DEPARTMENT OF ECOLOGY
State of Washington

Dioxins, Furans, and Dioxin-Like PCB Congeners: Ecological Risk Calculation Methodology for Upland Soil

Implementation Memorandum No. 13

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To: Interested Persons

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Acronyms

Ah	aryl hydrocarbon
CAS	Chemical Abstracts Service
DNA	deoxyribonucleic acid
EDL	estimated detection limit
EQL	estimated quantitation limit
KM	Kaplan-Meier
MTCA	Model Toxics Control Act
PCB	polychlorinated biphenyl
PCDD	chlorinated dibenzo-p-dioxin
PCDF	chlorinated dibenzofuran
PQL	practical quantitation limit
QAPP	Quality Assurance Project Plan
TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin
TCP	Toxics Cleanup Program
TEE	Terrestrial Ecological Evaluation
TEF	toxicity equivalency factor
TEQ	toxicity equivalency quotient
USEPA	United States Environmental Protection Agency
WAC	Washington Administrative Code

1.0 Purpose and Applicability

The purpose of this memorandum is to document an interpretation from the Department of Ecology (Ecology) regarding the different procedures that should be used to calculate site contaminant concentrations for three types of contaminants when conducting a Terrestrial Ecological Evaluation under the Model Toxics Control Act (MTCA) (WAC 173-340-7490 through -7494) (Ecology 2007a). The three contaminant types are:

- Chlorinated dibenzo-p-dioxins (PCDDs) (2,3,7,8-TCDD is a member of this class);
- Chlorinated dibenzofurans (PCDFs); and
- Polychlorinated biphenyls (PCBs) (includes both total PCBs and dioxin-like PCBs).

This memorandum specifically pertains to Ecological Risk Assessment and the Terrestrial Ecological Evaluation (TEE) under MTCA (WAC 173-340-7490 through -7494).

2.0 Background

2.1 Dioxin/Furans

PCDDs and PCDFs (*dioxins and furans*) are typically present in the environment as complex mixtures of chemically-related substances (*congeners*) that differ in the number and location of chlorine atoms (Ecology, 2007b). There are 210 of these dioxin and furan congeners present in the environment. The most toxic and best studied congener is **2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)** (Ecology 2007c), which is why TCDD is the standard for comparison in the methodologies outlined in this memo.

Because dioxin and furan congeners are typically present in the environment as complex mixtures, scientists developed a toxicity equivalency quotient (TEQ) methodology that evaluates the toxicity and assesses the risks associated with whole mixtures. With the TEQ method, each congener is assigned a TEF, or toxicity equivalency factor: the ratio of estimated toxicity for a particular congener to the toxicity of 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD) (Ecology 2007c). The TEQ approach is based on the concept that the various dioxin and furan congeners act through a common biological mechanism involving the aryl hydrocarbon (Ah) receptor.

Note: MTCA's Terrestrial Ecological Evaluation established separate screening levels for dioxins and furans in WAC 173-340-900 (Tables 749-2 and 749-3). However, when Table 749-2 or Table 749-3 is not used, the dioxins and furans should be treated as one mixture for the purposes of calculating and comparing to cleanup levels.

As a result, there are two processes to calculate site contaminant levels for dioxins and furans:

1. Comparing to screening levels using MTCA Table 749-2 or MTCA Table 749-3 (see Section 2.5), and

2. Calculating protective cleanup levels when MTCA Table 749-2 or Table 749-3 is not used (see Section 2.5).

**** KEY POINT ****

When evaluating if contaminants are of ecological concern:

- ✓ **Treat dioxins and furans as separate chemical mixtures** when comparing with the screening levels in Tables 749-2 or 749-3.

- ✓ **Treat dioxins and furans as one chemical mixture** when comparing cleanup levels through methods other than table values.

