**Hg Air Resources**

1. “Regional participation mercury trends in the eastern USA, 1998-2005: Declines in the Northeast and Midwest, no trend in the Southeast” (Butler et al, 2007)- Sara Ramotnik
   1. Decline in emissions in the Northeast (NE) more so than in the Midwestern (MW) and Southeastern (SE) regions of the US. Global emissions have also declined in Europe, but not Asia and Africa.
   2. The empirical relation between changing regional mercury emissions and changing precipitation mercury concentrations is suggestive, but it cannot be confidently assessed as of right now because a comprehensive mercury analysis record was not available during the 1998-2005 time period when the precipitation concentration analysis was also done.
   3. “Concentration of mercury in precipitation as measured by the MDN has declined significantly in the Northeastern and Midwestern USA regions from the period 1998-2005” (1591).
   4. “A pattern of regional mercury emission decline exists from early-to-mid 1990s to 2002 in all three regions, although estimating the total emission decline is difficult after 2002 because of the limited data on mercury emissions. Emission declines have been proportionately greater in the NE than the MW and SE regions in terms of emissions and emissions flux” (1591).
   5. “Better data regarding current and historical emission levels, in terms of frequency of reporting, speciation, and consistency between inventories, would allow a more thorough comparison between spatio-temporal changes in MDN concentration (and deposition) data and mercury emissions” (1591).
2. “Identifying Changes in Source Regions Impacting Speciated Atmospheric Mercury at a Rural Site in the Eastern United States” (Cheng et al, 2017)- Sara Ramotnik
   1. To investigate the effectiveness of emission reductions on the concentrations of gaseous elemental mercury (GEM), gaseous mercury (GOM), and particulate-bound mercury (PBM) at a rural site in Maryland (MD08), long-term (2005-14) measurements of speciated atmospheric mercury were analyzed using concentration-weighted trajectory (CWT) analysis. CWT results suggested that the number of major source regions contributing to GEM, GOM, and reactive mercury (RM=GOM+PBM) over the eastern United States and southeastern Canada declined over time. Across much of these regions, source contributions in 2011-14 decreased by up to 20% for GEM, by greater than 60% for GOM, and by 20-60% for PBM compared to 2006-08, largely because of the decreases in power-plant mercury emissions since 2009. Changes in the spatial distribution of the source regions were also observed over time. Increases in source contributions of GEM after 2011 over the northeastern United States and southeastern Canada were predominantly from emission increases in the metal and steel production and forest fire. Source contribution increases in PBM were more widespread, which can be attributed potentially to mercury transformation processes in the air or wood combustion rather than industrial resources.
   2. “Natural emissions were estimated to be twice as large as anthropogenic emissions on global scales, but a large portion of natural emissions originated from anthropogenic sources through atmospheric sources atmospheric deposition of Hg to the land surface followed by reemission” (2937).
   3. “These states (WV, OH, PA) are among the top 10 states in the United States for Hg emissions from power plants” (2937).
   4. “In this study, an assessment of Hg emissions reductions in North America on speciated atmospheric Hg at MD08 was carried out using the concentration-weighted trajectory (CWT) model” (2938).
   5. MD08→ Piney Creek Reservoir in Western Maryland (test site)
   6. CWT→ concentration-weighted trajectory
   7. GEM→ gaseous elemental mercury
   8. GOM→ gaseous oxidized mercury
   9. PBM→ particulate-bound mercury
   10. “The CWT method predicted that the number of major source regions declined, and source contributions of GEM, GOM, and RM over much of southeastern Canada and eastern United States also decreased over time, driven primarily by reductions in Hg emissions from power plants in the United States” (2946).
   11. GOM constitutes a larger fraction of the total Hg emissions from power plants than PBM
   12. “While this study focused on assessing the effectiveness of policies targeting mercury emissions from power plants, future work could examine the change in the impact of other emissions sectors that are under the Minamata Convention on mercury. Unprecedented increases in global surface temperatures over the recent decades also warrant further studies on the role of surface temperatures on mercury emissions from land and ocean surfaces and forest fire emissions” (2946).
