Mercury releases and tribal lands, what's in your backyard? Using GIS to study Mercury emissions.

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Abstract:

Mercury (chemical symbol: Hg), is a naturally occurring element, but is regulated as a Hazardous Air Pollutant in the 1990 amendments to the Clean Air Act because it is toxic to humans. Atmospheric emissions of Hg are dominantly the result of burning of coal in power plants, but are also generated through metallurgic processes and medical waste incineration. Mercury, once in the atmosphere, can undergo several chemical transformations to make it water soluble. Water soluble Hg is 'scrubbed' from the atmosphere by precipitation, and then incorporated into soils or water systems. Bacterial processes change the deposited Hg to methyl-Hg. Methyl-Hg in water systems concentrates up the food chain in fish tissue; a process known as 'bioaccumulation'. Fish consumption is the main Hg pathway to humans. The diets of many tribal members are rich in fish (some up to six times the average national consumption estimates). Thus, the emission of Hg to the environment is particularly relevant to tribal members.

To determine the reservation population affected by atmospheric mercury deposition, the Institute for Tribal Environmental Professionals (ITEP) used the tools of geographic information systems (GIS) to query national datasets. ITEP combined 2003 BIA reservation coverages that include population estimates, with 1999 NEI Hg point source emission estimates to spatially query for overlap at 5, 10, 25, 50, and 100 mile radii.

Using the 1999 national emissions inventory data set, it is determined that 53% of United States reservation population lives within 50 miles of a source that emits greater than 100 pounds per year of Mercury. Within 50 miles of Tribal lands, approximately 71,000 lbs (35 tons) of Hg is emitted, which equates to about 40% of all Hg emitted in the United States. Sixty eight percent of total reservation population (approximately 530,000 people on 245 reservations) lives within 100 miles of 216 facilities that produce more than 100 pounds per year Hg emission. The combined total of the facility output at 100 miles is 51 tons of Hg which was 57% of the total amount of Hg released in the US in 1999.

The pathway from emission source to deposition sink is not well constrained however. Once Hg is in the atmosphere, it is dispersed widely across the globe. It is estimated that only half of the Hg deposited in the US is generated in the US, the rest comes from a global pool. To determine if there is any general correlation between large Hg sources and deposition, ITEP queried other national data sets of soil and stream sediment samples, and then compared these results with fish tissue analyses and fish advisories to see if there was a consistent trend in the data. Monitoring data from the Mercury Deposition Network was also studied to see if there is any national trend in Hg concentrations. Soil and stream sediment analysis suggests there is a correlation, however, fish tissue analyses and monitoring data suggests there is more to the puzzle than the dataset can address.

I. **Introduction**

One of the most pressing concerns related to air pollution arises through an indirect pathway: the consumption of mercury in fish and seafood. Mercury (Hg) emitted into the atmosphere from the combustion of coal and from industrial processes such as gold mining is deposited in water bodies, where it becomes increasingly concentrated up the food chain in a process known as 'bioaccumulation'. When the mercury is consumed by pregnant women, it can have devastating effects. Mercury is a potent neurotoxin that can affect the brain, heart, and immune system. Children who are exposed to mercury before birth face a risk of impaired mental attributes such as attention, fine motor function, language skills, visual-spatial abilities and verbal memory. Developing fetuses and children are especially at risk; even low-level exposure to Hg can cause learning disabilities, developmental delays, lowered IQ, and problems with attention and memory. EPA scientists estimate that one in six women of child-bearing age has enough mercury in her body to put her child at risk should she become pregnant. Mounting evidence also indicates that mercury increases the risk of cardiovascular diseases in adult men[1].

The sources of Hg and its effects on humans and the environment are relatively well documented (i.e.: the EPA website http://www.epa.gov/mercury/about.htm shows much of the current knowledge base on the subject), but what is not well documented is the effect of Hg contamination on special populations, for instance, Native American tribal populations. Many Native American tribes have traditionally eaten diets rich in fish, and some tribal members still do so today. Such diets have not been adequately considered by the U.S. EPA in the process of setting emissions standards for mercury. Specifically, in developing its recent rule for mercury emissions from power plants, EPA considered two segments of the population to be relevant to its analysis: recreational anglers, and "high level" consumers such as some Native American and other ethnic populations. In calculating the risk to these groups, EPA used maximum fish consumption levels of 25 g/day for anglers and 170 g/day for high consumers. However, even this "high level" number may be far from adequate for some tribal populations. For example, a survey of Great Lakes area tribes produced a range of 189.6 to 393.8 g/day (317 lbs/year), and the Minnesota Chippewa has adopted 227 g/day as its treaty-protected subsistence quantity[2]. The EPA fish advisory website suggests a maximum fish intake of 12 oz per week (39 lbs/year) for women of child bearing age, and young children[3]. This suggests that some Great Lakes area tribes are consuming close to ten times the recommended amount of fish.

While the health effects of Hg are well documented, the pathway it takes from the source of emissions to the sink of deposition is not well constrained. There are several types of Hg pollution in the atmosphere. Each type is transported and deposited in a different way. Elemental Hg makes up approximately 95% of the total atmospheric Hg. This type of Hg can be transported for thousands of miles. It has a long atmospheric lifetime (0.5-1 yr) and can be distributed globally. It is not water soluble. Elemental Hg can be oxidized in the atmosphere and deposited as divalent Hg (also known as reactive gaseous mercury). This kind of Hg is very water soluble and has a shorter atmospheric lifetime (1 week or less) since it is easily entrained in precipitation. It can be deposited within tens to hundreds of miles from its emission source. Hg can also be present in the atmosphere as particles of Hg compounds.

This study was conducted to determine the reservation population that lives within potentially high concentrations of atmospheric Hg emissions, and to provide tribes with data as to the fate of Hg in their area. Generally, the closer you are to Hg emission sources and the more the prevailing winds blow from the sources towards you, the more likely you are to have Hg deposited in your area.

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[1] Joint Health group comments (American Public Health Association (APHA), American Nurses Association (ANA), Physicians for Social Responsibility (PSR)) Dec 19, 2005 Docket ID Number OAR-2002-0056

[2] From Bill Grantham, National Tribal Environmental Council, personal communication, 3/2006.

[3] http://www.epa.gov/waterscience/fishadvice/advice.html

II. Methods

Using ESRI's ArcGIS software (ArcMap 9.1) several data sources were queried to produce the results. Tribal reservation boundaries are from a 2002 Bureau of Indian Affairs (BIA) shapefile which also includes 2002 census data for reservations. Point source data is from the 1999 National Emissions Inventory (NEI) facility summary data which includes facility coordinates and Mercury emissions. The ArcGIS buffer tools were employed to select reservations and facilities which are within specific distances of each other.

