

# Dioxins, Furans, and PCBs: Calculation Methodology for Ecological Risk

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## Abstract

The purpose of this poster presentation is to document an interpretation from the Department of Ecology regarding the different procedures that should be used to calculate site contaminant levels for Ecological Risk Assessment for:

- Chlorinated dibenzo-p-dioxins (PCDDs); TCDD is a member of this class
- Chlorinated dibenzofurans (PCDFs); and
- Dioxin like polychlorinated biphenyls (PCBs)

The calculated contaminant levels are to be used for screening level and cleanup purposes. This poster is specific as it pertains to Ecological Risk Assessment and the Terrestrial Ecological Evaluation (WAC 173-340-7490 through 7494) (Ecology, 2007a).

## Background

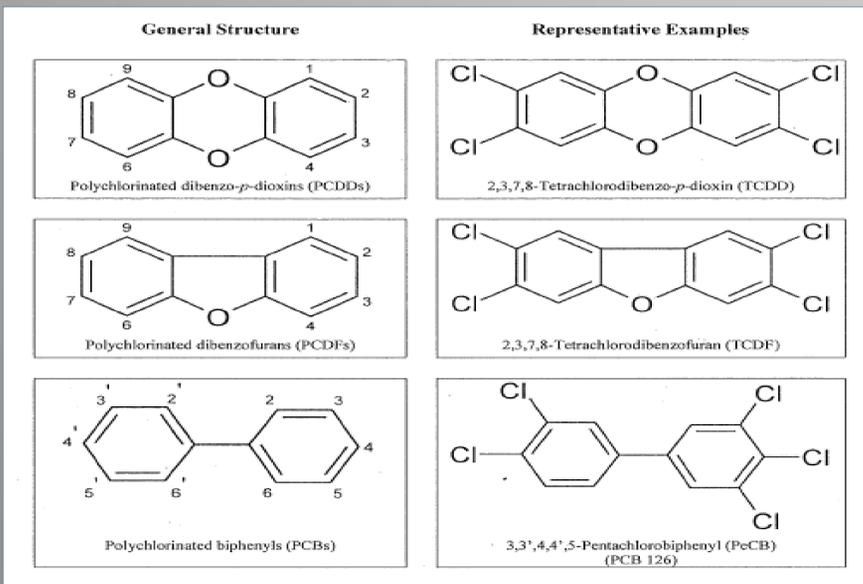
**Dioxin/Furans:** Polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran congeners (dioxins and furans) are generally present in the environment as a complex mixture of chemical "congeners" that differ in terms of the number and location of chlorine atoms. 2,3,7,8 – Tetrachlorodibenzo-p-dioxin (TCDD) is the most toxic and best studied of the 210 dioxin and furan congeners. Scientists have concluded that the 17 dioxin/furan congeners identified in MTCA act through a common biological mechanism and essentially behave like one chemical. The TEF approach is based on the concept that the various congeners of dioxin/furan essentially act as one chemical, affecting the Ah receptor (aryl hydrocarbon hydroxylase receptor) (Ecology, 2007b).

•Scientists have concluded that the 17 dioxin/furan congeners (identified in MTCA) act through a common biological mechanism and essentially behave as one chemical.

**PCBs:** Polychlorinated biphenyl (PCBs) are a group of synthetic organic chemicals that include 209 individual chlorinated biphenyl compounds. Commercial mixtures of PCBs were manufactured in the United States from (approximately) 1930 to 1977 under the trademark "Aroclor" followed by a four digit number; usually the first two digits indicate the parent biphenyl molecule and the last two digits indicate the percent chlorine by weight. PCBs were used as coolants and lubricants in electrical equipment, such as capacitors and transformers, because of their non-flammability, chemical stability, and insulating properties (Ecology, 2007b).

•Scientists have concluded there are 12 dioxin-like PCBs that have the same common biological mechanism as the 17 dioxins/furans.

**Figure 1:** Chemical Structure of PCDDs (dioxins), PCDFs (furans), and dioxin-like PCBs. Numbers by aromatic ring carbons in general structures represent potential chlorine substitutions (USEPA, 2008).



