

# Division of Science, Research and Technology

## Research Project Summary

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### ***New Jersey Atmospheric Deposition Network***

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#### ***Abstract***

Atmospheric deposition is an important source of a number of contaminants to the environment. The New Jersey Atmospheric Deposition Network (NJADN) was a collaborative research and monitoring effort between Rutgers University and the New Jersey Department of Environmental Protection (NJDEP). The objectives of the project were to quantify current concentrations and deposition fluxes of targeted contaminants and assess their spatial and seasonal trends, and, to the extent possible, to determine the importance of atmospheric deposition relative to other inputs. Contaminants measured included PCBs, PAHs, certain organochlorine pesticides, heavy metals, nutrients, and organic and elemental carbon particles. NJADN results have established baseline levels of the organic contaminants in the gas, particle, and precipitation phases and of the metals, nutrients, and organic and elemental carbon in the particle and precipitation phase. These baseline levels will be useful in the evaluation of long-term trends and determining the effectiveness of pollution control efforts.

#### **Introduction**

Driven by the recognition that atmospheric deposition provided potentially important inputs of a number of pollutants to the region's environment, NJADN began in 1997. It was expanded in 1998 to include nine sites. Much of the sampling work ended in May, 2001, although additional DEP support permitted operation of three sites until August, 2002 and operation of a tenth site until January, 2003. Related sampling work, supported by the Delaware River Basin Commission, took place in the Philadelphia area.

Over the course of the project, the concentrations and deposition fluxes of a number of substances were determined. These included 116 organic compounds representing polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and organo-chlorine pesticides (including chlordanes, DDTs, HCHs, Endosulfan I and II, Aldrin and Dieldrin), particulate organic and elemental carbon in fine aerosols (PM<sub>2.5</sub>), and 21 inorganic analytes including mercury and many other heavy metals, nitrate, and phosphate. Samples were collected on a twelve-day sampling cycle at ten sites throughout New Jersey.

The organic compounds examined in the NJADN project derive from combustion processes (PAHs, carbon), the remobilization of chemicals from historical uses in urban-industrial centers (PCBs), past agricultural practices (some organochlorine pesticides), and current, but geographically distant, pesticide use (certain other organochlorine pesticides). The trace metals included in the NJADN study are mostly associated with combustion

processes (power plants, incinerators, automobiles, trucks), mechanical wear and tear on automobiles and trucks, and soils.

#### **Methods**

##### ***Sampling***

For organic compounds, 24-hour air samples were collected using a modified high volume air sampler with a calibrated airflow of  $\sim 0.5 \text{ m}^3 \text{ min}^{-1}$ . Quartz fiber filters were used to capture the total particulate phase and polyurethane foam plugs were used to capture the gaseous phase. Wet-only automatic integrating precipitation samplers were used to collect integrated precipitation samples in a stainless steel funnel that drained through a glass column containing XAD-2 resin.

For inorganic analytes, integrated rain samples were collected using the automatic precipitation collectors, fitted with Keeler-type acrylic inserts to support polyethylene funnels and collection bottles for trace elements, nitrate, and phosphate samples, and glass funnels and Teflon collection bottles for Hg samples. Fine aerosols were collected on Teflon filters held in acid-cleaned polypropylene cartridges by pulling air through a Caltech low volume impactor at a flow rate to achieve an aerodynamic particle diameter cutoff of 2.5  $\mu\text{m}$ .

At each site, organic chemicals (PCBs, PAHs, organochlorine pesticides) were measured in precipitation and gaseous and particulate phases and trace elements were

measured in fine aerosols (PM<sub>2.5</sub>). Trace elements, nitrate, and phosphate were measured in precipitation at four NJADN sites with some coverage at Sandy Hook and Tuckerton by Y. Gao. Total suspended particulate matter (TSP) masses were also determined for the majority of sites. Atmospheric samples of gas and particulate phases (organics) were collected at all sites one day (24 hours) every 12<sup>th</sup> day, and wet-only integrated precipitation was collected over 12-24 days. Meteorological data were obtained from established meteorological stations at New Brunswick (Rutgers Gardens/PAMS site), Tuckerton (Rutgers Marine Station), from area airports (JFK, Newark, Philadelphia), and from other regional NOAA sites. Three-day back trajectories were calculated for some of the time periods using NOAA's HYSPLIT Model at locations in northern, middle and southern New Jersey.

