

An Update on The Toxicity of PCBs

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Although PCBs were banned in 1977, they remain a major public health and environmental concern because of their widespread presence. They have been found throughout the world, even in remote locations in the Arctic where no PCBs have ever been used. Estimates are that as much as 3.4 billion pounds of PCBs were manufactured worldwide and that 30 to 70% of the PCBs manufactured remain in use or in the environment (4). Once released into the environment, PCBs travel large distances by "hitchhiking" through the ecosystem, working their way up the food chain. They remain in the environment for long periods of time because they resist natural processes of decay.

Sources of Human Exposures

Although there are no known natural sources of PCBs, they are found in the air, water, and soil; in the mud of lakes, rivers and streams; in the ocean; in fish, birds, and other animals; and in people. PCBs can enter a waterway either from direct discharge from a facility, by leaking from a "reservoir" source such as a landfill or contaminated site, or from atmospheric deposition. Once

in a body of water, PCBs adsorb onto suspended particles and eventually settle to the bottom. Over time, PCBs in the water and sediment can be taken up by system biota and enter the food chain where the PCBs concentrate. Levels in fish can exceed 100,000 times the level in the water (1). The ingestion of food, in particular meat, fish, and poultry, is considered the main path of exposure for people.

Evidence of Human Exposure

PCBs that people ingest accumulate in their fatty tissue. Because of this accumulation and the widespread contamination of the food chain, virtually everyone has measurable levels of PCBs in their bodies. The National Human Adipose Tissue Survey (NHATS), conducted in 1982, found total PCBs in human adipose tissue ranged from 14 to 1,700 ng/g (parts per billion -- ppb) (lipid basis) (2). A more recent analysis of the NHATS data from 1970 to 1983 found that 66.4% of the U.S. population had less than 1 ppm PCBs, 28.9% had greater than 1 ppm, and 5.1% had greater than 3 ppm (7).

In the U.S., median PCB levels in breast milk fat ranges from 1.2 to 2 mg/kg (ppm). A survey of 1057 nursing mothers in Michigan found a mean level of 1.5 ppm on a lipid basis (12). The mean concentration in a survey of 733 women in North Carolina was 1.8 ppm, with a maximum of 17 ppm. (13).

The Toxicity of PCBs

Most of what is known about the toxicity of PCBs comes from animal studies and occupational studies involving workers. Occupational exposure has consistently been associated with skin irritations such as acne and rashes which in severe cases can include chloracne and abnormal liver function tests.

Traditionally the toxicity of PCBs has centered around whether it causes cancer or not. The first study to show that PCBs caused cancer in animals was published in 1973. Since then 7 other studies have all found PCBs to be carcinogenic in rats and mice. Plus, another 5 studies have found PCBs to cause precancerous lesions in the liver. In fact, all chronic studies, with the exception of studies in dogs, have demonstrated that PCB exposure produces cancer or precancerous lesions. These studies have been done mostly on PCBs mixtures. Based mostly on these findings, the World Health Organization's International Agency for Research on Cancer (IARC) considers PCBs to be probably carcinogenic to people (1987) and the U.S. National Toxicology Program similarly considers that PCBs may reasonably be anticipated to be a carcinogen (1989) (2).

There have been also many studies looking at workers exposed to PCBs. These studies have shown a consistent increase in kidney cancer," although the actual number of cases was small (3).

There is also strong evidence that PCBs are associated with cancer of the liver, biliary tract, and gall bladder in humans."

In one study, capacitor workers exposed to a series of commercial mixtures containing 41 to 54% chlorine had increased mortality from liver, gall bladder and biliary tract cancer (18); gastrointestinal cancer (19) or malignant melanoma (20). A separate study of workers' exposure to Arochlor 1254 found statistically increased malignant melanoma (21). A more recent study of electrical workers found statistically increased mortality from malignant melanoma and brain cancer (22). Still other studies have found a significant association between non-Hodgkin's lymphoma and PCB levels in adipose tissue (23) and in serum (24). In the general population in Japan and Taiwan, dietary consumption of rice oil accidentally contaminated with PCBs and chlorinated dibenzofurans (which are formed when PCBs are heated), was associated with significantly increased mortality from liver cancer and lung cancer (25).

