ADDENDUM TO THE TOXICOLOGICAL PROFILE FOR POLYCHLORINATED BIPHENYLS

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TABLE OF CONTENTS

LIST OF TABLES

Addendum for Polychlorinated Biphenyls
Supplement to the 2000 Toxicological Profile for Polychlorinated Biphenyls

Background Statement

This addendum for Polychlorinated Biphenyls supplements the Toxicological Profile for Polychlorinated Biphenyls that was released in November 2000.

Toxicological profiles are developed in response to the Superfund Amendments and Reauthorization Act (SARA) of 1986, which amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund). CERCLA mandates that the Administrator of ATSDR prepares toxicological profiles on substances on the Priority List of Hazardous Substances and that the profiles be revised "no less often than once every three years". CERCLA further states that the Administrator will "establish and maintain inventory of literature, research, and studies on the health effects of toxic substances" [Title 42, Chapter 103, Subchapter I, § 9604 (i)(1)(B)].

The purpose of this addendum is to provide to the public and other federal, state, and local agencies a non-peer reviewed supplement of the scientific data that were published in the open peer-reviewed literature since the release of the profile in 2000.

Chapter numbers in this addendum coincide with the Toxicological Profile for Polychlorinated Biphenyls (2000). This document should be used in conjunction with the profile. It does not replace it.

3. HEALTH EFFECTS

3.2 DISCUSSION OF HEALTH EFFECTS

The following sections provide summaries of some of the scientific literature (human and animal), regarding the health effects from exposure to PCBs, that has been published since 2000. Tables 3-17 and 3-18 provide more detailed information about the studies that have been summarized in the text.

3.2.2 Systemic Effects

3.2.2.2 Cardiovascular

3.2.2.2.2 Animal Studies

Jokinen et al.(2003) evaluated the effects of chronic exposure to dioxin (2,3,7,8,-tetrachlorodibenzo-p-dioxin [TCDD]) and a dioxin-like compound (3,3',4,4',5-pentachlorobiphenyl [PCB-126]) on the cardiovascular system in female Harlan Sprague-Dawley rats. Results indicate that the rat cardiovascular system is a target for dioxin and PCB-126 toxicity, which increases the incidence of spontaneous cardiomyopathy and arteritis of the coronary vessel. Lind et al. (2004) showed that female rats treated with to PCB-126 had raised levels of serum cholesterol, increased blood pressure, and increased myocardial mass, all attributable to that exposure. In the Lind et al., (2004) experiment, rats received a total dose of 224 µg/kg-bw in five intraperitoneal injections once every second week. The first two doses were 64 µg/kg-bw each to rapidly attain a significant body burden and the remaining three doses were 32 µg/kg-bw each.

3.2.2.5 Musculoskeletal

3.2.2.5.1 Human Studies

<u>Effects on bone mineral density (BMD)</u>
One study investigated the effects on bone mineralization from exposure to polychlorinated biphenyls (PCBs) in 115 Swedish men from the general population. No statistically significant relationship was observed between PCBs exposure and BMD (Glynn et al. 2000). Similar studies were conducted by Wallin et al. (2004, 2005), who investigated the effects on bone in male and female adults from Sweden.
A weak association was found between PCB-153 exposure and osteoporotic fractures, however, no significant relationship was found between BMD and exposure to PCB-153.
Similar findings were reported by Weiss et al. (2006), who assessed serum levels of the persistent PCB-153, hydroxylated polychlorinated biphenyl metabolites (OH-PCBs), polybrominated diphenyl ethers (PBDEs), and hexabromocyclododecanes (HBCDDs) in a group

of Swedish middle-aged and elderly women. No associations between BMD or the biochemical markers of bone metabolism and PCB-153 and PCB hydroxylated metabolites were found. The small number of participants limited the ability to detect weak or moderate associations in the study.

Another study was conducted from a population 60–81 years of age (154 males, 167 females) and living near the Baltic Coast. The results showed that the subjects (mainly males) who lived near a PCBs-contaminated river and who were exposed to relatively low levels of PCB congeners had reduced BMD after controlling for major confounding variables. In males, PCB-118 (dioxin-like PCB) exposure was negatively associated with BMD: the odds ratio for low BMD (*Z*-score less than −1) was 1.06 (95% confidence interval, 1.01–1.12) per 10 pg/mL PCB-118. The sum of the three most abundant non-dioxin-like PCBs (PCB-138, PCB-153, PCB-180) was positively associated with BMD, but not with a decreased risk of low BMD. In females, PCB-118 was positively associated with BMD, but this congener did not influence the risk of low BMD in women (Hodgson et al. 2008).

3.2.2.5.2 Animal Studies

Lundberg et al. (2006) studied the effects of perinatal exposure to PCB-153 and PCB-126 in female goat offspring. The goat dams were exposed to 98 µg/kg/day of PCB-153 or 49 ng/kg/day of PCB-126 in corn oil on gestation day (GD) 60 until delivery. The offspring were also exposed to PCBs during the lactation period of 6 weeks. The diaphyseal bone was analyzed at a distance of 18% and 50% of the total bone length, and the metaphyseal bone at a distance of 9%. Also, biomechanical three-point bending of the bones was conducted, with the load being applied to the mid-diaphyseal peripheral quantitative computed tomography (pQCT) measure point (50%). PCB-153 exposure significantly decreased the total cross-sectional area (125±4 mm^2) versus non-exposed (142±5 mm^2), decreased that of the marrow cavity (38±4 mm^2) versus non-exposed (50±3 mm^2), and decreased the moment of resistance (318±10 mm^3) versus non-exposed (371±20 mm^3) at the diaphyseal 18% measure point. At the metaphyseal measure point, the trabecular bone mineral density (121±5 mg/cm^3) was increased versus non-exposed (111±3 mg/cm^3). PCB-126 exposure did not produce any observable changes in bone tissue. No significant changes in bone parameters in the PCB-126-exposed group were observed. The biomechanical testing showed no significant differences between the exposed and control groups for either congener.

3.2.2.8 Endocrine effects

3.2.2.8.2 Human Studies

Serum from 196 men (median age 60 years) and 184 women (median age 64 years) was measured for PCB 153 concentrations in Swedish fishermen and their wives. Participants answered questions about whether they had diabetes and also about their medication and the onset of the disease. Elevated PCB-153 serum concentrations were significantly associated with diabetes mellitus type 2 prevalence even after adjustment for confounding variables. An increase of 100 ng PCB-53/g lipids was related to an odds ratio of 1.16 with 95% confidence interval (CI)

1.03-1.32, p value= 0.03. This study suggested that PCB exposure was strongly related to prevalence of type 2 diabetes mellitus (Rylander et al. 2005). Similarly, others have reported associations between incidences of type 2 diabetes mellitus and exposure to PCBs (Vasiliu et al. 2006; Chen et al. 2008; Codru et al. 2007; and Wang et al. 2005).

A cross-sectional study showed an association between diabetes mellitus prevalence and the concentrations of PCB-153 and p, p'-DDE in 544 serum samples among Swedish fishermen's wives (Rignell-Hydborn et al. 2007). Similar findings were reported by Lee et al. (2006, 2007a, b), where there were striking dose-response relationships between serum concentrations of six selected persistent organic pollutants (POPs) and the prevalence of diabetes.

Turyk et al. (2009) conducted a study on a cohort of Great Lakes sport fish consumers that was established in 1990 and followed through 2005. This study was designed to investigate the relationship between POPs, including several PCBs, body burdens and the incidence of diabetes mellitus in the studied cohort. The incident of diabetes (Type 2) was not associated with mono-ortho PCB-118, total PCBs, or years of sport fish consumption.

3.2.2.8.3 Animal Studies

Pregnant Sprague-Dawley rats were administered with 0, 0.1, 1, or 10 mg/kg Aroclor 1221 (A1221) on GD 16 and 18. In the low doses of A1221 given during this critical period of development on F1 and F2 female rats, litter sex ratio was skewed toward females. In the F1 generation, additional effects were found, including a significant alteration of serum luteinizing hormone in the 1 mg/kg A1221 group. The F2 generation showed more profound alterations, particularly with respect to fluctuations in hormones and reproductive tract tissues across the estrous cycle (Steinberg et al. 2008).

Lilienthal et al. (2000) measured the serum concentrations of vitamin D_3 metabolites 25-hydroxycholecalciferol (25-D) and 1,25-dihydroxycholecalciferol (1,25-D) in rat dams and offspring after exposure to a PCB mixture that was reconstituted according to the congener pattern found in human milk. The pattern of PCBs in human breast milk was reported elsewhere in the literature. Exposure of rat dams to the reconstituted PCB mixture at doses of 0, 5, 20, or 40 mg PCBs/kg diet caused dose-dependent reductions in their serum concentrations of 25-D during delivery but not during weaning of the offspring. This effect was also seen in the offspring at birth and at weaning in the two high-dose exposure levels. In the offspring, there was also a PCB-induced decrease of 1,25-D and 25-D levels in the group exposed to the highest dosage of PCBs. The results demonstrate that exposure to a human milk-like mixture of PCBs leads to a decrease in concentrations of a hormone involved in calcium homeostasis.

3.2.3 Immunological and Lymphoreticular Effects

3.2.3.2 Human Studies

The effects of prenatal exposure to PCBs on thymus size at birth in Eastern Slovakia neonates were examined (Park et al. 2008). Prenatal PCB exposure was associated with a smaller thymic index at birth [beta= -36 (natural log-transformed; nanograms per gram lipids); p = 0.047]. District of residence and delivery also predicted thymic index. Male sex, later gestational age, larger birth weight z-score, and Roma ethnicity were associated with a larger thymic index, whereas respiratory illness was associated with a lower thymic index (Park et al. 2008). This is the first evidence to date that PCB exposure in neonates is associated with a smaller thymic volume, suggesting possible impaired immunologic development.

