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DISPARITY BETWEEN STATE FISH CONSUMPTION ADVISORY SYSTEMS FOR METHYLMERCURY AND US ENVIRONMENTAL PROTECTION AGENCY RECOMMENDATIONS: A CASE STUDY OF THE SOUTH CENTRAL UNITED STATES

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Abstract: Fish consumption advisories are used to inform citizens in the United States about noncommercial game fish with hazardous levels of methylmercury (MeHg). The US Environmental Protection Agency (USEPA) suggests issuing a fish consumption advisory when concentrations of MeHg in fish exceed a human health screening value of 300 ng/g. However, states have authority to develop their own systems for issuing fish consumption advisories for MeHg. Five states in the south central United States (Arkansas, Louisiana, Mississippi, Oklahoma, and Texas) issue advisories for the general human population when concentrations of MeHg exceed 700 ng/g to 1000 ng/g. The objective of the present study was to estimate the increase in fish consumption advisories that would occur if these states followed USEPA recommendations. The authors used the National Descriptive Model of Mercury in Fish to estimate the mercury concentrations in 5 size categories of largemouth bass–equivalent fish at 766 lentic and lotic sites within the 5 states. The authors found that states in this region have not issued site-specific fish consumption advisories for most of the water bodies that would have such advisories if USEPA recommendations were followed. One outcome of the present study may be to stimulate discussion between scientists and policy makers at the federal and state levels about appropriate screening values to protect the public from the health hazards of consuming MeHg-contaminated game fish. *Environ Toxicol Chem* 2016;35:247–251. © 2015 SETAC

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INTRODUCTION

Methylmercury (MeHg) is an environmental toxin that contaminates freshwater fisheries throughout the United States [1–3]. Humans are exposed to MeHg when they consume fish, especially large predatory fish [4]. Fish consumption advisories are used to inform US residents about noncommercial game fish with hazardous levels of MeHg [5,6]. States, territories, and tribal agencies have primary responsibility for issuing site-specific fish consumption advisories that recommend limiting or avoiding consumption of fish from water bodies [5,6]. As of 2011, all states had issued fish consumption advisories because of high levels of MeHg in fish [7].

For issuance of fish consumption advisories, the US Environmental Protection Agency (USEPA) recommends that government agencies survey local waters to identify fish species that have concentrations of MeHg above predetermined screening values [5,8]. A screening value represents the concentration of a contaminant, such as MeHg, in fish that is of potential public health concern [5,8]. For MeHg, the USEPA suggests issuing a fish consumption advisory when concentrations in fish exceed a human health screening value of 300 ng/g [6,9]. Because MeHg concentrations are positively correlated with fish size [10], the USEPA also recommends collecting a range of sizes of fish and issuing advisories based on fish length [5].

The USEPA recommendations for issuing fish consumption advisories do not constitute a regulatory requirement, and states have authority to develop their own systems for issuing fish consumption advisories for MeHg [5]. Although many states use the USEPA screening value of 300 ng/g for MeHg, some states do not follow the USEPA recommendations and instead issue site-specific consumption advisories only when MeHg concentrations exceed higher levels, up to 1000 ng/g. The implication of this disparity between the USEPA's suggested screening value and some state advisory thresholds is that many water bodies that would have fish consumption advisories according to the USEPA recommendations do not currently have them.

The present study focused on site-specific fish consumption advisories in Arkansas, Louisiana, Mississippi, Oklahoma, and Texas. In these states, many water bodies contain fish that are highly contaminated with MeHg as a result of elevated levels of atmospheric mercury (Hg) deposition [1]. These states do not follow the USEPA recommendations but instead issue fish consumption advisories for the general human population when MeHg concentrations in fish exceed 700 ng/g to 1000 ng/g (Supplemental Data, Table S1). The objective of the present study was to estimate the percentage of water bodies in this 5-state region that do not have fish consumption advisories but would have advisories if the states applied the USEPA screening value of 300 ng/g.

METHODS

In the present study, we focused on site-specific fish consumption advisories for largemouth bass (*Micropterus salmoides*). Largemouth bass is a widely distributed [11] and economically important species of freshwater game fish [12]. It is a recommended target species for state fish contaminant monitoring programs [5], and it is commonly included in databases of contaminants in fish tissues [3]. Adult largemouth

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bass are piscivorous top predators that have high MeHg concentrations relative to other fish species [3,13].

