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Hearing on Nonpoint Source Pollution: Atmospheric Deposition and Water Quality

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Madame Chairwoman and members of the subcommittee, thank you for the opportunity to testify before you on the issue of atmospheric deposition and aquatic pollution. My name is Michael Slattery. I am the Director of the Institute for Environmental Studies at Texas Christian University, and a Full Professor in the Department of Geology. My area of expertise is human impact on watershed processes, particularly the transport and delivery of sediment and other pollutants from source areas to sinks. I also have an undergraduate degree in pollution meteorology.

My testimony today will focus on the atmospheric deposition of mercury (Hg) and its impact on aquatic ecosystems. First, I will provide a brief overview of studies of Hg in the environment and contamination of fishes in Texas reservoirs, and will show that there should be concern over current Hg levels in fish in Texas water bodies. I will then use atmospheric modeling to show that deposition of Hg from coal-fired Electricity Generating Units (EGUs), widely recognized as the largest single anthropogenic source of environmental Hg, is of widespread regional significance, even in areas where non-US sources are assumed to dominate. The dominant transport direction of the wind over Texas, coupled with the location of most of the EGUs, contributes to widespread deposition of Hg in the region, and will continue to do so if Hg emissions are not adequately controlled. I focus here on Texas, because it contains some of the highest Hg emitting coal-burning EGUs in the US and the State is currently embroiled in a debate over the construction of a further 17 coal-fired plants. The Governor has fast tracked the permitting process. As you may know, eleven of the 17 proposed EGUs would be operated by Texas Utilities (TXU). Although an agreement was recently reached between TXU and environmental groups to drop eight of the proposed units as a result of a major buyout, the deal is not yet final, and there is ongoing debate regarding the current effect of Hg emissions from existing plants and how those emissions will change in the future.

Context: Hg in the environment

Mercury is an environmental pollutant that biomagnifies in aquatic food webs to levels that threaten the health of wildlife and humans that consume contaminated fish (*1*). Generally, the concentrations of all forms of Hg in most natural waters are very low (*2*). However, inorganic Hg undergoes methylation by microbes in water bodies; this greatly increases the bioavailability and toxicity of Hg (*2*). Organisms at the base of the food web, such as phytoplankton, absorb methylmercury directly from the water (*3*) while consumers, including fish, are primarily exposed to methylmercury through their diet (*4*). Because Hg bioaccumulates from trophic level to trophic level, concentrations of methylmercury in fish can exceed those in ambient surface water by a factor of 10^6 to 10^7 (*2*). The biomagnification of Hg in aquatic food webs also leads to high concentrations in fish-eating birds and methylmercury can adversely affect adult bird survival, reproductive success and behavior (*2*).

To help reduce the risk of Hg exposure, fish consumption advisories regarding Hg contamination have been issued for 44 states as of 2004 (*5*). In Texas, the Department of State Health Services (DSHS) monitors fish in the State for the presence of environmental contaminants and alerts the public through bans (closures) and advisories when a threat to human health may occur from the consumption of contaminated fish. DSHS issues an advisory if the mean Hg concentration of the fish sampled exceeds a screening level of 700 ng g^{-1} ww, a much less stringent criteria than the USEPA value of 300 ng g^{-1} ww. Eleven lakes and the coastal waters of Texas currently have advisories on at least one fish species (Fig. 1). These advisories help to illustrate the extent of the Hg problem in Texas reservoirs. However, simply examining the number of fish advisories does not give a complete picture of the Hg contamination problem in Texas reservoirs. Caddo Lake along the Texas-Louisiana border is an example of this. Caddo Lake currently has a fish consumption advisory for largemouth bass (*Micropterus salmoides*) and freshwater drum (*Aplodinotus grunniens*). Samples from 319 fish in Caddo Lake showed that all species contained Hg (Fig. 2), at least half of which exceeded the USEPA limit. In some species, the concentrations of Hg were higher than the DSHS human health screening value but no consumption advisory is present for these species. These data illustrate that some species of fish not currently included in fish advisories have high levels of Hg and that additional Hg input to lakes like Caddo could push additional fish species over the Hg levels deemed safe by the DSHS.