The results of another study implied that exposure to PCBs is a possible cause of deficient immune function in children. Increased perinatal exposure to PCBs can adversely impact immune responses to childhood vaccinations (Heilman et al. 2006). Heilmann et al. (2006) examined sera, for antibody responses against diphtheria and tetanus vaccines from 119 children at 18 months and 129 children at 7 years of age. The antibody response to diphtheria vaccine decreased at age 18 months by 24.4% (95% CI, 1.63-41.9; p=0.04) for each doubling of the PCB exposure at the time of examination. Antibody response to tetanus vaccine was decreased at age 7 years by 16.5%. Furthermore, Langer et al. (2002) evaluated the possible long-term effects of PCBs by comparing the prevalence of glutamic acid decarboxylase (anti-GAD) antibodies with the development of diabetes mellitus. Although the prevalence of diabetes could not be determined in this retrospective study, the relationship between PCBs and the prevalence of anti-GAD antibodies supports the concept of an immunomodulatory effect of PCBs.

3.2.4 Neurological Effects

3.2.4.2 Human Studies

An occupational cohort study involving 17,321 workers indicated that exposure to PCBs likely has an effect on neurodegenerative diseases for women but not men. The total cohort showed no excess of neurodegenerative diseases mortality compared to what would be expected in the U.S. population. However, the data do show mortality excesses of amyotrophic lateral sclerosis (ALS—also known as motor neuron disease) among women, and of Parkinson disease and dementia (other than cerebrovascular dementia) among women in the high-exposure group. However, further investigations will be required to determine why women, and not men, would be susceptible to neurodegenerative disease from PCBs exposure (Steenland et al. 2006).

3.2.4.3 Animal Studies

3.2.4.3.1 Neurobehavioral Effects

Cromwell et al. (2007) examined the impact of PCBs on maternal odor conditioning in rat pups 12–14 days of age. PCB-77 exposure changed aspects of maternal-offspring interaction in rodents. The results suggest that exposure to PCBs decreases the preference for the maternal-associated cue but did not impair discrimination for a novel odor. Pups exposed to perinatal PCBs did not remain in the cue-associated location longer relative to the non-cue-related location and for the lower maternal dose of PCB (12.5 ppm). The pups actually spent significantly longer time in the non-cue location. These shifts in maternal cue preference were observed without significant changes in body weight, feeding, or olfactory function. Similarly, Cumming et al. (2005) reported that behavioral changes discerned through use of a cross-fostering paradigm suggest that changes in maternal behavior are likely to emerge from direct effects of PCB-77 on the dams as well as in response to effects of the PCB on the litter.

Orito et al. (2007) exposed female rat dams orally at GD15 to 30 µg/kg/day of PCB-126 in corn oil. At 4–5 weeks of age, male offspring were assessed by use of an open field test. Intrauterine exposure to PCBs resulted in a reduction in time spent in the center of an open field, a reduction in the number of rearings, and an extension of grooming duration. Interaction behavior, which is an index of anxiety level, was shortened in social interaction. The results suggest that exposure to PCBs may exert anxiogenic behavior in rats. The results of another study show that exposure to PCB-77 can have complex effects on the behavioral interactions between the dams and their litters, with a potential impact on the development of the offspring (Cummings et al. 2005, 2008).

Exposure to PCB-77 during gestation and lactation can have a significant effect on the maternal behavior of rat dams, as reported by Simmons et al. (2005). Exposure to 2 and 4 mg/kg of PCB-77 during GD 6–18 reduced the amount of nursing time in which the dams displayed high-crouch posture over postnatal days 1–6. The amount of maternal licking and grooming of the litters, the amount of time the dams spent on the nest, and pup mortality were increased at the high dose. At both the lower and the higher doses, the weight gain of the litters during the first 6 days of life was reduced.

3.2.3.3.2 Neurochemical Effects

Coburn et al. (2005) assessed the impact of PCBs on brain mechanisms of body fluid regulation, both in central and systemic vasopressin (VPs) release in response to acute dehydration after oral exposure to Aroclor 1254 in adult male rats. Central vasopressin release from magnocellular neuroendocrine cells in the supraoptic nucleus (SON) occurs within several hours after acute dehydration, and is an important autoregulatory mechanism. SON prepared from dehydrated PCB-naive rats released significantly more VP than did SON from control rats (4.9±0.8 vs. 2.7±0.4 pg/ml/µg of tissue weight In contrast, while PCB exposure had no effect on baseline

water intake, weight gain, or plasma osmolality responses to dehydration in PCB-fed rats, the SON failed to respond with increased VP release during dehydration. Dehydrated PCB-fed rats had an exaggerated increase in plasma VP. This indicates a limited inhibitory effect of central VP on plasma VP output.

3.2.4.3.3 Other Neurological Effects

In this experiment, pups were exposed to PCBs from conception to age of 16, 30, and 60 days when they were sacrificed and their brain tissues were stained with Timm's silver sulfide solution for mossy fiber in hippocampal tissue evaluation. Results from morphological analyses of brain tissue confirmed that, in continuously Aroclor 1254-treated rats at doses of 125 ppm, the relative size of the intra-and infra-pyramidal (II-P) mossy fiber was smaller than in control rats in all ages tested. Furthermore, this reduction in growth was selective for the II-P mossy fibers (Pruitt et al. 1999).

Dziennis et al. (2008) exposed rats to Aroclor 1254 (A1254) at 0.1 or 1 mg/kg/day in the maternal diet throughout gestation and lactation. Focal cerebral ischemia was induced at 6–8 weeks of age via middle cerebral artery occlusion, and infarct size was measured in the cerebral cortex and striatum at 22 hr of reperfusion. PCB levels and cortical and striatal expression of Bc12 and Cyp2c11 were quantified in the brain by gas chromatography and quantitative reverse transcriptase-polymerase chain reaction, respectively. Exposure during the development period resulted in significantly decreased striatal infarct in females and males at 0.1 and 1 mg/kg/day, respectively. Effects of A1254 exposure during development on Bcl2 and Cyp2C11 expression did not correlate with effects on infarct volume.

3.2.5 Reproductive Effects

3.2.5.2 Human Studies

The associations of time to menopause and environmental exposure to PCBs and related compounds were assessed in Michigan women (n=874, age 24y and older). Women were interviewed in 1997 about their menstrual periods and serum PCBs were taken at enrollment between 1976 and 1978. PCBs were measured in blood samples as Aroclor 1254 and the level of detection was 5 ppb. The serum level of PCBs was divided into low (≤5 ppb), moderate (>5–11 ppb), and high (≥11 ppb) concentrations in serum. No significant association between PCB levels and time to menopause was observed (Blanck et al. 2004).

3.2.5.3 Animal Studies

Gupta (2000) investigated the fetal long-term effect on the reproductive parameters of male mice offspring of pregnant mice which were fed 100 µg/kg/d of diethylstilbestrol (DES), 50 µg/kg/d of bisphenol A (BPA), and 50 µg/kg/d of Aroclor 1016 during GDs 16-18. The male offspring were examined at 3, 21, and 60 days after birth. The effects of PCB exposure were an increased anogenital distance, increased prostate size, and decreased epididymal weight, however, no effects were observed on testicular weight or size compared to control.

Pregnant rats were gavaged a single dose of 375 µg of PCB-118/kg body weight on GD 6. This dose was 100-fold higher than that found in human tissue which was reported by WHO in 1996. The rat offspring were hyperactive at PND 70-74, and the exposure had adverse effects on the male reproductive system at adulthood (PND 170). Rat offspring had smaller testes, epididymides, and seminal vesicles; decreases in sperm and spermatid numbers; and impairment of daily sperm production (Kuriyama et al. 2004).

Hsu et al. (2007) treated pregnant rats with a single dose of PCB-132 at 1 or 10 mg/kg on GD15 and assessed male offspring at adulthood (PND 84). The adult male rats had a decrease in cauda epididymal weight, epididymal sperm count, and motile epididymal sperm count. The spermatozoa of PCB-132-exposed offspring produced significantly higher levels of reactive oxygen species (*ROS*) than the controls. In the 1 mg/kg dose group, p53 was significantly induced and caspase-3 was inhibited, while in the 10 mg/kg dose group, activation of caspase-3 and -9 was significantly increased; at the same time the expressions of Fas, Bax, bcl-2, and p53 genes were significantly decreased.

3.2.6 Developmental Effects

3.2.6.2 Human studies

In Finland, a total of 34,457 infants born between 1997–2000 were examined for natal and neonatal teeth. Exposure of the infants to 36 PCB congeners and other related contaminants was evaluated by measuring the levels of PCB congeners in the children's mothers' milk samples when the children were 4–8 weeks old. The PCB median exposure level in milk was 7.24 picograms/gram (pg/g) in fat (measured as 2,3,7,8-TCDD toxicity equivalent). A total of 34 infants with teeth were observed (29 infants had one or two natal teeth and five neonates had neonatal teeth). The prevalence of natal and neonatal teeth was 1:1000, and therefore, no association was found between pollutant levels and occurrence of natal and neonatal teeth. This study suggested that exposure levels of PCBs in Finland are likely to be below the threshold to cause perinatal eruption of teeth (Alaluusua et al. 2002).

Four hundred thirty-two Slovenian children 8–9 years of age were evaluated for long-term exposure to PCBs. The total PCB serum concentrations in children were <200, 200–600, and >600 ng PCBs/g serum lipids. Standard dental indices were used to evaluate caries susceptibility, gingival health, and enamel defects. The proportion of deciduous and permanent teeth affected with enamel defects were significantly higher in the highest exposed children (>600 ng PCB/g group). Caries susceptibility, gingival health, or number of teeth was not affected significantly compare to controls; however, a dose-response relationship between PCB exposure and developmental enamel defects of permanent teeth in children was observed (Jan and Vrdic, 2000; Jan et al. 2007).

A prospective case-control study of 151 cord bloods (67 cryptorchid/84 matched control) and 125 colostrums (56 cryptorchid/69 matched control) was initiated to assess the incidence of cryptorchidism in male children who were exposed to PCBs during prenatal and postnatal life. The results of this study suggest a positive association (p=0.045) between high total PCB concentrations (perinatal exposure) and cryptorchidism in boys (Brucker-Davis et al. 2008).