3. “Variation in concentrations of three mercury (Hg) forms at a rural and a suburban site in New York State” (Choi et al, 2012)- Laura Exar
   1. Purpose: Tekran® Hg speciation systems were used at a rural site (Huntington Forest, NY; HF) and a suburban site (Rochester, NY; ROC) to measure gaseous elemental mercury (GEM), gaseous oxidized mercury (GOM), and fine particulate-bound mercury (PBM2.5) concentrations for two years (December 2007 to November 2009)
   2. Found that seasonal gaseous elemental mercury concentrations were similar at both the rural and urban sites and influenced by factors such as the planet boundary layer height and mercury emissions from snow, soil, and point sources
      1. In some seasons, O3 was negatively correlated with GEM at ROC and positively correlated with GEM at HF
   3. Found higher GEM concentrations in the daytime at rural site--probably related to ground surface emissions
   4. PBM2.5 concentrations were higher in winter at both sites due to local wood burning for indoor heating, increased sorption to particles at lower temperatures, and lower PBL in the winter
   5. Overall GEM concentrations were affected by O3, PBL, temperature, RH, and PM2.5
      1. GOM concentrations were related to O3, temperature, RH, SO2
   6. Indicated from GEM/CO and GOM/SO2 ratios that there were two different Hg emission sources or regions which can influence ambient air Hg concentrations in different ways at ROC
   7. Twice in the study, suburban GEM/CO ratios were poorly correlated with SO2/GOM, likely due to industries in Canada
4. “Atmospheric mercury measurements at a suburban site in the Mid-Atlantic United States: Inter-annual, seasonal and diurnal variations and source-receptor relationships” (Ren et al, 2016)- Sara Ramotnik
   1. “Different atmospheric mercury forms have been measured at a suburban site in Beltsville, Maryland in the Mid-Atlantic United States since 2007 to investigate their inter-annual, seasonal, and diurnal variabilities” (141).
   2. “Diurnal variation of GEM shows a slight peak in the morning, likely due to the shallow boundary layer. Seasonal variation of GEM shows lower levels in fall. Both diurnal variations of GOM and PBM shows peaks in the afternoon likely due to photochemical production of reactive mercury from the oxidation of GEM and the influence of boundary layer processes. Seasonally, GOM measurements show high levels in spring and constant low levels in the other three seasons, while PBM measurements exhibit higher levels in spring and constant low levels in the other three seasons, while PBM measurements exhibit high levels from late fall to early spring and lower levels from late spring to fall. These measurement data were analyzed using the HYSPLIT back trajectory model in order to examine possible source-receptor relationships at this suburban site. Trajectory frequency analysis shows that high GEM/GOM/PBM events were generally associated with high frequencies of the trajectories passing through areas with high mercury emissions, while low GEM/GOM/PBM levels were largely associated with the trajectories passing through relatively clean areas. This study indicates that local and regional sources appear to have a significant impact on the site and these impacts appear to have changed over time, as the local/regional emissions have been reduced” (141-142).
   3. “Atmospheric emissions of mercury are important, as atmospheric deposition is the most significant loading pathway for many ecosystems” (142).
   4. “The site is located on an agricultural area embedded within a suburban portion of the Washington DC metropolitan area and is representative of much of the semi-urban nature of the Chesapeake Bay watershed” (142).
   5. Seasonal variability had an impact on GEM concentrations and and they were the lowest in the fall but were pretty much constant for the other three seasons.
   6. Atmospheric mercury comes in three forms: GOM, PBM, and GEM and their proportions vary greatly within the atmosphere due to their geography.
   7. “This study indicates that the receptor site experienced impacts from mercury sources that are both local and regional in nature. Relationships between elevated GEM/GOM/PBM and wind direction indicate mercury measurements at this site may be influenced by nearby mercury sources. Back trajectory frequency analyses suggest potential relationships between mercury emissions and observed high concentrations of GEM, GOM, and PBM at this site, but the source-receptor relationships are varied and complex. Relationships among GOM, ozone and SO2 might suggest two sources of GOM: direct emissions from mercury and in situ photochemical production.
5. “Spatial Patterns and Temporal Changes in Atmospheric-Mercury Deposition for the Midwestern USA, 2001-2016” (Risch and Kenski 2018)- Sara Ramotnik
   1. “Spatial patterns and temporal changes in atmospheric mercury (Hg) deposition were examined in a five-state study area in the Midwestern USA where 32% of the stationary sources of anthropogenic Hg emissions in the continental USA were located” (1).
