ± 1.14	0.66	ND	ND
Methyl *tert*-Butyl Ether	4	1.44 ± 0.52	ND	ND	0.65	1.59	2.13	ND
Propionaldehyde	34	0.31 ± 0.04	0.13	0.31 ± 0.07	0.32 ± 0.07	0.33 ± 0.06	0.36	0.21 ± 0.1
Styrene	26	0.43 ± 0.12	0.21	0.83 ± 0.32	0.39 ± 0.12	0.55 ± 0.43	0.34	0.38
Tetrachloroethylene	4	0.34 ± 0.08	ND	ND	0.38 ± 0.04	ND	ND	ND
Toluene	38	8.37 ± 1.77	8.18	11.41 ± 0.72	8.69 ± 3.17	7.71 ± 2.06	6.52	11.00 ± 1
Trichloroethane, 1,1,1	20	0.19 ± 0.04	ND	0.19 ± 0.04	0.22 ± 0.08	0.15 ± 0.02	ND	0.16
Trichloroethylene	1	0.05	ND	ND	ND	ND	0.05	ND
Xylenes (total)	38	10.35 ± 1.36	13.07	16.26 ± 2.02	9.34 ± 2.04	10.74 ± 2.80	14.59	13.50 ± 1
		Total	65.26	64.39	52.77	52.70	78.00	66.42

ND = no detects

Table 6. Emissions Profile for Dichloromethane and Chloromethane in the San Juan, PR MSA

Pollutant	San Juan MSA Emissions (tpy)	Source Category	Facility	Emissions (tpy)
Dichloromethane	962	Pharmaceuticals – nearby BAPR	Abbott Healthcare	327
			Bristol-Myers Squibb	14
			Schering Plough	6
			Pfizer	4
		Pharmaceuticals – far from BAPR	Rest of MSA	186
		Solvent/paint stripping	Areawide	252

		Architectural Surface Coatings	Areawide	106
		Other area nonpoint sources	Areawide	67
Chloromethane	24	Prescribed Burnings	Areawide	14
		Architectural Surface Coatings	Areawide	10

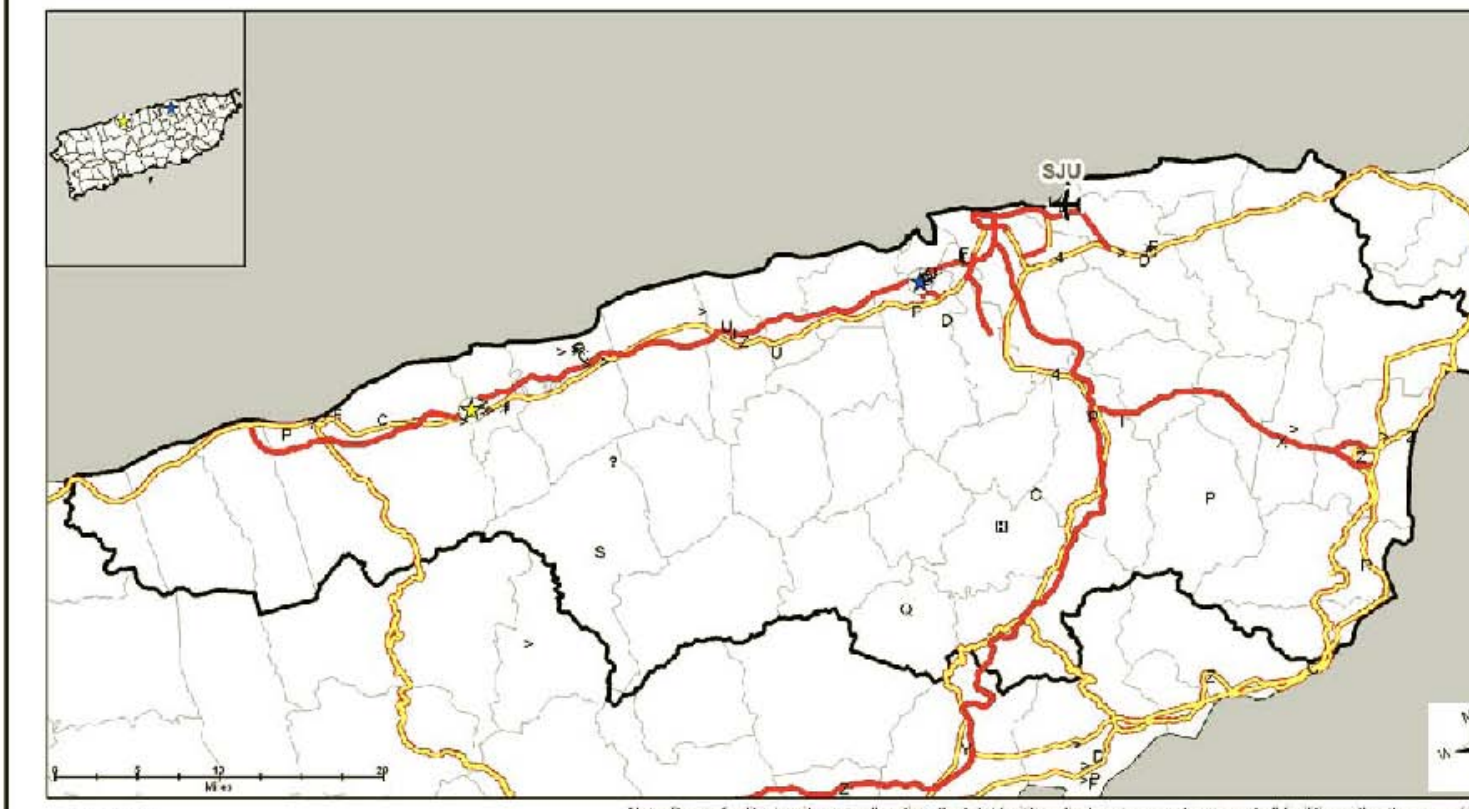
Table 7. Emission Source Profile for Selected HAPs in the San Juan, PR MSA **Table 8.** Upwind-Downwind HAP Concentration Differences

