WWF for a living planet

WWF-UK

Panda House, Weyside Park
Godalming, Surrey GU7 1XR
Britdoc DX 58352 Godalming 2
t: +44 (0)1483 426444
f: +44 (0)1483 426409

www.wwf.org.uk

Chain of Contamination: The Food Link (Fact Sheet)

POLYCHLORINATED BIPHENYLS (PCBs)

Background

PCBs (polychlorinated biphenyls) are a group of man-made chemicals first manufactured in the 1920s, but which are now banned worldwide. There are 209 different PCB molecules, known as “congeners”, and the commercial products were mixtures. PCBs are hazardous, persistent and bioaccumulative chemicals, which are classified as UNEP POPs (persistent organic pollutants) such that intentional production is now banned globally under the Stockholm Convention of 2001 (UNEP, 2006). Over the last decade considerable effort has been put into inventorying, collecting and destroying PCBs still in use. PCBs can also be formed unintentionally during combustion processes, where there is organic matter and chlorine.

The manufacture of PCBs in most European countries ceased in the 1970s after research increasingly showed that they were building up in the environment and evidence emerged of their potential for harmful effects in wildlife and humans. Despite this, PCBs still persist in the environment. This “persistence” (a resistance to being broken down in the environment, meaning they stick around for very long periods of time), combined with their “bioaccumulative” nature (a tendency to build up in living things) means that PCBs continue to contaminate ecosystems, wildlife and people all over the world. People in industrialised, developed countries, and also developing countries, are widely exposed to PCBs and are likely to have detectable amounts of PCBs in their blood, fat, and breast milk (see below).

PCBs can be found in air (Sun et al., 2006), water (Nie et al., 2005), river and marine sediments (Roose et al., 2005, Covaci et al., 2005), soils (Harrad et al., 1994), plants and vegetation (Schuhmacher et al., 2004) and other “biota” (living things, e.g. humans and wildlife) (Riget et al., 2004, Miao et al., 2000). PCBs can enter the air by evaporation from both soil and water and can be carried long distances around the globe (Gambaro et al., 2005). PCBs can precipitate in rainfall and snow and have been found in snow and sea water in areas such as the Arctic, far away from where they were released into the environment (Gustafsson et al., 2005). PCBs are taken up into the bodies of small organisms and fish in water and increase in concentration as they are taken up by animals higher up the food chain that feed on them (Borga et al., 2001). PCBs especially accumulate in fish and marine mammals such as seals and whales, reaching levels that may be many thousands of times higher than in water (Shaw et al., 2005, Weisbrod et al., 2001, Mossner et al., 1997). Particularly high levels have been found in polar bears (Skaare et al., 2000).

PCBs are found widely in human blood serum (e.g. Thomas et al., 2006, Sjodin et al., 2004), adipose (fat tissue) (Naert et al., 2006) and breast milk (Fangstrom et al., 2005, Poon et al., 2005, Kalantzi et al., 2004).

Major uses

Because they don’t burn easily and are good insulating materials, PCBs were used widely as coolants and lubricants in electrical equipment such as transformers and capacitors, as heat exchange fluids and as flame retardants (ATSDR, 2000). They were also used in building materials such as plaster and joint sealants (Herrick et al., 2004, Andersson et al., 2004), as paint additives, in carbonless copy paper and as a flame retardant additive in plastics (ATSDR, 2000). Consumer products that may contain PCBs include old fluorescent lighting fixtures, electrical devices or appliances containing PCB capacitors made before PCB use was banned.

How do PCBs get into the environment (and food chain)?

PCBs entered the air, water and soil during their manufacture and use. Waste containing PCBs was generated at that time, and was often placed in landfills. PCBs also entered the environment from accidental spills and leaks during the transport of the chemicals, or from leaks or fires in transformers, capacitors or other products containing PCBs. Today, PCBs can still be released into the environment from a variety of sources (Harrad et al., 1994), including poorly maintained hazardous waste sites, illegal or improper dumping of PCB wastes, and disposal of PCB-containing consumer products into municipal or other landfills not designed to handle hazardous waste. PCBs may be released into the environment by some waste burning in municipal and industrial incinerators (CDC, 2005).