Because MeHg concentrations in fish are positively correlated with fish length [10], the USEPA recommends taking fish size into account when issuing fish consumption advisories [5]. Therefore, in the present study, we examined MeHg in 5 sizes of largemouth bass corresponding to fisheries size designations from Gabelhouse [14]. The 5 categories and the associated minimum total lengths were stock (20 cm), quality (30 cm), preferred (38 cm), memorable (51 cm), and trophy (63 cm). We examined the 5 size categories of largemouth bass from each site, recognizing that water bodies have different state-issued size limits on harvested fish (e.g., minimum-length and slot-length limits [15]), and some sizes of largemouth bass may not be legally harvestable. In addition, the largest size categories of largemouth bass are rare and may not occur in all water bodies (e.g., Hungerford et al. [16]).

For the present study, we used the dataset of Hg concentrations in largemouth bass in Drenner et al. [1]. The dataset in Drenner et al. [1] included data on Hg concentration in largemouth bass from the National Fish Data Base [17], supplemental data from state agencies [1], and additional analyses of largemouth bass from Texas [18]. The dataset in Drenner et al. [1] consists of 18 919 fish samples collected over the period 1969 to 2010 (95% of the fish samples were collected between 1990 and 2010). Fish were collected from a variety of water body types that included lentic (e.g., oxbow lakes, reservoirs, human-made ponds) and lotic (e.g., creeks, rivers, streams, bayous) sites.

It can be difficult, and in some cases impossible, to collect fish of the same size from different sites over large regions [17]. To help with this problem, the US Geological Survey, in cooperation with the National Institute of Environmental Health Sciences, developed a statistical model using fish Hg concentration data from the National Listing of Fish and Wildlife Advisories dataset [17]. The model can be used to estimate Hg concentrations in sizes of fish that might occur at a site but were not sampled during the sampling event for that site [17]. In the present study, we specifically used the model (now called the National Descriptive Model of Mercury in Fish [17]) to estimate Hg concentrations in 5 size categories of largemouth bass–equivalent fish at each sampling site. The model output is total Hg concentrations in fish. We assumed that 100% of total Hg was MeHg in largemouth bass because Bloom [19] estimated that MeHg accounted for at least 95% of the total Hg in several species of fish, including largemouth bass. The USEPA [5] recommends analyzing total Hg in fish tissues as a proxy for MeHg.

Because largemouth bass were collected from some sites at different times and from different locations within a site, the model estimated multiple largemouth bass–equivalent fish values for some sites. To calculate a single largemouth bass–equivalent fish value from these sites, we averaged across time and location. If fish were collected from multiple locations within a lentic site (i.e., lake or reservoir), all largemouth bass–equivalent fish values from that lentic site were averaged to produce a single largemouth bass–equivalent fish value for that lentic site. If fish were collected from multiple locations within a lotic site (i.e., river, stream bayou), all values from largemouth bass–equivalent fish collected within 1 km of each other were averaged. This resulted in largemouth bass–equivalent fish values for 766 lentic and lotic sites within the 5 states (Supplemental Data, Figure S1).

We used a multistep approach to estimate the percentage of sites that would need new advisories if states followed the USEPA recommendations. For each size category of largemouth bass, we identified the sites in the database where concentrations of MeHg in largemouth bass exceeded 300 ng/g and classified these as sites that would have advisories if states followed the USEPA recommendations (Figure 1A). Using state websites (Supplemental Data, Table S2), we then identified which of the sites in Figure 1A currently have a state-issued advisory for either largemouth bass or for the entire fish community (Figure 1B). To calculate the number of sites that would need new advisories if the states followed USEPA recommendations (Figure 1C), we subtracted the number of sites that currently have state-issued advisories (Figure 1B) from the number of sites that would have advisories if states followed USEPA recommendations (Figure 1A). Finally, for each size category of largemouth bass, we calculated the percentage of sites where a new advisory would be needed if the states followed USEPA recommendations by dividing the number of sites that would need new advisories (Figure 1C) by the total number of sites in the database ($n = 766$; Supplemental Data, Figure S1) and multiplying by 100.