   2. “An extensive monitoring record for wet and dry Hg deposition was compiled for 2001-2016, including 4666 weekly precipitation samples at 13 sites and 27 annual litterfall-Hg samples at 7 sites. This study is the first to examine these Hg data for the Midwestern USA” (1).
   3. “This analysis suggests that local and regional, rather than exclusively continental or global Hg emissions were likely contributing to the extreme episodes and at least in part, to the spatial patterns of precipitation-Hg deposition in the study area. Statistically significant temporal decreases in weekly precipitation-Hg concentrations in the study area between the periods 2011-2013 and 2014-2016 were observed, coinciding with reported reductions in Hg emissions in the USA required by implementation of national Hg emissions-control rules. These decreases in atmospheric-Hg concentrations are believed to have resulted in the reduced atmospheric-Hg deposition recorded because precipitation depths between the two periods were not significantly different. The Hg-monitoring data for the study area identified an atmospheric deposition response to decreased local and regional Hg emission” (1).
   4. Mercury impact on humans: is a persistent environmental contaminant and can accumulate and concentrate in food webs as methylmerucry (MeHg), presenting a health risk to humans and wildlife. MeHG exposure can result in adverse neurological, cardiovascular and reproductive effects in humans. Developing infants and children are most susceptible to the harmful effects of MeHg but adults are also affected. “Because MeHg concentrations are highest at top levels in the aquatic food web, humans, wild mammals, and birds who consume fish risk exposure to harmful concentrations of MeHg. Public health agencies have issued advisories that warn about consumption of freshwater and marine fish because of risks from Hg” (2).
   5. Wet deposition→ precipitation-Hg deposition→ transfers of GOM and PBM from the atmosphere to the biosphere occur episodically in precipitation
   6. “The purpose of this study was to describe spatial patterns and temporal changes in atmospheric-Hg concentrations and Hg deposition and to relate the observations to potential contributing factors such as weather and Hg sources in a study area centered on Indiana and four surrounding Midwestern states in the USA (Illinois, Michigan Lower Peninsula, Ohio and Kentucky). Precipitation-Hg and dry-Hg deposition data for this study were compiled and summarized for 2001–2016. Interpretations from this study explain the long-term status of atmospheric-Hg deposition in an intensively monitored study area with substantial anthropogenic Hg emissions” (2).
   7. NADP→ National Atmospheric Deposition Program; has the primary atmospheric-Hg monitoring networks in the USA; an affiliation of federal, state, local, tribal, and private entities that sponsor the operation of individual monitoring sites or groups of sites
   8. LMMI→ Litterfall Mercury Monitoring Initiative; measures ambient litterfall-Hg deposition
   9. AMNet→ Atmospheric Mercury Network; measures semi-continuous, surface-air concentrations of GEM, GOM, and PBM
   10. Annual precipitation-Hg data for the study sites during 2001–2016 were derived from weekly monitoring data in the NADP-MDN data base
   11. \*Would suggest taking a look at the methods used and the analyses behind it all.
   12. “A conclusion is that some of the spatial patterns are attributable to deposition of atmospheric Hg transported from local and regional emissions sources, rather than exclusively continental and global sources. Another conclusion is that statistically significant differences in weekly precipitation-Hg concentrations between periods before and after implementation of rules requiring reductions in Hg emissions were a response to these rules. The reduced Hg concentrations led to the 19% decrease in precipitation-Hg deposition in the study area in recent years”(16).
