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Max Weintraub
US Environmental Protection Agency, Communities and Ecosystems Division, 75 Hawthorne Street (CED-4), San Francisco, CA 94105, USA

Linda S. Birnbaum
US Environmental Protection Agency, National Health and Environmental Effects Laboratory, Research Triangle Park, NC 27709, USA

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Review

Catfish consumption as a contributor to elevated PCB levels in a non-Hispanic black subpopulation

Max Weintrauba, a,*, Linda S. Birnbaum b

a US Environmental Protection Agency, Communities and Ecosystems Division, 75 Hawthorne Street (CED-4), San Francisco, CA 94105, USA
b US Environmental Protection Agency, National Health and Environmental Effects Laboratory, Research Triangle Park, NC 27709, USA

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A B S T R A C T

The human body burden of polychlorinated biphenyls (PCBs) sharply declined after production was banned in the US in 1979. For the 10% of the US population that remains most exposed to PCBs, fish consumption is the primary source. National Health and Nutrition Examination Survey (NHANES) data indicates that the highest remaining PCB levels exist in a non-Hispanic black subpopulation. Our review suggests that catfish consumption may be a significant PCB source for the one million non-Hispanic black anglers who fish for catfish. In comparison to non-Hispanic white anglers, non-Hispanic black anglers consume more catfish, are more likely to eat the whole fish rather than just the fillets that contain less PCBs, and are more likely to fish in watersheds with high PCB contamination. Efforts to diminish potential racial disparities in PCB exposure are challenged by geographic, economic, cultural, and educational barriers. In response, we propose that a fish consumption survey be performed that identifies the extent of subsistence fishing by non-Hispanic black anglers for catfish in watersheds with PCB contamination, the type and quantity of catfish subsistence fishing provides, and what actions would help moderate PCB exposure due to subsistence fishing for catfish in such areas. Understanding the contamination and consumption factors that contribute to higher PCB body burdens will help identify and offer solutions to racial disparities in exposure to PCBs while providing a model to prevent similar disparities in exposure to toxics ranging from mercury to polybrominated diphenyl ethers.

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1. Background

Polychlorinated biphenyls (PCBs) are a group of anthropogenic compounds that can alter a wide range of human body functions, including immune, reproductive, and neurological systems, and are a probable human carcinogen (Agency for Toxic Substances and Disease Registry (ATSDR), 2000). PCBs consist of two rings of six carbon atoms with a single bond between them and one to ten chlorine atoms at different positions on the rings. Hydrogen atoms fill any of the 10 positions where chlorine atoms are absent. Two hundred and nine different PCB configurations or “congeners” exist.

Between 1929 and 1978 more than 1.2 billion pounds of PCBs were manufactured in the US primarily to use as insulating oil in electrical equipment. Federal regulations that controlled PCB waste disposal in 1978 and banned PCB production in 1979 contributed to a sharp decrease in PCB levels in the US environment during the 1980s (Fensterheim, 1993). Because PCBs...
Table 1

Human PCB levels (ppb) by racial group

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Sample</th>
<th>Analyses</th>
<th>No. of participants</th>
<th>Concentration in completely or predominantly non-Hispanic black population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1959–1972</td>
<td>United States</td>
<td>Serum (wet weight, lipid adjusted)</td>
<td>Total PCBs</td>
<td>894</td>
<td>2.87 6% higher than in non-Hispanic white population</td>
</tr>
<tr>
<td>1963–1967</td>
<td>San Francisco Bay area</td>
<td>Serum</td>
<td>11 congeners</td>
<td>309</td>
<td>3.9 high concentration</td>
</tr>
<tr>
<td>1964–1971</td>
<td>Urban area of Charleston county, SC</td>
<td>Adipose tissue (lipid adjusted)</td>
<td>9 congeners</td>
<td>200</td>
<td>1.9 mean concentration</td>
</tr>
<tr>
<td>1968</td>
<td>United States</td>
<td>Serum</td>
<td>200</td>
<td>72</td>
<td>7% to 16% of population</td>
</tr>
<tr>
<td>1972–1976</td>
<td>San Francisco Bay area</td>
<td>Serum</td>
<td>11 congeners</td>
<td>5189</td>
<td>&gt;3000–concentration in 8% of population</td>
</tr>
<tr>
<td>1972–1983</td>
<td>United States</td>
<td>Adipose tissue (lipid adjusted)</td>
<td>Total PCBs</td>
<td>9096</td>
<td>&gt;3000–concentration in 10% of population</td>
</tr>
<tr>
<td>1986</td>
<td>United States</td>
<td>Adipose tissue (lipid adjusted)</td>
<td>4 congeners from 21 composite samples</td>
<td>671</td>
<td>&gt;3000–concentration in 5% of population</td>
</tr>
<tr>
<td>1994</td>
<td>National</td>
<td>Serum</td>
<td>22.0 ppm</td>
<td>21</td>
<td>7% to 16% of population</td>
</tr>
<tr>
<td>1995–1997</td>
<td>San Francisco Bay area</td>
<td>Serum</td>
<td>11 congeners</td>
<td>211</td>
<td>147–mean concentration</td>
</tr>
<tr>
<td>1998</td>
<td>National</td>
<td>Serum</td>
<td>1.9 ppm</td>
<td>2.3 ppm</td>
<td>3% to 7% of population</td>
</tr>
<tr>
<td>1999–2000</td>
<td>National</td>
<td>Serum</td>
<td>1.9 ppm</td>
<td>2.3 ppm</td>
<td>3% to 7% of population</td>
</tr>
</tbody>
</table>