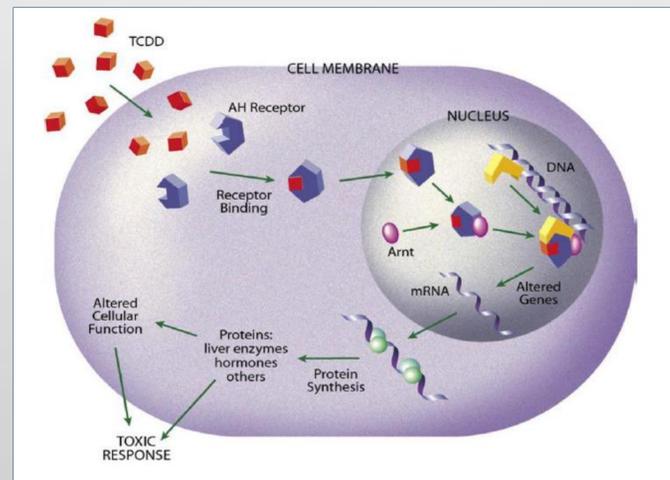
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## Common Mode of Action (Biological Mechanism)

**Aryl Hydrocarbon Receptor:** The [29] dioxin-like (dioxins, furans, PCBs) have a common mode of action binding to the Ah receptor resulting in both cancerous and non-cancerous effects.

**Figure 2:** Illustration of the common mode of action of dioxin-like congeners (dioxins, furans, PCBs). Dioxin-like congeners are stored in fat or liver cells, bind to the Aryl Hydrocarbon Receptor, enter into the nucleus, bind to strands of DNA altering genes, causing the toxic response (BEC, 2012).



## TEF Methodology for Ecological Risk Assessment

Toxic Equivalency Factors (TEF's) are used to convert Dioxin, Furan, and PCB congener data to Toxic Equivalency Quotients (TEQ's). Dioxin, Furan, and PCB TEQ's are then used to compare site data to screening levels or to establish protective cleanup levels. Mammalian TEF's should be used only for calculating TEQs for the mammalian predators (shrew) and mammalian herbivores (vole). Avian TEF's should be used for calculating TEQs for the avian predators (robin). Please see the TEF Table below for a complete summary of TEF values to be used for Ecological Risk Assessment. Either direct comparison or statistical methods (as described in WAC 173-340-740 (7)) shall be used for compliance sampling or monitoring (Ecology, 2007a).

