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Chapter 7

MERCURY DEPOSITION FROM RAIN AND SNOW IN VIRGINIA

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ABSTRACT

Automated stations to collect rain and snow have been used for several years to quantify the weekly amount of mercury in rain and snow, and the weekly amount of precipitation, over much of the United States. Data from the Virginia collection sites in central and west-central Virginia are compiled and may be compared constantly to the on-line data reported from all the collection sites. While the sources for mercury in the atmosphere are numerous, most comes from coal-burning electrical power plants. Other locally significant sources of mercury exist, but none are known in central Virginia. Data show that the atmospheric content of mercury increases during prolonged intervals without precipitation (for example, several weeks without any rain or snow), and that the atmospheric content of mercury is exceptionally low following unusually prolonged precipitation events (several days or rain or snow). The regional variations of atmospheric mercury precipitation do not serve to identify any particular source of mercury (i.e., any particular coal-burning power plant), but instead indicate significant mixing of atmospheric mercury.

Keywords: mercury, pollution, precipitation

1. INTRODUCTION

The National Atmospheric Deposition Program (http: // nadp.sws.uiuc.edu/mdn/) of the U.S. Geological Survey and the U.S. Environmental Protection Agency established the Mercury Deposition Network (MDN) in 1995. The MDN consists

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of several hundred stations (ours is in Culpeper, VA) to accurately measure the concentration of mercury in precipitation in the United States and Canada. Data from the early years (through the present) of MDN activity showed that the greatest total amount of mercury precipitation was in the southeastern United States, around the Gulf of Mexico, probably because the area has relatively high total precipitation. The greatest amount of mercury precipitation during individual precipitation events is in the southwestern United States, which has low and infrequent precipitation events.

Atmospheric mercury is not considered dangerous to humans, but it becomes harmful following deposition, due to bioaccumulation and the formation of toxic mercury compounds in fish. High levels of mercury in fish is known to be dangerous if consumed by pregnant women and young children, because it causes birth defects and tissue damage (Gobeille et al, 2005). The toxic organic compound of mercury, methylmercury, moves through protective tissues and barriers in humans, including the blood-brain barrier and the placenta. More than 75% of the fish consumption advisories in the United States are due to high levels of mercury.

The national MDN database has been gathered to evaluate potential correlations between sources of mercury emissions to the atmosphere and mercury concentrations. It was anticipated that these measurements, plus an understanding of air movement in the atmosphere, could reveal areas where excess amounts of mercury emission and deposition occur. The central Virginia MDN site is operated in the Center of Basic and Applied Science in Culpeper, Virginia by faculty and students at George Mason University in Fairfax, Virginia. This MDN site, number VA-08, began providing weekly rainfall measurements and mercury collections in the fall of 2002. It is located about 30 kilometers east of site VA-28 located in western Virginia. This site is in the Shenandoah National Park. Site VA-28, and is operated by the United States National Park Service. These two sites are in comparatively close proximity to one another, but at different elevations (160 meters above sea level for the central Virginia site and 1075 meters for the western Virginia site). It was thought that knowledge would be gained by comparing the results from these two sites over 3 years, 2002 through 2005.

More than 30% of the mercury in the atmosphere is estimated to come from the factory production of metal, and almost 10% from the factory production of paper (Table 1). For this study, the most likely source for the mercury found in precipitation in the study area were assumed to be the coal-burning electric power plants located within 200 kilometers of these Virginia MDN sites. Data from the EPA Toxic Release Inventory (www . epa.gov/triexplorer) show that almost 60% of the atmospheric mercury in Virginia comes from such power plants.

Determining if there is a significant correlation between mercury deposition by precipitation and proximity to coal-burning power plants has been a continuing effort among concerned scientists. Increased regulation of coal combustion products has reduced mercury emissions, but mercury emission levels vary depending on the source and type of coal used, and the operating conditions at the plant. Currently no combustion regulation system is designed specifically designed for mercury removal, but particulate matter cleansing mechanisms control mercury emissions sufficiently to meet most standards.