A cohort of 615 children who were born during the period 1959–1965 was selected at random from 12 U.S study centers. A complete data set was available for 195 children with sensorineural hearing loss. Exposures to PCBs were measured as total PCB concentration in maternal serum, with the median measured as 2.8 µg/L during the third trimester. This level was about twofold higher than in recent background levels in the United States. The geometric mean PCB concentration in whole blood for the 2003-2004 NHANES 12 year and older study population was 0.820 ppb (ng/g) (Patterson et al., 2009). Hearing evaluation was carried out when the children were about 8 years old. No significant adverse effects on the average hearing threshold across the frequencies required for speech recognition were observed (Longnecker et al. 2004).

A prospective cohort study was established for randomly selected children who breastfed exclusively for at least 4 months—25 of 353 healthy, full-term children who were born between April and June of 2000. Levels of PCB congeners (PCBs 105, 118, 138, 153, 156, and 180) were measured in colostrums and breast milk at 1 and 3 months after delivery. Visual function evaluations were carried out by P100 with latency visual evoked potentials (VEPs) being measured starting at 12 months of age. At 15 months of age, impaired VEP was significantly correlated (r=0.401–0.618) with all PCB congeners except for PCB-105. However, VEP at one hour was correlated (r=0.504) with PCB-180 only. This study suggests a weak correlation between PCB levels and impaired visual functions at 12 months of age (Riva et al. 2004).

Pregnant women (n=118, age 25–34 years of age) were selected to participate in a study to examine the association between transplacental exposure to dioxins/PCBs and thyroid and growth hormones in newborns. Cord sera from 118 newborns were analyzed for 12 dioxin-like PCB congeners, other related compounds such as dioxins, and thyroid and growth hormones. Statistical analyses showed independently and significantly decreased concentrations of free T4 (FT4) x TSH with increasing non-ortho PCBs ($r = –0.2$; $p < 0.05$). Differences in compositions and levels of exposure to PCBs might result in different health effects (Wang et al. 2005).

A cohort of 232 pregnant German women 18–42 years of age was recruited in a study from 2000–2002 (Cao et al., 2007). The authors investigated the effects of PCBs and dioxins on gonadal hormones. Maternal blood and milk samples were collected from a subset of 104 mother-infant pairs for chemical analyses of Σ_6 PCBs (28, 52, 101, 138, 153, and 180) as indicator PCBs, and 17 PCDD/F congeners. The median concentrations in maternal blood fat and milk fat for the sum of the indicator PCBs (28, 52, 101, 138, 153, and 180) were 149 and 177 ng/g.. The median concentrations of PCDD/F in maternal blood fat and milk fat were 15.3 and 13.1 pg WHO-TEq/, respectively.

Maternal sera and cord sera were also analyzed for testosterone and estradiol. The adjusted means ratio (MR) for testosterone hormonal level in cord serum samples was significantly reduced in girls (MR = 0.81, 95% CL 0.69–0.94 for Σ non-o-PCBs; MR = 0.72, 95% CL 0.57–0.90 for Σ mono-o-PCBs; MR = 0.76, 95% CL 0.61–0.96 for Σ_6 PCBs; MR = 0.69, 95% CL 0.53-0.90 for ΣPCDD/F) but not in boys. On other hand, estradiol levels were significantly reduced in boys but not in girls after PCB exposures. Estradiol levels were not significantly associated with any PCB category level. This study suggested that even low levels of PCBs had a robust negative impact on gonadal hormones in newborns (Cao et al. 2007).

However in another study, no strong association was found between umbilical cord PCB levels and testicular sizes, serum testosterone concentrations, or spermaturia in boys at 7 and 14 years of age (Mol et al. 2002).

A cohort of 138 girls (10–16.9 years old) from the Akwesasne Mohawk Nation, New York was studied by comparing blood PCB levels against attainment of menses. The cohort was exposed to PCBs via food, and 16 PCB congeners were detected in more than 50% of the blood samples. In this study, the presence or absence of menses at the time of the interview was recorded. The geometric mean (0.12 ppb) of estrogenic PCBs (PCB 52, 70, 90/101, 187) was associated with a significantly greater probability of having started menarche early (β=2.12), where 86% of 12-year-old girls were predicted to have reached menarche at the 75th percentile of estrogenic PCBs levels. The study suggested that even at low levels of estrogenic PCBs, the time to menarche attainment was decreased (Denham et al. 2005). The median age at menarche for this cohort (138 girls) was 12.2 years. However, Vasiliu et al. (2004) reported no association with maternal PCBs exposure.

The serum concentrations of PCBs 138, 153, and 180 and other related contaminants were measured in 200 individuals who lived in highly-, moderately-, lowly-, or non-contaminated areas, with a mean age of 17.4 years. In boys, the testicular volumes and pubic hair growth were measured; in girls, the adult stage of breast development was measured. Significantly fewer boys had reached the adult stage of genital and pubic hair development in the highest contaminated areas in comparison to controls. Fewer girls reached the adult stage of breast development in the highest contaminated area. The present study indicated that exposure to certain PCB congeners may interfere with human reproductive development (Den Hond et al. 2002).

3.2.6.3 Animal studies

Effects of *in-utero* exposure to 4-hydroxy-2,3,3',4',5-pentachlorobiphenyl (4-OH-PCB107) on development, sex steroid hormone levels, and female reproduction in rats were investigated by Meerts et al. (2004). The developmental effects observed following exposure to 4-OH-PCB 107 were a dose-related prolongation of the estrous cycle in female offspring, measured between PNDs 210 and 231, and increased estradiol:progesterone ratios. The effects of 4-OH-PCB 107 were considered to be sex-related, because no effects could be detected on male accessory sex organ weights or testosterone levels at PNDs 310 to 325.

Kobayashi et al. (2008) exposed Sprague-Dawley rat dams to PCB-153 (0, 16, or 64 mg/kg/day) orally from GD 10 through GD 16. At age 1 or 3 weeks, the male and female offspring were examined for changes in developmental parameters. Changes in body weight, body length, tail length, and weights of kidneys, testes, ovaries, and uterus were dose-dependent. There was a significant dose-dependent decrease in plasma concentrations of thyroxine (T4) and tri-iodothyronine (T3); however, there were no changes in plasma concentrations of growth hormone and insulin-like growth factor-1 in any dose group.

Pregnant Charles River rats were given 50 µg/kg/day of Aroclor 1016 dissolved in corn oil at GD 16-18. Aroclor 1016 increased anogenital distance, increased prostate size, and decreased epididymal weight compared to control. No effects were found on testicular weight or size in offsprings (Gupta, 2000).

Steinberg et al. (2007) exposed pregnant female rats by IP injection to low levels of Aroclor 1221 (0, 0.1, 1, or 10 mg/kg) on embryonic day 16 of F1. The exposure of offspring to Aroclor 1221 resulted in a significant reduction in their mating trial pacing, vocalizations, ambulation, and the female's likelihood to mate. Similar results on the reproductive developmental effects of female rats by PCB 126 were reported by Shirota et al. (2006).

Lyche et al. (2004) examined the possible adverse effects on the hypothalamic-pituitary-gonadal axis by measuring gonadotrophins and gonadal steroid hormone concentrations in goat offspring exposed during gestation and lactation to environmental doses of PCB-153 and PCB-126. The doses of PCBs 153 and 126 were estimated to be 98 µg/kg/day and 0.049 µg/kg/day, respectively. The results indicate that maternal exposure to low doses of PCB 153 during gestation and lactation suppressed prepubertal plasma luteinizing hormone concentrations and delayed the onset of puberty of the female offspring. PCB 126 did not produce any observed effects at the exposure level tested in this study. The resulting concentrations in adipose tissue 9 months post-partum in the goat offspring were 5.8 µg/g (fat weight) and 0.00049 µg/g (fat weight) for PCBs 153 and 126, respectively.

Crofton et al. (2000) compared the impact of prenatal versus postnatal exposure of rats to Aroclor 1254. In this study, primiparous rats received 0 or 6 mg/kg A1254 (po in corn oil) from GD 6 to PND 21. On the day of birth, half of treated litters and half of the control litters were cross-fostered. As a result, the experiment consisted of the following groups: Ctrl/Ctrl, A1254/A1254 (perinatal exposure), A1254/Ctrl (prenatal exposure only), and Ctrl/A1254 (postnatal exposure only). Serum thyroid hormone concentrations, liver and brain concentration of PCBs, body weight, mortality, age of eye opening, auditory startle amplitudes, and auditory thresholds for 1 kHz and 40 kHz tones were assessed. The results demonstrated that postnatal exposure alone was responsible for ototoxicity. These cross-fostering experiments also showed that prenatal-only exposure led to small postnatal hypothyroxinemia, which recovered by the end of lactation, whereas the hypothyroxinemia that occurred following postnatal-only exposure matched that seen with perinatal exposure within a few days after birth.

Kenet et al. (2007) exposed pregnant rats orally to non-coplanar PCBs (6 mg/kg/day of PCB-95) during the gestational period and throughout 3 subsequent suckling weeks. Exposure to non-coplanar PCBs resulted in abnormal development of the primary auditory cortex in pups; however, the hearing sensitivity and brainstem auditory response of the pups were normal.

3.2.8 Cancer

3.2.8.2 Human studies

The impact of exposure to PCBs and other organochlorines on the risk of non-Hodgkin's lymphoma was investigated in a population-based case-control study in the United States.

Certain PCBs congeners, particularly the higher chlorinated PCBs (PCB 156,180,194) were associated with increased risk of non-Hodgkin's lymphoma development, with odds ratios for the highest versus lowest quartile ranging from 2.7 to 3.5, and significant trends ($p<0.05$) across categories (De Roos et al. 2005).

Prostate Cancer

Hardell et al. (2004) found that blood concentrations of PCBs were higher in mothers of patients with testicular cancer than in controls, a finding that supports the hypothesis regarding the fetal etiology of testicular cancer (Hardell et al. 2003).