Disposal of waste products containing PCBs and emissions from industrial processes – power stations, iron and steel works, sewage sludge applications to land – can all contribute to environmental inputs. Following release, PCBs accumulate in the environment (air, water, sediment, soil, vegetation) and in the food chain (fish, mammals, birds) due to their persistent nature.

How are people exposed to PCBs?

Although PCBs are no longer made or used in the UK or Europe, people can still be exposed to them by breathing contaminated indoor air (PCBs were used in building materials, lighting and electrical appliances) (Andersson et al., 2004 Herrick et al., 2004), or by coming into contact with PCBs at or near hazardous waste sites. However, the main route of exposure is via the diet, as they are common contaminants in the food chain (due to their ubiquitous presence and widespread distribution in the environment) (see below). The developing foetus can be exposed to PCBs in the womb (Gray et al., 2005) and as PCBs can accumulate in breast milk (Kalantzi et al., 2004), newborn babies can ingest PCBs during breastfeeding. Nevertheless, the balance of scientific evidence confirms that the benefits of breastfeeding outweigh any risks from exposure to PCBs in mother’s milk.

Once PCBs are in the body, some may be changed by the body’s systems into other related chemicals called metabolites which may leave the body in faeces in a few days (Hu & Bunce, 1999). Others can remain in body fat for many months. Unchanged PCBs may be stored for years or even decades, mainly in the fat and liver, but smaller amounts can be found in other organs as well.

PCBs in food

The major dietary sources of PCBs are fish, in particular oily fish (e.g. salmon, herring, sardines, fresh tuna, anchovies, swordfish) and those caught in contaminated lakes or rivers, fish oils, meat and dairy products. There are numerous studies on PCB contamination of foodstuffs. For example, the UK Food Standards Agency (FSA) published a study in 2003 on PCBs (and dioxins) in food samples ranging from bread, milk and poultry to green vegetables, fruit and nuts (FSA, 2003). More selected examples from the literature can be seen in the table below.

Note: PCBs in the context of food contamination are divided into two different groups, based on their biochemical and toxicological properties: the dioxin-like PCBs (DL-PCBs) and the non-dioxin-like PCBs (NDL-PCBs). Over 90% of human exposure to NDL-PCBs is through food and as a result, these compounds have built up in the human body, primarily in fat tissue (EFSA, 2005). Although levels of NDL-PCBs in food have gradually decreased since environmental legislation on use and disposal of PCBs was introduced by the European Union (EU) in the 1980s (see also Baars et al., 2004), human exposure to NDL-PCBs is still considered to be high (EFSA, 2005). The toxicity of dioxin-like PCBs (DL-PCBs) is much higher than that of NDL-PCBs. NDL-PCBs and DL-PCBs accumulate together along the food chain and higher concentrations are found in food of animal origin (particularly carnivores and predatory fish) compared to fruits and vegetables (EFSA, 2005).

Food item	**Reference(s)**	**Comments**
Fish and shellfish	Food Standards Agency UK (2006) – Dioxins and dioxin-like PCBs in farmed and wild fish and shellfish www.food.gov.uk/science/surveillance	Analysis of 47 farmed and wild species – dioxins and PCBs found in all samples. Higher levels in oily than non-oily spp.
Salmon (farmed and wild)	Hites et al (2004). Science, 303, pp226-229	Farmed salmon contained much higher levels of organochlorines
Swordfish	Stefanelli et al (2004). Mar. Poll. Bull., 49, pp938-950	Swordfish caught in the Mediterranean and Azores
Butter	Weiss et al (2005). Ambio, 34(8) pp589-597. Kalantzi et al (2001). Env. Sci. Technol., 35 (6), pp1013-1018.	Worldwide surveys of PCBs and other organochlorines in butter
Pork	Covaci et al (2004). Chemosphere, 56, (8), pp757-766.	
Meat (hamburger, bacon, chicken fat, pork fat, beef fat)	Huwe J.K. & Larsen, G.L. (2005). Env. Sci. Technol., 39 (15), pp5606-5611.	Analysis of PCBs (and other persistent pollutants) in US meat
Olive oil	Yague et al., (2005). J. Agric. Food. Chem., 53 (13), pp5105-5109.	Analysis of 19 different Spanish olive oils.
Eggs	Food Safety Authority of Ireland, 2004 http://www.fsai.ie/surveillance/food/dioxin_report04/Dioxin_04.pdf Food Standards Agency UK (1997) - Dioxins and PCBs in the UK diet: 1997 Total diet study http://www.food.gov.uk/science/surveillance/fsis2000/4diox#h_5	FSAI - PCBs, dioxins, furans in battery, free-range, barn organic eggs FSA (UK) - Total diet study (included eggs)
Milk	Sewart A & Jones KC (1996). Chemosphere, 32(12), pp2481-2492.	Survey of PCB congeners in U.K. cows' milk.