HAP	San Juan MSA Total Emissions (tpy)	San Juan MSA Mobile Emissions (tpy)	Mobile Emissions Upwind of SJPR (tpy)	Mobile Emissions Upwind of BAPR (tpy)
Acetaldehyde	321	275	99	35
Benzene	2,146	1965	653	261
Formaldehyde	987	692	248	88
Toluene	6,764	5,500	1,825	733
Total Xylenes	5,258	4,793	1,601	641
Total (from above)	15,476	13,225	4,426	1,758

Pollutant	# Paired Easterly Days	Downwind Concentration (µg/m3)	Upwind Concentration (µg/m3)	Concentration Difference (µg/m3)
Acetaldehyde	28	1.43 ± 0.29	5.82 ± 2.55	**-4.39 ± 2.35**
Acrolein	2	0.57 ± 0.54	1.01 ± 0.51	-0.44 ± 1.05
Benzene	28	1.09 ± 0.13	2.05 ± 0.32	**-0.96 ± 0.27**
Bromomethane	11	0.06 ± 0.01	0.08 ± 0.02	**-0.03 ± 0.02**
Butadiene, 1,3	18	0.18 ± 0.04	0.28 ± 0.07	**-0.10 ± 0.08**
Carbon Tetrachloride	28	0.65 ± 0.05	0.63 ± 0.07	0.02 ± 0.06
Chloroethane	7	0.04 ± 0.02	0.10 ± 0.06	-0.06 ± 0.07
Chloroform	9	0.17 ± 0.03	0.24 ± 0.05	**-0.08 ± 0.03**
Chloromethane	28	2.44 ± 0.23	2.08 ± 0.23	**0.36 ± 0.26**
Dichlorobenzene, *p*-	15	0.68 ± 0.17	1.18 ± 0.48	-0.50 ± 0.51
Dichloroethane, 1,2	1	0.12	0.20	-0.08
Dichloromethane	25	7.04 ± 2.92	0.87 ± 0.35	**6.18 ± 2.96**
Ethylbenzene	28	0.68 ± 0.09	1.34 ± 0.21	**-0.66 ± 0.19**
Formaldehyde	28	0.68 ± 0.13	2.20 ± 0.28	**-1.52 ± 0.34**
Hexachlorobutadiene	1	0.11	0.21	-0.11
Methyl Ethyl Ketone	7	2.64 ± 1.51	2.74 ± 1.15	-0.11 ± 1.92
Methyl Isobutyl Ketone	3	0.22 ± 0.06	1.09 ± 0.83	-0.87 ± 0.87
Methyl *tert*-Butyl Ether	3	0.41 ± 0.13	1.45 ± 0.69	**-1.05 ± 0.78**
Propionaldehyde	26	0.07 ± 0.04	0.33 ± 0.05	**-0.26 ± 0.06**
Styrene	20	0.19 ± 0.03	0.43 ± 0.14	**-0.23 ± 0.14**
Tetrachloroethylene	3	0.79 ± 1.00	0.38 ± 0.04	0.41 ± 1.03
Toluene	28	3.69 ± 0.55	8.37 ± 2.33	**-4.68 ± 2.23**
Trichloroethane, 1,1,1	15	0.13 ± 0.01	0.20 ± 0.06	-0.06 ± 0.06
Trichloroethylene	1	0.05	0.05	0
Xylenes (total)	28	4.91 ± 0.74	9.88 ± 1.67	**-4.96 ± 1.41**