Hardell et al. (2006) reported an association between persistent organophosphates (POPs) and prostate cancer, significantly so for PCB 153 in the total study population of 58 cases. PCB-153 was the congener with the highest adipose tissue concentration of the 38 PCB congeners studied. For most of the studied POPs, OR increased further in the case group with PSA greater than 16.5 ng/mL. Similar studies suggested that long-term low-dose exposure to specific organochlorine pesticides and PCBs in the general population may contribute to an increased risk of prostate cancer and recommended further investigation (Ritchie et al. 2003, 2005).

3.2.8.3 Animal studies

Nyska et al. (2004) evaluated the effects of chronic exposure to dioxin and multiple dioxin-like PCBs on the pancreas of the female Harlan Sprague-Dawley rat. Animals were treated by gavage for up to two years with PCB-126. The specific dose used in the TEF mixture study was 33.3 ng/kg PCB-126. The study indicates that the pancreatic exocrine acini represent a target tissue of the PCB-126 inducing mainly degenerative, inflammatory, and atrophic lesions and possibly also sporadic acinar adenomas and carcinomas.

Exposure by gavage of female Harlan Sprague–Dawley rats to PCB-126 at doses of 0, 30, 100, 175, 550, and 1,000 ng/kg/day assuming that PCB-126 TEF of 0.1 for up 2 years resulted in a dose-related increase in the incidence of bronchiolar metaplasia of the alveolar epithelium, as reported by Brix et al. (2004). Exposure to PCB-126 increased the incidences and severity of neoplastic and nonneoplastic lesions in the lung.

Groups of Harlan Sprague-Dawley rats were treated by gavage with PCB-153 in corn oil:acetone (99:1) at doses of 10, 100, 300, 100, or 3,000 µg/kg 5 days/week for up to 105 weeks. Exposure at the highest dose (3,000 µg/kg) continued for 30 weeks, then treatment changed to vehicle only for the rest of the study. This two-year gavage study found equivocal evidence of carcinogenic activity of PCB-153 in female Harlan Sprague-Dawley rats; the evidence was based on the occurrence of cholangioma of the liver. PCB-153 administration caused increased incidences of nonneoplastic lesions of the liver, thyroid gland, ovary, oviduct, and uterus in female rats (NTP 2006a).

Groups of 81 female Harlan Sprague-Dawley rats were treated by gavage with PCB-126 in corn oil: acetone (99:1) at doses of 30, 100, 175, 300, 550, or 1,000 ng/kg 5 days/week for up 104 weeks. Another 50 female rats were exposed to the highest dose (1,000 µg/kg) for 30 weeks and

then only to vehicle for the rest of the study. This two-year oral gavage study revealed clear evidence of carcinogenic activity of PCB-126 in female Harlan Sprague-Dawley rats on the basis of increased incidences of cholangiocarcinoma of the liver, squamous neoplasms of the lung (cystic keratinizing epithelioma and squamous cell carcinoma), and gingival squamous cell carcinoma of the oral mucosa. Hepatocellular adenoma and hepatocholangioma of the liver were also considered to be related to the administration of PCB-126. Neoplasms of the adrenal cortex and cholangioma of the liver may have been related to administration of PCB-126 (NTP 2006b). The administration of PCB-126 by oral gavage for two years produced an increased incidence of nonneoplastic lesions of the liver, lung, adrenal cortex, pancreas, kidney, heart, thyroid gland, thymus, spleen, clitoral gland, and mesenteric artery in female rats (NTP 2006b).

Another two-year oral gavage NTP study showed clear evidence of carcinogenic activity of a constant ratio binary mixture of PCB-126 and PCB-153 in female Harlan Sprague-Dawley rats. The daily doses were 10, 100, 300, or 1,000 ng of PCB-126, each with 1,000 times more PCB-153, per kilogram body weight. The evidence was based on increased incidences of cholangiocarcinoma, hepatocholangioma, and hepatocellular neoplasms (predominantly adenomas) of the liver, squamous neoplasms of the lung (predominantly cystic keratinizing epithelioma), and gingival squamous cell carcinoma of the oral mucosa. Increased incidences of pancreatic acinar neoplasms were also considered to be related to the administration of the binary mixture of PCB-126 and PCB153. The increased incidences of uterine squamous cell carcinoma may have been related to administration of the binary mixture of PCB-126 and PCB-153. The uterine squamous cell carcinoma is rare type of cancer. Administration of the binary mixture of PCB-126 and PCB-153 caused increased incidences of non-neoplastic lesions in the liver, lung, oral mucosa, pancreas, adrenal cortex, thyroid gland, thymus, kidney, nose, and fore stomach (NTP 2006c). Similar results of carcinogenic activity were found for the binary mixture of PCB-126 and PCB-118 in a 2-year oral gavage study (NTP 2006d).

In another 2-year oral gavage study, female rats were exposed to ratios of one part TCDD, two parts PeCDF, and ten parts PCB-126. The dose formulation was intended to give approximately equal toxic contributions from each substance. The administered doses were 10, 22, 46, or 100 ng toxic equivalents/kg body weight in corn oil:acetone (99:1) by gavage, daily for 5 days /week, for up to 105 weeks. There was clear evidence of carcinogenic activity of the mixture of TCDD, PeCDF, and PCB-126 in female Harlan Sprague-Dawley rats; the evidence was based on increased incidences of hepatocellular adenoma and cholangiocarcinoma of the liver and cystic keratinizing epithelioma of the lung. Neoplasms of the pancreatic acinus may have been related to administration of this mixture. This is a rare cancer, forming only 1% of all pancreatic tumors. In this case cancer arises from acinar cell of the pancreas and secretes pancreatic enzymes, mostly lipase. Also, this mixture caused increased incidences of nonneoplastic lesions of the liver, lung, pancreas, adrenal cortex, oral mucosa, uterus, thymus, ovary, kidney, heart, bone marrow, urinary bladder, mesenteric artery, and thyroid gland in female rats (NTP 2006e).

Table 3-17 Summaries of Recent Epidemiologic Studies of Human Exposures to PCBs.

Table 3-17 Summaries of Recent Epidemiologic Studies of Human Exposures to PCBs

Health effect/outcome	Levels of Exposure	Study population and design	Study Period	Outcome	Comments	Reference
Cancer/ Non-Hodgkin's lymphoma	PCBs and other organochlorines	100 untreated cases and 100 controls	Population-based case-control study	PCBs 156,180, and 194 associated with increased risk of non-Hodgkin's lymphoma	Odds ratios for the highest versus lowest quartile range from 2.7 to 3.5. TEQ was associated with 35% increased risk /10TEQ pg/g lipid (95% CI 1.02–1.79) (restate this for clarification). Certain PCBs are more potent than others.	De Roos et al. 2005
Cancer/ Prostate cancer	30 PCBs and 18 organochlorine pesticide	58 cases matched by age in 5- year increments to 99 and controls	x	PCB 180 were associated with an increase of risk of prostate cancer	Long exposure to low levels of certain OCP and PCBs may contribute to an increased risk of prostate cancer.	Ritchie et al. 2003
Cancer/ PSA levels	PCBs and other POPs (Chlordane, DDE) (	58 cases and 20 controls	x	In cases with PCB 153 > than the median concentration among controls, the OR=3.15 (95% CL =1.04–9.54)	In cases with PSA levels > the median level of 16.5 ng/ml, for PCB 153 the OR 30.3 (95% CL = 3.24-284) Lower chlorinated PCBs increased the risk significantly.	Hardell et al. 2006
Cancer/prostate	30 PCB congeners in serum	58 cases vs. 99 controls	Case-control (pilot study)	Odds of high exposure group > twice that of lowest exposure group	Effects associated with moderately chlorinated PCBs or with PCBs with Phenobarbital-like activities.	Ritchie et al. 2005

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Health effect/outcome	Levels of Exposure	Study population and design	Study Period	Outcome	Comments	Reference
Cancer/Prostate cancer	Both high exposure to electromagnetic fields and PCBs	387 cases and 5 controls/case (nested case-control) / at least 2 years note that these were workers	1987–1994	No association after adjusting for confounders	Exposure to high EMF and prostate cancer deserve further investigation	Charles et al. 2003
Cancer/Testicular / Seminoma	38 PCB congeners, DDT, hexachlorobenzene, chlordanes	61 cases and 58 age-matched controls; Cases and control mothers 44/45 also participated	x	PCBs yielded odds ratio 3.8, 95% CL, 1.4–10 among case mothers	Risk pattern was inconsistent clarify	Hardell et al. 2003
Cancer/Testicular Cancer	37 PCBs exposure	58 cases	1997-2003	The study showed that the concentrations of PCBs are higher in mothers to patients with testicular cancer	The study supports the hypothesis regarding fetal etiology of testicular cancer	Hardell et al. 2004
Development al/(hearing thresholds)/ Sensorineural hearing loss (SNHL	2.8 µg/L serum total PCBs; mothers in 3rd trimester	615 children selected @ random; 195 children with complete data/ intrauterine	1959–1966	The mean of mother's serum PCB concentrations not related to the adjusted odds of SNHL	Mother serum concentrations in Faroe Islands cohort is about twice that of the recent background in USA	Longnecker et al. 2004
Developmental Natal and neonatal teeth	TEQ 11.9 pg/g fat PCDD/F TEQ 7.24 pg/g fat	29 natal; 5 neonatal/intra uterine exposures	1997–2000	No association	The prevailing levels of toxicants were below threshold to cause perinatal eruption	Alaluusua et al. 2002