The notion that PCBs are carcinogenic has been recently challenged by industry. The details of this challenge revolved around a recent study which found that different mixtures of PCBs had different potencies and thus different toxicity (14) and the discovery that PCB mixtures found in the environment are different from commercial PCB mixtures (6). This occurs because the PCBs released into the environment change their form due to transformation and degradation processes.

EPA did decide to re-evaluate the data on PCBs. In short, EPA agreed that some mixtures of PCBs are more likely to cause cancer than others, but they also found that this new data actually "strengthens the case that all PCBs mixtures can cause cancer"(6, 17). As a result, the agency no longer uses a single cancer potency slope factor for PCBs. Instead they use a range of potencies that reflects the changes that result from environmental transformation and degradation processes which may alter the toxicity of PCBs.

Neurologic and Developmental Effects

The most exciting research into the toxicity of PCBs is looking at non cancer effects, primarily on neurologic and developmental effects, but also reproductive effects. There are three important studies that have linked PCB exposure encountered in the general population to adverse neurologic and developmental effects in children. The first of these efforts is an on-going study being conducted by Joseph and Sandra Jacobson at Wayne State University in Detroit, Michigan. This study has found that exposure to PCBs in the womb at levels only slightly higher than those in the general population can have a long term impact on intellectual function. These researchers have evaluated 236 children of mothers who ate fish from Lake Michigan, which is contaminated with PCBs and other pollutants. In their first report, they found that children born in 1980-81 to mothers who ate three fish meals per month for at least 6 years before giving birth were born sooner (shorter gestation period) and weighed less (26) and had more neonatal behavioral anomalies and poorer recognition memory than the children of mothers who did not eat Great Lakes fish (27). The effect on physical growth persisted beyond the fetal and infant periods. Jacobson reported that at 4 years of age, these children weighed 1.8 kg less, on average, than the least exposed children (28). At this age, these children continued to show poorer short-term memory functioning (29). At 11 years of age, these children showed lower IQ, poor reading comprehension, difficulty paying attention, and memory problems. The most highly exposed children were three times more likely to have lower IQ scores and twice as likely to be at least two years behind in reading comprehension. The IQ scores of the most highly exposed group averaged 6.2 points lower than those of other exposure groups (30).

The second study is being conducted by a Dutch research group in the Netherlands which evaluated the children of mothers exposed to typical background levels of PCBs and dioxins. In this study, lower birth weight and delayed growth for three months was correlated with higher PCB levels measured in cord plasma and mother's blood. Similarly, adverse neurological effects at birth and at 18 months, but not at 42 months, were correlated with higher PCB levels. At 42 months, poorer cognitive functioning was correlated with higher PCB levels in maternal blood (31,32).

The third study is being conducted in North Carolina by a group of researchers at the NIEHS directed by Dr. Walter Rogan. This study is following 858 children of mothers exposed to typical background levels of PCBs as measured in breast milk. Thus far, these children showed slowed reflexes at birth (33) and lower psychomotor developmental scores at 6 and 12 months associated with higher transplacental exposure to PCBs (34).

The neurotoxic effects of PCBs were reviewed by Rogan and Gladden (33). They reported that workers exposed to thermally degraded PCBs during the clean-up of fires involving PCBs showed slowed nerve conduction and some CNS symptoms but no correlation with plasma PCB levels. They also reported that developmental impairment in children "has been documented to occur at levels far below any other form of morbidity associated with PCBs in humans." According to this review, PCBs alter dopamine concentrations in the CNS and interfere with thyroid function, especially in newborns, but the mechanism by which PCBs damages the brain and peripheral nervous system is not known.