BOLD = statistically significant difference at α=0.05

Figure 1. San Juan, PR MSA **Figure 2.** Composite 24-Hour Back Trajectory at the BAPR Monitoring Site



Note: Due to facility density and collocation, the total facilities displayed may not represent all facilities within the area of

Legend

UATMP sites

- BAPR
- SJPR

Major Road Classification

- Limited Access
- Highways
- San Juan-Caguas-Guaynabo, PR MSA
- County boundary

Source Category Group (No. of Facilities)

- Agricultural Chemicals Production Industrial Facility (1)
- Business Services Facility (1)
- Chemicals & Allied Products Facility (6)
- Electrical & Electronic Equipment Facility (5)
- Fabricated Metal Products Facility (4)
- Fuel Combustion Industrial Facility (5)
- Incineration Industrial Facility (3)
- Industrial Machinery & Equipment Facility (1)
- Liquids Distribution Industrial Facility (5)
- Medical, Dental, & Hospital Equipment and Supplies (1)
- Miscellaneous Manufacturing Industries (1)
- Miscellaneous Processes Industrial Facility (5)
- Petroleum/Nat. Gas Proc. & Refining Industrial Facility (3)
- Pharmaceutical Production Processes Industrial Facility (18)
- Primary Metal Industries Facility (3)
- Production of Organic Chemicals Industrial Facility (2)
- Rubber & Miscellaneous Plastic Products Facility (1)
- Stone, Clay, Glass, & Concrete Products (2)
- Surface Coating Processes Industrial Facility (1)
- Transportation Equipment (1)
- Unknown (2)