6. “Trends in mercury wet deposition and mercury air concentrations across the U.S. and Canada” (Weiss-Penzias et al, 2016)- Laura Exar
   1. Purpose: examined the spatial and temporal trends of mercury (Hg) in wet deposition and air concentrations in the United States (U.S.) and Canada between 1997 and 2013
   2. 53% of the 19 sites studied in the United States and Canada between 1997 and 2013 had significant negative trends in Hg concentration in wet deposition
      1. No sites had significant positive trends
      2. However, between 2007–2013, 17% of the sites had significant positive trends and 13% had significant negative trends
      3. Between 2008–2013, 30% of the sites had significant positive trends and 6% had significant negative trends
   3. Significant positive trends in Hg concentration in the Rocky Mountains, Plains, and Upper Midwest regions for the recent time periods
      1. Also significant positive trends in Hg deposition for the entire continent
   4. Sulfate concentration trends in wet deposition were negative in all regions, so local Hg sources may not be important
   5. Most sites that displayed negative trends for the time periods with data starting in 1997 or 2001 were no longer displaying negative trends when the data started in 2007 or 2008
      1. However, there were very few sites displaying positive trends when the data started in 1997 or 2001, but for data starting in 2007 or 2008, there are many sites with positive trends
   6. All regions had negative SO4 concentration regional mean slopes, for all time periods, which is consistent with decreasing SO2 emissions in the U.S. over the past two decades
   7. Most significant positive trends in Hg concentration and deposition were observed at sites in the central and western part of the continent, perhaps due to air flow patterns
   8. Speculate that many drivers of Hg concentration in wet deposition will act to produce positive trends in the future
7. “Observed decrease in atmospheric mercury explained by global decline in anthropogenic emissions” (Zhang et al, 2016)- Laura Exar
   1. Purpose: construct an improved global emission inventory for the period 1990 to 2010 accounting for the following factors: that previous inventories have three major flaws--(i) they do not account for the decline in atmospheric release of Hg from commercial products; (ii) they are biased in their estimate of artisanal and small-scale gold mining emissions; and (iii) they do not properly account for the change in Hg0/HgII speciation of emissions from coal-fired utilities after implementation of emission controls targeted at SO2 and NOx
   2. Found a 20% decrease in total Hg emissions and a 30% decrease in anthropogenic Hg0 emissions, with much larger decreases in North America and Europe offsetting the effect of increasing emissions in Asia
      1. Reflects the phase-out of Hg from commercial products as well as the cobenefit from SO2 and NOx emission controls on coal-fired utilities
   3. Declining atmospheric concentrations can be explained by the phase-out of Hg from commercial products and by shifts in the speciation of Hg emissions driven by air pollution control technologies
   4. Results indicate a 30% global decline of anthropogenic Hg0 emissions from 1990 to 2010
      1. Declines are steepest from 1990 to 2000 but continue through 2010
   5. Global increase of 9% in HgII emissions between 1990 and 2010, due to growth in coal combustion in India and China
   6. Determined that decreasing riverine discharges are insufficient for forcing the global atmospheric trend
   7. All in all, they found that revising anthropogenic emissions with the most up-to-date information can explain the observed large-scale decline in atmospheric Hg over the past two decades

**Emissions and Deposition**

1. Atmospheric Mercury Temporal Trends in the Northeastern United States from 1992 to 2014: Are Measured Concentrations Responding to Decreasing Regional Emissions?” (Zhou et al., 2017)- Sara Ramotnik
   1. “Long-term atmospheric mercury measurements at Underhill, VT (VT99), and Huntington Forest, NY (NY20), from 1992 to 2014 and 2005 to 2014 respectively, were used to determine concentration trends using Mann-Kendall’s tau test with Sen’s slope estimator. These data, measured generally downwind of large Hg sources in the Midwestern United States, provide the longest record of ambient Hg concentrations available in the United States” (91).
   2. “Overall, the results indicate that decreased mercury concentrations measured during the past decade are consistent with decreased Hg emissions from regional point sources and that increasing global emissions have not overwhelmed those decreases” (91).
   3. “Direct anthropogenic mercury emissions in the United States have declined from the early to mid 1990s to the present, due to efforts to reduce mercury in waste streams, added pollution control equipment, and the closure of many waste incinerators and coal burning facilities. Further reductions in North America mercury emissions are expected because of recent regulations and economic drivers. However, emissions from countries in Asia such as China and India have increased in part because of rapidly increasing energy consumption” (91).
   4. GEM concentration trends at both sites were positive in spring and negative for the other three seasons at the VT99 site (94).