2.2 PCBs

PCBs are a group of synthetic organic chemicals comprised of 209 individual chlorinated biphenyl compounds. Commercial mixtures of PCBs were manufactured in the United States from about 1930 to 1977 and known primarily by their industrial trade names. The most common trademark in the U.S. was "Aroclor" with a four-digit number (USEPA 2013). The first two digits usually indicated the parent biphenyl molecule; the last two digits usually indicated the percent chlorine by weight.

PCBs were used as coolants and lubricants in electrical equipment such as capacitors and transformers due to their insulating properties, nonflammability, and chemical stability (Ecology 2007b). Although no longer commercially produced in the United States, PCBs may be present in products and materials produced before the 1979 PCB ban, and as contaminants in products produced since the use of PCBs was banned (Ecology 2014).

PCBs used in products such as those listed below are chemical mixtures made up of a variety of individual chlorinated components known as congeners. Examples of products that may contain PCBs include:

- Transformers and capacitors
- Other electrical equipment including voltage regulators, switches, reclosers, bushings, and electromagnets
- Oil used in motors and hydraulic systems
- Old electrical devices or appliances containing PCB capacitors
- Fluorescent light ballasts
- Cable insulation

- Thermal insulation material including fiberglass, felt, foam, and cork
- Adhesives and tapes
- Oil-based paint
- Caulking
- Plastics
- Carbonless copy paper
- Floor finish

MTCA's Terrestrial Ecological Evaluation has established two approaches for evaluating the ecological risks associated with environmental concentrations of PCBs. Both of these approaches are discussed in Sections 6.0 and 7.0 in this memo:

1. Total PCB Concentration using EPA Method 8082 and
2. Congener Specific Analyses using EPA Method 1668.

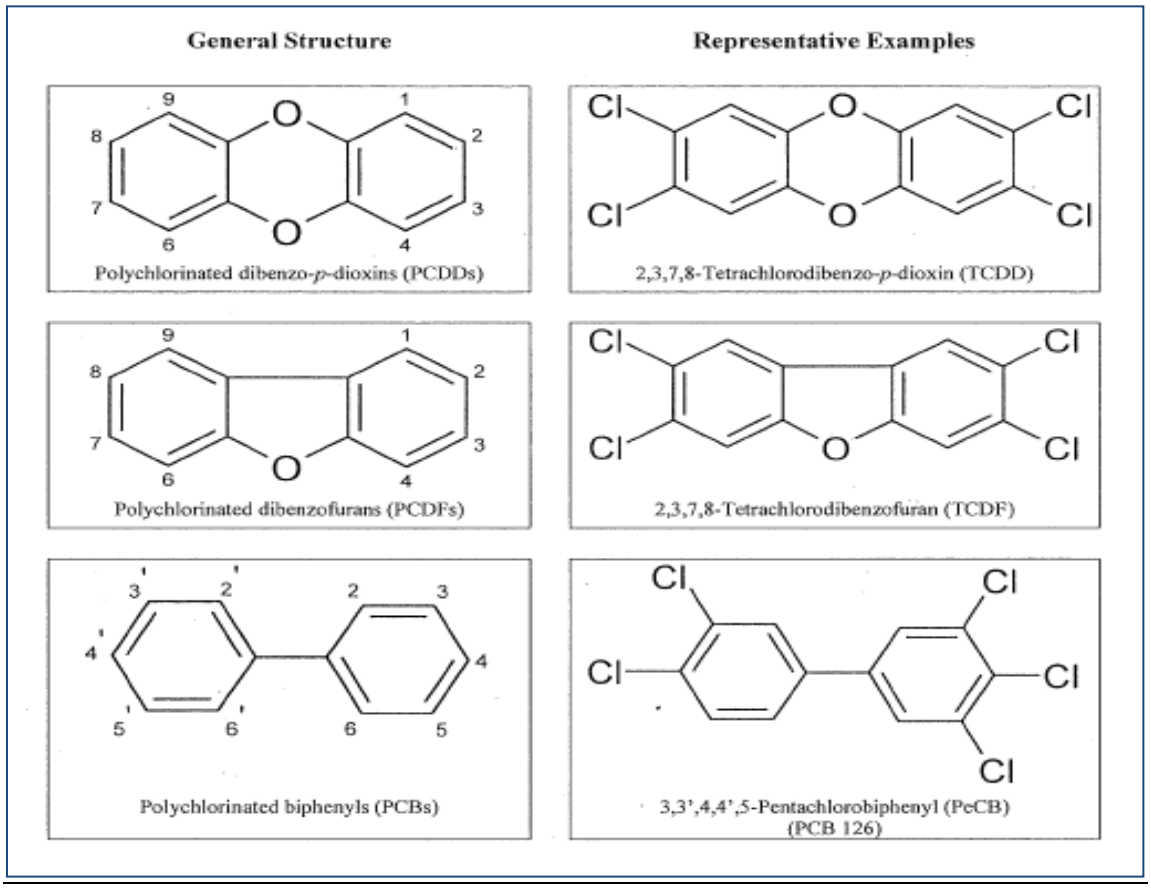

Figure 1. Chemical structure of PCDDs (dioxins), PCDFs (furans), and dioxin-like PCBs. Numbers by aromatic ring carbons in general structures represent potential chlorine substitutions (USEPA 2008).

2.3 Aryl Hydrocarbon Receptor

The 29 dioxin-like congeners comprise 7 dioxins, 10 furans, and 12 PCBs. The most common mode of action, or *biological mechanism,* for these congeners is binding to the aryl hydrocarbon receptor (Ah receptor).

Figure 2 illustrates how the dioxin or dioxin-like congener binds with the Ah receptor and enters the nucleus of a cell. The protein dioxin complex then binds to the strands of DNA (switching certain genes on and off) and causes the toxic response (BEC 2012).