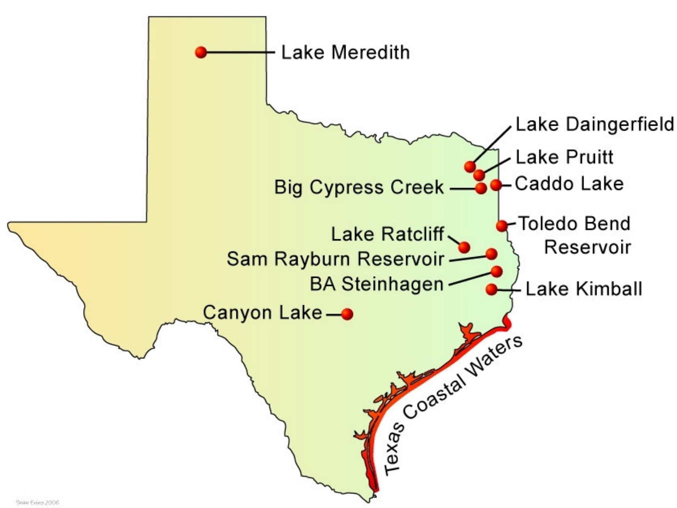

Fig. 1. Fish consumption advisories for Hg in freshwater reservoirs and the Texas coastline. Information taken from the www.tpwd.state.tx.us website.