### Analyses

PCB samples were injected with surrogate standards before extraction, and then extracted and fractionated. They were analyzed with gas chromatography. There are many different specific molecules, or congeners, that comprise the category known as PCBs. NJADN measured congeners that were found in the mixtures of PCBs that were produced and intentionally used. PAH samples were analyzed with similar methods. Organochlorine compounds were analyzed in fractionated sample extracts by gas chromatograph-mass spectrometry. Trace metal concentrations in rain were measured by ICP-MS after acidification of samples. Precipitation samples collected from 7/13/99 to 6/30/00 (except at Jersey City, 9/3/99 to 7/24/00) were analyzed for NO<sub>3</sub><sup>-</sup> by ion chromatography (IC) and samples collected after 6/30/00 (7/24/00 Jersey City) were analyzed for NO<sub>3</sub><sup>-</sup> + NO<sub>2</sub><sup>-</sup> by colorimetric assay. The detection limit for the IC method was 1.9 μM, and the detection limit for the colorimetric method was 0.2 μM. A colorimetric method was also used for phosphates. Total Hg in precipitation was measured in 150 ml rain subsamples by SnCl<sub>2</sub> reduction and cold vapor atomic fluorescence spectrometry after oxidation with bromine monochloride. Duplicate analyses of two rain samples by the laboratory used by the National Atmospheric Deposition Program (NADP) indicate that the concentrations of Hg in rain samples collected as part of NJADN are comparable to those collected as part of the NADP within an uncertainty of about 30%. Fine particle (PM<sub>2.5</sub>) samples were digested with acidic solutions and some were split for trace metal and mercury analysis. Trace metal concentrations in the PM<sub>2.5</sub> digestates were measured as described above for precipitation. Analytical procedures are described in detail in the NJADN final report.<sup>1</sup>

## Results

### PCBs

Gas-phase Σ PCB concentrations were found to vary over more than two orders of magnitude from site to site in the region, with highest concentrations typically occurring in the urbanized areas of Camden and Jersey City. These concentrations were not high enough, however, to present

significant health risk to humans due to inhalation. They are high enough, however, to suggest the presence of relatively large local or regional sources. Typically, less than 10% of the total atmospheric Σ PCB burden was found in the particle phase. The percentage is also higher for the higher molecular weight PCBs. The spatial distribution demonstrates that, like gas-phase PCBs, particle-phase PCBs in this region arise from sources that are highly localized in urban areas. Volume-weighted mean (VWM) precipitation concentrations of Σ PCBs at the eight sites at which precipitation was collected varied over two orders of magnitude. The spatial variations in concentrations mirrored those of the gas-phase, and also suggest that highly localized, urban sources of PCBs exert an influence over atmospheric concentrations and deposition fluxes over a distance of a few tens of km.

*PCB Deposition flux estimates:* Based on the measured gas, particle, and precipitation phase concentrations, NJADN researchers estimated the atmospheric deposition flux, or flow, of Σ PCBs at the different sites. They factored in wind speeds, the chemical and physical properties of the congeners, and known and estimated relationships between these properties and rates of absorption onto water and land surfaces. For particles, a deposition velocity of 0.5 cms<sup>-1</sup> was chosen.<sup>2</sup> At most sites, the component of deposition that reflects the transfer of gas phase molecules to surfaces makes the largest contribution to overall deposition. The wet deposition component is relatively small at all sites. The deposition estimates reflect the flow of PCBs from the atmosphere to the ground or to water surfaces, but they do not include estimates of the reverse flow. If a water body, for example, has a relatively large concentration of PCBs, some of this concentration will typically vaporize,