The reservation boundary file provided by the BIA includes all types of tribal lands (Figure 1). These lands are classified by the BIA as:

Description	Abbreviation
American Indian Reservation	AIR
American Indian Reservation (State recognized)	AIRS
Oklahoma Tribal Statistical Area	OTSA
Alaska Native Village Statistical Area	ANVSA
Alaska Native Regional Corporation	ANRC
Federally Recognized Tribal Entity	FRTE
Public Domain Allotment	PDA
State Designated American Indian Statistical Area	SDAISA
Tribal Designated Statistical Area	TDSA
Trust Land Related to a Federally Recognized Reservation	ORTL
Trust land for which no reservation exists	TRUST

For this project, populations of the AIR, OTSA, ANVSA, and ORTL lands were used to develop the statistics. The shapefile delineates population for some of the reservations by portions of the reservation. For instance, the Alamo chapter of the Navajo Nation reports its population as 1,528 persons, while the main portion of the Navajo Nation reports 157,716 persons.

The mercury emissions in the 1999 NEI facility summary file are the sum total of all hazardous air pollutants (HAPs) that contain mercury. The HAPs are:

POLLUTANT_CODE	POLLUTANT_CODE_DESC	HAP_CATEGORY_NAME
199	Mercury & Compounds	Mercury Compounds
200	Elemental Gaseous Mercury	Mercury Compounds
201	Gaseous Divalent Mercury	Mercury Compounds
202	Particulate Divalent Mercury	Mercury Compounds
22967926	Mercury (Organic)	Mercury Compounds
593748	Methyl Mercury	Mercury Compounds
62384	Mercury Acetato Phen	Mercury Compounds
7439976	Mercury	Mercury Compounds
7487947	Mercuric Chloride	Mercury Compounds

Only facilities that emit 100 pounds or more of mercury compounds were queried to limit the amount of time per query (Figure 2). A total of 435 facilities match these criteria.

To produce the geo statistical analysis, ITEP used the buffer wizard function in ESRI ArcMap9.1®. Buffers of the above mentioned tribal lands were created at 5, 10, 25, 50, and 100 miles (Figure 3). Facilities that fall within these buffer zones were selected, and their emissions were summed. Likewise, tribal lands that are within 5, 10, 25, 50 and 100 miles of facilities that emit more than 100 pounds of mercury per year were queried, and their populations were summed.

For the second part of this study, determining the distribution of Hg deposition in the US, several other national data sets were investigated. The United States Geological Survey (USGS) Environmental

Mercury Mapping, Modeling, & Analysis (EMMMA) provides data sets dealing with the distribution of Hg across the US (http://emmma.usgs.gov/datasets.aspx). One of the EMMMA sources, the National Geochemical Survey Database (http://tin.er.usgs.gov/geochem/), gathers Hg concentrations for soils and stream sediments from federal and state agencies, industry, and academia to produce a national dataset that EMMMA then incorporates into its spatial data files (Figures 4 and 5). Fish tissues samples from sample sites throughout the US are gathered by EMMMA from various sources (i.e.: the National Pesticide Monitoring Program), the sample sites are shown in Figure 6. Fish tissue samples are from a variety of fish species, but are grouped as one in this study to see if there is a national trend for Hg concentrations. The soil, stream sediment, and fish tissue datasets all represent the same Hg analysis technique (Cold Vapor Atomic Absorption) with units in parts per million (ppm). To make the maps legible, the analysis also selected only non-zero data. The concentrations of each of the sample sites are presented as graduated symbols that represent the relative concentration of Hg at each site.

State fish advisory data were found through the EPA National Listing of Fish Advisories (http://epa.gov/waterscience/fish/advisories/), which provides 2004 information. This data was input into the state map. The advisories were delineated into several categories based on the types of water bodies for which they were developed. The data include the number of advisories for each state.

Mercury monitor locations were obtained from the Mercury Deposition Network website (http://nadp.sws.uiuc.edu/mdn/), which is part of the National Atmospheric Deposition Program. The website provides the coordinates for each of the monitors, and their current operational status (active or inactive). Deposition and concentration datasets are also supplied on the website with the most current data recorded in 2004. These tables are linked to the monitor sites to show Hg activity.

III. Results

Emissions statistics (based on 1999 NEI data on facilities that emit greater than 100 lbs/year Hg compounds). Table 1 shows the number of facilities within specified distances from tribal lands, and the total Hg emissions (in pounds per year) of those facilities. The emissions are then compared to the total emissions of all US facilities (emitting greater than 100 labs Hg/year) to determine what percentage of total US emissions are released within specified distances from tribes. One line in Table 1 would read: "Within 50 miles of tribal lands there are 216 facilities that emit a total of 70,643 pounds of Hg/year. The 70,643 pounds represent 38.6% of the total Hg emissions in the US, based on the 1999 NEI."

Table 1: Facilities within specified distances from tribal lands and the sum total of their emissions, based on the 1999 National Emissions Inventory. Note that only facilities that emit greater than 100 pounds per year are recorded.

Distance from facility to Tribal Lands (Miles)	Number of Facilities	Sum total of Hg emissions (Lbs/year)	% of total US Hg emissions
5	26	9,666	5.3%
10	35	15,096	8.3%
25	78	33,813	18.5%
50	132	70,643	38.6%
100	216	103,720	56.7%
All facilities	435	182,870	100%

Tribal population statistics (based on 2002 BIA land boundaries and 2002 census data, using the categories of American Indian Reservation and related trust land, Oklahoma Tribal Statistical Area, and Alaskan Native Village Statistical Area). Table 2 shows the number of reservations within specified distances from Hg emitting facilities, and the sum total of their population. It is important to note that the query treats the reservations as an entire entity, thus the population recorded is representative of the entire reservation, not the proportion within, say, five miles of a facility. Thus, the Navajo Nation, which has

two major coal fired power plants on the reservation, makes up a large portion of the statistics. The effected population is then compared to the sum total of all reservation land population statistics to determine what percentage of the total US reservation population lives within specified distances of Hg emitting facilities. One line in Table 2 would read: "Within 50 miles of an Hg emitting point source (greater than 100 lbs/yr), there are 144 reservations. The sum total population of these reservations is 415,953 people, which represent 53.2% of the total population of all US reservations."

Table 2: Reservation population and their proximity to facilities.

Distance from Tribes to Facilities (Miles)	Number of Reservations	Sum Total of Effected Reservation Population	% of Total Population on Reservations
5	16	182,720	23.3%
10	28	228,401	29.2%
25	71	315,123	40.3%
50	144	415,953	53.2%
100	245	535,441	68.5%
All tribal lands	567	781,859	100%

Soil sample site concentration of Hg (based on USGS National Geochemical Survey data). Figure 7 shows that the highest concentration of Hg in soils appears in four regions: southwest Idaho-southeast Oregon, the Reno area of western Nevada, the California central valley, and the Florida pan handle in the Tallahassee region. Site concentrations in these areas range from 5 to 22 ppm. The figure also shows the soil concentrations relative to facility emissions based on the 1999 NEI. The NEI data shows large point sources of Hg emissions in northern Nevada and northern California, the Texas and Louisiana Gulf Coast, and a cluster of point sources along the Ohio River Valley.