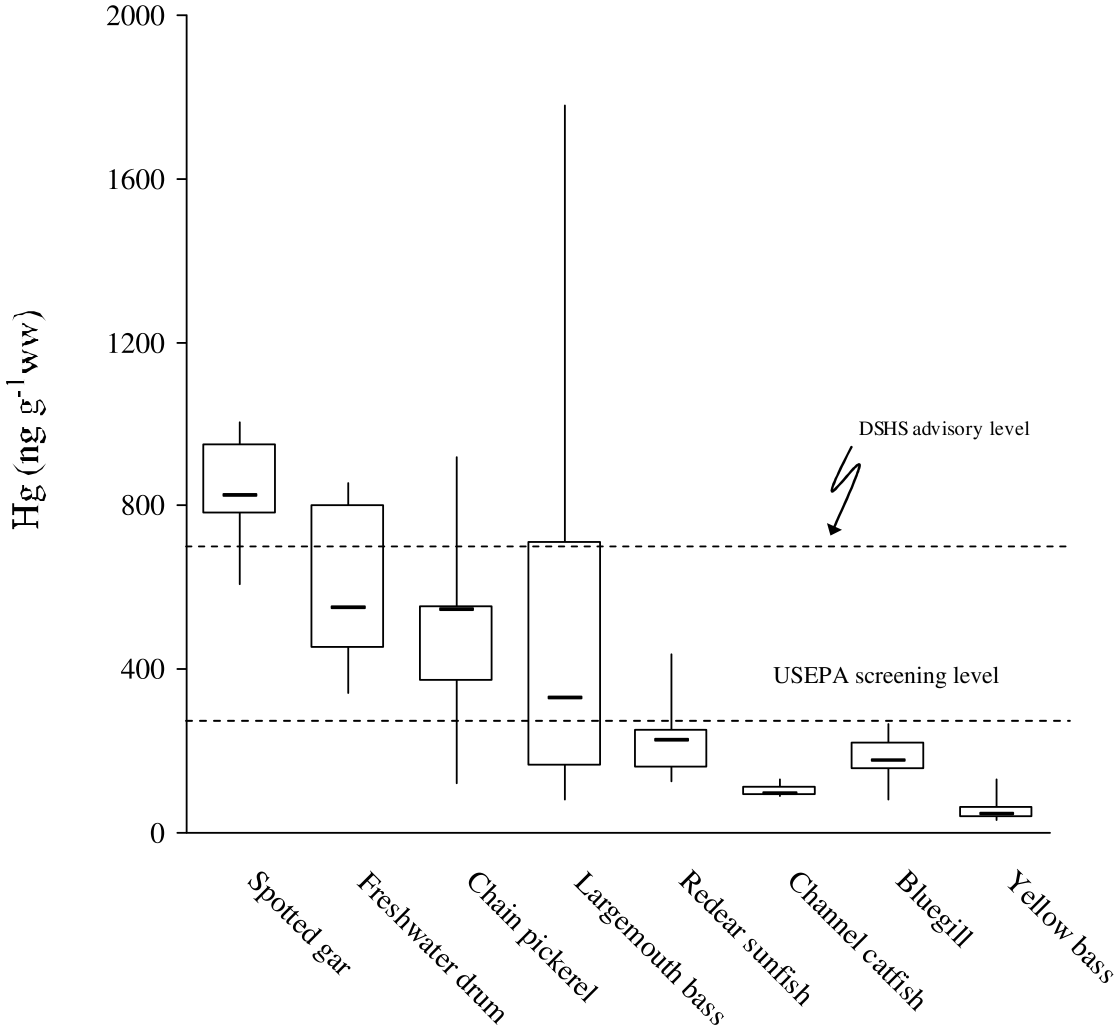

Fig. 2. Box and whisker plot of total Hg concentrations in fish species from Caddo Lake, Texas. Dashed lines indicate USEPA (300 ng g^{-1}ww) and DSHS (700 ng g^{-1}ww) screening levels.

Source, Transport, and Fate of Atmospheric Hg in Texas

The largest single anthropogenic source of environmental Hg is emissions from coal-burning EGUs, and coal consumption is predicted to increase over the next decade because it is a low cost fuel (*6, 7*). Figure 3 presents the geographic distribution of power plant Hg emissions in North America. The largest concentration of Hg emissions occurs in the US Midwest and Southeast, regions that depend heavily on coal-fired power plants. East Texas, which relies primarily on lignite coal, is also a high Hg emitting area. In fact, East Texas is one of the highest Hg emitting areas in North America, with TXU's Monticello, Martin Lake, and Big Brown plants being three of the largest emitters of Hg in the US.

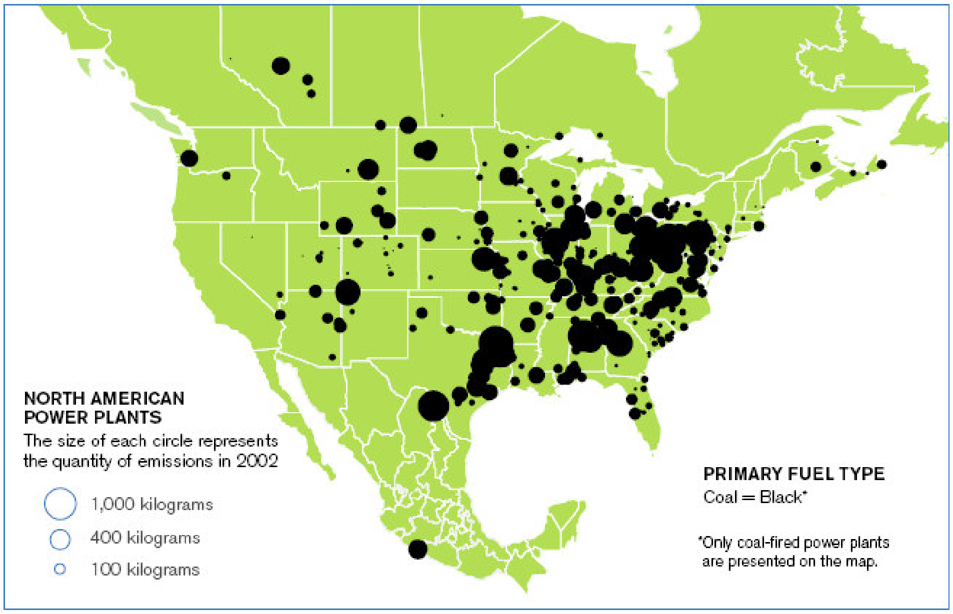

Fig. 3: Geographic distribution of power plant Hg emissions in North America in 2002 (Source: Miller and Van Atten, 2004)

At first glance, there appears to be a strong geographic correlation between the east Texas fish consumption advisories (Fig. 1) and the northeast-southwest axis of emissions from Texas' coal-fired power plants (Fig. 3). However, the coal industry continues to deny this apparent causal relationship. For example, the Center for Energy and Economic Development, a non-profit group that represents the interests of the coal industry, claims in several company reports that power plants are not the major source of Hg emissions in the US, local deposition of Hg from power plants is not prevalent, and that there are currently no Hg advisories on Texas' power plant lakes (see CEED, http://www.ceednet.org/). This view is clearly at odds with the consensus among the general scientific community (*8, 9*).