2. Elevated PCB levels in fish

Catfish is the most frequently pursued fish by non-Hispanic black anglers with 50 percent of such anglers pursuing catfish (Henderson, 2004). Since about 6% of the non-Hispanic black population are anglers, and half of those anglers fish for catfish, approximately 1 million non-Hispanic black anglers fish for catfish. Catfish are the fish most likely contributing to the higher PCB levels in a non-Hispanic black subpopulation.

PCB concentrations averaged between 0.1 and 0.01 ppm in fish tissue composite samples collected primarily of catfish collected in 2000–2003 from lakes and reservoirs nationwide (USEPA, 2005a). However, as Table 3 illustrates, numerous locations exist where catfish with PCB levels >1 ppm are present (USEPA, 2005b; West Virginia Department of Health and Human Resources, 2006; Wisconsin Department of Natural Resources, 2006; Virginia Department of Environmental Quality (VDEQ), 2003, 2004; United States Fish and Wildlife Service, 2006; Michigan Department of Environmental Quality, 2004; Schlumberger Ltd, 2003; Toaspern, 2003; Delaware River Basin Commission, 2004; Brown et al., 2005; ATSDR, 2005a,b).

3. Human health risks from elevated PCB levels in fish

The use of fish tissue data to identify health risks from PCBs started in the early 1970s when federal agencies identified high PCB levels in 58 composite fish tissue samples collected in major US watersheds (Veith et al., 1979). Most samples had a PCB concentration greater than 2 ppm. In the third of the samples degrade slowly, they bioaccumulate in fatty tissues and biomagnify as they move up the food chain.

The primary source of PCBs for the 10% of the US population currently most exposed to PCBs are fish high on the food chain consumed from PCB-contaminated lakes, streams, and estuaries (Judd et al., 2004). This represents a significant shift from studies in the 1960s through 1980s that often attributed the highest PCB body burdens in humans to occupational exposure. As summarized in Table 1 and Fig. 1, the higher PCB levels in US populations during that era were found in completely or predominantly non-Hispanic black populations (Finklea et al., 1972; James et al., 2002; Krieger et al., 1994; Lordo et al., 1996; Robinson et al., 1990; United States Environmental Protection Agency (USEPA), 1980; Gray et al., 2005; Kutz et al., 1991; National Research Council, 1991). National Health and Nutrition Examination Survey (NHANES) data suggest such racial disparities persist.

PCBs concentrate in fat tissues throughout the body. The most common method for measuring PCBs is in the lipid fraction of blood serum. Although most people in the US have PCBs in fatty tissue, relatively few have levels high enough to be detected in the lipids present in serum. As Table 2 illustrates, the NHANES detected thirteen PCB congeners in serum lipids of at least 5% of the non-Hispanic black population in the US in 1999–2000 (Centers for Disease Control and Prevention (CDCP), 2003). When compared to the 95th percentile level for the non-Hispanic white population, the concentration for each PCB congener was higher in the non-Hispanic black population. While the disparity diminished, the 2001–2002 NHANES results continued to detect the majority of the PCB congeners examined at the 95th percentile in higher concentrations in the non-Hispanic black population (CDCP, 2005). Given the racial disparity in PCB body burden, and the finding that fish is the primary contributor to high-level PCB exposure, we reviewed how a non-Hispanic black population may be exposed to PCBs from fish consumption.
where catfish constituted at least half of the fish tissue tested, the PCB concentrations tended to be greater and included one sample from Lake Hartwell, SC with a PCB concentration of 140 ppm.