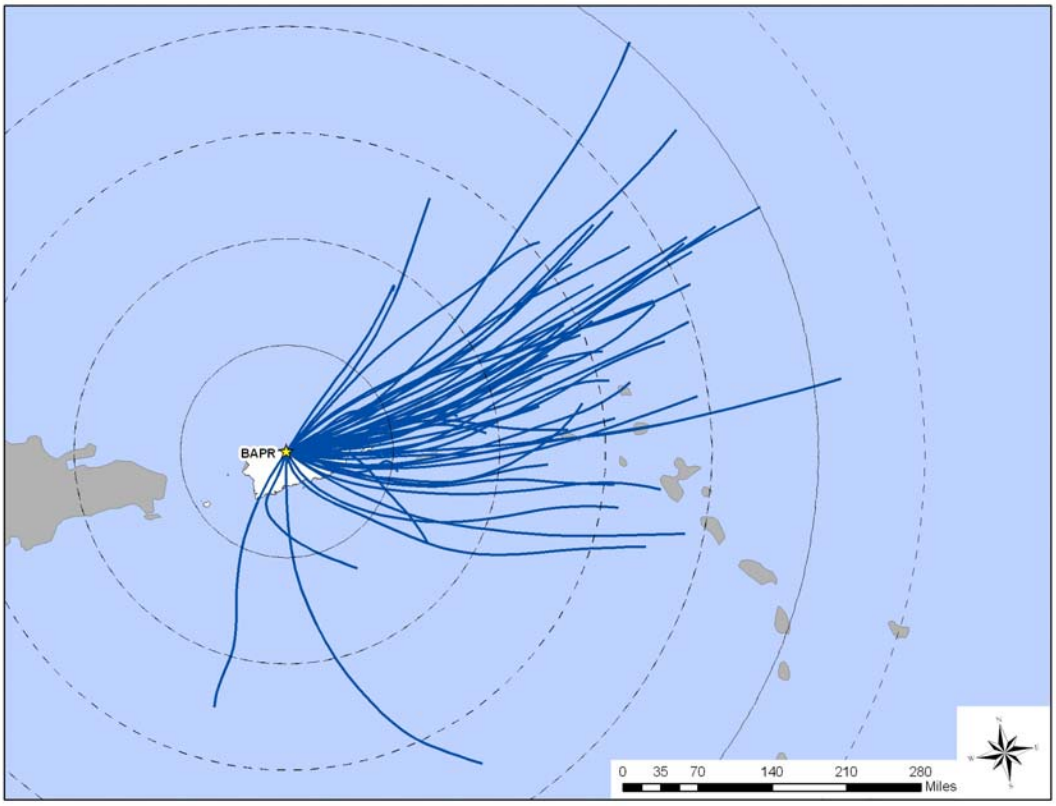
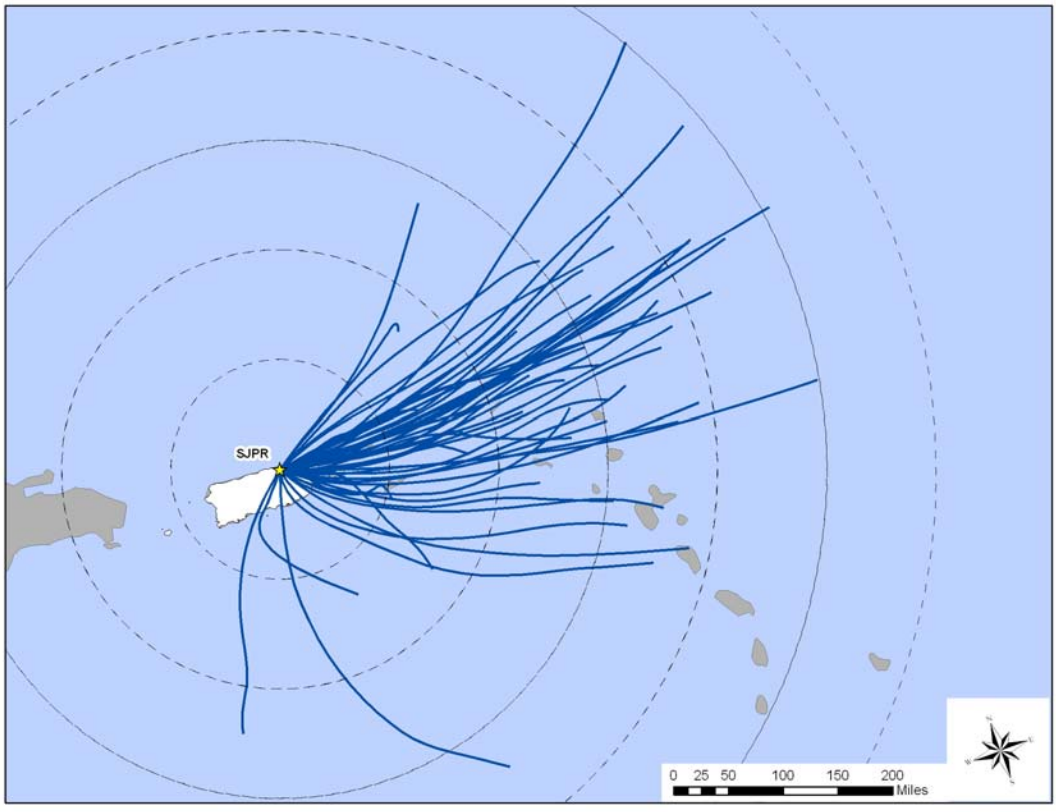