The USEPA has stated that regional transport of Hg from coal-fired EGUs in the US is responsible for very little of the total Hg in US waters (*10*). I have used NOAA's HYSPLIT model developed at the Air Resources Laboratory to simulate Hg plumes over Texas and surrounding regions. The goal of this work was to clarify Hg source-sink relationships and determine the extent to which, under prevailing wind regimes, pollution plumes emitted from existing and proposed power plants in south-central and east Texas could potentially impact aquatic ecosystems in Texas and beyond. Archived meteorological data from 2005 were used to simulate atmospheric deposition of Hg. I modeled 24-hour deposition plumes on days where winds were from the dominant direction (i.e., statistically, the most frequently occurring direction) on two or more consecutive days.

Hg deposition from existing and proposed EGUs

Seventeen EGUs in Texas currently emit ~ 5.5 Mg Hg yr^{-1} (Table 1). Under the most dominant atmospheric transport condition (i.e., winds from the S, SSE and SSW), modeled plumes (Fig. 4) covered an area of >15,000 mi^2 with highest Hg deposition occurring within 125 miles of the plants. Twenty-four hour deposition rates are on the order of 1 x 10^{-2} μg m^{-2} (3.5 to 4.0 μg m^{-2} yr^{-1}). Because of considerable overlap and mixing between plumes, I hypothesize that actual deposition is much higher than the single plume rates. The plumes reach as far north as Lake Michigan, although deposition rates at that distance are much smaller, on the order of 1 x 10^{-4} μg m^{-2} (0.3 to 0.4 μg m^{-2} yr^{-1}).

Table 1. Hg emissions for Texas EGUs in 2004, in tons. Note that eight plants rank in the top 50 US power plant Hg polluters (Source: http://www.environmentalintegrity.org/pubs/Dirty%20Kilowatts%20report.pdf); of those, five are in the top ten.

FACILITY	CITY	COUNTY	HG (tons)	RANK
MARTIN LAKE STEAM ELECTRIC STATION	TATUM	RUSK	0.872	1
MONTICELLO STEAM ELECTRIC STATION	MT PLEASANT	TITUS	0.665	4
BIG BROWN STEAM ELECTRIC STATION	FAIRFIELD	FREESTONE	0.591	6
H.W. PIRKEY POWER PLANT	HALLSVILLE	HARRISON	0.561	7
LIMESTONE ELECTRIC GENERATING STATION	JEWETT	LIMESTONE	0.544	8
W. A. PARISH ELECTRIC GENERATING STATION	THOMPSONS	FORT BEND	0.456	16
SANDOW STEAM ELECTRIC STATION	ROCKDALE	MILAM	0.279	41
J. .T DEELY J. K. SPRUCE GENERATING COMPLEX	SAN ANTONIO	BEXAR	0.267	44
WELSH POWER PLANT	PITTSBURG	CAMP	0.216	
SAM SEYMOUR POWER PLANT	LA GRANGE	FAYETTE	0.163	
TWIN OAKS POWER L P	BREMOND	ROBERTSON	0.149	
HARRINGTON STATION	AMARILLO	POTTER	0.131	
SAN MIGUEL ELECTRIC COOPERATIVE INC	CHRISTINE	ATASCOSA	0.125	
GIBBONS CREEK POWER PLANT	CARLOS	GRIMES	0.124	
TOLK STATION	SUDAN	LAMB	0.104	
COLETO CREEK POWER PLANT	FANNIN	GOLIAD	0.084	
OKLAUNION POWER STATION	VERNON	WILBARGER	0.081	

Current rates of Hg deposition in Texas and Oklahoma are 1.5 to 3 times higher than those found in the western US (Fig. 5), a region recognized as having high levels of Hg deposition from sources outside the US, predominantly long-range transport from China (*11*). This 1.5- to 3-fold increase in Hg can only be the result of accelerated deposition from local sources. There is no other logical conclusion. Importantly, the modeling also shows that Hg from the power plants is deposited beyond Texas' borders and is very likely contributing to areas like Arkansas, a state with watersheds that already contain fish with very high concentrations of Hg (Fig. 6). Our simulations show these watersheds are in the direct path of Hg emissions from power plants in Texas, as evident in Figure 4. Moreover, many of these watersheds require a 75% reduction of Hg to meet the methylmercury criterion of Hg in fish tissue at the present time (*12*).