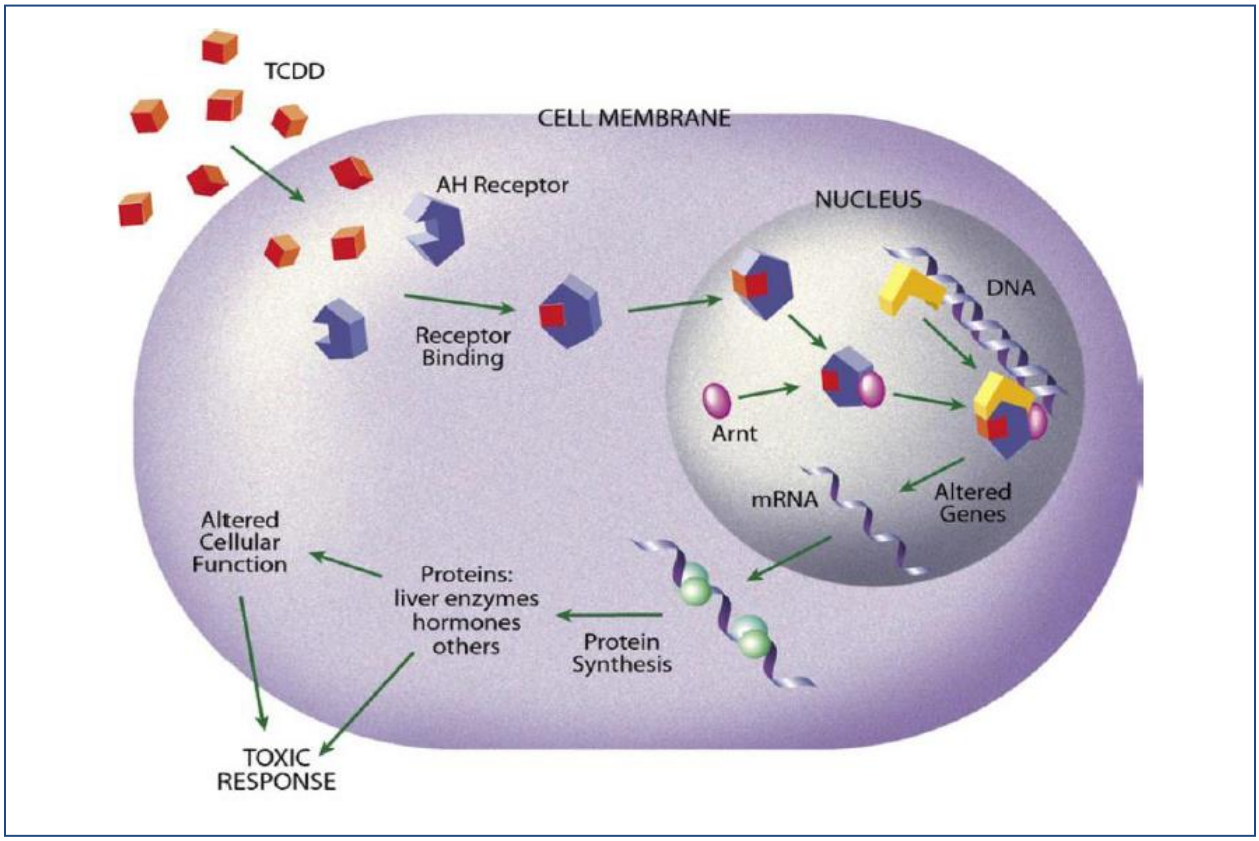

Figure 2: Illustration of the toxic response created by any of the 29 dioxin-like congeners (BEC 2012).

2.4 Screening Levels for Dioxins, Furans, and PCBs

The screening levels (*ecological risk assessment*) for dioxins, furans, and PCBs that are included in the TEE (WAC 173-340-7490 through -7494) are listed in Table 1.

Table 1: TEE screening levels for dioxins, furans, and PCBs

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
Above levels are for both unrestricted and industrial/commercial land use.	

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

2.5 Summary of TEQ Methodology

The toxicity equivalency (TEQ) methodology is a tool to assess cumulative toxicity of a complex mixture of PCDDs, PCDFs, and dioxin-like PCBs, and can be used when conducting an Ecological Risk Assessment for a cleanup site.

From a toxicological point of view, any calculated screening or cleanup level should apply to all dioxins, furans, and dioxin-like PCBs, but before 2001 there were very limited data available on the prevalence of dioxin-like PCBs. Since 2001, more data on the presence of dioxin-like PCBs have become available. In 2006, maximum levels for the sum of TEQs for dioxins, furans, and dioxin-like PCBs were set, since this was determined to be the most appropriate approach (Gueguen et al., 2011). Based on current toxicological methods used to evaluate the toxicity and assess the risk of complex chemical mixtures, it is recognized that one screening level should encompass PCDDs, PCDFs, and dioxin-like PCBs. The TEQ methodology was therefore developed as a tool for assessing the cumulative toxicity of a complex mixture of dioxin-like PCDDs, PCDFs, and PCBs (USEPA 2008).

As Table 1 indicates, however, it is important to note that the current MTCA regulations allow for individual contaminant mixtures (PCDDs, PCDFs, and PCBs) to be compared to the screening levels listed in WAC 173-340-900 (Tables 749-2 or 749-3) to help establish contaminants of ecological concern. Several sections in this memo address how to do this:

☐ **Using the screening levels in WAC 173-340-900?**

Reference the following sections and figure when comparing site contaminant levels to the screening levels in WAC 173-340-900 (Tables 749-2 or 749-3):

Section 3.0: General procedure for determining compliance for dioxins, furans, and PCBs using the TEE table values in WAC 173-340-900.

Section 4.0: Step-by-step procedure for determining compliance for mixtures of dioxins, furans, and PCBs using the TEE table values in WAC 173-340-900 and EPA Method 1668.

Figure 3: Summary of calculating contaminant levels for use when comparing screening levels to MTCA Table 749-2 or 749-3.