**Figure 3:** PCDD, PCDF, and PCB TEFs for Mammals and Avians (Van den Berg et al., 1998, 2006).

CAS Number	Hazardous Substance	Mammalian TEF <sup>(1)*</sup>	Avian TEF <sup>(1)</sup>
<b>Dioxin Congeners</b>			
1746-01-6	2,3,7,8-Tetrachloro dibenzo-p-dioxin	1	1
40321-76-4	1,2,3,7,8-Pentachloro dibenzo-p-dioxin	1	1
39227-28-6	1,2,3,4,7,8-Hexachloro dibenzo-p-dioxin	0.1	0.05
57653-85-7	1,2,3,6,7,8-Hexachloro dibenzo-p-dioxin	0.1	0.01
19408-74-3	1,2,3,7,8,9-Hexachloro dibenzo-p-dioxin	0.1	0.1
35822-46-9	1,2,3,4,6,7,8-Heptachloro dibenzo-p-dioxin	0.01	<0.001
3268-87-9	1,2,3,4,6,7,8,9-Octachloro dibenzo-p-dioxin	0.0003	0.0001
<b>Furan Congeners</b>			
51207-31-9	2,3,7,8-Tetrachloro dibenzofuran	0.1	1
57117-41-6	1,2,3,7,8-Pentachloro dibenzofuran	0.03	0.1
57117-31-4	2,3,4,7,8-Pentachloro dibenzofuran	0.3	1
70648-26-9	1,2,3,4,7,8-Hexachloro dibenzofuran	0.1	0.1
57117-44-9	1,2,3,6,7,8-Hexachloro dibenzofuran	0.1	0.1
72918-21-9	1,2,3,7,8,9-Hexachloro dibenzofuran	0.1	0.1
60851-34-5	2,3,4,6,7,8-Hexachloro dibenzofuran	0.1	0.1
67562-39-4	1,2,3,4,6,7,8-Heptachloro dibenzofuran	0.01	0.01
55673-89-7	1,2,3,4,7,8,9-Heptachloro dibenzofuran	0.01	0.01
39001-02-0	1,2,3,4,6,7,8,9-Octachloro dibenzofuran	0.0003	0.0001
<b>PCB Congeners</b>			
32598-13-3	3,3',4,4' TetraCB (77)	0.0001	0.05
70362-50-4	3,4,4',5 TetraCB (81)	0.0003	0.1
32598-14-4	2,3,3',4,4' PeCB (105)	0.00003	0.0001
74472-37-0	2,3,4,4',5 PeCB (114)	0.00003	0.0001
31508-00-6	2,3',4,4',5 PeCB (118)	0.00003	0.00001
65510-44-3	2',3,4,4',5 PeCB (123)	0.00003	0.00001
57465-28-8	3,3',4,4',5 PeCB (126)	0.1	0.1
38380-08-4	2,3,3',4,4',5 HxCB (156)	0.00003	0.0001
69782-90-7	2,3,3',4,4',5' HxCB (157)	0.00003	0.0001
52663-72-6	2,3',4,4',5,5' HxCB (167)	0.00003	0.00001
32774-16-6	3,3',4,4',5,5' HxCB (169)	0.03	0.001
39635-31-9	2,3,3',4,4',5,5' HpCB (189)	0.00003	0.00001

**Figure 4:** Table 749-2 and 749-3 Screening Values for Dioxins, Furans, and PCBs (Ecology 2007a).

Contaminant	TEE - Simplified Evaluation (Table 749-2)
Chlorinated dibenzofurans (total)	3E-06 mg/kg
Chlorinated dibenzo-p-dioxins (total)	5E-06 mg/kg
PCB mixtures (total)	2 mg/kg
Contaminant	TEE - Site-Specific Evaluation (Table 749-3)
Chlorinated dibenzofurans (total)	(Wildlife = 2E-06 mg/kg)
Chlorinated dibenzo-p-dioxins (total)	(Wildlife = 2E-06 mg/kg)
PCB mixtures	(Plants = 40 mg/kg) (Wildlife = 0.65 mg/kg)

## Summary of Calculating Dioxin, Furan, and Dioxin-Like PCBs for Comparison with Table 749-2 or 749-3

From a toxicological point of view, any level set should apply to all dioxin-like-dioxins, furans, and PCBs, but in 2001 there was very limited data available on the prevalence of dioxin-like PCBs. Since 2001, however, more data on the presence of dioxin-like PCBs have become available; therefore maximum levels for the sum of dioxins and dioxin-like PCBs have been set in 2006, as this is the most appropriate approach from a toxicological point of view (Gueguen et al., 2011). From current toxicological standards it is recognized that any screening level intended to be protective of [Chlorinated dibenzo-p-dioxins (PCDDs), Chlorinated dibenzofurans (PCDFs), and Dioxin-like polychlorinated biphenyls (PCBs)] should encompass all three contaminants. The toxicity equivalency methodology is a tool for assessing the cumulative toxicity of a complex mixture of dioxin-like PCDDs, PCDFs, and PCBs (USEPA, 2008).

With that understanding, the constraints of MTCA require calculation of the individual (PCDDs, PCDFs, PCBs) contaminants be compared to the screening levels listed in Table 749-2 or Table 749-3 to establish Contaminants of Ecological Concern (note that for cleanup purposes all dioxin-like congeners should be included). If a contaminant is above the respective Table Level (Table 749-2 or Table 749-3), then cleanup levels should be set that would be protective of the ecological receptors as per WAC 173-340-7490 through 7494.