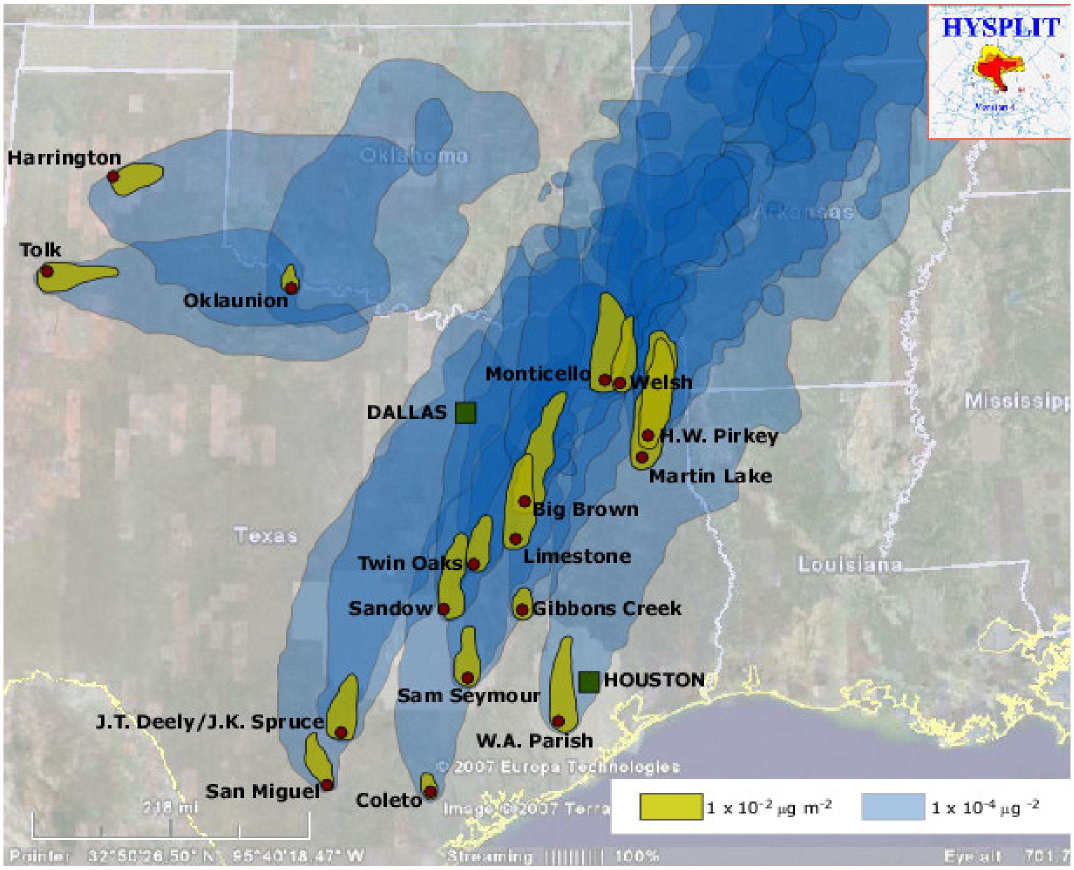

Fig. 4. Hg deposition (µg m^{-2}) for the 24-hour period as at 000UTC 6 November 2005. For central Texas, the dominant transport classes are S, SSE and SSW (43% of the year, shown here), N, NNE and NNW (21% of the year) and ESE and SE (10% of the year).

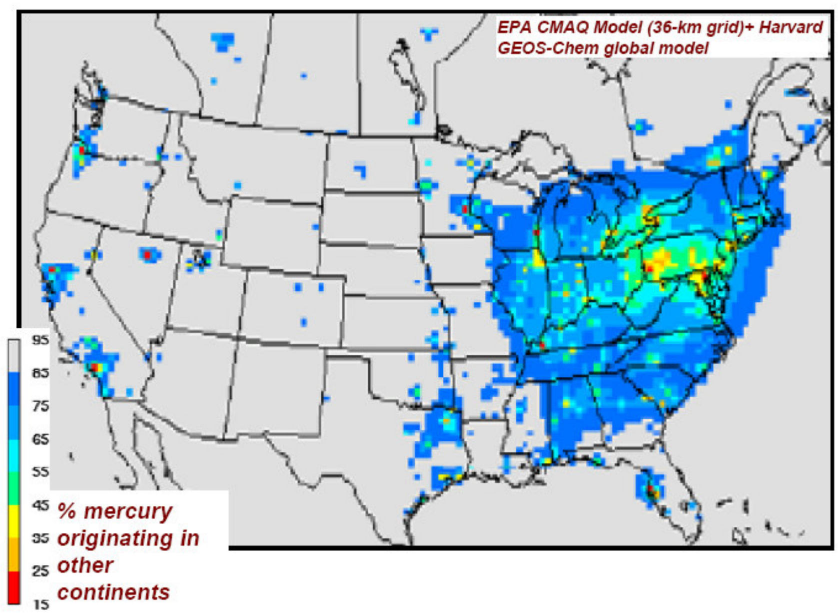

Fig. 5: Estimate of US Hg deposition originating from non-US sources (Source: EPA, cited in TCEQ, 2006).