☐ **Not using the screening levels in WAC 173-340-900?**

Use the traditional TEF methodologies that sum all dioxin-like PCDDs, PCDFs, and PCBs and compare site contaminant levels to calculated protective values of 2,3,7,8-TCDD. Follow the recommendations in:

Section 8.0: Step-by-step procedure for calculating site-specific dioxin, furan, and PCB ecologically protective cleanup levels and determining compliance (when using methods other than MTCA Table 749-2 or Table 749-3).

☐ **Ready to determine if contaminants are of ecological concern? See:**

Section 5.0: How to determine if dioxins, furans, or PCBs are contaminants of ecological concern.

☐ **Concluded that dioxin-like PCDD, PCDF, and PCBs are not a concern at the site?**

Reference the following sections to determine total PCBs using EPA Method 8082 for comparison with WAC 173-340-900 screening levels:

Section 3.0: General procedure for determining compliance for dioxins, furans, and PCBs using the TEE table values in WAC 173-340-900.

Section 6.0: What method do I use to analyze PCBs?

Section 7.0: Step-by-step procedure for determining compliance for mixtures of PCBs using the tables in WAC 173-340-900 and EPA Method 8082.

2.6 TEQ Methodology for Ecological Risk Assessment

TEF's are used to convert dioxin, furan, and PCB congener concentrations to TEQ's. Each congener is adjusted by its TEF to calculate a TEQ concentration, which expresses the concentration of that congener as if it were present in the form of TCDD. The TEQ concentrations for all the congeners are summed, then the total TEQ concentration is compared to the concentration of 2,3,7,8-TCDD that has been determined to be protective of the ecological receptor(s) of interest.

Mammalian TEF's should only be used 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). Table 2 summarizes the TEF values to be used for an Ecological Risk Assessment. Either direct comparison or statistical methods (as described in WAC 173-340-740 (7)) may be used for evaluating compliance.

Table 2: PCDD, PCDF, and PCB toxicity equivalency factors for mammals and avians

CAS Number	Hazardous Substance	Mammalian TEF(1)*	Avian TEF(1)
Dioxin Congeners			
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
Furan Congeners			
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
PCB Congeners			
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

(1) Source: Van den Berg, et al. (2006) and Van den Berg et al. (1998). The 2005 World Health Organization re-evaluation of human and mammalian toxicity equivalency factors for dioxins and dioxin-like compounds. *Toxicological Sciences, 2006 93*(2), 223-241; doi:10.1093/toxsci/kfl055.

3.0 General Procedures for Determining Compliance for Dioxins, Furans, and PCBs using the TEE Table Values in WAC 173-340-900

Table 3: General procedures for determining compliance for dioxins, furans, and PCBs using the TEE table values in WAC 173-340-900

To Determine Compliance for	Use this Procedure	Procedure No.
Dioxin congeners	Compare the sum of the TEF-adjusted concentrations (TEQ) for the seven (7) dioxin congeners to the appropriate screening level (Table 749-2 or Table 749-3, as appropriate for the site) for "chlorinated dibenzo-p-dioxins (total)."	**1**
Furan congeners	Compare the TEQ for the ten (10) furan congeners to the appropriate screening level (Table 749-2 or Table 749-3) for "chlorinated dibenzofurans (total)."	**2**
To Measure	**Use this Procedure**	**Procedure No.**
Total PCB concentrations using EPA Method 8082	Compare the total Aroclors (no adjustments using TEFs) to the "PCB mixtures (total)" screening level (Table 749-2 or Table 749-3).	**3**
PCB congeners using EPA Method 1668	Compare the total PCB Congener Analysis (no adjustments using TEFs) to the "PCB mixtures (total)" screening level (Table 749-2 or Table 749-3); **AND** Compare the sum of the TEQs equivalency for the twelve (12) dioxin-like PCB congeners to the appropriate screening level (Table 749-2 or Table 749-3) for "chlorinated dibenzo-p-dioxins (total)."	**4A** **4B**
Mixtures of dioxin, furans and PCBs	Use **Procedure 4A** (above) to calculate and compare a "PCB mixtures (total)" screening level (Table 749-2 or Table 749-3); **AND** Use **Procedures 1, 2, and 4B** (above) for each component of the dioxin, furan, and dioxin-like PCB congeners.	**5A** **5B**
	Summary: 1. Adjust the concentration of each congener by the appropriate TEF. 2. Sum to calculate a total TEQ concentration (which includes dioxins, furans, and dioxin-like PCBs). 3. Compare this total TEQ concentration with the screening level (Table 749-2 or Table 749-3) for "chlorinated dibenzo-p-dioxins (total)."	