Stream sediment concentration of Hg (based on USGS National Geochemical Survey data). See Figure 8. The highest stream sediment readings appear in western Alaska and western Arizona on the Nevada border.

Fish tissue concentrations of Hg (from USGS EMMMA data that is compiled of many datasets (see reference 1)). Figure 9 shows the northern Midwest region in Minnesota with the highest overall tissue concentrations of Hg. A caveat to this data can be seen in Figure 6, in that the national coverage of fish tissue sample locations is relatively sparse.

Statewide fish advisory counts (from EPA NLFA website for 2004). Figure 10 shows the total number of fish advisories for each state. The fish advisories vary by water body type.

Mercury deposition network monitor data (from MDN website). Figures 11 and 12 show Hg concentrations measured at monitoring sites across the country and into Canada. Figure 11 shows atmospheric concentration of Hg (in ng/L)

IV. References

Point source emissions data: Environmental Protection Agency National Emissions Inventory point source facility summary data of 1999 (http://www.epa.gov/ttn/chief/net/1999inventory.html).

Stream sediment and Soil Hg concentration data: United States Geological Survey Environmental Mercury Monitoring, Mapping and Analysis Stream Sediment and Soils datasets (http://emmma.usgs.gov/datasets.aspx) updated 6/13/2005. See the National Geochemical Survey database (http://tin.er.usgs.gov/geochem/) for information on collection and analysis methodology.

Fish tissue Hg concentration data: United States Geological Survey Environmental Mercury Monitoring, Mapping and Analysis Stream Sediment and Soils datasets (http://emmma.usgs.gov/datasets.aspx) updated 6/13/2005. Based on data from several sources:

- National Contaminant Biomonitoring Program (NCBP)
- National Pesticide Monitoring Program (NPMP)
- Biomonitoring of Environmental Status and Trends (BEST) datasets of the USFWS and USGS. http://www.cerc.cr.usgs.gov/data/data.htm
- Environmental Monitoring and Analysis Program (EMAP): http://www.epa.gov/emap/
- Regional EMAP (REMAP) of USEPA http://www.epa.gov/emap/remap/index.html
- State agency data as compiled in USEPA's National Listing of Fish and Wildlife Advisory (NLFWA) database http://map1.epa.gov/

State fish advisory counts: Environmental Protection Agency National Listing of Fish Advisories (http://epa.gov/waterscience/fish/advisories/) national maps and graphics.

Mercury monitor data: Mercury Deposition Network (http://nadp.sws.uiuc.edu/mdn/) site list and data access.

General references:

"Frequently Asked Questions about Atmospheric Deposition: A Handbook for Watershed Managers" United States Environmental Protection Agency. September 2001, EPA-453/R-01-009

"Atmospheric Mercury Deposition Impacts of Future Electric Power Generation" Mark Cohen, NOAA Air Resources Laboratory, Paul Miller Commission for Environmental Cooperation. December 8, 2003. NOAA reference number (50-22) MAC000/RR1JMA60

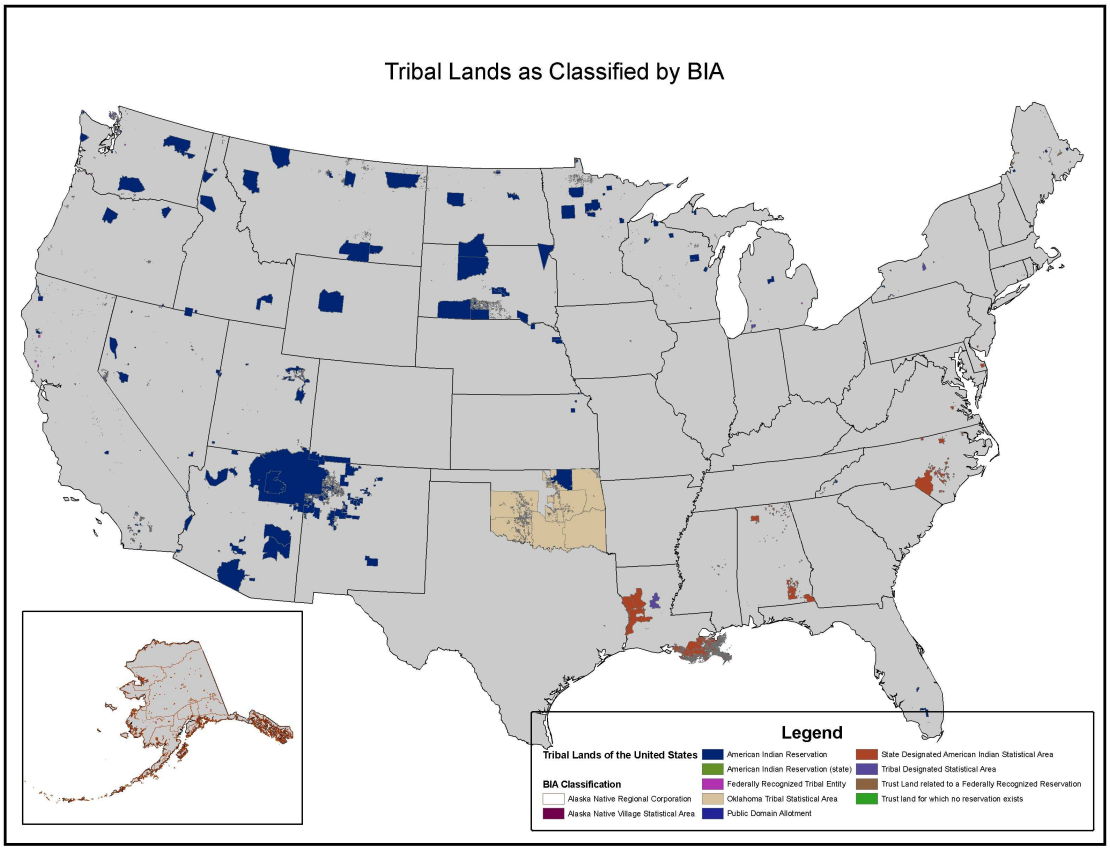

Figure 1: Tribal Lands of the US as classified by the Bureau of Indian Affairs (2003).