Some of the sites that we determined would need new advisories if states followed USEPA recommendations (Figure 1C) have fish with concentrations of MeHg above the states' advisory thresholds. Thus, the absence of an advisory could be caused not only by states not using the USEPA screening value but also by states not issuing an advisory for sites with fish above the states' own MeHg threshold. To examine this, we determined the number of sites in Figure 1C that exceeded state thresholds but for which an advisory was not issued (Figure 1D). For each size category of fish, we then calculated the percentage of sites where the concentration of MeHg in largemouth bass exceeded state thresholds but for which an advisory was not issued by dividing the number of sites where the states did not issue advisories (Figure 1D) by the total number of sites in the database ($n = 766$; Supplemental Data, Figure S1) and multiplying by 100.

RESULTS

We found that the 5 states in the south central United States examined in the present study have issued fish consumption advisories for fewer than one-half of the water bodies that would have advisories if the USEPA recommendations were followed. For example, we found that the number of sites in the database that would have advisories if states followed the USEPA recommendations ranged from 149 to 693 sites for stock-sized to trophy-sized fish, respectively (Figure 1A). The number of these sites that currently have state-issued advisories following state guidelines ranged from 69 to 195 sites for stock-sized to trophy-sized fish, respectively (Figure 1B), resulting in 80 to 498 sites that would need new advisories for stock-sized to trophy-sized fish, respectively, if states followed the USEPA recommendations (Figure 1C). There were 0 to 184 sites for stock-sized to trophy-sized fish, respectively, that exceeded state thresholds but for which an advisory was not issued by the states (Figure 1D).

The percentage of sites needing new advisories if the states followed USEPA recommendations would range from 10% to 65% for stock-sized to trophy-sized fish, respectively (Figure 2). The percentage of sites that exceeded state thresholds but for which an advisory was not issued ranged from 0% to 24% for stock-sized to trophy-sized fish, respectively (Figure 2). The