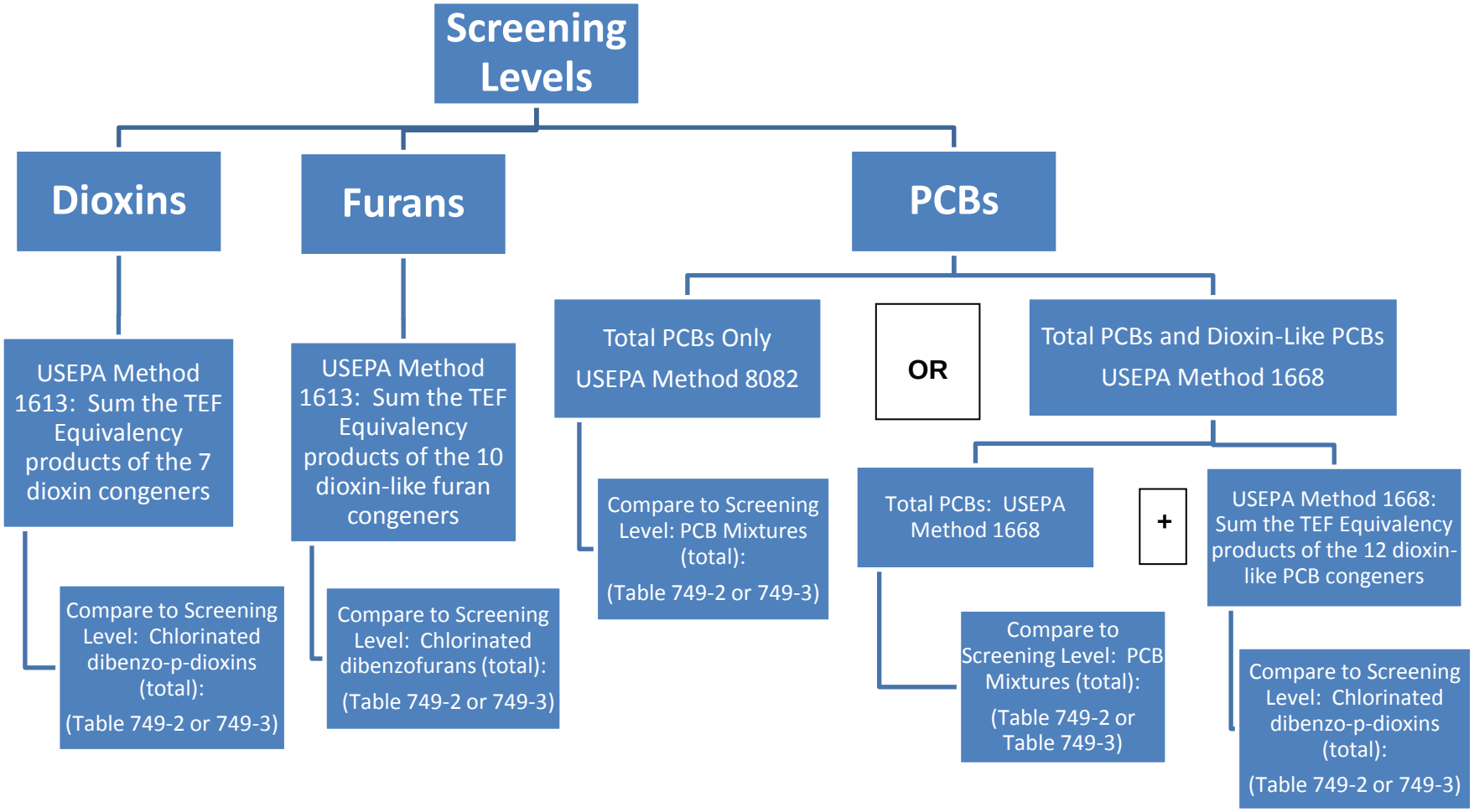

Figure 3: Summary of calculating contaminant levels for use when comparing screening levels to MTCA Table 749-2 or 749-3. Methods include EPA Method 1613 (USEPA 1994) for Dioxin/Furan analysis, and EPA Methods 1668 (USEPA 2008) and EPA Method 8082 (USEPA 2007) for PCB analysis.

Note: Total Aroclors (USEPA Method 8082) is an acceptable method to determine Total PCB concentrations. However, only PCB Congener Analyses (EPA Method 1668) should be used to evaluate the 12 dioxin-like PCB congeners at the site.

4.0 Step-by-Step Procedure for Determining Compliance for Mixtures of Dioxins, Furans, and PCBs Using the TEE Table Values in WAC 173-340-900 and EPA Method 1668

Overview:

When establishing and determining compliance using the screening level tables in WAC 173-340-900, mixtures of dioxins should be considered a single hazardous substance, mixtures of furans should be considered another separate single hazardous substance, and mixtures of PCBs shall be considered a third separate single hazardous substance.

Which screening levels should be used to determine compliance?

- Use the **Simplified TEE screening levels (MTCA Table 749-2)** only at sites where it has been determined that a Simplified TEE (WAC 173-340-7492) will meet the Ecological Risk Assessment requirements of WAC 173-340.

- Use the **Site-Specific TEE screening levels (MTCA Table 749-3)** at any site.

Step 1. Calculate the total TEQ for the dioxin congeners.

For each of the seven (7) dioxin congeners, multiply the individual congener analytical result by the appropriate TEF. Sum the resulting calculations to determine a total TEQ for the dioxin congeners.