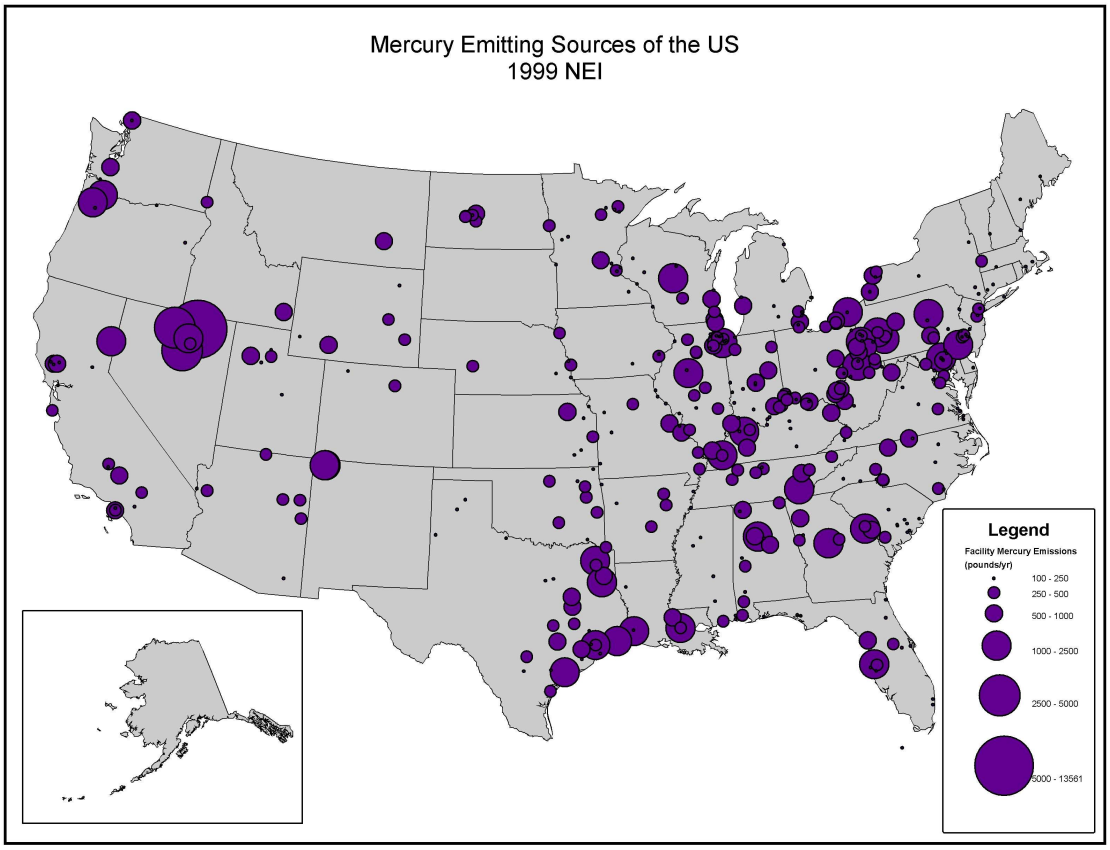

Figure 2: Mercury emitting facilities of the US. Facilities > 100 lbs/year Hg emissions.