Table 1: PCB residues in food items – examples from the literature.

The European Commission has set maximum levels for dioxins and PCBs in food. The limits will take effect from November 2006. Any food or feed in which the sum of dioxins and dioxin-like PCBs exceeds these maximum levels will not be allowed to be marketed in the EU.
http://europa.eu/rapid/pressReleasesAction.do?reference=IP/06/119&format=HTML&aged=0&language=EN

In addition, in various European countries there is national legislation on selected PCB congeners for some food items such as meat, eggs, dairy and fish.
http://www.apug.de/risiken/forschungsprojekte/umweltkontaminanten.htm.

What health effects are associated with exposure to PCBs?

It is difficult for scientists to establish a clear association between PCB exposure levels and health effects. However, the World Health Organisation (WHO) acknowledges that data from human and experimental animal studies clearly indicate that exposure (particularly prenatal exposure) to PCBs can have adverse effects on neurological development and behaviour (Damstra et al., 2002).

PCBs have been shown to adversely affect neurological development (the development of the brain and associated nervous system) in children. Studies in Michigan, New York, the Faroe Islands, Germany, the Netherlands and Taiwan have all shown negative associations between prenatal PCB exposure and cognitive function in infancy and childhood (for review, see Schantz et al., 2003). It is thought that such effects on brain development could be due to prenatal disruption of the thyroid hormone system (crucial for infant growth and development) and alterations in thyroid function and circulating thyroid hormones in newborns have been associated with increased prenatal PCB exposure (Wang et al., 2005). More information on the neurodevelopmental and hormone disrupting effects of PCBs and other pollutants can be found in the WWF-UK report "Compromising our Children"
(http://www.wwf.org.uk/filelibrary/pdf/compromising_our_children.pdf).

Excessive exposure to PCBs may affect the brain, eye, heart, immune system, kidney, liver, reproductive system, skin, thyroid gland and the unborn child, and may cause cancer. Both the US Environmental Protection Agency and the International Agency for Research on Cancer (IARC) have determined that PCBs are probably carcinogenic to humans.

Many of the human health issues regarding environmental exposure to PCBs are concerned with prenatal exposure of the developing foetus and subsequent negative effects on health during infancy and childhood. The unborn child can be exposed to PCBs in the womb and via breast milk following birth. As development continues, children are exposed to PCBs in the same way as adults (through the diet, water and indoor air). During these early stages of life, the brain, nervous system, immune system, thyroid, and reproductive organs are all undergoing crucial development changes, and so the effects of PCBs (possibly acting as endocrine disrupters) on these target systems may be more profound, making foetuses and children more susceptible to PCBs than adults.

PCBs can also affect the developing immune system. In Inuit populations, exposed via their traditional diet of fish and marine mammal fat, studies have demonstrated the "immunotoxic" potential of organochlorines, including PCBs (Dallaire et al., 2006, 2004). In these studies, prenatal exposure top PCBs was associated with increased incidence of acute infections (respiratory, middle ear and gastrointestinal) in Inuit children.

A study on Swedish fisherman (and their wives) consuming fish from the highly contaminated Baltic Sea has revealed an association between levels of PCBs (and DDE) in their serum and prevalence of type-2 diabetes in this population, suggesting these kinds of chemicals might contribute to type 2 diabetes (Rylander et al., 2005).