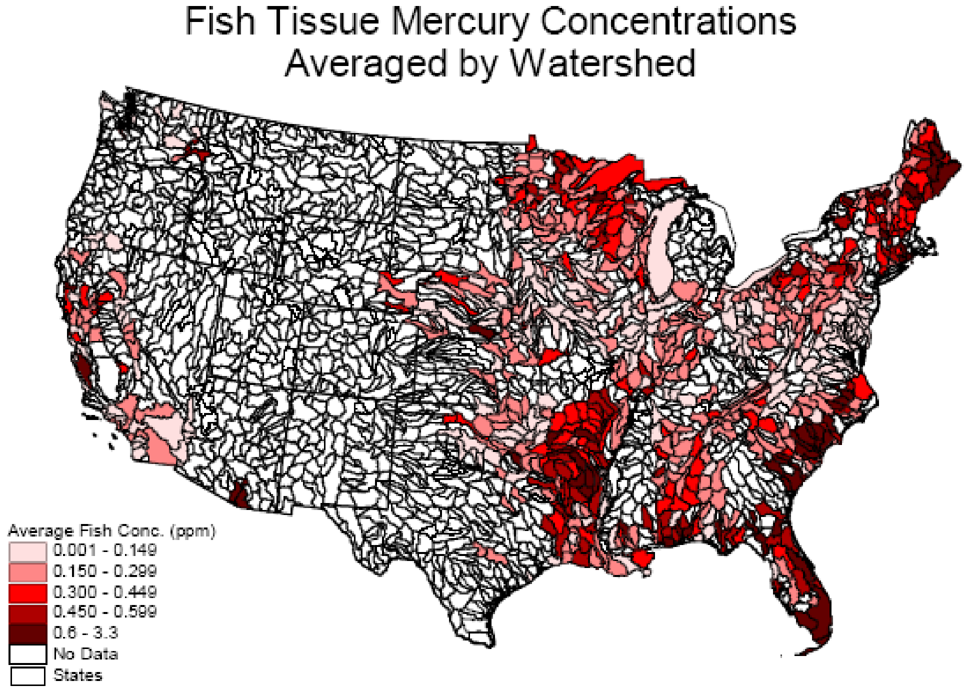

Fig. 6: National data set of Hg fish tissue averaged across USGS HUC-8 watersheds (Source: http://www.epa.gov/waterscience/maps/report.pdf)