**Table 1: Σ PCB Deposition Fluxes at the NJADN Sites.**

Site	Gas Absorption		Dry Deposition ng m <sup>-2</sup> d <sup>-1</sup>	Wet Deposition	
	Actual <sup>a</sup> ng m <sup>-2</sup> d <sup>-1</sup>	Modeled <sup>b</sup> ng m <sup>-2</sup> d <sup>-1</sup>		VWM conc ng L <sup>-1</sup>	Flux ng m <sup>-2</sup> d <sup>-1</sup>
Alloway Creek	7.3 (4.0)	10	2.0	0.74	2.2
Camden	224 (4.4)	295	52	13 <sup>c</sup>	44 <sup>c</sup>
Chester	4.1 (1.4)	21	2.1	0.52 <sup>c</sup>	1.1 <sup>c</sup>
Delaware Bay	2.5 (1.1)	18	6.5	NM	NM
Jersey City	127 (4.9)	119	23	3.9 <sup>c</sup>	11 <sup>c</sup>
New Brunswick	5.1 (1.7)	19	8.5	1.3 <sup>c</sup>	3.0 <sup>c</sup>
Pinelands	5.8 (2.8)	13	2.0	0.38 <sup>c</sup>	1.0 <sup>c</sup>
Sandy Hook	53 (5.4)	43	5.1	0.80 <sup>c</sup>	2.1 <sup>c</sup>
Tuckerton	15 (5.0)	18	2.9	0.35 <sup>c</sup>	0.85 <sup>c</sup>
Washington Crossing	19 (4.0)	24	3.8	NM	NM

<sup>a</sup> Gas absorption flux calculated using actual wind speeds (average wind speed in m s<sup>-1</sup> given in parentheses).

<sup>b</sup> Gas absorption flux calculated assuming a constant wind speed of 5 m s<sup>-1</sup>.

<sup>c</sup> From Van Ry et al. 2002.

NM = not measured

i.e., move from the water to the air. This flow can be large enough in some cases to overwhelm the flow of PCBs from the air to the water, making for a net flow, or flux, from water to air. NJADN made estimates of the net flux of PCBs in the Hudson River Estuary, but did not make similar estimates for other water bodies due to lack of sufficient information on PCB concentrations in the waters themselves. See Table 1, "PCB Deposition Fluxes at the NJADN Sites" below.

In the case of the Hudson River Estuary, the atmospheric deposition of PCBs is small compared to other inputs, such as from known PCB contaminated locales in the Upper Hudson. Nevertheless, the atmospheric load of PCBs is large enough to be of concern there, and may well be a concern for other water bodies as well; it is likely that the atmosphere is a large enough source of PCBs to many water bodies to mean that current water quality criteria cannot be met without substantial decreases in atmospheric PCB concentrations.

#### PAHs

Atmospheric concentrations of polycyclic aromatic hydrocarbons (PAHs) were measured in the gas and particle phases in air and in precipitation at nine New Jersey sites at regular intervals from October 1997 through May 2001. Gas phase and particle phase  $\Sigma_6$ PAH concentrations ranged from 0.45 to 118 ng/m<sup>3</sup> and 0.046 to 172 ng/m<sup>3</sup>, respectively, and precipitation concentrations ranged from 11 to 16200 ng/L. PAH concentrations vary spatially across the State of New Jersey with the highest concentrations occurring at the most heavily urban and industrial locations. Although the absolute concentrations vary spatially, the PAH profiles are statistically similar at nine of the ten sampling sites indicating that the mix of sources around New Jersey is the same. Gas phase PAH concentrations increase in the warmer seasons; whereas for predominantly particle phase PAHs concentrations reach a maximum in colder seasons.

Increased emission of PAH attributed to elevated fossil fuel use in winter is believed to drive the particle phase PAH concentrations at most of the NJADN sites. PAH concentrations measured in urban/industrial New Jersey (Jersey City and Camden) are similar to those measured in other urban areas in the U.S. PAH concentrations were also measured in rainfall.

#### PAH Deposition flux estimates:

Atmospheric deposition fluxes of PAHs were estimated based on the measurements and models that are described in detail in the NJADN final report. The distribution of specific PAHs between the gas and particle phases in the atmosphere is important in determining the dominant deposition process and the magnitude of total atmospheric deposition. Fluxes of low molecular weight PAHs are dominated by gas absorption. Wet and dry particle deposition play a larger role in the flux of medium weight PAHs. Dry particle deposition plays the largest role for high molecular weight PAHs. Annual average  $\Sigma_{36}$ PAH total atmospheric deposition fluxes in New Jersey range from  $5.4 \times 10^2$  to  $7.3 \times 10^3$  ug/m<sup>2</sup> year. The order of highest to lowest fluxes follows the trend: Jersey City, Camden, Sandy Hook, Tuckerton, New Brunswick, Alloway Creek, Pinelands, and Chester.