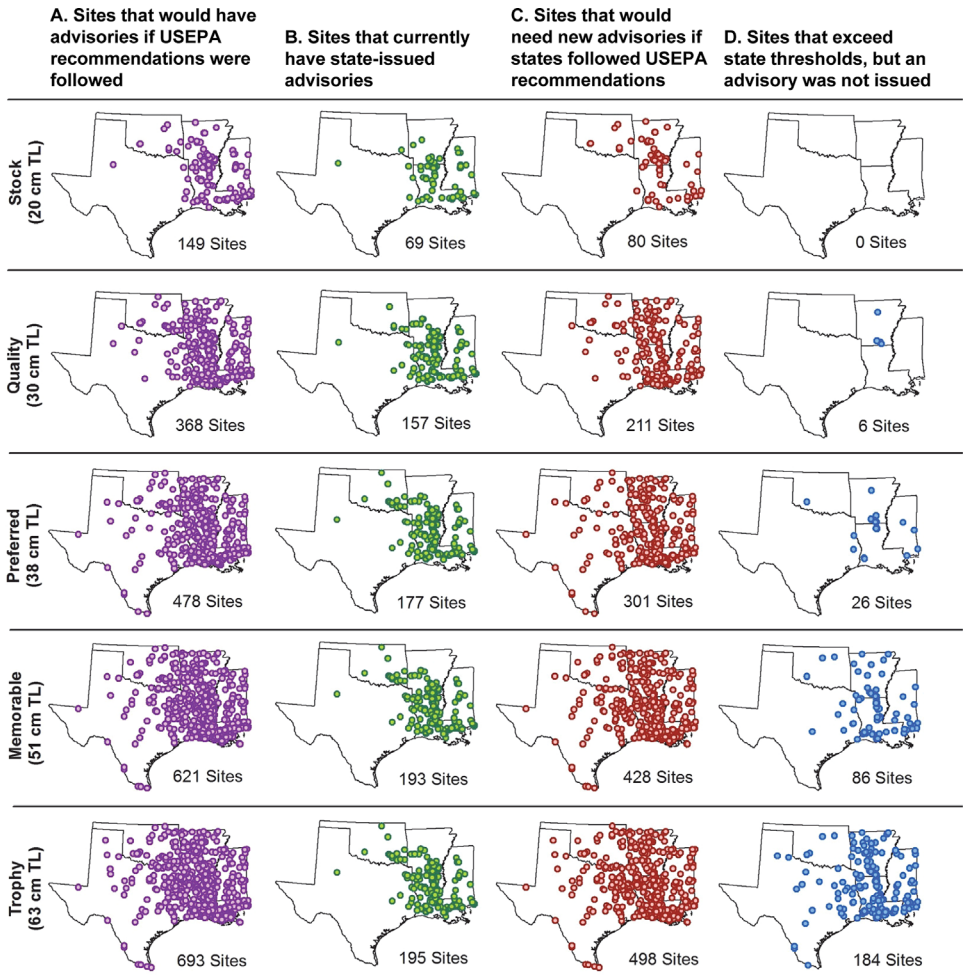

Figure 1. Sites in the south central United States that (**A**) would have advisories if the US Environmental Protection Agency (USEPA) recommendations were followed, (**B**) currently have state-issued advisories, (**C**) would need new advisories if the USEPA recommendations were followed, and (**D**) exceeded state thresholds but for which no advisory has been issued by the states for 5 size categories of largemouth bass. TL = total length.

potential impact of following the USEPA recommendations on fish advisories in the region is represented by the difference between the percentage of sites needing new advisories if the states followed the USEPA recommendations and the percentage of sites where MeHg concentrations in fish exceeded state thresholds but for which an advisory was not issued (Figure 2). For example, there would be a 10% increase in the number of advisories needed for stock-sized fish and a 41% increase for trophy-sized fish after accounting for the percentage of sites where MeHg concentrations in fish exceeded state thresholds but for which an advisory was not issued (Figure 2).

DISCUSSION

The present study is the first to examine the effect of states not following the USEPA's recommended screening value. We found that the 5 states examined in the present study have issued fish consumption advisories for fewer than one-half of the water bodies that would have advisories if the USEPA recommendations were followed. Our analyses also indicate that the need for fish consumption advisories would be greatest for the largest size categories of fish. Up to 65% of the sites in our database would need new advisories for trophy-sized fish if the USEPA recommendations were followed.

Our database of 766 sites is a small subset of the water bodies in the region, and the percentages reported in Figure 2 can be considered a proxy for the percentage of water bodies in the 5-state region that would need new advisories if the USEPA recommendations were followed. For example, our database includes only 350 lentic water bodies, whereas there are 3568 lentic water bodies with surface areas >1 km^2 in the 5 states examined in the present study [20]. This suggests that the number of sites that would need new advisories if states followed the USEPA recommendations may be much greater than the number estimated using our dataset.

The USEPA recommends that state agencies issue fish consumption advisories based on the analysis of multiple size classes of fish and that states should give size-specific advice on contaminant concentrations as appropriate [5]. In practice, it is difficult for state agencies to collect a wide range of size classes of fish from each site. Although small fish are abundant and readily captured, large fish, especially memorable-sized and trophy-sized fish, are rare and difficult to capture (e.g., Hungerford et al. [16]). This may in part explain why the percentage of sites where advisories were not issued according to state guidelines increases with fish size (Figure 2). Modeling tools, such as the National Descriptive Model of Mercury in Fish [17], might be useful to estimate Hg concentrations in all sizes of fish even when states are unable to collect a complete size range of fish. Model estimates could also be used to determine when additional sampling by states might be warranted.