Table 3-17 Summaries of Recent Epidemiologic Studies of Human Exposures to PCBs

Health effect/outcome	Levels of Exposure	Study population and design	Study Period	Outcome	Comments	Reference
Developmental/ Genital development and pubic hair growth	PCBs (138, 153, 180) Dioxin-like compounds	200 adolescents; mean age 17.4 years	Not reported	Doubling of serum PCB 153 and dioxin-like chemicals significantly affected sexual maturation clarify	Exposure to high concentrations of PCBs and dioxin-like chemicals may hinder the sexual maturation and adversely impact human reproduction	Den Hond et al. 2002
Developmental	**X**		X	In Polish cohort of this study, PCB-153 correlated negatively with the portion of y-bearing fraction of spermatozoa	Some exposure scenarios may contribute to varying Y: X chromosome ratios	Rignell-hydbom et al. 2006
Developmental	French cohort	Total 283 boys: *151 cord* blood (67 cryptorchid/84 controls; *125 colostrums* 56 cryptorchid/69 controls	3 years prospective study	At birth, Cryptorchidism associated with higher prenatal exposure to PCBs.		Brucker-Davis et al. 2008
Developmental/ Age at menarche in offspring	PCBs and DDTs Retrospective cohort study for two generations	213 female offspring (20–50 years old) 151 (71%) participated, intrauterine exposure	1973–1991	No association with maternal PCB exposure	Association with DDT was found.	Vasiliu et al. 2004

Table 3-17 Summaries of Recent Epidemiologic Studies of Human Exposures to PCBs

Health effect/outcome	Levels of Exposure	Study population and design	Study Period	Outcome	Comments	Reference
Developmental/ Gingival health by standard dental indices and enamel by FDI index	Children living near industrial area contaminated with PCBs	432 children age 8–9 years. Control <200; group 1 200-600; group 2 >600 ng PCBs /g serum lipids, exposure period 8-9 years	8-9 years	Enamel defects in deciduous teeth significantly high in higher exposed children (Chi (2) = 8.35; p=0.03). For permanent teeth with any enamel defects (Chi (2) 7.237; p=0.027). The extent of enamel defects is significantly greater in high PCB exposure group (Chi (2) 10.714; p=0.005)	A dose relationship was emerged between PCB exposure and enamel defects of permanent teeth.	Jan et al. 2007
Developmental/ Menses attainment	16 PCB congeners	138 girls (10–16.9 year-old)	Exposure via food	PCBs levels are significant predictors of menarcheal status	The study suggests that the attainment of menarche of Mohawk girls may be sensitive to low levels of certain PCB congeners	Denham et al. 2005
Developmental/ Visual function	Breastfed for 4 month and examined at12 month of age	x/ 4 months	12 months	P100 with latency evoked potentials (VEPs) at 60 min. related to PCB 180 (r= -0.504)	The effect of impairment was no longer evident after controlling for the plasma level of long chain polyunsaturated fatty acids (LC-PUFAs) as found in the infant a few days after birth.	Riva et al. 2004

Table 3-17 Summaries of Recent Epidemiologic Studies of Human Exposures to PCBs

Health effect/outcome	Levels of Exposure	Study population and design	Study Period	Outcome	Comments	Reference
Developmental/ Developing dental enamel The prevalence of enamel development effects /	Concentration of PBCs in diet/	202children 8- to 14-year-old exposed children and 202 matched controls	x	Enamel development defects were found in 71.3% exposed vs. 49.5% control (Statistically significant differences (Chi^2 = 84.18; p= 0.0019).	In deciduous development: no significant changes	Jan and Vrbic 2000
Developmental/Hormone levels and sexual differentation/ Tanner stages, testicular size	Prenatal exposure to PCBs. Umbilical cord specimens were collected.	196 boys/ prenatal exposure and continued	Examined at 7and 14 years of age	20 boys with cryptochidism; Other 58 with spermaturia	Occurrence of spermaturia in 58 of the 176 boys was not associated with PCB exposure . and definite associations with the Tanner stages and testicular sizes	Mol et al. 2002
Endocrine / type 2 diabetes mellitus	POPs	544 serum samples, median age 50 years	x	OR=1.6; 95% CL 1.0-2.7 associated with an increase of CB-153 of 100 ng/g lipid;	Association between PCB-153 and diabetes mellitus prevalence	Rignell-hydbom et al. 2007.
Endocrine / type 2 diabetes mellitus	PCBs exposure	x	x	Positive linear association of PCB levels with diabetes at the time of enrolment in women	This study supportive of other studies where such findings were observed	Vasiliu et al. 2006.

Table 3-17 Summaries of Recent Epidemiologic Studies of Human Exposures to PCBs

Health effect/outcome	Levels of Exposure	Study population and design	Study Period	Outcome	Comments	Reference
Endocrine/ diabetes mellitus / thyroid antibodies Glutamic acid decarboxylase antibodies (anti-GAD)	Retrospective study	240 occupationally exposed and 704 age-matched controls	x	Anti-GAD 4 times higher than that of all controls (<0.001)	Possible relation between anti-GAD antibodies and an immunomodulatory effects of PCBs. These antibodies may present long time before development of diabetes.	Langer 2002
Endocrine/ Testosterone and estradiol	Healthy mother-infant German cohort initiated in 2000. Blood and milk samples were analyzed. PCBs concentrations 149 ng/g in blood and 177 ng/g in milk	104 mother-infant pairs, Perinatally exposed	X	Testosterone and estradiol levels were less in babies with high PCB concentrations	PCBs adversely affected endocrine system	Cao et al. 2008
Endocrine/ Thyroid and growth hormones	118 pregnant women (ages 25–34 years); Placental tissues and cord blood samples. Analyses for 12 dioxin-like PCBs	118 newborn children, intrauterine exposure	x	Significant negative associations between FT4, TSH and the increase of non-ortho PCBs (r=-0.2; p<0.05)	In utero exposure to non-ortho PCBs may alter the FT4 feedback to the hypothalamus	Wang et al. 2005
Endocrine/Diabetes mellitus	PCBs 153	196 men (median age 60); 184 women 64 years), life time	x	PCB 153 significantly associated with diabetes (an increase of 100 ng/g lipid corresponded to OR =1.16 95% CL 1.03-1.32, p=(0.03)	Diabetes mellitus consistently associated with the level of PCB 153 in men.	Rylander et al. 2005

Table 3-17 Summaries of Recent Epidemiologic Studies of Human Exposures to PCBs

Health effect/outcome	Levels of Exposure	Study population and design	Study Period	Outcome	Comments	Reference
Endocrine/Diabetes mellitus risk	Cross-sectional study.	1,054 (378 exposed and 370 matched references),	1993–2003	OR = 2.1 (95% CL 1.1–4.5) for women. Women with chloracne OR= 5.5 (95% CL 2.3–13.4) for diabetes	Higher exposure levels of PCBs and PCDFs as evident from the fact that chloracne increased the incidences of diabetes.	Wang et al. 2008
Endocrine/Diabetes mellitus/ Glucose blood levels	PCB congeners, and chlorinated pesticides	352 adults, > 30 yrs old	1995-2000	The prevalence of diabetes was 20.2%. The OR of having diabetes for participants in the highest tertile of total PCB concentration compared with the lowest tertile was 3.9 (95% confidence interval, 1.5–10.6).	Serum concentrations of total PCBs, two single PCB congeners, DDE, and HCB were positively associated with an elevated incidence of diabetes in an adult Native-American population.	Cordru et al. 2007
Endocrine/Diabetes mellitus/ Insulin sensitivity	12 PCB congeners exposure	40 pregnant women	x	PCBs (123,126 and 169) were significant associated with insulin activity ($r = -0.34$, $p < 0.05$)	Insulin sensitivity was significantly associated with age- and pre-pregnancy body mass indices-adjusted for decreasing TEQ of PCBs	Chen et al. 2008

Table 3-17 Summaries of Recent Epidemiologic Studies of Human Exposures to PCBs

Health effect/outcome	Levels of Exposure	Study population and design	Study Period	Outcome	Comments	Reference
Endocrine/type 2 diabetes/ Homeostasis model assessment of Insulin resistance (HOMA-IR	Persistent organic pollutants (POPs); 19 POPs in 5 subclasses	Cross-sectional study 749 nondiabetic; age > or =20 years, 20 year of exposures	x	Association were observed between HOMA-IR and two nondioxin-like PCBs	Exposure to nondioxin-like may be associated with type 2 diabetes risk by increasing insulin resistance	Lee et al. 2007 Lee et al. 2006
Immunological/ Antibodies for tetanus and diphtheria toxoids	Two cohorts from Faroe Islands, mother serum (during pregnancy) and milk PCB levels were analyzed. Antibodies for tetanus and diphtheria were measured.	119 children examined at 18 mo and 129 children at 7 years of age. Children serums examined for PCBs, tetanus and diphtheria antibodies, in utero exposures	x	For each doubling of PCBs serum conc, Ab for diphtheria toxoid decrease by 24.4% at age 18 months (95% CL, 1.63–41.9; p=0.04). Ab for tetanus toxoid decrease by 16.5% at age 7 y (95% CL, 1.51–29.3; p=0.03)	Perinatal exposures may adversely affect children's immune response from vaccinations	Heilmann et al. 2006
Immunological/rheumatoid arthritis	Cross-sectional study, 1721; 20y or more of age; dioxin and non-dioxin-like PCBs	**x**	NHANES 1999-2002	Ors 1.0, 2.1, 3.5, and 2.9 across quartiles of dioxin-like PCBs. ODs for non dioxin-like PCBs quartiles are 1.0, 1.6, 2.6, and 2.5. P for trends =0.02. Men no clear association	High PCB exposure may be in involve in arthritis pathogenesis in women	Lee DH, 2007