      1. Spring→ March, April, May
      2. Summer→ June, July, August
      3. Fall→ September, October, November
      4. Winter→ December, January, February

**Deposition and Bioaccumulation**

1. “Methylmercury in Freshwater Fish Linked to Atmospheric Mercury Deposition” (HAMMERSCHMIDT et al, 2006)- Laura Exar
   1. Purpose: compared results of data sets and show that state-wide average concentrations of MeHg in a cosmopolitan freshwater fish, the largemouth bass Micropterus salmoides, are related positively to wet atmospheric Hg fluxes among most of the 25 states that are analyzed, which span a 5-fold range in Hg deposition
   2. The results of this study suggest that inputs of atmospherically derived Hg may be an important factor influencing MeHg bioaccumulation in wild fish populations remote from direct industrial or geologic sources of Hg
   3. Suggests that the accumulation of MeHg in wild fish populations is linked to atmospheric Hg loadings, two-thirds of which are estimated to be from anthropogenic sources
   4. Mean levels of MeHg in largemouth bass are related positively to the average annual wet atmospheric Hg flux among 22 of the 25 states analyzed
   5. Bass MeHg concentrations are relatively similar among geographical regions that receive comparable wet atmospheric Hg fluxes
      1. This study did not include Maryland, Virginia, Delaware, or Pennsylvania
   6. Differences in the relative number of lakes, reservoirs, or rivers sampled for bass had no discernible effect on variations in MeHg concentration among states
   7. Mean air temperature has no substantial effect on MeHg in largemouth bass
      1. But infers that the growth rate of bass varies largely as a function of climate/temperature
   8. Found correlation between state-wide average levels of MeHg in largemouth bass and mean surface water pH
      1. Average surface water pH is correlated with wet atmospheric deposition of Hg, acid, and sulfate
   9. Results suggest that wet atmospheric fluxes of sulfate may not be a major control on the net production and bioaccumulation of MeHg
2. “Geological and Biological Controls over Methylmercury Production and Degradation in Aquatic Ecosystems” (Benoit et al., 2003)- Sara Ramotnik
   1. “In particular, this chapter focuses on recent developments in Hg bioavailability and uptake by methylating bacteria on the competing roles of sulfate and sulfide in the control of methylation, and in pathways for demethylation” (262).
   2. “Lastly, we provide a synthesis of the variability in the methylation response to Hg inputs across ecosystems. We suggest that although methylation is a function of Hg concentration, the range of methylation rates across ecosystems is larger than the range in Hg deposition rates. Overall, we conclude that factors in addition to the amount Hg deposition play a large role in controlling CH3Hg production and bioaccumulation in aquatic ecosystems” (262).
   3. “While inorganic Hg is the major source of Hg to most aquatic systems, it is methylmercury (CH3Hg) that bioaccumulates in aquatic food webs and is the source of health advisories worldwide that cautions against the consumption of fish containing elevated CH3Hg” (263).
   4. In situ formation→ formation within the watershed
   5. “The current consensus, based mainly on temperature-dependency of Hg methylation and its response to biological substrates is that biological methylation of inorganic Hg to CH3HG is more important than abiotic processes in natural systems. Biological methylation was first demonstrated in the late 1960’s and it is now generally accepted that sulfate reducing bacteria (SRB) are the key Hg methylators although a number of organisms besides SRBs have been shown to produce CH3Hg in pure culture from added Hg(II)” (263).
   6. \*Lots of chemical formulas that you might want to glance over.
   7. “Thus we suggest that the in situ CH3Hg concentration across a series of sites within an ecosystem can be used to predict which site is likely to be more active in terms of methylation and likely in terms of bioaccumulation, all else being equal. However, there is too little information at present to determine the degree to which these relationships can be used in a quantitatively predictive fashion between ecosystems. Overall, in comparing across systems, the greatest difficulty is in assessing the pool of Hg available for methylation, which is crucial to estimating realistic accurate methylation rates. To this point, we have not been able to measure bioavailable pools of Hg to bacteria, nor have we been able to mimic the speciation of in situ Hg with added Hg. Therefore, short term production remains more qualitative than quantitative. Both of these questions are the focus of ongoing research (282).
   8. “However, it is clear that there is some aspect of the mechanism of Hg methylation that allows some bacteria to methylate Hg while others do not. The ability to methylate Hg is not confined to one phylogenetic group of sulfate-reducing bacteria but is scattered throughout the phylogenic tree of sulfate-reducing eubacteria” (286).