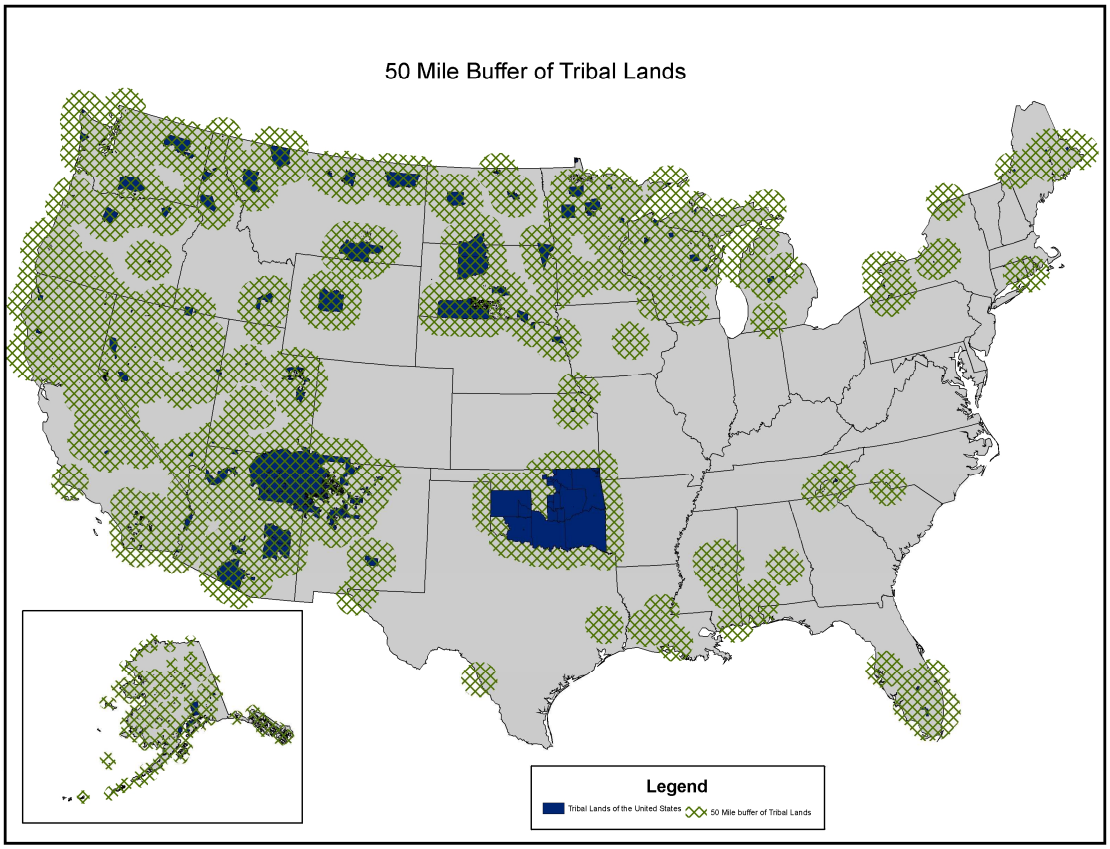

Figure 3: Fifty mile buffer boundary of tribal lands

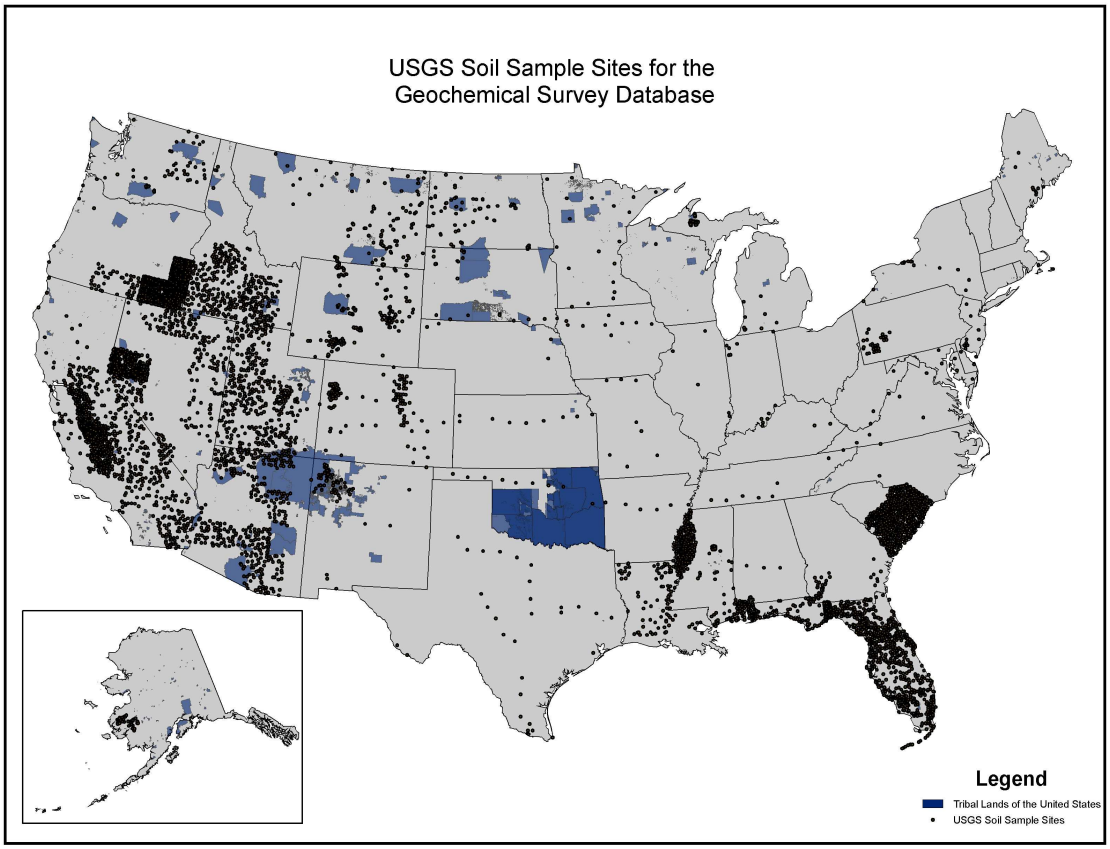

Figure 4: USGS soil sample sites.

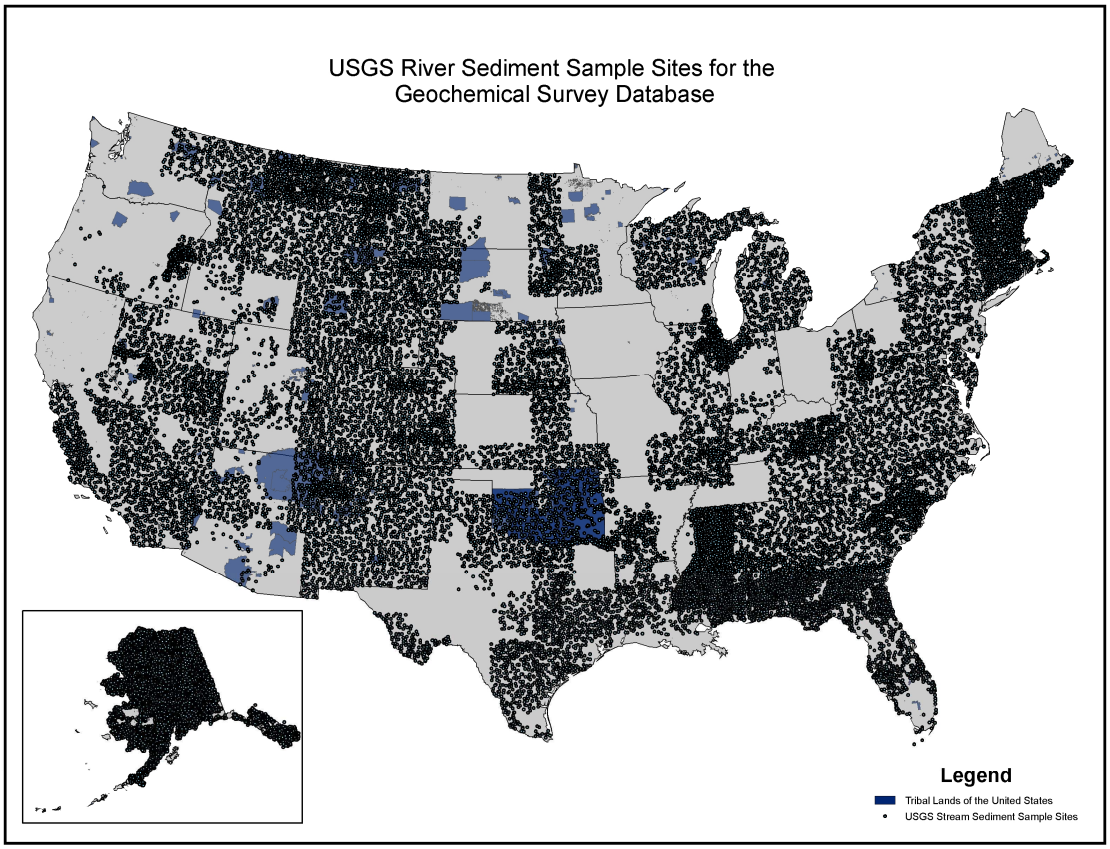

Figure 5: USGS river sediment sample sites.