Shortly thereafter, the Food and Drug Administration (FDA) established a 2 ppm tolerance level for PCBs in fish on the basis that such a level posed minimal cancer risk to the typical market shopper. The FDA also concluded that providing similar protection to subsistence anglers was prohibitively expensive and beyond FDA jurisdiction (Institute of Medicine, 1991).

Most states currently issue fish advisories for PCBs based upon the FDA 2 ppm tolerance level. PCBs have triggered more advisories to halt or limit fish consumption in the US than any substance other than mercury and include fish found in more than 7200 square miles of lakes and 110,000 miles of rivers (USEPA, 2005c). Our review of current fish advisories for PCBs nationwide found that 25 states have issued 75 “Do Not Consume” advisories for catfish to the general public and an additional 45 “Do Not Consume” advisories for all fish in areas where catfish are present (USEPA, 2006a). States have also issued more than 200 additional fish advisories for PCBs to limit consumption of catfish by women of childbearing age and children.

States are beginning to refine the risk basis for issuing fish advisories using USEPA standards that consider subsistence anglers. USEPA established a PCB concentration of 0.097 ppm as the threshold for unlimited fish consumption (USEPA, 1999a). Between 10% and 25% of a bottom-feeding fish sample composed primarily of catfish, in a 2000–2003 national study of chemical residues in lake fish, had a PCB concentration that exceeded the USEPA threshold (USEPA, 2006c, 2002b).

EPA also incorporated the risk from consumption of such catfish into water quality criteria. The PCB water quality criteria established by the USEPA is 64 pg/L (USEPA, 2002a). The cancer risk from consuming fish from watersheds that meet the PCB water quality criteria is one in a million. Thus, the risk that a person consuming fish from watersheds that exceed the PCB water quality criteria by 10-fold will develop cancer is one out of 100,000. A 2003 EPA study of 150 watersheds in 12 states (out of 2100 watersheds nationwide) identified 20 watersheds that exceed the water quality criteria for PCBs by 10-fold (USEPA, 2003).

The non-Hispanic black population in the US exceeds the national average (i.e., 13%) in only a fifth of the 3000 US counties. A random distribution suggests that only four of the 20 watersheds should have a non-Hispanic black population greater than the national average. Instead, our demographic review of the 2003 EPA study found, as Table 4 illustrates, that 10 of the 20 watersheds that exceed the PCB water quality criteria by 10-fold had a non-Hispanic black population exceeding thirteen percent (USEPA, 2006b).

In the case of the Middle Chattahoochee watershed straddling the border of Alabama and Georgia, the non-Hispanic black population approaches 50%. The Middle Coosa watershed located nearby was not included in the USEPA study, but also has a non-Hispanic black population in excess of 25% of the total population and very high PCB levels in catfish. The watershed includes the Choccolocco Creek and Lake Logan Martin, where the 2003 reported PCB levels in catfish were up to 49 and 58 ppm, respectively (Lorentz, 2005).

### 4. Racial differences in consumption of catfish

Community demographics of watersheds that substantially exceed water quality criteria for PCBs are only one geographic measure of potential disparities in PCB exposure. Ninety percent of non-Hispanic black anglers fish in the Midwest, Northeast, and South regions of the US (Henderson, 2004), where more than three-quarters of fish advisories for PCBs have been issued (USEPA, 1999b). Within those regions, the non-Hispanic black
There is a cultural component to such practices. During slavery, there was a reliance on subsistence fishing to supplement diets, develop knowledge of rivers along the Underground Railroad, and, in some cases, earn money (Cecelski, 2001). Jim Crow legislation limiting economic opportunity and access to arable land perpetuated subsistence fishing. That legacy may help explain why the rate of fishing among non-Hispanic black anglers is consistent regardless of income (RBBF, 2002; Henderson, 2004; Toth and Brown, 1997). Hundreds of soul food festivals nationwide each year recognize that history and promote catfish consumption.

To be effective, fish advisories must overcome these demographic, geographic, economic, and cultural forces to eliminate potentially high PCB exposure in the non-Hispanic black subsistence angler population. Fish advisories may not be meeting the challenge. It is unlikely subsistence anglers seek fish advisory information from a website upon which a state relies to disseminate advisories (Webber, 2006). Advisories may not respond to angler needs or, as a river flows through various jurisdictions, present different recommendations despite constant contamination (Campbell et al., 2002; Beehler et al., 2001; Burger, 2004; McDermott et al., 2003; Knuth et al., 2003; Chess et al., 2005). Such confusing and inaccessible guidance helps to explain why the non-Hispanic black population in the Northeast US and urban areas are more likely to be restrained from fishing due to general water pollution concerns rather than specific fish advisories (Burger and Waishwell, 2001).