   9. Bioreporters→ genetically engineered microorganisms designed to rapidly assess the bioavailable concentrations of contaminants or the rate of contaminant degradation
3. “Methylmercury in Mosquitoes Related to Atmospheric Mercury Deposition and Contamination” (HAMMERSCHMIDT et al, 2005)- Laura Exar
   1. Purpose: examine MeHg in adult mosquitoes from subtropical (Florida), maritime (California), continental (Michigan), and arctic (Alaska) regions of North America that span a range in wet atmospheric Hg deposition between July 17 and September 21, 2003
   2. Found that MeHg concentrations in North American mosquitoes were related to loadings of inorganic Hg, mostly from wet atmospheric deposition
      1. Suggests that the supply of inorganic Hg to freshwater systems may be a major factor influencing the accumulation of MeHg in mosquitoes, and by extension, other organisms
   3. Found that more than 90% of the Hg in mosquitoes was MeHg, and concentrations varied among locations
   4. Differing levels may be related to differences in biogeochemical characteristics of the aquatic habitat that affect dietary accumulation of MeHg during the larval stage
   5. Mosquito MeHg was related positively to wet atmospheric Hg deposition among locations where atmospheric deposition is the principal source of Hg
      1. Suggests that MeHg in mosquitoes may be a useful and sensitive indicator of Hg loadings to aquatic systems
   6. Mosquito MeHg was lowest in Orange County, CA, and Arctic Alaska and greatest in Lake County, CA, regardless of mosquito species
      1. Geographical variation in mosquito MeHg bioaccumulation may reflect local/regional differences in the degree of inorganic Hg contamination among sampling locations
   7. On average, MeHg comprised 92% of the total Hg in adult mosquitoes
   8. Certain mosquito species either may accumulate MeHg more efficiently than others or species-specific preferences in breeding habitats may confer variations in MeHg production and accumulation within a general area
   9. Inferred that dietary exposure during the aquatic larval stage is the principal source of MeHg in these insects
   10. Mean levels of MeHg in mosquitoes were related positively to wet atmospheric deposition of total Hg
4. “Decadal Declines of Mercury in Adult Bluefish (1972−2011) from the Mid-Atlantic Coast of the U.S.A.” (Cross et al., 2015)- Laura Exar
   1. Purpose: Concentrations of total mercury were measured in muscle of adult bluefish collected in 2011 off North Carolina and compared with similar measurements made in 1972
   2. The 1972 study showing higher concentrations of mercury for any given weight
   3. Found that concentrations of mercury decreased by 43% in the fish between the two time periods, with an average rate of decline of about 10% per decade
      1. Implies that:
         1. Reductions in the release of mercury across northern North America were reflected quickly in the decline of mercury in adult bluefish
         2. Marine predatory fish may have been contaminated by anthropogenic sources of mercury for over 100 years
         3. A reduction in the intake of mercury by the fish-consuming public has occurred, if bluefish are surrogates for other predators in the Mid-Atlantic Bight
   4. Wet deposition of mercury has been declining in the upper Midwest and northeast parts of the U.S. and in southeastern Canada since at least the 1980s
   5. Relationships concerning environmental mercury and biological amplification in higher trophic level fish:
      1. Atmospheric mercury deposition rates at a majority of locations in the midlatitudes of North America have declined
      2. Concentrations of mercury in higher trophic level freshwater fish have been declining at many similar latitudes
      3. There is a well-documented positive and causal relationship between mercury deposition rate and the concentration of mercury in freshwater fish
   6. Suggested that declines in the consumption of coal and improvements in smokestack pollution abatement technology may result in a continued decline of mercury inputs into the Mid-Atlantic Bight
      1. Projected that mercury concentrations in marine fish should begin to decline months to decades after emission controls have been initiated
   7. Determined that observed temperature change is unlikely to be responsible for the decrease in mercury concentrations we observed between 1972 and 2011
      1. EPA analysis indicates that the blood levels of mercury in women declined nationally between 1999 and 2010 with an 18% decrease in total mercury and a 34% decrease in methylmercury
         1. The Atlantic coastal population of women had the highest mean mercury blood levels