Other dietary studies have focussed on cancer and non-cancer health effects associated with consumption of fish (salmon) contaminated with PCBs and other organochlorine compounds (Huang et al., 2005, Hites et al., 2004, Foran et al., 2005).

How can exposure to PCBs be reduced?

As exposure to PCBs is primarily through the diet, and in particular through the consumption of oily fish, it is worth following the advice of the UK Food Standards Agency (FSA) with regards to the frequency of fish consumption and the types of fish that should be consumed. Details of FSA analyses of fish and other foods for PCBs (and other chemicals) can be found here - http://www.food.gov.uk/science/surveillance/**.** As the developing foetus can be exposed *in utero* to PCBs, the FSA offers specific consumption advice for pregnant mothers in order to avoid any potential adverse effects of exposure. See table 2 below for FSA advice on fish consumption.

	Oily fish	**White fish**	**Tinned tuna****	**Marlin, shark, swordfish**
Girls (under 16)	Up to 2 portions* a week	No limit	No limit on tinned	Do not eat
Boys (under 16)	Up to 4 portions a week	No limit	No limit on tinned	Do not eat
Pregnant women and those who may become pregnant	Up to 2 portions a week	No limit	Up to four medium-sized cans	Do not eat
Breastfeeding women	Up to 2 portions a week	No limit	No limit on tinned	Up to one portion a week
Women who are not intending, or can't become pregnant	Up to 4 portions a week	No limit	No limit on tinned	Up to a portion a week
Men	Up to 4 portions a week	No limit	No limit on tinned	Up to a portion a week

Table 2- Oily fish: who should eat what? Reproduced from the UK Food Standards Agency (FSA) website – http://www.food.gov.uk/news/newsarchive/2004/jun/fishportionslifestagechart.

* A portion = 140g

** Fresh tuna counts as oily fish, but tinned tuna as white because the oils are lost in the canning process

Limiting contact with old building materials, fluorescent lighting and electrical appliances and components can also help minimise exposure to PCBs e.g. wearing protective clothing, breathing apparatus and minimising the generation of dust during renovation or DIY work in old buildings (Andersson et al., 2004 Herrick et al., 2004).

References

Andersson M, Ottesen RT, Volden T. (2004). Building materials as a source of PCB pollution in Bergen, Norway. Science of the Total Environment., 325(1-3), pp139-44.

Baars AJ, Bakker MI, Baumann RA, Boon PE, Freijer JI, Hoogenboom LA, Hoogerbrugge R, van Klaveren JD, Liem AK, Traag WA, de Vries J. (2004). Dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs: occurrence and dietary intake in The Netherlands. Toxicol Lett. , 151(1), pp51-61.

Borga K, Gabrielsen GW, Skaare JU. (2001). Biomagnification of organochlorines along a Barents Sea food chain. Environmental Pollution., 113(2), pp187-98.

Centers for Disease Control and Prevention (CDC) (2005) - Third National Report on Human Exposure to Environmental Chemicals. http://www.cdc.gov/exposurereport

Covaci A, Gheorghe A, Voorspoels S, Maervoet J, Steen Redeker E, Blust R, Schepens P. (2005). Polybrominated diphenyl ethers, polychlorinated biphenyls and organochlorine pesticides in sediment cores from the Western Scheldt river (Belgium): analytical aspects and depth profiles. Environment International, 31(3), pp367-75.

Dallaire F, Dewailly E, Vézina C, Muckle G, Weber JP, Bruneau S, and Ayotte P. (2006). Effect of prenatal exposure to polychlorinated biphenyls on incidence of acute respiratory infections in preschool Inuit children. Environmental Health Perspectives, (in press).

Dallaire F, Dewailly E, Muckle G, Vezina C, Jacobson SW, Jacobson JL, Ayotte P. (2004). Acute infections and environmental exposure to organochlorines in Inuit infants from Nunavik. Environmental Health Perspectives, 112(14), pp1359-1365

Damstra T, Barlow S, Bergman A, Kavlock R, Van Der Kraak G. (2002). Global Assessment of the State-of-the Science of Endocrine Disruptors. WHO/PCS/EDC/02.2. Geneva: World Health Organization, International Programme on Chemical Safety.