The limited effectiveness of fish advisories is also evident from persistent racial disparities in fish consumption. Non-Hispanic black anglers are often found to consume 50% to 100% more fish than non-Hispanic white anglers (California Environmental Protection Agency, 2001; USEPA, 1997; Toxicology Excellence for Risk Assessment, 1999; Gibson and McClafferty, 2005). Several studies in Pennsylvania and South Carolina have found that non-Hispanic black anglers have higher consumption rates than non-Hispanic white anglers (California Environmental Protection Agency, 2001; USEPA, 1997; Toxicology Excellence for Risk Assessment, 1999; Gibson and McClafferty, 2005). Studies of fish consumption among African-American anglers in the United States have also found higher consumption rates compared to non-African-American anglers (Burger and Waishwell, 2001). The resulting PCB exposure from such consumption is likely disproportionately high as non-Hispanic black anglers are also less likely to trim off the fat, and are more likely to eat whole fish, than non-Hispanic white anglers (Burger et al., 1999). Whole fish can have a five- to 10-fold greater concentration of PCBs than fillets. Leaving on the skin may allow twice the quantity of PCBs to remain than would be present if the skin (and associated layer of fat beneath) were removed (Strauss, 2004).

### Table 3
Catfish tissue levels from 2000–2004

<table>
<thead>
<tr>
<th>Catfish</th>
<th>Waterbody</th>
<th>State</th>
<th>Date</th>
<th>Maximum PCB (ppm)</th>
<th>Study author and publication date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown bullhead</td>
<td>Brier creek reservoir</td>
<td>NC</td>
<td>2003</td>
<td>1.7</td>
<td>ATSDR (2005a, b)</td>
</tr>
<tr>
<td>Channel catfish</td>
<td>Chattahoochee river</td>
<td>MI</td>
<td>2003</td>
<td>2.4</td>
<td>DBRC (2004)</td>
</tr>
<tr>
<td>Channel catfish</td>
<td>Ashabula river</td>
<td>OH</td>
<td>2002</td>
<td>1.4</td>
<td>USFWS (2006)</td>
</tr>
<tr>
<td>Channel catfish</td>
<td>Lake Hartwell</td>
<td>SC</td>
<td>2003</td>
<td>2.1</td>
<td>Schlumberger Ltd. (2003)</td>
</tr>
<tr>
<td>Channel catfish</td>
<td>Knox creek</td>
<td>VA</td>
<td>2004</td>
<td>2.6</td>
<td>VDEQ (2004)</td>
</tr>
<tr>
<td>Channel catfish</td>
<td>Fox river</td>
<td>WI</td>
<td>2004</td>
<td>&gt;1.9</td>
<td>WDNR (2006)</td>
</tr>
<tr>
<td>Channel catfish</td>
<td>Monongahela river</td>
<td>WV</td>
<td>2002</td>
<td>1.9</td>
<td>WVDHHR (2006)</td>
</tr>
<tr>
<td>Channel catfish</td>
<td>Ohio river</td>
<td>WV</td>
<td>2004</td>
<td>2.7</td>
<td>WVDHHR (2006)</td>
</tr>
<tr>
<td>Flathead catfish</td>
<td>Roanoke river</td>
<td>VA</td>
<td>2004</td>
<td>1.6</td>
<td>WVDHHR (2006)</td>
</tr>
<tr>
<td>Flathead catfish</td>
<td>Lower Schuykill river</td>
<td>PA</td>
<td>2004</td>
<td>1.0</td>
<td>Brown et al. (2005)</td>
</tr>
</tbody>
</table>

### Table 4
Watersheds that exceed PCB water quality criteria by 10-fold and a non-Hispanic black population that exceeds the national percentage