Table 3-17 Summaries of Recent Epidemiologic Studies of Human Exposures to PCBs

Health effect/outcome	Levels of Exposure	Study population and design	Study Period	Outcome	Comments	Reference
Immunological/thymus atrophy	15 PCB congeners in neonates?	**x**	x	Smaller thymus	Suggestive of impair immune system in neonates	Park et al. 2008
Metabolism/Enzyme biomarker/ Caffeine breath test (CBT) as probe for CYP1A2	PCBs exposures via food (serum PCB concentrations)	103 individuals interviewed and serum sampled	x	Positive association with the serum levels of 9 PCB congeners	CBT can be used as an early biological marker of PCB's effects or exposures (or selected PCB exposure leads to CYP1A2 induction, but this was the author's interpretation of the data)	Fitzgerald et al. 2005
Musculoskeletal	This is part of the study of Swedish fisherman's wives	779 women responded to questionnaires and subset of 184 was analyzed.	2000-2006	No association found between PCB-153 and OH-PCBs and bone mineral density or biochemical markers of bone metabolism	This study examined relatively high concentrations of CB-153(median 260 ng/g fat) in elderly women.	Weiss et al. 2006
Musculoskeletal system/ Bone mineral density using x-ray absorptiometry	Swedish fishermen and their wives (west coast high exposure) vs. east coast fishermen and their wives (control)	196 men (median age 59 y) and 184 women (median age 62y)	x	After adjustment for age and body mass index, the significant negative relationship between PCB-153 and BMD was not valid anymore	No significant relation between exposure to PCB-153 and BMD	Wallin et al. 2005

Table 3-17 Summaries of Recent Epidemiologic Studies of Human Exposures to PCBs

Health effect/outcome	Levels of Exposure	Study population and design	Study Period	Outcome	Comments	Reference
Musculoskeletal system/Bone mineral density (BMD)	5 dioxin-like PCBs and 3 non-dioxin-like PCBs blood levels.	154 males and 167 females aged 60–81 years	x	Male Odds ratio negatively associated with BMD 1.6 (95% CL, 1.01–1.2) per 10 pg/ml CB-118	Exposure to organochlorine may affect BMD in males	Hodgson et al. 2008
Musculoskeletal/ Bone mineral density	Persistent organochlorines (PCBs, DDT)	115 men/ mean age 63 y, range 40–75 y	x	PCBs do not cause (was not associated with?) significant effects on bone density	After the subjects were divided according to estrogenic, anti-estrogenic, and anti-androgenic groups and according to the level of exposure, weak association emerged with exposure to DDT	Glyn et al. 2000
Neurological/Neuro degenerative diseases (Parkinson's disease, amyotrophic lateral sclerosis, or dementia)	Retrospective mortality study, PCB levels of workers is about 10 times higher than the PCB levels in community (control) in 1970.	17,321 workers exposed at least for 90 days. at least 90 days	1940s–1970s	Overall no significant effects (SMR= 1.40, 1.11, and 1.26, respectively Women's amyotropic lateral (SMR = 2.26; 95% CL = 1.08–4.15)	The study suggested that women are more sensitive to neurodegenerative effects of PCBs than men.	Steenland et al.2006
Reproductive/ Time to menopause	Halogenated biphenyl (PCBs, PBB) blood samples	874 cases examined at 24 year or older age (interviewed at 1997)	1976-1978 Blood sampling period	No association with either PCBs or PBB	Smoking associated significantly with shorter time to menopause	Blanck et al., 2004

Table 3-18 Summaries of Recent Animal Studies on Health Effects from the Exposure to PCBs (Treatment).

Species	Study designs	Health effects (Findings)	Reference
Rats (Sprague-Dawley)	Aroclor 1221 (0, 0.1, 1, or 10 mg/kg). In utero exposed female offspring (F1) and (F2); Gd 16 and 18	In both generations, litter sex ratio was skewed toward females.	Steinberg et al. 2008
Mice (CD-1)	Aroclor 1016, fed 50 ug/kg/d; Gd 16-18; offspring examined at D3, D21, and D60	Increase prostate size, anogenital distance, decrease epididymal weight	Gupta C. 2000
Rats (Sprague-Dawley)	Gavage 5 d/wk, 1000 ng/kg, PCB 126; for 2 years or corn oil/acetone vehicle (99:1 mixture)	Increase of Degenerative cardiovascular lesions, cardiomyopathy and chronic active arthritis with dose	Jokinen et al. 2003
Rats	Diets containing 0, 5, 20, or 40 mg PCBs/kg diet ; exposure started 50 days before mating and terminated at birth	Reduced 1, 25-dihydroxycholecalciferol during pregnancy	Lilienthal et al. 2000
Rats (Sprague-Dawley)	2 years, Gavage, PCB 126 Control corn oil-acetone vehicle	Cytoplasmic vacuolation , chronic active inflammation, atrophy in exocrine pancreas	Nyska et al. 2004
Rats (Sprague-Dawley)	125 ppm Aroclor 1254 in diet, pregnant rats	Reduce growth of hippocampal intra-and infra-pyramidal (II-P) mossy fiber	Pruitt et al. 1999
Rats (22-24/dose)clarify	0 or 6 mg/kg A1254 (po in corn oil) GD6-PND 21. Cross fostered the offspring resulted in 4 groups (ctrl/ctrl; A1254/A/1254 perinatal exposure; A1254/ ctrl, prenatal exposure only; ctrl/A1254, postnatal exposure only	Permanent hearing deficits in A1254/ A1254 and ctrl/ A1254 groups	Crofton et al. 2000
Rats (Sprague-Dawley)	females, gavage exposure to PCB 126	Bronchiolar metaplasia	Brix et al. 2004
Adult male rats	A1254 (diet) (30 mg/kg/day for 15 days)	Dehydrated PCB-fed rats had 863% increase in plasma vasopressin (VP); for the dehydrated control, a 241% increase in VP	Coburn et al., 2005
Rats (Sprague-Dawley)	Single dose Gavage of 375 ug PCB 118/kg on GD 6	Hyperactivity and smaller testes, epididymides, seminal vesicles, decrease in sperm and spermatid numbers in offspring on PND 170.	Kuriyama et al. 2004
Rats (females)	40 rats exposed to PCB 126 alone, vehicle, ovariectomy , or sham operation(2x2 factorial design) for 12 weeks	PCB 126 increases heart weight and serum cholesterol in both groups. PCB 126 increases blood pressure in sham-operated rats only.	Lind et al. 2004

Table 3-18 Summaries of Recent Animal Studies on Health Effects from the Exposure to PCBs (Treatment).

Species	Study designs	Health effects (Findings)	Reference
Goat (kids)	Goat kids exposed to PCB 153 and PCB 126 during gestation and lactation. The average PCB Concentrations in goat kids' fat at age of 9 months were 5800 ng/g and 0.49 ng/g fat weight for PCB 153 and PCB 126 respectively.	At puberty, low LH, delayed puberty, higher progesterone level in group exposed to PCB 153. PCB 126 has no effect at these levels	Lyche et al. 2004
Pregnant rats	0, 0.5, and 5.0 mg /kg bt of 4-OH-CB107 or Aroclor 1254 (25 mg/kg bt) during GD 10-GD16.	At 0.5 and 5.0 mg of 4-OH-PCB 107 a significant prolongation of the estrous. A 50% increase in plasma estradiol levels in female offspring in animals treated with 5 mg 4-OH-CB107/kg bw. Aroclor 1254 treatment had no significant effects of estradiol levels	Meerts et al. 2004
Female rats (Sprague-Dawley)	Binary mixture of 1000 ng/kg PCB 126 + 1000 ng/kg PCB 153; PCB 126 = PCB 118 (216 and 360 ng TCDD equivalent/kg	Hyperplasia of respiratory epithelium and metaplasia of olfactory epithelium, acute inflammatory exudates observed within the lumen of nasal cavity covering the affected area	Nyska et al. 2005
Long-Evans 5day pregnant rats	2 or 4 mg/kg/ subcutaneous injection of PCB 77 on GD 6-18	Nursing time was reduced in both treatments. At 4 mg/kg body wt, the amount of licking time and pup mortality were increased	Simmons et al. 2005
Rats (Sprague-Dawley)	PCB 126 + PCB 153; PCB 126+PCB 118; PCB 126 alone; PCB 153 alone; TCDD+PCB 126+PeCDF; By Gavage/2years	In all mixture, the incidences of gingival squamous cell hyperplasia were increased significantly. In TCCD, PCB 126, and PCB 126+PCB 153 treated groups, squamous cell carcinoma were increased significantly	Yoshizawa et al. 2005
Pregnant Rat	2 mg/kg PCB 77 Gd 6-18 and gestation	Increase frequency of nursing bouts and amount of maternal auto-grooming.	Cummings et al. 2005
Rats	2-yrs gavage PCB 153 dose?	Increased incidences of non neoplastic lesions of the liver, thyroid gland, ovary, oviduct, and uterus in female rats	NTP 2006a
Rats	2-yrs gavage PCB 126 dose?	Increased incidences of cholangiocarcinoma of the liver, squamous neoplasms of the lung (cystic keratinizing epithelioma and squamous cell carcinoma), and gingival squamous cell carcinoma of the oral mucosa	NTP 2006b

Table 3-18 Summaries of Recent Animal Studies on Health Effects from the Exposure to PCBs (Treatment).

Species	Study designs	Health effects (Findings)	Reference
Rats	PCBs on maternal odor conditioning in rat pups 12–14 days of age.	Significantly depressed the preference for the maternal-associated cue, but did not impair discrimination for a novel odor.	Cromwell et al. 2007
Rats	Pregnant rats administered single doses of PCB 132 at 1 or 10 mg/kg on gestational day 15. Male offspring were assessed on postnatal day 84	Decreased cauda epididymal weight, epididymal sperm count and motile epididymal sperm count in adult offspring. The spermatozoa of PCB 132-exposed offspring produced significantly higher levels of ROS than the controls. Low-dose PCB 132 group, p53 was significantly induced and caspase-3 was inhibited. High-dose group, activation of caspase-3 and -9 was significantly increased, while the expressions of Fas, Bax, bcl-2, and p53 genes were significantly decreased	Hsu et al. 2007
Rats	Noncoplanar PCBs were fed to rat dams during gestation and throughout three Subsequent nursing weeks.	Abnormal development of the primary auditory cortex (A1)	Kenet et al. 2007
Female Goat	Goat dams were orally dosed with PCB 153 in corn oil (98 microg/kg body wt/day) or PCB 126 (49 ng/kg body wt/day) from day 60 of gestation until delivery. The offspring were exposed to PCB in utero and through maternal milk. The suckling period lasted for 6 weeks.	Perinatal exposure to PCB 153, but not PCB 126, resulted in altered bone composition in female goat offspring	Lundberg et al. 2006
Female Rats (Sprague-Dawley)	Binary Mixture PCB 126 and PCB 153 dose?	Increased incidences of non-neoplastic lesions in the liver, lung, oral mucosa, pancreas, adrenal cortex, thyroid gland, thymus, kidney, nose, and fore stomach	NTP 2006c
Female Rats (Sprague-Dawley)	Binary Mixture PCB 126 and PCB 118	Increased incidences of non-neoplastic lesions in the liver, lung, oral mucosa, pancreas, adrenal cortex, thyroid gland, thymus, kidney, nose, and fore stomach	NTP 2006d
Female Rats (Sprague-Dawley)	Mixture of TCDD, PeCDF and PCB 126	Increased incidences of non-neoplastic lesions of the liver, lung, pancreas, adrenal cortex, oral mucosa, uterus, thymus, ovary, kidney, heart, bone marrow, urinary bladder, mesenteric artery, and thyroid gland in female rats	NTP 2006e

Table 3-18 Summaries of Recent Animal Studies on Health Effects from the Exposure to PCBs (Treatment).