### Comparison to Screening Levels (Table 749-2 or 749-3) Procedures

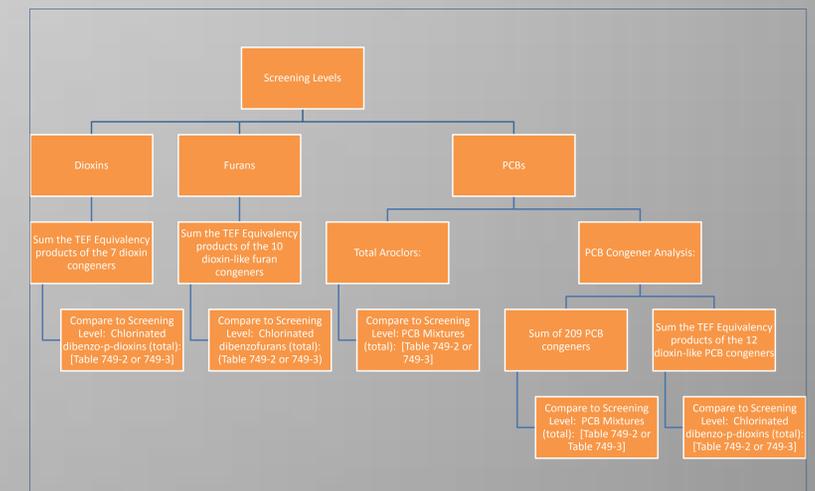
•The sum of the TEF equivalency [commonly referred to as the toxicity equivalency quotient (TEQ)] for the [7] dioxin congeners is compared to the appropriate screening level table (Table 749-2 or Table 749-3) for Chlorinated dibenzo-p-dioxins (total) using USEPA Method 1613/8290.

•The sum of the TEF equivalency for the [10] furan congeners is compared to the appropriate screening level table (Table 749-2 or Table 749-3) for Chlorinated dibenzofurans (total) using USEPA Method 1613/8290.

•If not required to use a congener specific analysis, USEPA Method 8082 should be sufficient (either total Aroclors or limited congener analysis). Total PCBs (or Aroclors) are calculated and compared to PCB mixtures (total) screening level table (Table 749-2 or Table 749-3).

•If required to use a congener specific analysis (see PCB summary analysis in Dioxin/Furan PCB Calculation Methodology [Memorandum to Dave Bradley] for determination), USEPA Method 1668 should be used with the lowest possible PQL. The sum of the [209] individual congeners is compared to PCB mixtures (total) screening level table (Table 749-2 or Table 749-3), and the sum of the TEF equivalency for the [12] PCB congeners is compared to the appropriate screening level table (Table 749-2 or Table 749-3) for Chlorinated dibenzo-p-dioxins.

**Figure 5:** Diagram of procedures for calculating values to be compared with Table 749-2 or 749-3.



## Procedures for Calculating Dioxin/Furan/PCB Levels For Determination of Protective Cleanup Levels (other than Table 749-2 or 749-3)

When determining protective cleanup levels (using methods other than table 749-2 or 749-3), the seven [7] Chlorinated Dibenzo-p-dioxin (PCDDs), ten [10] Chlorinated dibenzofuran (PCDFs), and twelve [12] Dioxin-like polychlorinated biphenyls (PCBs) should be included in the TEQ calculation to be compared with an established protective contaminant level for 2,3,7,8 TCDD (Van den Berg et al., 1998).

**Figure 6:** If not using Table 749-2 or Table 749-3; Dioxins, Furans, and Dioxin-Like PCBs should be considered one contaminant to be compared with a protective level for 2,3,7,8 TCDD (Van den Berg et al., 1998).

$$TEQ = \sum (PCDDi \times TEFi) + \sum (PCDFi \times TEFi) + \sum (PCBi \times TEFi)$$

Where:

PCDD	= Polychlorinated dibenzo-p-dioxin
PCDF	= Polychlorinated dibenzofuran
PCB	= Polychlorinated biphenyl