<table>
<thead>
<tr>
<th>Watershed name</th>
<th>USGS number</th>
<th>Non-Hispanic black population (%)</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle Chattahoochee/</td>
<td>03130003</td>
<td>&gt; 45</td>
<td>Columbus, GA</td>
</tr>
<tr>
<td>Walter F. George Rese</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle Chattahoochee/</td>
<td>03130002</td>
<td>&gt; 35</td>
<td>La Grange, GA</td>
</tr>
<tr>
<td>Lake Harding</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detroit</td>
<td>04090004</td>
<td>&gt; 25</td>
<td>Detroit, MI</td>
</tr>
<tr>
<td>Lower Ogeeche</td>
<td>03060202</td>
<td>&gt; 25</td>
<td>Brooklet, GA</td>
</tr>
<tr>
<td>Lake Michigan</td>
<td>04060200</td>
<td>&gt; 20</td>
<td>Lake</td>
</tr>
<tr>
<td>Lake St. Clair</td>
<td>04090002</td>
<td>&gt; 20</td>
<td>St. Clair, MI</td>
</tr>
<tr>
<td>Brandywine–Christina</td>
<td>02040205</td>
<td>&gt; 15</td>
<td>Bridgeton, PA</td>
</tr>
<tr>
<td>Cohanse–Maurice</td>
<td>02040206</td>
<td>&gt; 15</td>
<td>Delafield, PA</td>
</tr>
<tr>
<td>Delaware Bay</td>
<td>02040204</td>
<td>&gt; 15</td>
<td>Lake Erie</td>
</tr>
</tbody>
</table>

Economic status also likely contributes to disparities in PCB exposure. The rate of poverty remains elevated in the non-Hispanic black population and supports the persistence of subsistence fishing (DeNavas-Walt et al., 2006; Brown and Toth, 2001). Non-Hispanic black anglers spend less money than non-Hispanic white anglers and are more likely to fish from shore for catfish than from boats for other fish (Recreational boating and fishing foundation (RBBF), 2002; Henderson, 2004).
tissue concentrations exceeding health-based national water quality criteria for PCBs by more than 10-fold; (2) areas with general population “Do Not Consume” advisories for catfish; and (3) areas that exceed the percentage of the non-Hispanic black population found nationwide.

The survey should identify the extent of subsistence fishing for catfish, the type and quantity of catfish subsistence fishing provides, and what actions would help moderate or replace subsistence fishing for catfish in areas with high levels of PCB contamination. Data collected should include sources of catfish, frequency of catfish consumption, quantity of catfish consumed, factors encouraging catfish consumption, barriers to alternate sources of catfish, and alternatives to catfish consumption. The analysis of the survey results should model the potential PCB exposure resulting from subsistence fishing for catfish.

### 6. Implications

Additional exposure to PCBs from farmed catfish may also be a concern. Catfish farming is the largest aquaculture industry in the United States (Harvey, 2005). A survey of 3600 farmed catfish consumers found farmed catfish are consumed by 60% of the non-Hispanic black population and 45% of the non-Hispanic white population (Engle, 1998). If another survey of 1400 farmed catfish consumers is correct in its findings that up to a quarter of farmed catfish consumers are catfish anglers (House et al., 2003), then it is likely that most catfish anglers also eat farmed catfish.

FDA measurements of the toxicity of farmed catfish fillets have not included dioxin-like PCBs. Farmed salmon studies suggest such examination is warranted. Total dioxin toxic equivalent (TEQ) (Van den Berg et al., 2006) levels up to 2.8 ppb have been found in farmed salmon, have triggered recommendations to limit consumption, and are due primarily to the presence of dioxin-like PCBs (Foran et al., 2005). FDA studies of dioxins and furans (i.e., absent analysis for dioxin-like PCBs) in 2003–2004 found higher TEQ in farmed catfish than farmed salmon (FDA, 2005). TEQ levels in farmed catfish due to dioxins and furans have also been found to exceed > 2.0 ppt as a result of dioxin contamination of fish feed (Hayward et al., 1999) or use of exposure modeling which included the TEQ contribution of dioxins that may be present at low levels (Jensen and Bolger, 2001). Examining the impact of dioxin-like PCBs on TEQ of farmed catfish would complement the dioxin and furan studies and enable a more complete evaluation of consumption risks.

If high-end consumers of catfish in the non-Hispanic black population are exposed to elevated levels of PCBs, any harmful effects will be exacerbated by increased rates of poverty and residential segregation, decreased rates of high-quality food access and healthcare, and other racial stressors (Gee and Payne-Sturges, 2004; House and Williams, 2000). Minimizing exposure to PCBs may diminish such impacts and also provide lessons to prevent disparities in exposure to toxics ranging from mercury to polybrominated diphenyl ethers (PBDEs) through subsistence fishing (USEPA, 2004; Mahaffrey et al., 2004; Hale et al., 2003; Schecter et al., 2004a,b; Schecter et al., 2006; Staskal et al., 2006).

### References