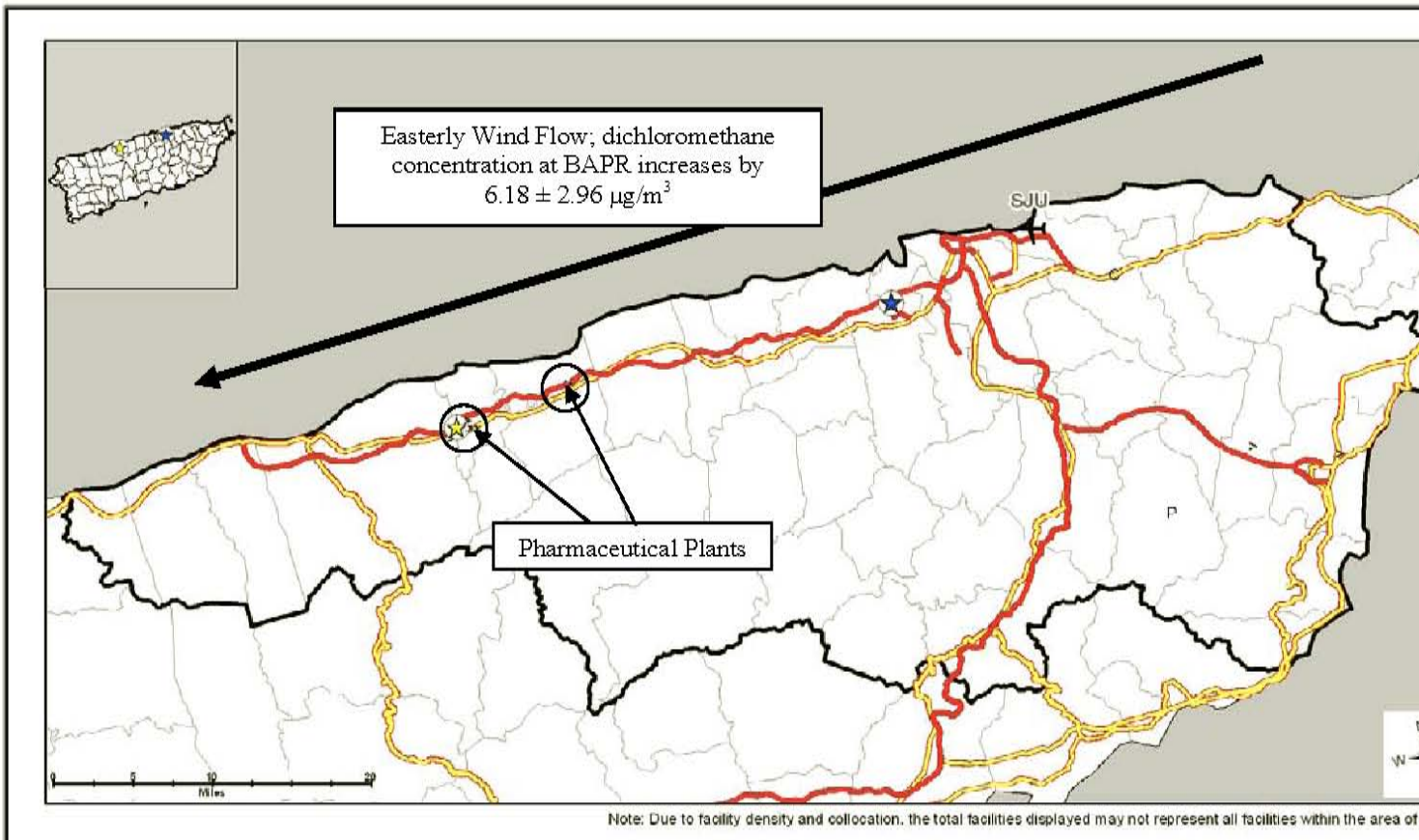