Donato F, Magoni M, Bergonzi R, Scarcella C, Indelicato A, Carasi S, Apostoli P. (2006) Exposure to polychlorinated biphenyls in residents near a chemical factory in Italy: The food chain as main source of contamination. Chemosphere (in press).

European Food Safety Authority (EFSA) - Panel on contaminants in the food chain (CONTAM) (2005). Non-dioxin like PCB contaminant levels decreasing in food and animal feed - continuing effort needed to further reduce possible risks to human health. http://www.efsa.eu.int/press_room/press_release/1230_en.html

Fangstrom B, Strid A, Grandjean P, Weihe P, Bergman A. (2005). A retrospective study of PBDEs and PCBs in human milk from the Faroe Islands. Environmental Health, 4, p12.

Food Standards Agency (FSA) UK (2003). Dioxins and dioxin-like PCBs in the UK diet: 2001 total diet study samples. 38/03, July 2003.

Foran JA, Carpenter DO, Hamilton MC, Knuth BA, Schwager SJ. (2005). Risk-based consumption advice for farmed Atlantic and wild Pacific salmon contaminated with dioxins and dioxin-like compounds. Environmental Health Perspectives, 113(5), pp552-556.

Gambaro A, Manodori L, Zangrando R, Cincinelli A, Capodaglio G, Cescon P. (2005). Atmospheric PCB concentrations at Terra Nova Bay, Antarctica. Environ Sci Technol., 39(24), pp9406-11.

Gray KA, Klebanoff MA, Brock JW, Zhou H, Darden R, Needham L, Longnecker MP. (2005). In utero exposure to background levels of polychlorinated biphenyls and cognitive functioning among school-age children. Am J Epidemiol., 162(1), pp17-26.

Gustafsson O, Andersson P, Axelman J, Bucheli TD, Komp P, McLachlan MS, Sobek A, Thorngren JO. (2005). Observations of the PCB distribution within and in-between ice, snow, ice-rafted debris, ice-interstitial water, and seawater in the Barents Sea marginal ice zone and the North Pole area. Sci Total Environ., 342(1-3), pp261-79.

Harrad SJ, Sewart AP, Alcock R, Boumphrey R, Burnett V, Duarte-Davidson R, Halsall C, Sanders G, Waterhouse K, Wild SR, Jones KC. (1994). Polychlorinated biphenyls (PCBs) in the British environment: sinks, sources and temporal trends. Environmental Pollution, 85(2), pp131-46.

Herrick RF, McClean MD, Meeker JD, Baxter LK, Weymouth GA. (2004). An unrecognized source of PCB contamination in schools and other buildings. Environmental Health Perspectives., 112(10), pp1051-3.

Hites RA, Foran JA, Carpenter DO, Hamilton MC, Knuth BA, Schwager SJ. (2004). Global assessment of organic contaminants in farmed salmon. Science, 303(5655), pp226-229

Hu K, Bunce NJ. (1999). Metabolism of polychlorinated dibenzo-p-dioxins and related dioxin-like compounds. J Toxicol Environ Health B Crit Rev., 2(2), pp183-210.

Huang X, Hites RA, Foran JA, Hamilton C, Knuth BA, Schwager SJ, Carpenter DO (2005). Consumption advisories for salmon based on risk of cancer and noncancer health effects. Environmental Research (in press)

Kalantzi OI, Martin FL, Thomas GO, Alcock RE, Tang HR, Drury SC, Carmichael PL, Nicholson JK, Jones KC. (2004). Different levels of polybrominated diphenyl ethers (PBDEs) and chlorinated compounds in breast milk from two U.K. Regions. Environmental Health Perspectives, 112(10), pp1085-91.

Miao XS, Swenson C, Woodward LA, Li QX. (2000). Distribution of polychlorinated biphenyls in marine species from French Frigate Shoals, North Pacific Ocean. Sci Total Environ., 257(1), pp17-28.