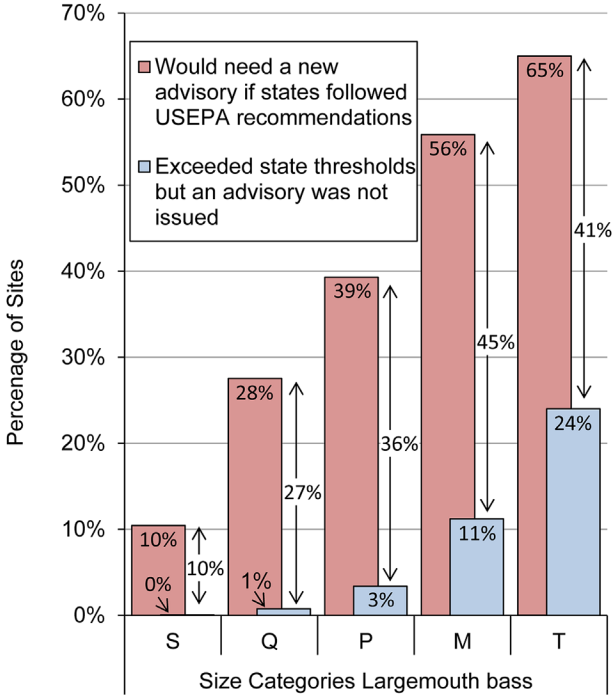

Figure 2. Percentage of sites in the present study that would need new advisories if the US Environmental Protection Agency (USEPA) recommendations were followed (percentages inside red bars), and the percentage of sites for which states did not issue advisories according to their own thresholds (percentages inside blue bars) for 5 size categories of largemouth bass (stock [S], quality [Q], preferred [P], memorable [M], trophy [T]). The potential impact of following USEPA recommendations on fish advisories in the region is represented by the percentages associated with arrows. These percentages indicate the difference between the percentage of sites needing new advisories if the states followed USEPA recommendations (red bars) and the percentage of sites where MeHg concentrations in fish exceeded state thresholds but for which an advisory was not issued (blue bars).

As an alternative to site-specific advisories, states can issue statewide fish consumption advisories. Statewide fish consumption advisories place all water bodies in the state under advisory [7]. Although statewide advisories would inform the public about potential MeHg contamination in fish, they would create another problem in that sites with fish below the USEPA screening value would be erroneously characterized as having fish with hazardous levels of MeHg. Because of the high nutritional content of fish, the restriction or removal of fish from the diet could itself introduce health risks [8,21]. In addition, limiting fish in the diets of indigenous populations may have social and cultural impacts [8]. Unwarranted advisories could also reduce angler use of water bodies and potentially cause economic impacts to surrounding business and property owners [22,23]. However, because of the widespread nature of Hg contamination and the large number of water bodies in this region, many of which have never been sampled, statewide advisories may be an effective approach to inform citizens about fish with hazardous levels of MeHg.

In conclusion, many fisheries in the south central United States contain fish with hazardous concentrations of MeHg. Although fish consumption advisories are used to inform the public about MeHg-contaminated fish, they are considered by many policy makers to be an interim public health necessity [23]. However, fish consumption advisories for MeHg will have to be used for the foreseeable future, because human activities continue to result in Hg emissions of approximately 2000 metric tons/yr [24]. Even if national regulations, such as the Mercury Air Toxics Standards [25], and international efforts, such as the Minamata Convention [26], are successful at reducing Hg emissions, Hg previously deposited and reemitted may keep cycling in the environment for thousands of years [27,28]. Thus, fish consumption advisories will continue to be an important tool to advise the public about the hazards of MeHg-contaminated fish. Because of the disparity between the USEPA's suggested screening value and some state advisory thresholds in the south central United States, there are likely thousands of water bodies without fish consumption advisories that would have such advisories if the USEPA recommendations were followed. One outcome of the present study may be to stimulate discussion between scientists and policy makers at the federal and state levels about appropriate screening values to protect the public from the health hazards of consuming MeHg-contaminated game fish.

Supplemental Data—Supplemental Data are available on the Online Wiley Library at DOI: 10.1002/etc.3185.

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Data availability—Data are available upon request from Ray Drenner (r.drenner@tcu.edu).