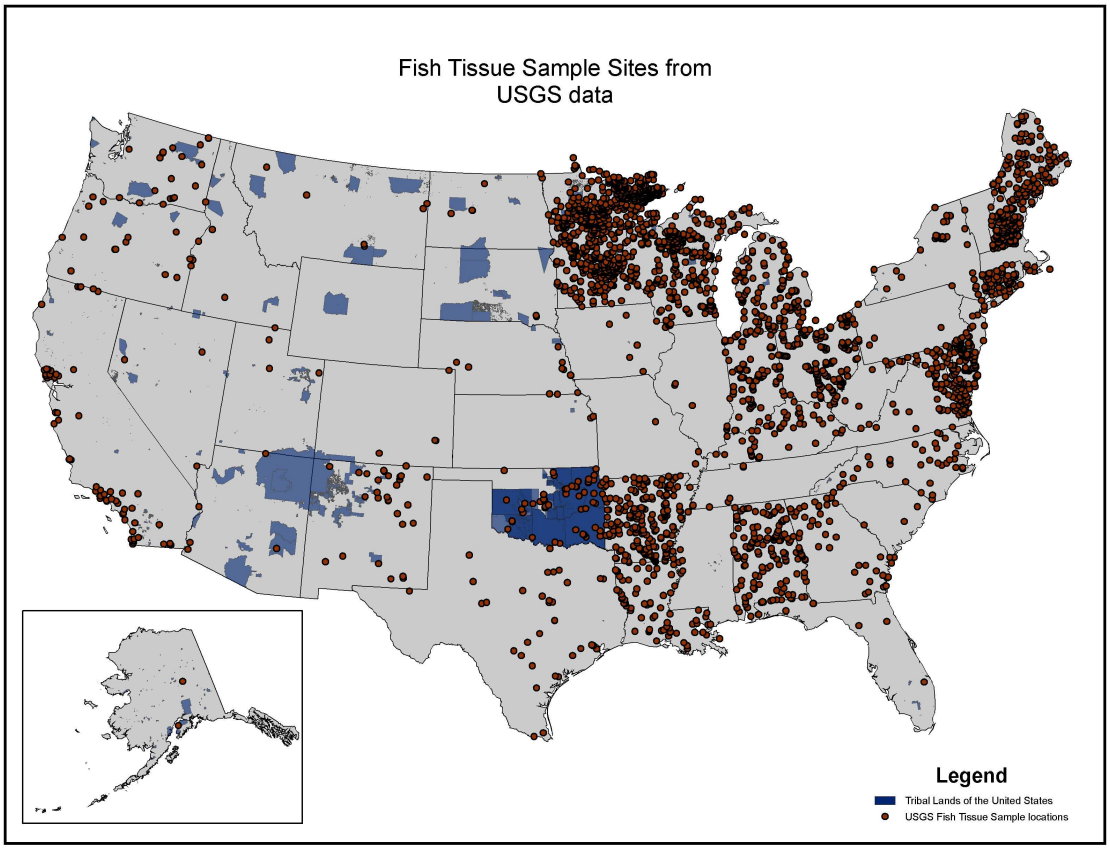

Figure 6: Fish tissue sample sites from USGS data.

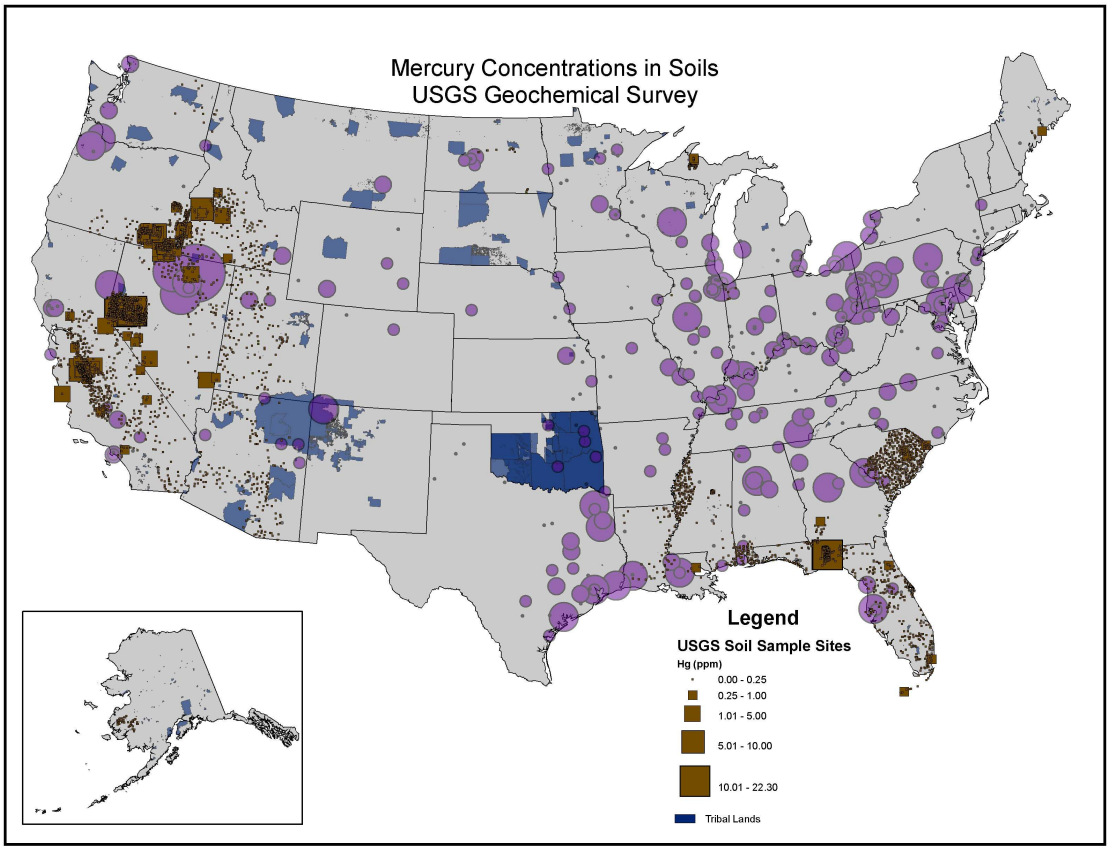

Figure 7: Soil concentrations of Hg from USGS data. Box size shows relative concentration of Hg (1999 NEI). Facility emissions circle size indicates relative emission amount, larger circles denote greater emissions (see Figure 2).