Species	Study designs	Health effects (Findings)	Reference
Female Rats (Sprague-Dawley)	Daily oral administration of vehicle (corn oil) or 1 or 3 µg/kg of PCB-126 from 2 weeks prior to mating with intact males until 20 days after delivery were examined from birth until puberty.	Direct effect on the ovary and adverse effects female puberty by altering the morphological and functional development of the female reproductive system	Shirota et al. 2006
Adult Female Rats (Sprague-Dawley)	Prenatal exposure to the PCB mixture Aroclor 1221 on adult female	Mating trial pacing, vocalizations, ambulation and the female's likelihood to mate were these impaired?	Steinberg et al. 2007
Female Mice (C57BL/6)	Temporal analysis, mice were orally gavaged with PCB126 or sesame oil as vehicle and sacrificed after 2, 4, 8, 12, 18, 24, 72, 120, or 168 h. In the dose-response study, mice were gavaged with 0.3, 1, 3, 10, 30, 100, 300, 1000 µg/kg PCB126, 30 or 100 µg/kg TCDD and sacrificed after 72 h	251 and 367 genes were differentially expressed by PCB 126 at one or more time points or doses, respectively, significantly less than elicited by TCDD. At 300 µg/kg PCB 126 elicited a subset of weaker effects compared with 30 µg/kg TCDD in immature, ovariectomized C57BL/6 mice	Kopec et al. 2008
Rats	Pregnant rats were treated orally with PCB 126 at a dose of 30 microg/kg or corn oil, its vehicle, on gestational day 15, and their male offspring were subjected to locomotor activity and anxiety related test, social interaction, and rotating test at 4–5 weeks old.	% time spent in the center, social interaction time, and number of rearing were significantly reduced in PCB treated group.	Orito et al. 2007
Female Rats (Sprague-Dawley)	The rats were treated orally for up to 2 years with a ternary mixture of TCDD, PCB 126 and PeCDF dose?	A variety of pulmonary lesions were observed in all the studies. Non-neoplastic lesions were bronchiolar metaplasia and squamous cell metaplasia of the alveolar epithelium. Cystic keratinizing epithelioma was the most commonly observed neoplasm	Walker et al. 2007
Female Rats	Pre- and/or postnatal exposure to PCB 77. Pregnant rats were treated with oil or PCB dissolved in oil (2 mg/kg b.w.) on gestation days 6–18 and then given pups that had been exposed to either the oil vehicle or PCB during gestation. Female offsprings were monitored until adulthood	None of the treatments (preferred to exposed) affected female sexual behavior	Cummings et al. 2008

Table 3-18 Summaries of Recent Animal Studies on Health Effects from the Exposure to PCBs (Treatment).

Species	Study designs	Health effects (Findings)	Reference
Adult Rats	PCB mixture Aroclor 1254 (A1254) at 0.1 or 1mg/kg/day in the maternal diet throughout gestation and lactation. Focal cerebral ischemia was induced at 6-8 weeks of age via middle cerebral artery occlusion, and infarct size was measured in the cerebral cortex and striatum at 22 hr of reperfusion	Significantly decreased striatal infarct in females and males at 0.1 and 1 mg/kg/day, respectively. Effects of developmental A1254 exposure on Bcl2 and Cyp2C11 expression did not correlate with effects on infarct volume	Dziennis et al. 2008
Female Rats (Sprague-Dawley)	Pregnant Sprague-Dawley rats (Crj: CD (SD) IGS) were given PCB 153 (0, 16, or 64 mg/kg/day) orally from gestational day (GD) 10 through GD 16. Male and female offspring 1 or 3 weeks of age clarify	Significant dose-dependent decrease in T3 and T4 plasma concentrations in treated group. However, thyroid stimulating hormone levels not changed significantly.	Kobayashi et al. 2008
Mice	Single gavage dose (150 micromol/kg body weight) of PCB 77, PCB 104, PCB 153 (as a mixture)	Induction of pro-inflammatory mediators in livers, lungs and brains. The strongest expression of pro-inflammatory proteins occurred 24 h following the PCB administration independent of the class of PCB congeners	Sipka et al. 2008

4. CHEMICAL AND PHYSICAL INFORMATION

No updated data.

5. PRODUCTION, IMPORT/EXPORT, USE, AND DISPOSAL

No updated data.

6. POTENTIAL FOR HUMAN EXPOSURE

6.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

CDC publishes the National Report on Human Exposures to Environmental Chemicals which is an ongoing assessment of the exposure to environmental chemicals in the general U.S. population. The Fourth Report contains data for years 1999–2000, 2001–2002 and 2003–2004 from participants in National Health and Nutrition Examination Survey (NHANES). Detailed information on the design and conduct of NHANES is available at http://www.cdc.gov/nchs/nhanes/about_nhanes.htm. In general, serum concentrations of PCBs were found to reflect cumulative past exposure in the general U.S. population.

CDC measured polychlorinated biphenyls in serum from a random one-third subsample of participants aged 12 years and older in 1999–2000 and in 2003–2004. In 2001–2002, coplanar PCBs were measured in a random one-third subsample of participants aged 20 years and older, while other PCBs were measured in a random one-third subsample of participants aged 12 years and older. The dioxin-like PCBs (coplanar and mono-ortho-substituted PCBs), and non-dioxin-like PCBs that were included in the Fourth Report are listed in Table 6–30. Tables 6-31a and 6-31b provide serum concentrations of PCB153, both lipid adjusted and whole weight, as an example of the type of data CDC has produced for each congener listed in Table 6-30. PCB153 is one of the congeners present at concentrations above 3% in A1254 and in highest concentration in some human milk samples.

Table 6-30 Coplanar, Mono-ortho and Non-Dioxin-like Polychlorinated Biphenyls from the Fourth National Report on Human Exposure to Environmental Chemicals.

Coplanar polychlorinated biphenyls (IUPAC number)	**CAS number**
3,4,4',5-Tetrachlorobiphenyl (PCB 81)	70362-50-4
3,3',4,4',5-Pentachlorobiphenyl (PCB 126)	57465-28-8
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169)	32774-16-6
Mono-*ortho*-substituted polychlorinated biphenyls (IUPAC number)	**CAS number**
2,3,3',4,4'-Pentachlorobiphenyl (PCB 105)	32598-14-4
2,3',4,4',5-Pentachlorobiphenyl (PCB 118)	31508-00-6
2,3,3',4,4',5-Hexachlorobiphenyl (PCB 156)	38380-08-4
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB 157)	69782-90-7
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167)	52663-72-6
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189)	39635-31-9
Non-dioxin-like polychlorinated biphenyls (IUPAC number)	**CAS number**
Polychlorinated biphenyls (general class)	1336-36-3
2,4,4'-Trichlorobiphenyl (PCB 28)	7012-37-5
2,2',3,5'-Tetrachlorobiphenyl (PCB 44)	41464-39-5
2,2',4,5'-Tetrachlorobiphenyl (PCB 49)	41464-40-8
2,2',5,5'-Tetrachlorobiphenyl (PCB 52)	35693-99-3
2,3',4,4'-Tetrachlorobiphenyl (PCB 66)	32598-10-0
2,4,4',5-Tetrachlorobiphenyl (PCB 74)	32690-93-0
2,2',3,4,5'-Pentachlorobiphenyl (PCB 87)	38380-02-8
2,2',4,4',5-Pentachlorobiphenyl (PCB 99)	38380-01-7
2,2',4,5,5'-Pentachlorobiphenyl (PCB 101)	37680-73-2
2,3,3',4',6-Pentachlorobiphenyl (PCB 110)	38380-03-9
2,2',3,3',4,4'-Hexachlorobiphenyl (PCB 128)	38380-07-3
2,2',3,4,4',5'-Hexachlorobiphenyl (PCB 138)	35065-28-2
2,3,3',4,4',6-Hexachlorobiphenyl (PCB 158)	74472-42-7
2,2',3,4',5,5'-Hexachlorobiphenyl (PCB 146)	51908-16-8
2,2',3,4',5',6-Hexachlorobiphenyl (PCB 149)	38380-04-0
2,2',3,5,5',6-Hexachlorobiphenyl (PCB 151)	52663-63-5
2,2',4,4',5,5'-Hexachlorobiphenyl (PCB 153)	35065-27-1
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB 170)	35065-30-6
2,2',3,3',4,5,5'-Heptachlorobiphenyl (PCB 172)	52663-74-8
2,2',3,3',4,5',6'-Heptachlorobiphenyl (PCB 177)	52663-70-4
2,2',3,3',5,5',6-Heptachlorobiphenyl (PCB 178)	52663-67-9
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB 180)	35065-29-3
2,2',3,4,4',5',6-Heptachlorobiphenyl (PCB 183)	52663-69-1
2,2',3,4',5,5',6-Heptachlorobiphenyl (PCB 187)	52663-68-0
2,2',3,3',4,4',5,5'-Octachlorobiphenyl (PCB 194)	35694-08-7
2,2',3,3',4,4',5,6-Octachlorobiphenyl (PCB 195)	52663-78-2
2,2',3,3',4,4',5,6'-Octachlorobiphenyl (PCB 196)	42740-50-1
2,2',3,3',4,5,5',6'-Octachlorobiphenyl (PCB 199)	52663-75-9
2,2',3,4,4',5,5',6-Octachlorobiphenyl (PCB 203)	52663-76-0
2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl (PCB 206)	40186-72-9
2,2'3,3'4,4'5,5'6,6'-Decachlorobiphenyl (PCB 209)	2051-24-3

*Table modified from the Fourth National Report on Human Exposure to Environmental Chemicals (CDC 2009).