Figure 3. Composite 24-Hour Back Trajectory at the SJPR Monitoring Site **Figure 4.** Dichloromethane Point Source Emissions **Figure 5.** Mobile Source Emissions of Acetaldehyde, Benzene, Formaldehyde, Toluene, and Total Xylenes





Note: Due to facility density and collocation, the total facilities displayed may not represent all facilities within the area of

Legend

UATMP sites

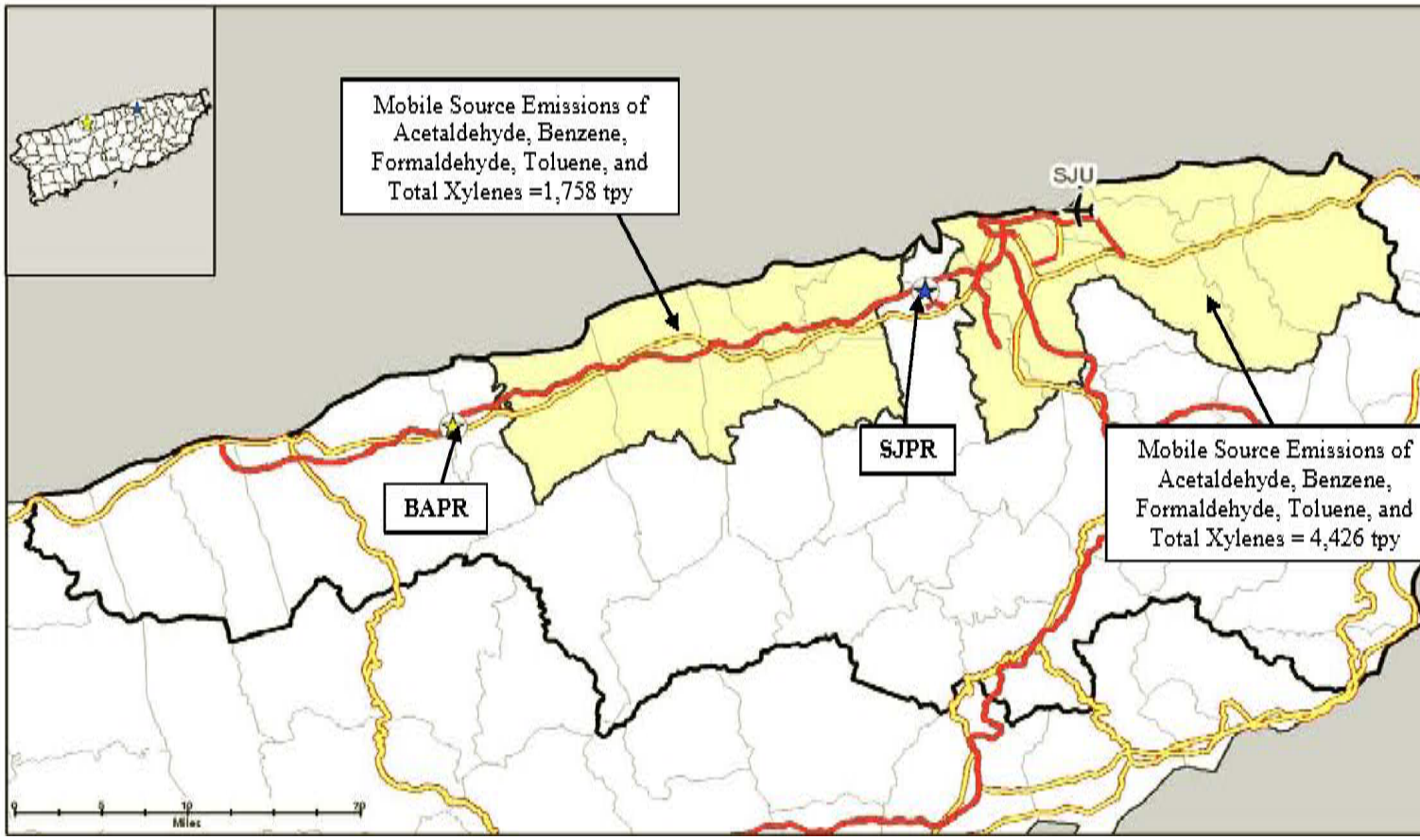
- BAPR
- SJPR

Major Road Classification

- Limited Access
- Highways
- County boundary
- San Juan-Caguas-Guaynabo, PR MSA

Source Category Group (No. of Facilities)

- Business Services Facility (1)
- C Chemicals & Allied Products Facility (1)
- P Miscellaneous Processes Industrial Facility (1)
- Pharmaceutical Production Processes Industrial Facility (7)


Mobile Source Emissions of Acetaldehyde, Benzene, Formaldehyde, Toluene, and Total Xylenes =1,758 tpy
SJU
SJPR
BAPR
Mobile Source Emissions of Acetaldehyde, Benzene, Formaldehyde, Toluene, and Total Xylenes = 4,426 tpy
Miles