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PCBs, Aroclors & dioxin-like PCB's, what are they?

Eurofins Environment Testing has supported the analysis of PCB congeners in air, water, soil and sediment for over 30 years. We have worked with clients and agencies to develop methods with differing levels of sensitivity and selectivity, to meet the program requirements of projects ranging from source emissions to ambient air monitoring to complex sediment investigations as well as human health and ecological risk assessments (HHERA). Capitalising on over 30 years of experience in organic extractions, we've built a laboratory dedicated to the challenges involved with preparing PCB congeners samples and to meet the requirements of New Zealand's regulators. Currently, there is some confusion with respect to what PCBs are required to be analysed under the National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (NESCS) and in this EnviroNote we have tried to outline the technical details as well as explain what needs to be done to meet the requirements listed in Table B3 of the NESCS.

Polychlorinated biphenyls – what are they?

Polychlorinated biphenyls (PCBs) are a group of chemicals that contain 209 individual compounds (known as congeners) with varying harmful effects. The difference between congeners is the number and locations of chlorine atoms attached to the biphenyl ring. Information on specific congener toxicity is very limited however dioxin-like PCBs have some known equivalencies to the most toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) – see table on Page 3. Most toxicity testing has been done on specific commercial mixtures; however, PCB mixtures found in the environment will differ in composition from the commercial mixtures because of partitioning, biotransformation, and bioaccumulation. The U.S. Environmental Protection Agency (EPA) treats all PCBs as being potentially hazardous based on results from some formulations. However, this can have large uncertainty for any given mixture situation.

There are 209 discrete PCB congeners, in which 1 to 10 chlorine atoms are attached to the biphenyl rings. The difference between congeners is the number and locations of chlorine atoms attached to the biphenyl ring.

There are several PCB congener naming conventions. The first is structural nomenclature—based on the attachment locations of the chlorine atoms to the biphenyl molecule. PCB congeners are numbered sequentially from 1 to 209, with increasing congener numbers reflecting increased chlorination.

Aroclors – what are they?

From 1929 to 1976, PCBs were produced and commercially marketed in the United States under the "Aroclor®" trademark by Monsanto Chemical Corporation. Aroclors were not a single PCB congener but rather a complex mixture of multiple congeners. Aroclors were manufactured by flowing vaporised chlorine through biphenyl until the desired weight percent of chlorine was achieved. This process allowed for the production of Aroclors with different levels of chlorination. Example Aroclors produced included Aroclor 1242, 1248, 1254, and 1260, among other Aroclors. Specific Aroclors carried a four-digit reference number (e.g., Aroclor 1242, 1248, 1254, and 1260), which indicates the molecule size and the weight percent of chlorine in the formulation. For example, Aroclor 1242 is so named because the PCB molecule has 12 carbons (corners of the biphenyl rings) and is composed of a mixture of congeners such that the material weight is 42% chlorine. The only exception to the naming convention is Aroclor 1016, which was actually similar to the composition of Aroclor 1242, with a chlorine percentage of 41.5%.

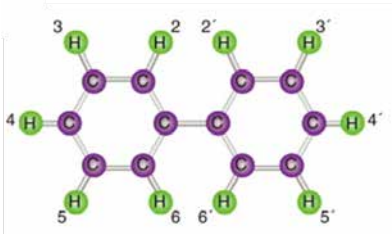

Figure 1: Structure of the PCB Molecule adapted from Introduction to Environmental Forensics, Third Edition 2015 Introduction to Environmental Forensics Edited by: Brian L. Murphy and Robert D. Morrison

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Although banned for decades in most parts of the world, PCBs were widely used in a variety of industrial and commercial applications, including electrical and hydraulic equipment, plasticizers in paint, plastics, rubber products, pigments, dyes, and carbonless copy paper. Their hydrophobic and lipophilic properties, as well as their resilience to breakdown, made them useful for industrial applications. However, this persistence also leads to their remaining in the environment, cycling through soil and water, and eventually accumulating in plants and crops. PCBs cause a variety of adverse health effects in animals, including cancer and non-cancerous effects like diseases of the immune, reproductive, nervous, and endocrine systems.