Step 2. Compare the PQL/EQLs for each dioxin congener to the quantitation limits established in Implementation Memo No. 11.

Review the Laboratory Quality Assurance Project Plan (QAPP) to verify that the Laboratory Quantitation Limit (PQL/EQL) for each dioxin congener is at (or lower than) the Quantitation Limit established for each congener listed in Ecology's Implementation Memo No. 11: *Dioxins, Furans, and Dioxin-Like PCB Congeners: Addressing Non-Detects and Establishing PQLs for Ecological Risk Assessments in Upland Soil* (Ecology 2015a).

Step 3a. If the following four criteria have been met, assign non-detected congeners a value of one-half (1/2) the detection limit for compliance calculations:

- Congener has been detected at the site (EDL);
- Congener is not detected in the sample of concern (EDL);
- Lab PQL/EQL detection limits are no greater than the PQL/EQL established in Ecology Implementation Memo No. 11; and
- The department does not require a lower quantitation limit as per WAC 173-340-830(2) (e).

Step 3b. If the following three criteria have been met, assign non-detected congeners a value of zero (0) for compliance calculations:

- Congener is not detected in any sample at the site (EDL);
- Lab PQL/EQL detection limits are no greater than the PQL/EQL established in Ecology Implementation Memo No. 11; and
- The department does not require a lower quantitation limit as per WAC 173-340-830(2) (e).

Step 3c: If the following conditions apply, other approved statistical procedures can be used, such as the Kaplan-Meier (KM) Product Limit Estimator for the treatment of non-detected congeners (USEPA, 2011) (Ecology 2015a):

- Some fraction of the congeners are non-detect; and
- There are at least three detected congeners.