Table 6-31a Serum concentrations of 2, 2', 4, 4', 5, 5'-Hexachlorobiphenyl (PCB 153) (lipid adjusted)

Geometric mean and selected percentiles of serum concentrations (in ng/g of lipid or parts per billion on a lipid-weight basis) for the U.S. population from the National Health and Nutrition Examination Survey.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total	99-00	*	< LOD	< LOD	**77.8** (70.2-87.3)	**114** (93.0-133)	1926
	01-02	**27.2** (24.7-30.1)	**30.1** (26.1-34.3)	**57.8** (52.1-63.2)	**94.7** (86.5-104)	**126** (109-142)	2306
	03-04	**19.8** (18.8-20.9)	**20.8** (18.4-22.2)	**43.3** (39.1-46.9)	**71.8** (64.4-82.8)	**97.1** (88.8-111)	1896
Age group							
12-19 years	99-00	*	< LOD	< LOD	< LOD	< LOD	668
	01-02	*	< LOD	**12.5** (11.1-14.1)	**21.2** (17.4-26.7)	**31.9** (23.1-64.7)	757
	03-04	**5.86** (5.25-6.55)	**5.40** (4.70-6.21)	**8.50** (7.80-9.85)	**15.7** (12.9-18.4)	**20.7** (16.9-28.3)	596
20 years and older	99-00	*	< LOD	< LOD	**83.2** (75.9-91.8)	**122** (100-139)	1258
	01-02	**32.6** (29.5-36.1)	**35.1** (31.1-39.0)	**62.8** (57.6-68.0)	**99.5** (90.7-110)	**132** (116-146)	1549
	03-04	**23.7** (22.3-25.1)	**24.2** (21.8-27.4)	**47.1** (43.3-50.5)	**77.5** (68.0-87.9)	**101** (92.9-119)	1300
Gender							
Males	99-00	*	< LOD	< LOD	**75.0** (66.7-86.2)	**111** (87.7-128)	917
	01-02	**28.5** (25.5-32.0)	**31.5** (26.7-35.2)	**57.7** (48.3-66.2)	**97.5** (82.1-110)	**126** (104-150)	1074
	03-04	**20.0** (18.7-21.3)	**19.7** (17.7-21.2)	**42.9** (37.4-47.6)	**72.7** (60.4-88.8)	**107** (86.8-122)	947
Females	99-00	*	< LOD	< LOD	**79.0** (70.2-92.0)	**119** (91.4-142)	1009
	01-02	**26.1** (23.6-28.8)	**29.0** (25.1-33.4)	**57.9** (52.1-62.9)	**94.3** (87.8-98.2)	**128** (105-145)	1232
	03-04	**19.7** (18.4-21.1)	**21.9** (19.0-24.1)	**43.8** (39.4-47.7)	**70.9** (63.0-81.5)	**93.3** (83.8-100)	949
Race/ethnicity							
Mexican Americans	99-00	*	< LOD	< LOD	< LOD	**67.5** (59.5-71.8)	634
	01-02	**12.5** (10.8-14.4)	**11.1** (<LOD-13.3)	**24.5** (18.2-33.9)	**47.4** (36.2-60.3)	**66.7** (55.2-72.3)	567
	03-04	**8.75** (7.39-10.4)	**7.86** (6.17-9.40)	**15.6** (11.4-22.2)	**30.3** (25.2-34.9)	**37.8** (31.1-45.2)	425
Non-Hispanic blacks	99-00	*	< LOD	**59.4** (<LOD-82.0)	**121** (90.3-159)	**176** (130-287)	412
	01-02	**30.0** (26.2-34.4)	**31.0** (25.8-36.4)	**65.1** (54.2-82.7)	**127** (97.1-152)	**170** (126-246)	515
	03-04	**22.8** (19.1-27.2)	**20.9** (17.0-28.7)	**54.1** (37.3-69.2)	**126** (92.9-158)	**194** (126-294)	464
Non-Hispanic whites	99-00	*	< LOD	< LOD	**76.4** (69.3-83.9)	**102** (87.8-127)	725
	01-02	**29.9** (26.8-33.4)	**33.0** (28.7-37.1)	**61.2** (55.8-66.7)	**96.3** (86.5-109)	**126** (104-142)	1061
	03-04	**21.3** (19.7-23.1)	**22.2** (20.4-25.9)	**44.9** (39.7-49.5)	**70.9** (60.4-82.1)	**91.3** (82.1-103)	885

Limit of detection (LOD, see Data Analysis section) for Survey years 99-00, 01-02, and 03-04 are 55.6, 10.5, and 1.1, respectively.
< LOD means less than the limit of detection, which may vary for some chemicals by year and by individual sample.
* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

http://www.cdc.gov/exposurereport/data_tables/LBX153_DataTables.html

Table 6-31b Serum concentrations 2,2',4,4',5,5'-Hexachlorobiphenyl (PCB 153) (whole weight)

Geometric mean and selected percentiles of serum concentrations (in ng/g of serum or parts per billion) for the U.S. population from the National Health and Nutrition Examination Survey.

	Survey years	Geometric mean (95% conf. interval)	Selected percentiles (95% confidence interval) 50th	75th	90th	95th	Sample size
Total	99-00	*	**< LOD**	**< LOD**	**.530** (.490-.560)	**.750** (.610-.840)	1926
	01-02	**.167** (.151-.185)	**.190** (.170-.210)	**.380** (.340-.410)	**.620** (.560-.690)	**.860** (.760-.950)	2306
	03-04	**.121** (.114-.128)	**.135** (.120-.144)	**.283** (.258-.310)	**.477** (.439-.518)	**.624** (.575-.733)	1896
Age group							
12-19 years	99-00	*	**< LOD**	**< LOD**	**< LOD**	**< LOD**	668
	01-02	*	**< LOD**	**.060** (.050-.070)	**.110** (.080-.140)	**.150** (.110-.310)	757
	03-04	**.030** (.027-.033)	**.027** (.025-.031)	**.044** (.039-.055)	**.076** (.062-.098)	**.101** (.079-.129)	596
20 years and older	99-00	*	**< LOD**	**< LOD**	**.560** (.510-.610)	**.790** (.670-.880)	1258
	01-02	**.206** (.187-.228)	**.220** (.200-.250)	**.410** (.380-.450)	**.670** (.600-.740)	**.900** (.820-1.04)	1540
	03-04	**.148** (.139-.158)	**.156** (.141-.179)	**.313** (.283-.339)	**.512** (.452-.563)	**.671** (.603-.756)	1300
Gender							
Males	99-00	*	**< LOD**	**< LOD**	**.530** (.470-.560)	**.690** (.580-.850)	917
	01-02	**.177** (.159-.198)	**.200** (.170-.220)	**.380** (.340-.430)	**.610** (.510-.730)	**.850** (.700-1.04)	1074
	03-04	**.123** (.115-.133)	**.127** (.111-.146)	**.277** (.253-.310)	**.474** (.413-.522)	**.608** (.533-.794)	947
Females	99-00	*	**< LOD**	**< LOD**	**.530** (.480-.590)	**.770** (.610-.880)	1009
	01-02	**.158** (.142-.175)	**.180** (.150-.210)	**.380** (.340-.400)	**.630** (.570-.710)	**.860** (.760-.950)	1232
	03-04	**.119** (.110-.128)	**.138** (.113-.149)	**.291** (.253-.319)	**.492** (.439-.541)	**.624** (.578-.689)	949
Race/ethnicity							
Mexican Americans	99-00	*	**< LOD**	**< LOD**	**< LOD**	**.470** (.380-.540)	634
	01-02	**.075** (.063-.089)	**.060** (<LOD-.080)	**.150** (.120-.210)	**.330** (.270-.420)	**.470** (.380-.550)	567
	03-04	**.053** (.044-.064)	**.047** (.038-.057)	**.100** (.078-.144)	**.205** (.164-.241)	**.323** (.213-.435)	425
Non-Hispanic blacks	99-00	*	**< LOD**	**.370** (<LOD-.510)	**.750** (.620-.890)	**1.27** (.820-1.64)	412
	01-02	**.169** (.146-.195)	**.180** (.140-.200)	**.390** (.330-.490)	**.780** (.580-.950)	**1.05** (.830-1.43)	515
	03-04	**.129** (.108-.156)	**.126** (.098-.149)	**.330** (.236-.425)	**.734** (.562-1.06)	**1.26** (.892-1.60)	464
Non-Hispanic whites	99-00	*	**< LOD**	**< LOD**	**.520** (.480-.560)	**.740** (.580-.850)	725
	01-02	**.185** (.165-.207)	**.210** (.180-.230)	**.390** (.370-.430)	**.640** (.570-.720)	**.840** (.740-.990)	1061
	03-04	**.131** (.121-.143)	**.144** (.127-.170)	**.295** (.268-.329)	**.474** (.412-.518)	**.600** (.519-.689)	885

< LOD means less than the limit of detection for the lipid adjusted serum level, which may vary for some chemicals by year and by individual sample.
* Not calculated: proportion of results below limit of detection was too high to provide a valid result.

http://www.cdc.gov/exposurereport/data_tables/LBX153_DataTables.html

7. ANALYTICAL METHODS

No updated data.

8. REGULATIONS AND ADVISORIES

No updated data.

9. REFERENCES

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