#### Organochlorine Pesticides

Organochlorine Pesticides (OCPs) were measured in 2000-2001 at six locations in New Jersey as part of NJADN. It was found that higher air temperatures are associated with higher concentrations of most OCPs. Lower than expected concentrations were observed when the air mass came from the northwest (Canada and Great Lakes), whereas higher than expected concentrations showed no correlation with the air mass origin. Using estimation methods similar to those used for PCBs and PAHs, NJADN researchers estimated the atmospheric deposition flux for the measured OCPs. These values are shown in Table 2 "OCP Atmospheric Deposition Fluxes" below.

**Table 2: OCP Atmospheric Deposition Fluxes**  
Units are ng m<sup>-2</sup> d<sup>-1</sup>. Blank spaces indicate the pesticide was not detected in that phase at that site.

	Gas Absorption						Dry Particle Deposition					Wet Deposition		
	CC	DB	JC	NB	PL	SH	CC	DB	JC	NB	PL	CC	JC	PL
alpha-HCH	42	8.1	11	43	26	9.7								
gamma-HCH	68	10	11	34	22	9.1								
sum HCHs	110	18	22	77	48	19								
Heptachlor	10	0.12	11	5.1	1.7	1.6								
Dieldrin	25	2.4	3.2	15	15	4.2			1.2					
Aldrin	7.4	0.00048	0.43	2.6	0.19	0.20			0.10					
Endosulfan I	33	4.1	5.4	80	22	6.3	0.87	0.36	0.42	0.22	0.39	0.46	0.14	0.46
Endosulfan II	NC	NC	NC	NC	NC	NC	1.8	1.0	0.70	0.90	0.94	2.4	0.88	0.85
Endosulfan sulfate							0.72	0.44	0.35	0.43	0.60	1.3	0.66	1.1
Oxychlorane							0.052			0.097	0.027	0.0095	0.010	0.025
$\Sigma$ -Chlordanes	144	16	34	147	39	27	2.8	0.42	2.7	1.8	0.46	0.52	0.55	0.20
$\Sigma$ -DDTs	31	2.1	8.7	62	8.0	14	1.5	0.71	2.1	1.2	0.25	0.57	1.1	0.17

NC = Not calculated.  
CC = Camden, DB = Delaware Bay, JC = Jersey City, NB = New Brunswick, PL = Pinelands, SH = Sandy Hook

The NJADN data represent the first measurements of organochlorine pesticides in New Jersey air, and allow the first estimates of atmospheric deposition of such pesticides to the region. Because of the uncertainties inherent in the calculation of deposition fluxes from atmospheric concentrations, it is difficult to detect significant differences in deposition fluxes between any of the NJADN sites. However, it may be reasonably assumed that higher concentrations will lead to higher deposition fluxes. Atmospheric concentrations of dieldrin, aldrin, and the HCHs are similar to those measured in the Great Lakes region, suggesting that New Jersey receives atmospheric deposition fluxes of these compounds that are similar to those received by the Great Lakes. In contrast, concentrations of DDTs, chlordanes, and heptachlor are higher in NJADN than in the Great Lakes region. In New Jersey, no clear correlation was found between urbanization and high atmospheric levels of OCPs. High atmospheric OCP levels are likely to be associated with past or present pesticide use (i.e., agricultural areas). High OCP levels at New Brunswick are therefore not surprising, as this site is located within Rutgers Gardens and less than a mile from the fields used by Rutgers and Cook College for decades of agricultural research. It is speculated that the high OCP levels observed in Camden may be due to its location downwind of rich agricultural areas in eastern Pennsylvania, not to its urban character. Also, DDT was once manufactured in the Philadelphia region.

### Organic carbon and elemental carbon

NJADN also measured organic carbon (OC) and elemental carbon (EC) associated with particles less than 2.5 micrometers in diameter (PM<sub>2.5</sub>) at five locations in New Jersey representing different geographical land-uses. No distinct seasonal patterns in OC<sub>2.5</sub> or EC<sub>2.5</sub> concentrations or in the OC/EC ratio were observed. Periods of secondary organic aerosol formation and periods during which OC<sub>2.5</sub> arose mainly from primary emissions were identified using ozone, carbon monoxide and meteorological data. Ozone was used as an indicator of periods of photochemical activity, while CO was used as an indicator of combustion sources. Around 40% of the data at all sites display evidence of secondary organic aerosol formation. See Table 3, “Concentrations of OC and EC Associated with PM<sub>2.5</sub>”, below.