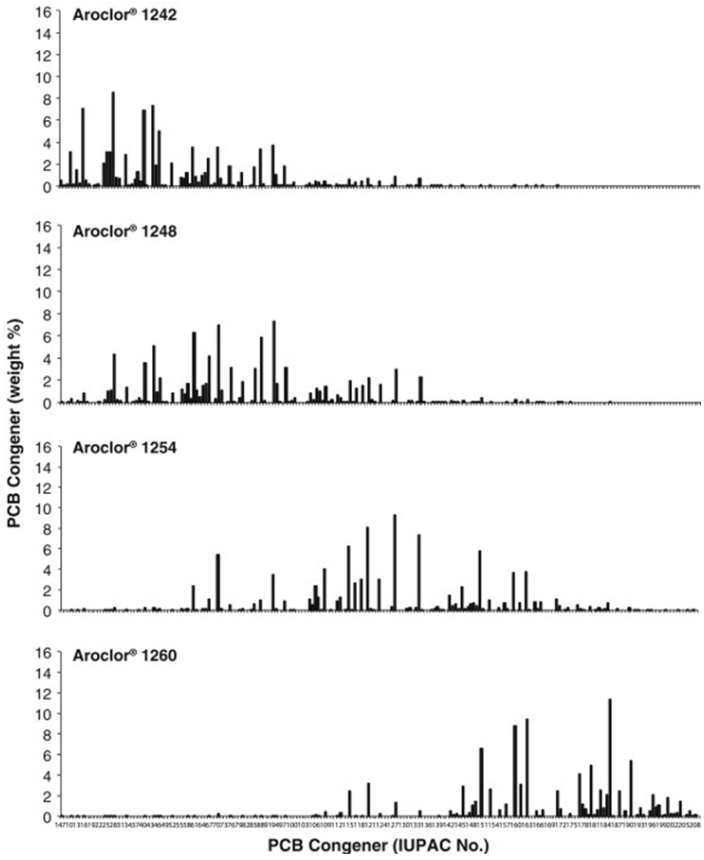

Figure 2: Congener-specific compositions of example marketed Aroclors. (Adapted from Frame et al., 1996)

Dioxin-like Polychlorinated biphenyls – what are they?

According to their free rotation around the central axis, non-ortho and mono-ortho substituted PCBs may adopt a similar spatial structure to 2,3,7,8-TCDD and therefore exhibit comparable toxic effects as dioxins. Non-ortho PCBs are composed of PCB 77, PCB 81, PCB 126 & PCB 169 while the mono-ortho PCBs are PCB 105, PCB 114, PCB 118, PCB 123, PCB 156, PCB 157, PCB 167 & PCB 189. Each dioxin-like-PCB has its individual toxicity expressed as a TEF (Toxic Equivalency Factor). The TEQ or toxic equivalence value represents the total dioxin-like PCB concentration of a sample, taking into account the different toxicity of the 12 individual dioxin-like PCBs as shown in Table B3.

$$TEQ = \sum_{i=1}^{n} (C_i \, x \, TEF_i)$$

Where Ci is individual concentration in environmental media
TEFi is the Toxicity Equivalence Factor for individual dioxin-like PCBs – see TEQ is the TCDD toxicity equivalence.

Consideration of the limit of reporting (LOR) for TEQ calculation

Using the 2005 WHO TEFs (Van den Berg et. al. 2006), the TEQ for each dioxin-like PCB is estimated by multiplying the measured dioxin-like PCB concentration by the TEF corresponding to the dioxin-like PCB. The TEQ for the media sample is determined by summing the individual TEQ for TCDD as per the above equation. It should be noted that in the case of single dioxin-like PCB congeners which are not quantifiable, three different concepts exist for calculating the TEQ:

a). The concept of “upperbound” requires using the limit of reporting for the contribution of each non-quantified congener to the TEQ

b). The concept of “mediumbound” requires using the half of the limit of reporting calculating the contribution of each non- quantified congener to the TEQ

c). The concept of “lowerbound” requires using zero for the contribution of each non-quantified congener to the TEQ.

The European Commission mandates that upperbound values are used for all food types when looking for compliance with EU regulations but usually mediumbound values are used for environmental media.

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National Environmental Standard for Assessing & Managing Contaminants in Soil to Protect Human Health

The National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (NESCS) is a nationally consistent set of planning controls and soil contaminant values. It ensures that land affected by contaminants in soil is appropriately identified and assessed before it is developed - and if necessary the land is remediated or the contaminants contained to make the land safe for human use.

The five standard land-use scenarios for which soil contamination standards (SCSs) have been derived and a summary of the SCSs are presented in Table B3 where the 12 priority soil contaminants: arsenic, boron, cadmium, chromium, copper, lead, mercury, benzo(a)pyrene, DDT, dieldrin, PCP and dioxin (including dioxin-like PCBs) are defined in regulation 7 of the NES.

Taking into account the concept of TEQ calculations for dioxin-like PCBs and the compliance with the values outlined in Table B3 of the NES it is therefore very important when assessing submission of your data that it complies with the requirements. At Eurofins we offer unsurpassed technologies for the determination of the dioxin-like PCBs with limits of reporting that meet the most stringent requirements for these land types.

Table B3. Contaminant Standards for Health (SCSs(Health)) for Organic Compounds

Scenario	BaP mg/kg TEQ	DDT mg/kg	Dieldrin mg/kg	PCP mg/kg	TCDD µg/kg TEQ	Dioxin-like PCBs µg/kg TEQ
Rural residential / lifestyle block 25% produce	6	45	1.1	55	0.12	0.09
Residential 10% produce	10	70	2.6	55	0.15	0.12
High-density residential	24	240	45	110	0.35	0.33
Recreation	40	400	70	150	0.6	0.52
Commercial / industrial outdoor worker (unpaved)	35	1000	160	360	1.4	1.2

Logistics

Eurofins offers accredited testing in accordance with the latest USEPA methods as required by clients. For a PCB testing facility with integrity, choose Eurofins Environment Testing. We offer quality analysis, superior customer service, and consistent reliability. To discuss logistical details for upcoming projects, please contact your Analytical Service Manager or one of our Business Development Team.

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