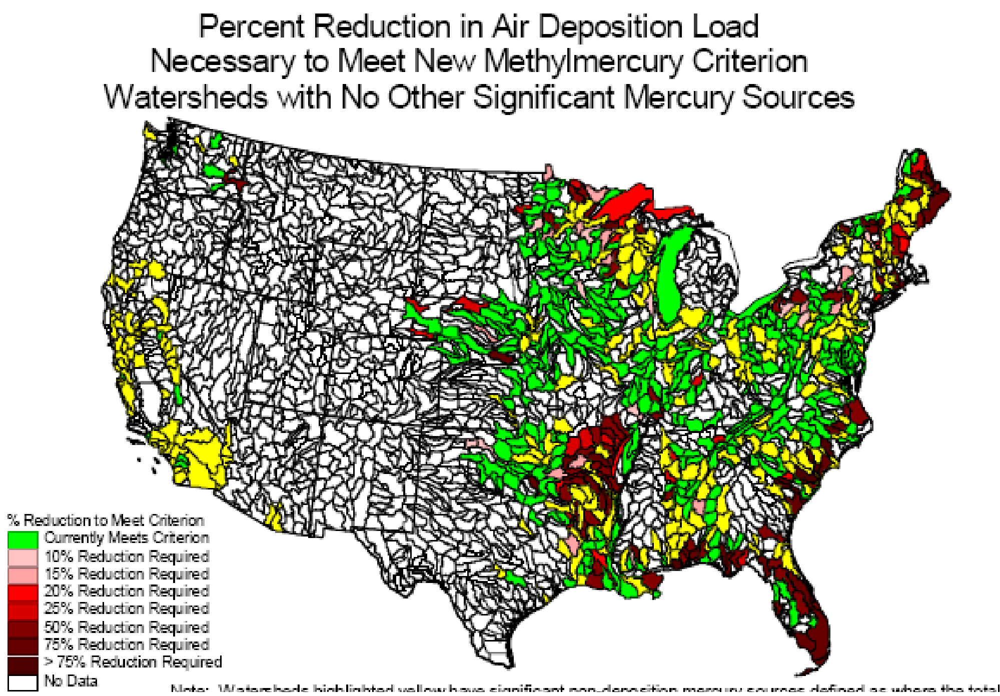

Fig. 7: Estimates of percent air deposition reductions, by watershed, required to meet the new methylHg criterion. Watersheds colored red indicate where fish concentrations exceed the criterion, while those colored green indicate watersheds in which no reductions are necessary and are unlikely to have a fish advisory. (Source: http://www.epa.gov/waterscience/maps/report.pdf)

Hg emission rates from the proposed TXU EGUs are shown in Table 2. The four major emitters of Hg (Big Brown, Martin Lake, Monticello, and Sandow) currently emit 2.184 tpy. After proposed offsets, these four plants would emit ~0.857 tpy (a reduction of ~60%). The bottom section of Table 2 lists the ten new units proposed by TXU. Eight of these units have Hg targets of 0.08 tpy with the lignite units at Oak Grove targeted for 0.36 tpy/unit. Total Hg emitted from the ten new units equals 1.36 tpy. Thus, Hg output from the proposed EGUs shows an overall **increase** of 1.5% once all plants, including the existing units at Big Brown, Martin Lake, Monticello and Sandow, become operative.

Table 2. Hg emissions data from current and proposed TXU EGUs.

Plant	**Location**	**County**	**Lat.**	**Long.**	**Emissions [tpy]**	**Reduction [%]**
Current EGUs						
Big Brown	Fairfield	Freestone	31.8192	96.0558	0.5362	
Martin Lake	Tatum	Rusk	32.2578	94.5689	0.7911	
Monticello	Mt. Pleasant	Titus	33.0906	95.0375	0.6033	
Sandow	Rockdale	Milam	30.5603	97.0675	0.2531	
Total					**2.184**	
Current EGU's (with offsets)						
Big Brown	Fairfield	Freestone	31.8192	96.0558	0.1930	-64
Martin Lake	Tatum	Rusk	32.2578	94.5689	0.3560	-55
Monticello	Mt. Pleasant	Titus	33.0906	95.0375	0.2172	-64
Sandow	Rockdale	Milam	30.5603	97.0675	0.0911	-44
Total					**0.857**	
Proposed EGUs						
Big Brown	Fairfield	Freestone	31.8192	96.0558	0.08	
Lake Creek	Waco	McLennan	31.4606	96.9867	0.08	
Martin Lake	Tatum	Rusk	32.2578	94.5689	0.08	
Monticello	Mt. Pleasant	Titus	33.0906	95.0375	0.08	
Oak Grove (2)	Franklin	Robertson	31.1819	96.4875	0.72	
Sandow	Rockdale	Milam	30.5603	97.0675	0.08	
Tradinghouse (2)	Waco	McLennan	31.5722	96.9631	0.16	
Valley	Savoy	Fannin	33.6283	96.3675	0.08	
Total					**1.36**	
Summary:						
Current EGUs					**2.184**	
Current EGUs (with assumed offsets)					**0.857**	
Proposed EGU's					**1.36**	
Current and proposed EGUs (with assumed offsets)					**2.217**	

Implications for Texas and surrounding states

A key point to emerge from the modeling analysis is that deposition rates of 3.5 to 4.0 $\mu g/m^2/yr$ from any single plume would be **new Hg added to the environment**, over and above deposition from existing sources, be they natural or anthropogenic. If we assume no plume synergy, thereby keeping the deposition rates conservative, this would represent a 30-45% increase in Hg deposition for the DFW Metroplex and east-Texas region over current average annual values. If considerable plume mixing occurs, which is highly probable, deposition rates could potentially be higher.