**Table 3: Concentrations of OC and EC Associated with PM<sub>2.5</sub>**

Site	Average OC <sub>2.5</sub> ± SD μg/m <sup>3</sup>	Min. OC <sub>2.5</sub> Mg/m <sup>3</sup>	Max. OC <sub>2.5</sub> μg/m <sup>3</sup>	n OC <sub>2.5</sub>	Average EC <sub>2.5</sub> ± SD μg/m <sup>3</sup>	Min. EC <sub>2.5</sub> μg/m <sup>3</sup>	Max. EC <sub>2.5</sub> μg/m <sup>3</sup>	N EC <sub>2.5</sub>	Average OC/EC	Min. OC/EC	Max. OC/EC	n OC/EC
Camden	3.7±1.7	1.1	8.9	51	0.83±0.52	0.3	3.7	51	4.9±1.8	1.2	9.1	51
Jersey City	5.4±2.3	1.2	12	71	1.7±1.7	0.20	7.1	71	4.5±3.8	0.68	28	70
New Brunswick	3.4±1.5	1.2	9.0	116	0.74± 0.5	0.13	3.1	116	5.8±3.7	1.6	29	113
Pinelands	2.7±1.3	1.1	5.8	56	0.34±0.17	0.16	0.92	52	9.9±5.8	3.3	28	58
Sandy Hook	3.5±2.9	1.2	23	83	0.45±0.28	0.18	1.6	76	8.0±3.5	2.9	41	76

(Mean ± 1 standard deviation).

### Heavy Metals

Concentrations in precipitation and in small atmospheric particles (PM 2.5) of a number of inorganic chemicals, including a number of heavy metals, were measured as part of NJADN. These measurements permitted a calculation of the wet deposition of these substances, and an estimation of the dry deposition due to particle fall-out. These results are summarized in Table 4 “Deposition Fluxes of Inorganic Chemicals in NJ Precipitation” and Table 5 “Dry Particle Deposition Fluxes of Inorganic Chemicals in NJ” below.

**Table 4: Deposition Fluxes of Inorganic Chemicals in NJ Precipitation**

Annual deposition fluxes (μg m<sup>-2</sup> y<sup>-1</sup>)

BD = flux not calculated since all VWM concentrations were below the detection limit.

NA = not analyzed.

Element	New Brunswick	Jersey City	Pinelands	Camden	Alloway Creek
Ag	25	21	59	38	BD
Al	35,000	28,000	24,000	56,000	34,000
As	67	160	65	150	130
Cd	62	76	23	71	39
Cl	340,000	750,000	220,000	560,000	NA
Co	46	130	22	160	30
Cr	150	180	56	310	65
Cu	1,500	2,200	490	2,000	790
Fe	47,000	47,000	23,000	87,000	38,000
Hg	11	14	11	14	5
Mg	65,000	81,000	54,000	84,000	89,000
Mn	2,500	1,900	2,900	3,400	2,700
Ni	650	1,200	290	980	270
NO <sub>3</sub> -N	360,000	360,000	390,000	420,000	310,000
PO <sub>4</sub> -P	7,100	5,200	8,300	8,100	NA
Pb	1,700	2,500	650	3,500	770
Pd	10	20	8.1	18	3.6
Sb	85	170	140	140	310
SO <sub>4</sub> -S	570,000	770,000	670,000	900,000	NA
V	580	880	410	1,100	430
Zn	7,800	8,800	5,500	12,000	10,000

**Table 5: Dry Particle Deposition Fluxes of Inorganic Chemicals in NJ**  
 Fluxes ( $\mu\text{g m}^{-2} \text{y}^{-1}$ ) were estimated from the concentrations of metals in fine aerosols (PM<sub>2.5</sub>) and a deposition velocity of 0.5 cm/s.