Mossner S, Ballschmiter K. (1997). Marine mammals as global pollution indicators for organochlorines. Chemosphere, 34(5-7), pp1285-96.

Naert C, Piette M, Bruneel N, Van Peteghem C. (2006). Occurrence of polychlorinated biphenyls and polybrominated diphenyl ethers in Belgian human adipose tissue samples. Arch Environ Contam Toxicol., 50(2), pp290-6.

Nie X, Lan C, Wei T, Yang Y. (2005). Distribution of polychlorinated biphenyls in the water, sediment and fish from the Pearl River estuary, China. Mar Pollut Bull., 50(5), pp537-46.

Poon BH, Leung CK, Wong CK, Wong MH. (2005) Polychlorinated biphenyls and organochlorine pesticides in human adipose tissue and breast milk collected in Hong Kong. Arch Environ Contam Toxicol., 49(2), pp274-82.

Riget F, Dietz R, Vorkamp K, Johansen P, Muir D. (2004). Levels and spatial and temporal trends of contaminants in Greenland biota: an updated review. Sci Total Environ., 331(1-3), pp29-52.

Roose P, Raemaekers M, Cooreman K, Brinkman UA. (2005). Polychlorinated biphenyls in marine sediments from the southern North Sea and Scheldt estuary: a ten-year study of concentrations, patterns and trends. J Environ Monit., 7(7), pp701-9.

Schantz, SL, Widholm JJ and Rice, DC (2003). Effects of PCB exposure on neuropsychological function in children. Environmental Health Perspectives, 111(3), pp357-376

Schuhmacher M, Nadal M, Domingo JL. (2004). Levels of PCDD/Fs, PCBs, and PCNs in soils and vegetation in an area with chemical and petrochemical industries. Environmental Science and Technology, 38(7), pp1960-9.

Shaw SD, Brenner D, Bourakovsky A, Mahaffey CA, Perkins CR. (2005). Polychlorinated biphenyls and chlorinated pesticides in harbor seals (Phoca vitulina concolor) from the northwestern Atlantic coast. Mar Pollut Bull., 50(10), pp1069-84.

Sjodin A, Jones RS, Focant JF, Lapeza C, Wang RY, McGahee EE 3rd, Zhang Y, Turner WE, Slazyk B, Needham LL, Patterson DG Jr. (2004). Retrospective time-trend study of polybrominated diphenyl ether and polybrominated and polychlorinated biphenyl levels in human serum from the United States. Environmental Health Perspectives, 112(6), pp654-8.

Skaare JU, Bernhoft A, Derocher A, Gabrielsen GW, Goksoyr A, Henriksen E, Larsen HJ, Lie E, Wiig. (2000). Organochlorines in top predators at Svalbard--occurrence, levels and effects. Toxicol Lett., 15(112-113), pp103-9.

Sun P, Basu I, Hites RA. (2006). Temporal trends of polychlorinated biphenyls in precipitation and air at Chicago. Environmental Science and Technology, 40(4), pp1178-83

Thomas GO, Wilkinson M, Hodson S, Jones KC. (2006). Organohalogen chemicals in human blood from the United Kingdom. Environmental Pollution, 141(1), pp30-41

UNEP - United Nations Environment Program (2006). Persistent Organic Pollutants. United Nations Environment Program – Chemicals. http://www.chem.unep.ch/pops/

Wang SL, Su PH, Jong SB, Guo YL, Chou WL, Papke O (2005). In utero exposure to dioxins and polychlorinated biphenyls and its relations to thyroid function and growth hormone in newborns. Environmental Health Perspectives, 113(11), pp1645-1650.

Weisbrod AV, Shea D, Moore MJ, Stegeman JJ. (2001) Species, tissue and gender-related organochlorine bioaccumulation in white-sided dolphins, pilot whales and their common prey in the northwest Atlantic. Mar Environ Res., 51(1), pp29-50.

Further Information

www.atsdr.cdc.gov/ToxProfiles/
www.checnet.org/healthehouse/home/index.asp
http://www.chem.unep.ch/pops/