Although Hg emissions from the US power sector are estimated to account for only about 1% of total global emissions, this does not mean that Hg from US coal-fired EGUs does not deposit in regions near the plants, nor that deposition has negligible environmental impacts on those regions. Under the new Clean Air Hg Rule (CAMR), utilities will be required to meet a national cap, rather than reduce emissions at all facilities. If adequate Hg emission control strategies are not used, the construction of new plants in Texas would add new Hg to areas already impacted by deposition which could lead to further Hg contamination of aquatic ecosystems.

It is also clear that pollutants within the plumes will be transported and deposited beyond Texas' borders. Current fish advisories for Hg for states surrounding Texas show 20 advisories in Arkansas, 38 in Louisiana and a statewide advisory in Oklahoma[1]. It is highly likely that fallout from the Texas plumes will impact these regions because the Hg deposition from the plants adds to Hg deposition from the atmosphere. Although some of the emitted Hg is not deposited locally or regionally, and would contribute to the global Hg pool (eventually being deposited at remote sites around the world), the most significant impacts are regional. A simple catch-phrase may help to clarify this: "If you live in Paris, France, Hg emissions from Texas power plants will have no immediate impact. However, if you live in Paris, Texas, the impacts are likely to be widespread."

Finally, the USEPA has stated that regional transport of Hg from coal-fired EGUs in the US is responsible for very little of the total Hg in US waters (*10*). According to the EPA website, "the agency has conducted extensive analyses on Hg emissions from coal-fired power plants and subsequent regional patterns of deposition to US waters. Those analyses conclude that regional transport of Hg emission from coal-fired power plants in the US is responsible for very little of the Hg in US waters. That small contribution will be significantly reduced after EPA's Clean Air Interstate Rule and Clean Air Hg Rule are implemented." In some regions, like the western US, that may well be the case. But requiring utilities to meet a national cap will have very little effect in areas such as the north Texas and surrounding regions, where the addition of new Hg from new plants will very likely lead to increased deposition in certain areas. This will be particularly problematic in areas that are already affected by Hg deposition, such as the Ark-La-Tex region, that will require significant reductions to meet the USEPA's screening criterion.

[1] http://www.deq.state.ok.us/factsheets/land/fishmerc.pdf

Conclusions

In this report I have (i) provided a brief review of the importance of Hg in the environment, specifically as it relates to Hg contamination of fishes in Texas reservoirs, (ii) modeled pollutant plumes under dominant transport conditions for existing and proposed EGU's, and (iii) predicted Hg deposition to the environment. From this work I conclude the following:

1. There is currently cause for concern with respect to Hg contamination in fish in Texas and surrounding states. Many reservoirs in the region contain fish with concentrations of Hg hazardous to human health and consumption advisories have been issued by the State. Some species of fish not currently included in fish advisories have high levels of Hg and additional Hg input could push other fish species over the Hg levels deemed safe by the Texas Department of State Health Services (DSHS) and the US Environmental Protection Agency (USEPA);
2. Mercury emitted from EGUs in central Texas is carried by the dominant transport winds and impacts aquatic ecosystems in north and east Texas and surrounding areas. Mercury concentrations in the region's ecosystems may increase further with proposed increased coal combustion if Hg emissions are not adequately controlled. This Hg will biomagnify once it enters the aquatic food chain and be at highest concentrations in piscivorous fish and wildlife;
3. Any new coal-fired power plant will add new Hg to an environment that is affected by Hg deposition;
4. Hg deposition rates in north Texas and surrounding regions are currently ~ 1.5- to 3-fold higher than deposition in the western US, a region dominated by non-US sources. Mercury deposition in areas in north-central Texas is currently dominated by local, anthropogenic sources;
5. Pollution plumes from Texas' coal-burning power plants do (and will continue to) travel well beyond State boundaries. The modeling has shown that states including Louisiana, Oklahoma, and Arkansas, as well as those as far north as Illinois and Ohio, will potentially be affected even within 24 hours of emission from the proposed EGUs.

The Hg linkage, from air to water to fish and other biota, is a complex one that challenges state and federal regulators charged with controlling airborne emissions and with decreasing Hg deposition to levels that meet standards for concentrations in fish tissue. The scientific evidence in peer-reviewed scientific papers clearly shows that the global Hg problem is driven by anthropogenic emissions of Hg into the air, the subsequent atmospheric transport and deposition of Hg, and finally the biological transformation and biomagnification in aquatic ecosystems.

Thank you again for the opportunity to offer my thoughts on this issue. Please enter my entire written and oral testimony into the published record. I look forward to responding to your questions.

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