Element	NB	JC	PL	CC	WC	TK	XQ	SH	DB	AC
Ag	33	130	13	32	5.7	4.6	7.0	5.9	5.0	14
Al	7,200	13,000	9,700	12,000	9,700	6,900	5,400	15,000	8,300	7,000
As	100	150	75	110	100	160	140	99	100	77
Cd	32	100	16	44	30	16	30	23	21	21
Co	160	84	55	66	28	21	28	35	29	250
Cr	12,000	960	4,100	3,900	750	300	1,600	430	480	20,000
Cu	2,200	2,700	1,200	1,300	4,600	1,100	240	640	310	1,000
Fe	66,000	38,000	28,000	40,000	17,000	12,000	12,000	21,000	8,300	97,000
Hg	1.2	1.8	0.8	2.5	1.0	0.9	2.2	1.2	1.2	2.0
Mg	4,100	6,400	13,000	8,800	5,700	5,100	1,600	12,000	5,600	2,900
Mn	1,700	700	580	800	380	240	310	560	210	2,500
Ni	10,000	2,000	3,400	2,900	1,700	570	1,100	880	370	16,000
Pb	1,100	4,200	460	900	1,100	520	430	830	350	480
Pd	8.8	4.0	10	14	2.8	4.1	3.4	3.3	3.7	14
Sb	130	840	64	210	96	64	53	110	45	52
V	440	1,600	310	820	400	560	230	1,000	420	498
Zn	3,600	5,500	2,600	5,300	3,400	3,500	4,300	5,200	3,600	2,600

CC = Camden, DB = Delaware Bay, JC = Jersey City, NB = New Brunswick, PL = Pinelands, SH = Sandy Hook, WC = Washington's Crossing, TK = Tuckerton, XQ = Chester, AC = Alloway Creek

**Arsenic (As), cadmium (Cd), copper (Cu), and lead (Pb):** These elements, emitted from a variety of industrial and municipal sources are, except for As, strongly associated with particulate matter. The atmospheric concentrations and deposition of As, Cd, Cu, and Pb are generally lowest in the Pinelands and highest in Jersey City and Camden. Seasonal variations in the volume mean weighted concentrations in precipitation of As, Cd, and Cu were not uniform across New Jersey indicating the importance of local sources and/or atmospheric transport processes to the deposition of these trace elements in the state. In contrast, the seasonal variation in the concentrations of Pb was similar at all sites and showed the highest levels in the spring and the lowest levels in the fall or winter. The atmospheric deposition fluxes of Cd, Cu, and Pb illustrate the presence of an urban signal above the regional background that may indicate local sources. The wet deposition fluxes of Cd, Cu, and Pb at the urban/suburban NJADN sites (New Brunswick, Jersey City, and Camden) are two to nine times higher than those measured in the early 1990's at rural sites in Maryland and Florida (Landing et al. 1995). These differences do not appear to be the result of methodological difference since precipitation fluxes of Cd, Cu, and Pb in the New Jersey Pinelands are similar to those in rural Maryland and Florida. This trend is similar for the dry particle fluxes of Cd, Cu, and Pb.

**Mercury:** Mercury (Hg) is of environmental concern because of the enrichment and toxicity of methylmercury in aquatic biota, birds, mammals and humans.

Concentrations of mercury in precipitation measured through NJADN varied widely, but were generally in the range of 15 to 115 pM (3 to 23 ng/l). Concentrations in precipitation show a strong seasonal pattern, with the highest in summer and fall and the lowest in winter and spring. The same seasonal pattern has been observed elsewhere. The maximum differences in rain water Hg concentrations among four of the New Jersey sites (excluding Alloway Creek) were also greater in the summer and fall (35–40 pM) than in the winter and spring (20–28 pM), suggesting that localized phenomena are responsible for much of the increase in Hg concentrations in New Jersey rain in the summer and fall. Localized phenomena may include greater emissions from local sources and/or higher Hg oxidation rates as a result of increased levels of atmospheric oxidants such as O<sub>3</sub>.