Table 1. Estimates of mercury emissions in the Virginia EPA Toxic Release Inventory

Source of Mercury in the Atmosphere	**Emission in Kilograms**	**Percent of Total**
Coal-Burning Electric Utilities	575	58 %
Metal Production	320	33 %
Paper Production	70	7 %
Petroleum and Tobacco Production	11	1 %
Stone, Clay and Glass Production	7	1 %
Chemical and Other Production	< 1	trace

The processes by which trace elements like mercury are caught during the formation of cloud droplets, and then rain, sleet, hail or snow, or caught up by the impaction of precipitation drops, is well known (Walcek, 2003). What makes mercury more interesting is that most trace elements do not a typically occur in the gaseous state. At least in theory, atmospheric mercury should be deposited quickly, locally in proximity to, for example, the Virginia coal-burning electrical power plants.

2. METHODS

At all the MDN sites, precipitation is collected over 7 days in ultra-clean glass bottles, using a motorized collector that opens during the intervals of precipitation (Olson and DeWild, 1999). The cumulative weekly total precipitation is recorded, and with the water sample is sent to an EPA-approved laboratory to determine the mercury concentrations. From these data, total mercury and mercury concentrations are calculated, and these are shared among the MDN site operators. Mercury deposition data has recently been tabulated and made available on the Internet for the entire United States (NADP, 2007).

3. RESULTS

The annual mercury concentration in precipitation was about 7.5 ng/L (Table 2), which is similar to mercury deposition at the other MDN sites in Virginia and

adjacent states (Gay et al, 2006). The mercury concentrations tended to be higher in the summer and fall, which was also during these the time of highest precipitation, so the total amount of precipitated mercury is highest during these seasons. It has been speculated that higher atmospheric temperatures, which occurred during these seasons, facilitate greater dispersion of mercury (Banic et al, 2005).

It also appears that very large precipitation events can measurably reduce the atmospheric concentration of mercury. In the third week of 2003, Hurricane Isabel caused unusually steady and voluminous precipitation (plus high winds) over several days. The concentration of mercury in the precipitation was relatively low, probably because the early-storm precipitation washed most of the mercury out of the atmosphere in central Virginia (Kolker et al, 2004).

Table 2. Record of Mercury Deposition at VA-08 in central Virginia

Interval	**Concentration (ng/L)**	**Precipitation (**cm)	**Total Deposition (micrograms/square meter)**
Winter 02-03	5.7	9.2	0.5
Spring 2003	4.6	31.2	1.5
Summer 2003	10.3	42.3	4.3
Fall 2003	10	45.6	5.0
Winter 03-04	6.2	31.8	1.9
Spring 2004	8.8	12.0	1.0
Summer 2004	7.9	35.0	2.8
Fall 2004	7.0	37.0	2.6
Winter 04-05	4.3	31.2	1.4
Spring 2005	5.3	21.0	1.2
Summer 2005	7.9	21.9	1.8
Fall 2005	10.2	44.1	4.5
Winter 05-06	3.9	33.3	1.4

Mercury depositional network site VA-28, in the Shenandoah National Park in western Virginia, showed a generally similar pattern of mercury deposition to our central Virginia site. However, in the spring and summer, total mercury deposition at the higher-in-elevation western Virginia site was greater than at the lower central Virginia site, but the mercury was lower in concentration (Table 3). It seems likely that the greater total amount of precipitation at the western Virginia site brought down more mercury out the atmosphere, but diluted the mercury, compared to the central Virginia site.