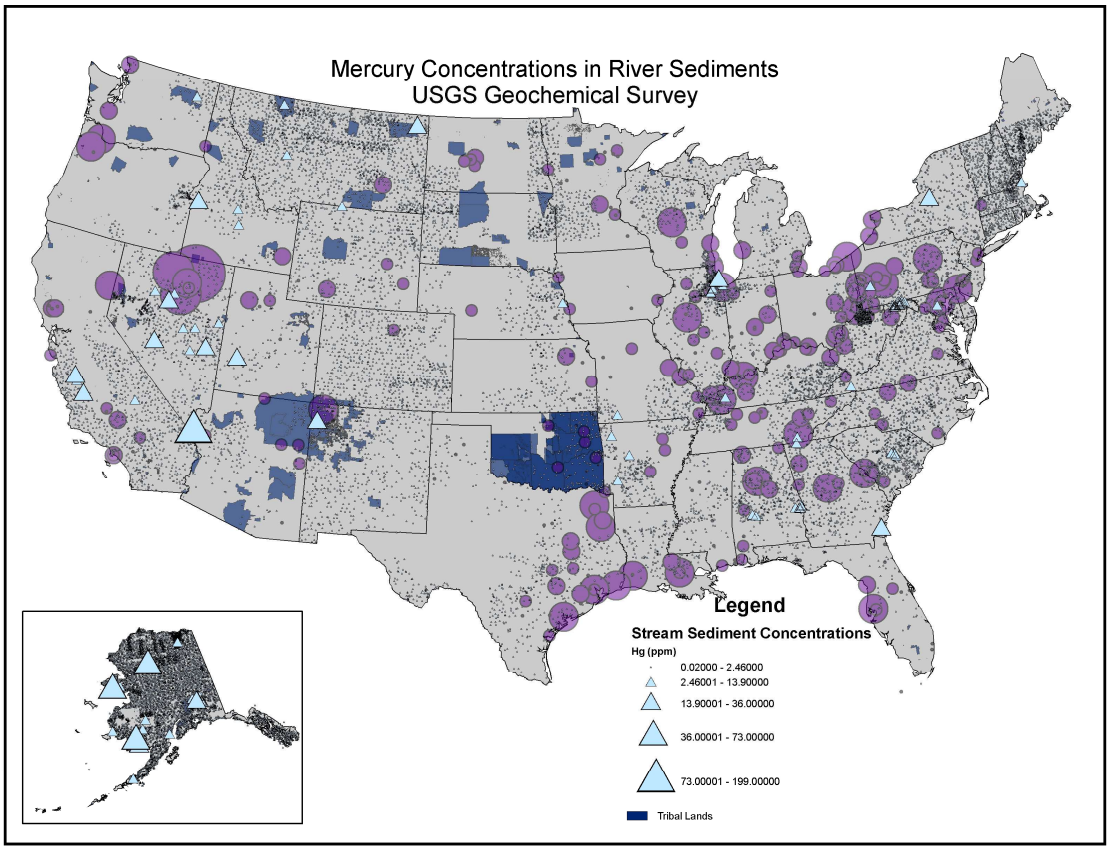

Figure 8: Stream sediment Hg concentrations compared to 1999 NEI facility emissions.

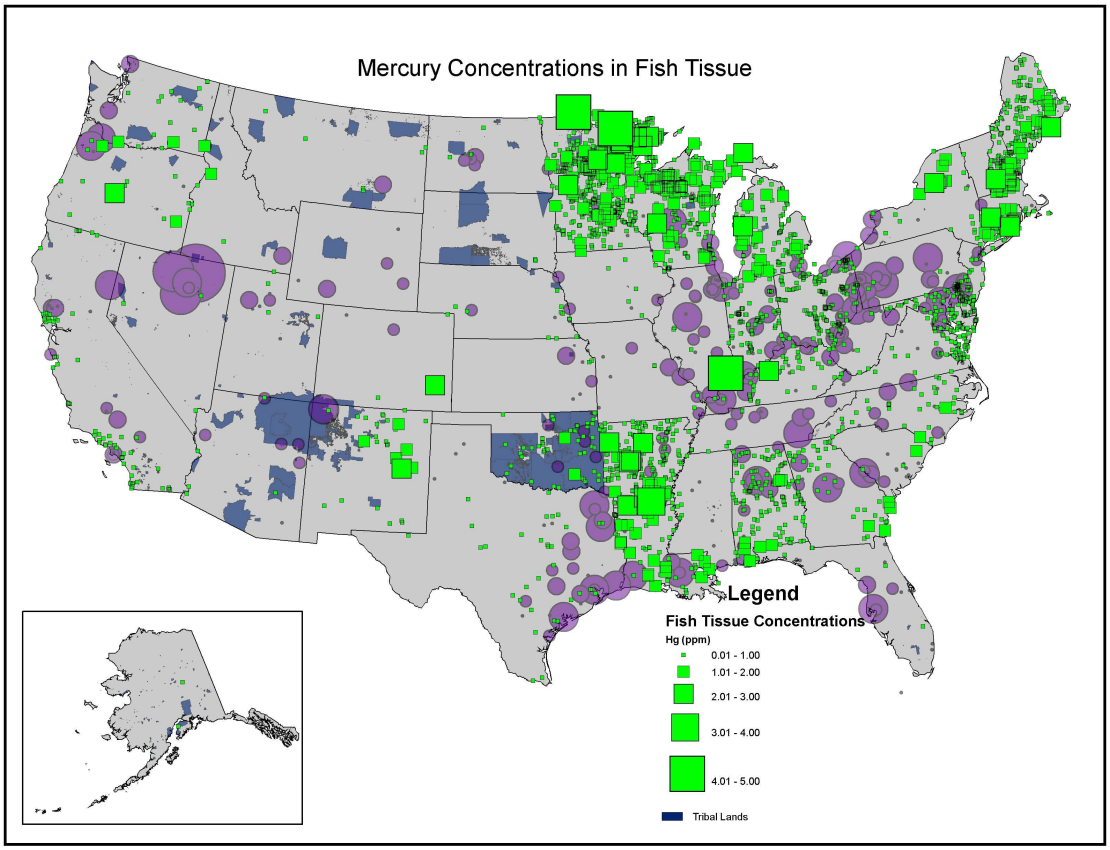

Figure 9: Fish tissue concentrations from USGS data.

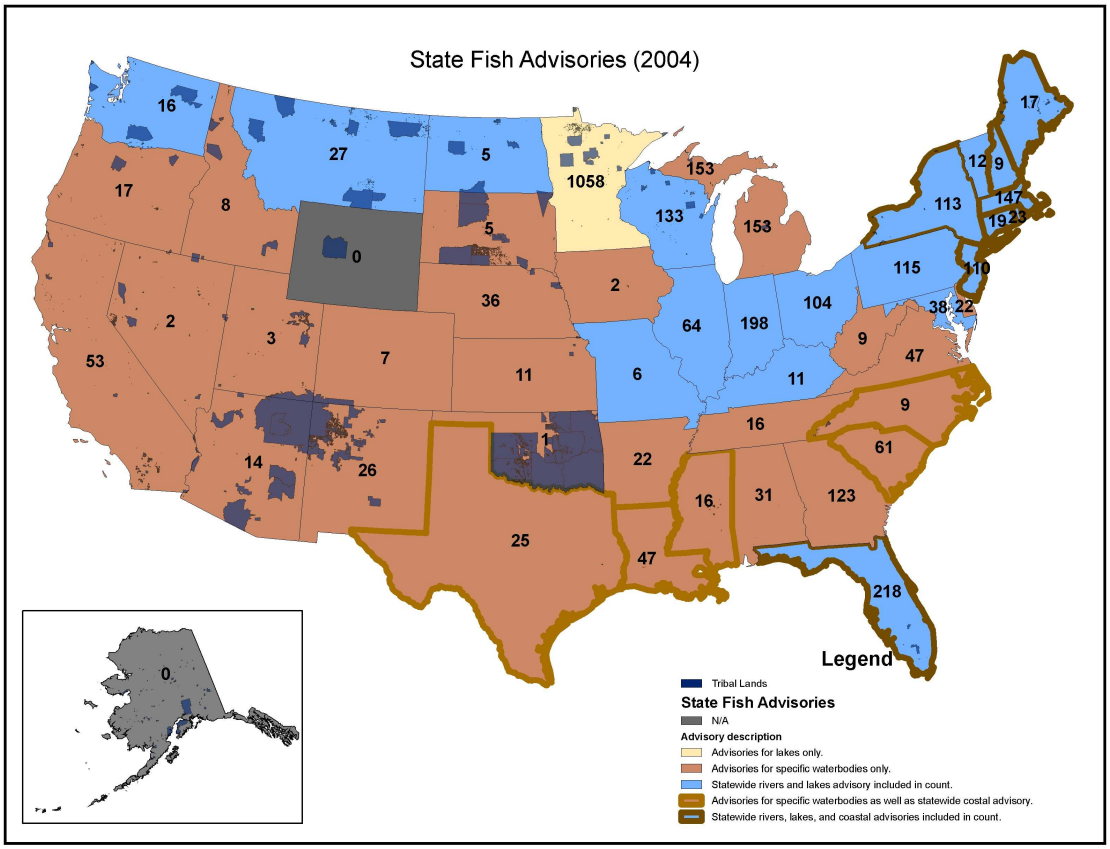

Figure 10: Total number of fish consumption advisories for 2004 (EPA NLFA).