REFERENCES

1. Drenner RW, Chumchal MM, Jones CM, Lehmann CM, Gay DA, Donato DI. 2013. Effects of mercury deposition and coniferous forests on the mercury contamination of fish in the south central United States. *Environ Sci Technol* 47:1274–1279.
2. Hammerschmidt CR, Fitzgerald WF. 2006. Methylmercury in freshwater fish linked to atmospheric mercury deposition. *Environ Sci Technol* 40:7764–7770.
3. Kamman NC, Burgess NM, Driscoll CT, Simonin HA, Goodale W, Linehan J, Estabrook R, Hutcheson M, Major A, Scheuhammer AM, Scruton DA. 2005. Mercury in freshwater fish of northeast North America—A geographic perspective based on fish tissue monitoring databases. *Ecotoxicology* 14:163–180.
4. Mergler D, Anderson HA, Chan LHM, Mahaffey KR, Murray M, Sakamoto M, Stern AH. 2007. Methylmercury exposure and health effects in humans: A worldwide concern. *Ambio* 36:3–11.
5. US Environmental Protection Agency. 2000. Guidance for assessing chemical contaminant data for use in fish advisories. EPA 823/B-00/007. Washington, DC.
6. US Environmental Protection Agency. 2001. Mercury update: Impact on fish advisories. EPA 823/F-01/011. Washington, DC.
7. US Environmental Protection Agency. 2011. 2011 National listing of fish advisories. EPA 820/F-13/058. Washington, DC.
8. Dellinger J, Dellinger M, Yauck JS. 2012. Mercury exposure in vulnerable populations. In *Mercury in the Environment: Pattern and Process*. University of California Press, Oakland, CA, USA, pp 289–300.
9. US Environmental Protection Agency. 2009. The national study of chemical residues in lake fish tissue. EPA 823/R-09/006. Washington, DC.
10. Chumchal MM, Drenner RW, Fry B, Hambright KD, Newland LW. 2008. Habitat-specific differences in mercury concentration in a top predator from a shallow lake. *Trans Am Fish Soc* 137:195–208.
11. Lee DS, Gilbert CR, Hocutt CH, Jenkins RE, McAllister DE, Stauffer JR Jr. 1980. *Atlas of North American Freshwater Fishes*. North Carolina State Museum of Natural History, Raleigh, NC, USA.
12. US Department of the Interior, Fish and Wildlife Service, and US Department of Commerce, US Census Bureau. 2011. National survey of fishing, hunting, and wildlife-associated recreation. FHW/06-NAT. Washington, DC.
13. Chumchal MM, Hambright KD. 2009. Ecological factors regulating mercury contamination of fish from Caddo Lake, Texas, USA. *Environ Toxicol Chem* 28:962–972.

14. Gabelhouse DW Jr. 1984. A length-categorization system to assess fish stocks. *North American Journal of Fisheries Management* 4:273–285.
15. Wilde GR. 1997. Largemouth bass fishery responses to length limits. *Fisheries* 22:14–23.
16. Hungerford T, Brock R, Smith C, Durocher P. 2009. Eagle Mountain Reservoir. Performance Report for Federal Aid Project F-30-R-34. Texas Parks and Wildlife Department, Austin, TX, USA.
17. Wente SP. 2004. A statistical model and national data set for partitioning fish-tissue mercury concentration variation between spatiotemporal and sample characteristic effects. USGS Scientific Investigation Report 2004–5199. US Geological Survey, Washington, DC.
18. Drenner RW, Chumchal MM, Wente SP, McGuire M, Drenner SM. 2011. Landscape-level patterns of mercury contamination of fish in North Texas. *Environ Toxicol Chem* 30:2041–2045.
19. Bloom NS. 1992. On the chemical form of mercury in edible fish and marine invertebrate tissue. *Can J Fish Aquat Sci* 49:1010–1017.
20. Simley JD, Carswell WJ Jr. 2009. The national map—Hydrography. US Geological Survey Fact Sheet 3054. Washington, DC.
21. Mahaffey KR, Sunderland EM, Chan HM, Choi AL, Grandjean P, Mariën K, Oken E, Sakamoto M, Schoeny R, Weihe P. 2011. Balancing the benefits of n-3 polyunsaturated fatty acids and the risks of methylmercury exposure from fish consumption. *Nutr Rev* 69:493–508.
22. Jakus P, Bevelhimer M, Downing M, Fly M. 1997. Do fish consumption advisories affect reservoir anglers' site choices? *Am J Agric Econ* 79:1705–1705.
23. Swain EB, Jakus PM, Rice G, Lupi F, Maxson PA, Pacyna JM, Penn A, Spiegel SJ, Veiga MM. 2007. Socioeconomic consequences of mercury use and pollution. *Ambio* 36:45–61.
24. Krabbenhoft DP, Sunderland EM. 2013. Global change and mercury. *Science* 341:1457–1458.
25. US Environmental Protection Agency. 2015. Mercury and Air Toxics Standards. Washington, DC. [cited 2015 March 4]. Available from: http://www.epa.gov/airquality/powerplanttoxics/
26. United Nations Environmental Programme. 2015. Minamata Convention on Mercury. Geneva, Switzerland. [cited 2015 March 4]. Available from: http://www.mercuryconvention.org/
27. Amos HM, Jacob DJ, Streets DG, Sunderland EM. 2013. Legacy impacts of all-time anthropogenic emissions on the global mercury cycle. *Global Biogeochem Cycles* 27:410–421.
28. Selin NE. 2009. Global biogeochemical cycling of mercury: A review. *Annu Rev Environ Resour* 34:43–63.