Neurotoxic effects have been reported in a group of French Canadian fish eaters from the Upper St. Lawrence River area (35). In this study, people who ate fish from the St. Lawrence River performed poorly on tests that required cognitive flexibility, word naming, auditory recall, and complex motor tasks.

These deficits are consistent with a diminished capacity for information processing. The interpretation of these results is complicated by the finding of heavy metals, pesticides, and other chemicals in the fish. In other studies, a 19% prevalence of numbness was reported among farm families who consumed dairy products and beef that were contaminated with PCBs (11) and a relationship between Parkinson's Disease and higher concentrations of PCBs (as well as DDE and dieldrin) has also been reported (36).

There have also been studies of children whose mothers were accidentally exposed to rice oil used for cooking that was contaminated with PCBs and dioxins in two very similar incidents, in Japan in 1968 (the "Yusho" incident) and in Taiwan in 1979 (the "Yu-Cheng" incident). In both instances, slowed nerve conduction, especially of sensory nerves was documented in children born to exposed mothers (3, 33). Among these children, skin pigmentation and low birth weight were common (1, 37). In Japan, these children had lower birth weight, retarded growth, and abnormal tooth development (1). In Taiwan, children born to exposed mothers had lower IQs, behavioral effects, and delayed growth (37). The attribution of these effects to PCBs in both studies is complicated by the presence of furans and dioxins in the rice oil, as well as PCBs.

Reproductive Effects

Women occupationally exposed to PCBs gave birth to children who were approximately 60 grams lighter than children of women from the same plan who were less exposed (38). This difference was attributed to shortened gestation period rather than to retardation of intrauterine growth.

Several other studies of women exposed to background levels of PCBs also found that these women gave birth to slightly lighter babies (26, 39). Other studies, however, have shown no effect (40) and an increase in weight with high PCB levels (41, 42). Blood PCB levels among 89 women with repeated miscarriages were found to be significantly higher than the general population (43). A similar study of women with miscarriages found higher blood PCB levels in these women than in women with normal deliveries, but many complicating factors related to PCB levels were not adjusted for (44). A recent study of women who ate more than one fish meal per month from PCB-contaminated Lake Ontario had statistically shorter menstrual cycles compared to women who did not eat fish (45). These authors also found a small, but statistically insignificant delay in the time it took to get pregnant. Several studies of sperm function in occupationally exposed workers have failed to find any effect (46, 47). Two stillbirths occurred among 13 pregnancies and reduced birth weight was common among Yusho mothers (1).

Immunologic Effects

Researchers in Wisconsin found PCB exposure to be associated with the frequency of infectious illness in the first four months of life (42). Several other studies of background exposed populations suggest that PCBs may account for alterations in levels of lymphocyte subtypes (48, 49), but these findings are in populations where dioxins or fatty acids from fish might confound the PCB-lymphocyte relationship. In mothers and their children in the Dutch studies, background levels of PCB exposure as measured in breast milk were associated with lower maternal thyroid hormone levels (T3 and T4) and higher infant TSH levels although the hormone levels observed were within normal limits (50). The interpretation of this study is complicated by the presence of dioxin in the milk. These researchers also reported that the frequency of infectious illness among breast-fed infants was unrelated to PCB levels (49).

Other Effects

Occupational exposure to PCBs has been consistently associated with chloracne, a severe skin disorder (1, 3) and abnormal liver function tests (3). In addition, skin abnormalities, including hyperpigmentation, have been associated with higher plasma PCBs levels (51). Background exposure to PCBs in a community where some people had high levels due to fish consumption, was associated with increased blood pressure (52), although this association has not been replicated elsewhere.

Summary

In summary, although recent studies have improved the scientific understanding of PCB toxicity, these studies in no way alter the scientific conclusions that PCBs are toxic and carcinogenic. The EPA has incorporated the new findings into their risk assessment process and concluded that the new data actually "strengthens the case that all PCB mixtures can cause cancer." In addition, numerous new studies continue to document the neurological, developmental, and reproductive effects of exposure to PCBs. As is the case with dioxin, additional exposures to PCBs need to be eliminated.

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