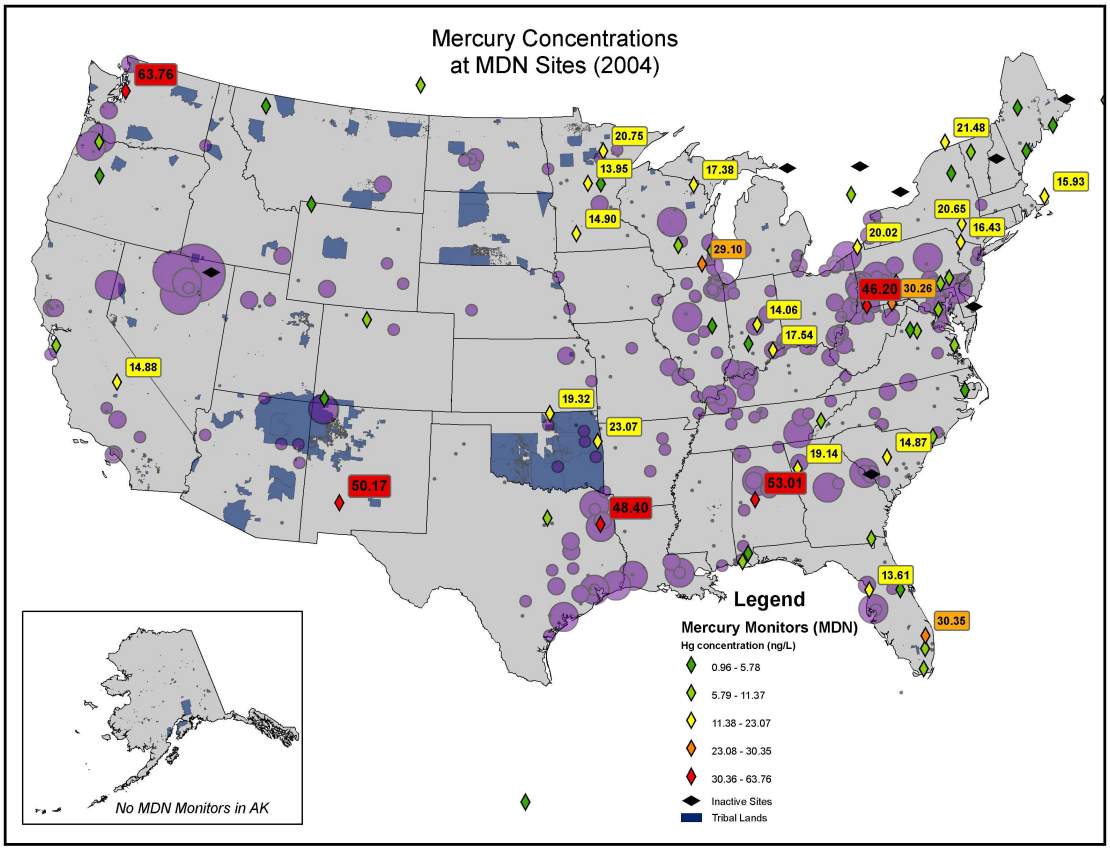

Figure 11: Concentration of mercury at MDN sites (in ng/L).

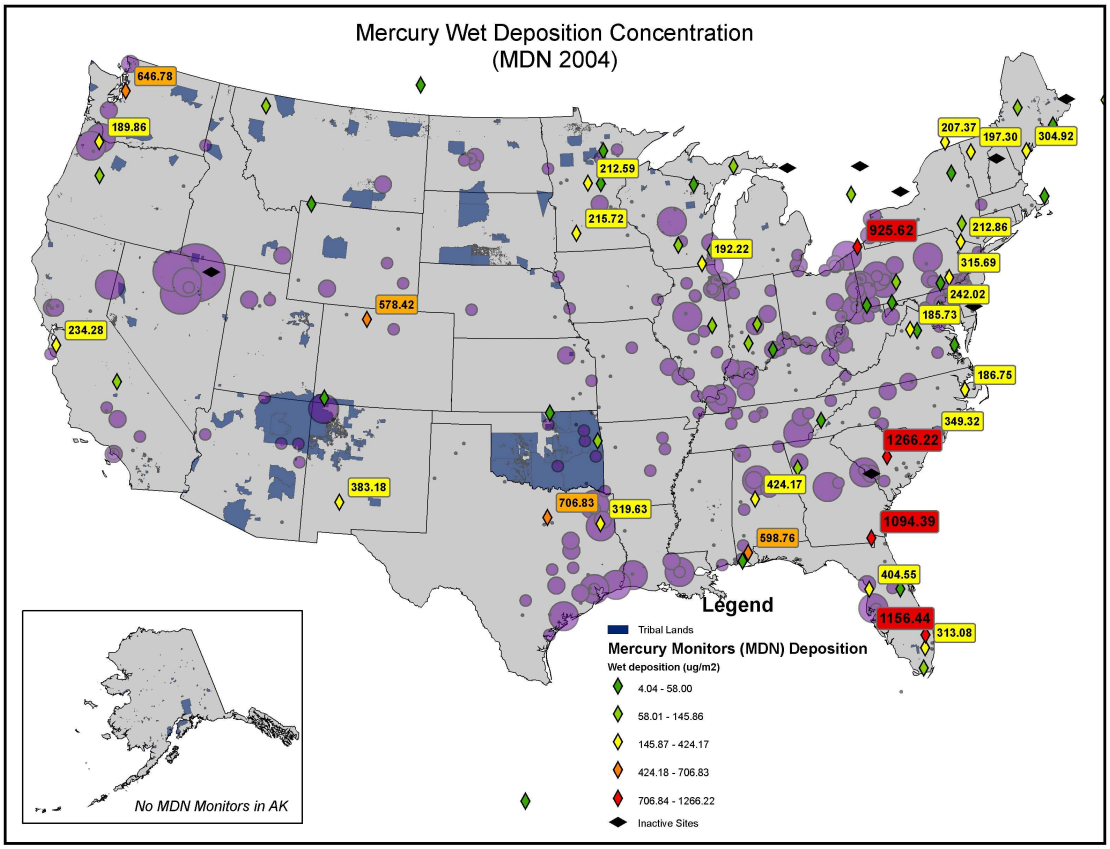

Figure 12: Wet deposition of mercury at MDN sites (concentration in µg/m^2).