The mercury data collected through NJADN do not include gaseous forms of mercury, which are also called reactive gaseous mercury (RGM) or oxidized mercury. These forms are present in the atmosphere and comprise a significant portion of anthropogenic mercury emissions. As reactive gases, RGM species are expected to have relatively high deposition velocities similar to gases such as HNO<sub>3</sub>. Thus low concentrations of RGM could nevertheless account for significant Hg deposition. For example, with an RGM concentration of 40 pg m<sup>3</sup> (average concentration measured for Solomons, MD<sup>1</sup>) and a deposition velocity of 1 cm s<sup>-1</sup>, the estimated annual deposition of RGM (13 μ m<sup>2</sup>/y) is comparable to wet deposition

fluxes measured across New Jersey (14-18  $\mu\text{g m}^2/\text{y}$ ).

### Discussion

Research is needed to improve understanding of dry deposition, including both particles and gaseous molecules, especially for mercury. The wet deposition fluxes of Hg in suburban New Brunswick and the rural Pinelands were lower than those recorded at the more urban/industrial Jersey City and Camden locations suggesting that in addition to the regional Hg signal, local phenomena are also important to the wet deposition of Hg in New Jersey. Lower Hg concentrations in rain measured at rural sites (DE, NY, VT, and PA) than at more developed locations in New Jersey, Maryland, and Florida suggest that differences in local sources, meteorology, and atmospheric chemistry affect the variability of Hg concentrations in east coast rain. The New Jersey wet deposition fluxes of Hg, together with the nearly synoptic NADP results for Pennsylvania, show something of a spatial gradient in Hg deposition with relatively low Hg deposition rates at the central Pennsylvania sites (Cambria and Tioga counties), higher deposition rates in eastern Pennsylvania (Valley Forge), and the highest deposition fluxes in New Jersey. This west to east increase in Hg wet deposition could be the result of increasing Hg emissions, changes in atmospheric chemistry at this mid-Atlantic latitude, or both. A careful inventory of Hg emissions coupled with an assessment of the variation in atmospheric oxidant concentrations in this region could address this issue.

Also, as noted above, NJADN measurements of mercury did not include reactive gaseous forms (RGM). Although there are significant uncertainties in estimating the contribution of RGM to total mercury deposition, it is likely that this contribution is significant. The ambient concentrations, formation, and seasonal cycle of RGM in New Jersey need to be studied in order to assess the full impact of the atmospheric deposition of Hg in the State. Research on mercury should also include efforts to better understand the transport and fate mechanisms of mercury in the atmosphere, especially those that mediate its oxidation from elemental forms to reactive forms.

More information is necessary on PCBs. Their concentrations continue to be high enough in the Delaware Estuary and NY/NJ Harbor to be problematic, and numerous fish advisories for PCBs continue to be necessary. Local transport modeling and source apportionment studies should be supported and used to identify the major emissions sources of PCBs to the atmosphere. Included in this work should be investigation of possible fresh sources of PCBs to the environment from ongoing industrial processes (as opposed

to emissions from legacy PCBs), including some congeners not investigated through NJADN.

The NJADN work also identified other issues associated with atmospheric deposition of toxics and other substances. Included is the need to better quantify and identify organic nitrogen deposition, and its sources. Also, assessments of the concentrations and deposition fluxes of emerging atmospheric contaminants such as brominated compounds are needed in the Mid-Atlantic region. In addition, studies focused on the evaluation of the watershed retention and runoff and ecosystem impacts of atmospheric contaminants are needed to evaluate the real impacts of atmospheric deposition as a major non-point source of contaminants to surface waters.

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### References

See the full NJADN report and summary material, available at the NJDEP Division of Science, Research & Technology web site, at <http://www.state.nj.us/dep/dsr/>

<sup>1</sup> Reinfelder, John, Lisa Totten, and Steven Eisenreich, 2004, *The New Jersey Atmospheric Deposition Network, Final Report to the NJDEP*, Michael Aucott, project manager, NJDEP Division of Science, Research, & Technology, May, 2004 (NJADN Final Report).

<sup>2</sup> The chosen deposition velocity was selected to capture the deposition of all size classes of atmospheric particles, but may underestimate the flux of elements primarily associated with large particles and over estimate the deposition of elements primarily associated with small particles.

<sup>3</sup> Sheu, G.R., Mason, R.P., 2001, *Environ. Sci. Technol.* 35, 1209-1216.

<sup>4</sup> Reinfelder, et al. 2004.

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# RESEARCH PROJECT SUMMARY