Table 3. Record of Mercury Deposition at VA-28 in western Virginia

Interval	**Concentration (ng/L)**	**Precipitation (cm)**	**Total Deposition (micrograms/square meter)**
Winter 02-03	3.6	27.8	1.0
Spring 2003	4.4	47.1	2.0
Summer 2003	16.5	49.2	6.8
Fall 2003	9.9	64.4	4.2
Winter 03-04	4.8	39.0	1.8
Spring 2004	4.9	19.3	0.9
Summer 2004	8.4	37.9	3.2
Fall 2004	5.5	77.9	4.2
Winter 04-05	3.8	31.4	1.2
Spring 2005	4.1	24.3	1.0
Summer 2005	6.9	21.5	1.5
Fall 2005	6.9	41.7	3.1
Winter 05-06	3.4	51.5	1.1

4. CONCLUSION

Using the mercury data from MDN sites VA-08 in central Virginia and VA-28 in western Virginia, plus measurements from other MDN stations in the eastern United States, no correlations between mercury deposition and the location of mercury emissions into the atmosphere could be discovered. This is contrary to the anticipated results, but may have happened because: (1) The coal-burning plants do not, as is thought, generate most of the mercury in the atmosphere, (2) The majority of the mercury put into the atmosphere by the coal-burning precipitates well before it reaches sites in the MDN system, (3) The majority of the mercury, because of some not-understood process, is carried in the atmosphere well beyond the MDN sites in Virginia and adjacent states, and/or (4) more data from MDN sites are required to discover the depositional pathway for atmospheric mercury.

In the absence of measurements proving otherwise, it appears that the mercury deposition by precipitation in Virginia cannot be assigned or related to any of the mercury producing facilities in Virginia or elsewhere. The very similar mercury deposition record of the western and central Virginia sites suggests that mercury sources, including more nearby local sources, do not impact one MDN site more than another. At the present time, it appears that the pattern of mercury deposition is related to a large-scale source of atmospheric mercury. We suspect that the source from which the mercury deposited in central Virginia may, in the extreme,

involve most of the planetary atmosphere. In this model, the world's atmosphere contains a "pool" of disseminated mercury that continues to fall in the precipitation of Virginia and the rest of the planet's surface.

5. REFERENCES

Banic, C., Blanchard, P., Dastoor, A., Hung, H., Steffen, A., Tordon, R., Poissant,. L., and Wiens, B., 2005, Atmospheric distribution and long-range transport of mercury. Chapter 9 of Mineralogical Association of Canada Short Course 34, Halifax, Nova Scotia, Canada, May 14-15, 2005. Parsons, M.B., Percival, J.B., eds., Mercury- Its Sources, Measurements, Cycles and Effects, p. 157-177.

Gay, D., Prestbo, E., Brunette, R., and Sweet, C., 2006, Wet deposition of mercury in the U.S. and Canada, 1996-2004: Results, trends, and future directions of the NADP mercury deposition network (abs.): 8th Annual International Conference on Mercury as a Global Pollutant Abstracts, T-208, p. 242.

Gobeille, A.K., Morland, K.B., Bopp, R.F., Godbold, J.H., and Landrigan, P.J., 2005, Body burdens of mercury in lower Hudson River area anglers. Environmental Research, v. 101, p. 205-212.

Kolker, A., Mose, D.G., and Sptizer, S., 2004, Filling a gap with VA-08 (Culpeper) and VA-28 (Shenandoah National Park- Big Meadows) in Virginia (abs.): National Atmospheric Deposition Program (NADP), 2004 Scientific Symposium, Halifax, Nova Scotia, Canada.

NADP, 2007, National Atmospheric Deposition Program 2006 Summary, NADP Data Report 2007-01, Illinois State Water Survey, Champaign, Il., 16 p.

Olson, M.L., and DeWild, J.F., 1999, Low-level collection techniques and species-specific analytical methods for mercury in water, sediment and biota: U.S. Geological Survey Water Resources Investigation Report 01-466, 14 p.

Walcek, C., 2003, Fate of atmospheric trace gases: Wet Deposition, Chapter 19 of Potter, T.D., and Colman, B.R., eds., Handbook of Weather, Climate and Water: Atmospheric Chemistry, Hydrology, and Societal Impacts: John Wiley & Sons, Inc., p. 357-371.