Step 4. Calculate the total TEQ for the furan congeners.

For each of the ten (10) furan congeners, multiply the individual congener analytical result by the appropriate TEF. Sum the resulting calculations to determine a total TEQ for the furan congeners.

Step 5. Compare the PQL/EQLs for each furan congener to the quantitation limits established in Implementation Memo No. 11.

Review the Laboratory QAPP to verify that the Laboratory PQL/EQL for each furan congener is at (or lower than) the Quantitation Limit established for each congener listed in Ecology Implementation Memo No. 11 (Ecology 2015a).

Step 6a: If the following four criteria have been met, assign non-detected congeners a value of one-half (1/2) the detection limit for compliance calculations:

- Congener has been detected at the site (EDL);
- Congener is not detected in the sample of concern (EDL);
- Lab PQL/EQL detection limits are no greater than the PQL/EQL established in Ecology Implementation Memo No. 11; and
- The department does not require a lower quantitation limit as per WAC 173-340-830(2) (e).

Step 6b: If the following three criteria have been met, assign non-detected congeners a value of zero (0) for compliance calculations:

- Congener is not detected in any sample at the site (EDL);
- Lab PQL/EQL detection limits are no greater than the PQL/EQL established in Ecology Implementation Memo No. 11; and
- The department does not require a lower quantitation limit as per WAC 173-340-830(2) (e).

Step 6c. If the following conditions apply, other approved statistical procedures can be used (such as the Kaplan-Meier (KM) Product Limit Estimator for the treatment of non-detected congeners (USEPA 2011) (Ecology 2015a):

- Some fraction of the congeners are non-detect; and
- There are at least three detected congeners.

Step 7. Calculate the total TEQ for the dioxin-like PCB congeners.

For each of the twelve (12) dioxin-like PCB congeners, multiply the individual congener analytical result by the appropriate TEF. Sum the resulting calculations to determine a total TEQ for the PCB congeners.

Step 8. Compare the PQL/EQLs for each dioxin-like congener to the quantitation limits established in Implementation Memo No. 11.

Review the Laboratory QAPP to verify that the Laboratory PQL/EQL for each dioxin-like congener (PCDD, PCDF, PCB) is at (or lower than) the Quantitation Limit established for each congener listed in Ecology Implementation Memo No. 11 (Ecology 2015a).

Step 9a. If the following four criteria have been met, assign non-detected congeners a value of one-half (1/2) the detection limit for compliance calculations:

- Congener has been detected at the site (EDL).
- Congener is not detected in the sample of concern (EDL);
- Lab PQL/EQL detection limits are no greater than the PQL/EQL established in Ecology Implementation Memo No. 11; and
- The department does not require a lower quantitation limit as per WAC 173-340-830(2) (e).

Step 9b. If the following three criteria have been met, assign non-detected congeners a value of zero (0) for compliance calculations:

- Congener is not detected in any sample at the site (EDL);
- Lab PQL/EQL detection limits are no greater than the PQL/EQL established in Ecology Implementation Memo No. 11; and
- The department does not require a lower quantitation limit as per WAC 173-340-830(2) (e).

Step 9c. If the following conditions apply, other approved statistical procedures can be used, such as the Kaplan-Meier (KM) Product Limit Estimator for the treatment of non-detected congeners (USEPA 2011) (Ecology 2015a):

- Some fraction of the congeners are non-detect; and
- There are at least three detected congeners.

5.0 How do I determine if dioxins, furans or PCBs are contaminants of ecological concern?

Table 4: How to determine if dioxins, furans, or PCBs are contaminants of ecological concern

To determine if these contaminants are of ecological concern:	Compare:	To the appropriate WAC 173-340-900 screening levels (Table 749-2 or 749-3) for:
Dioxins	Total TEQ for dioxin congeners	"Chlorinated dibenzo-p-dioxins (total)"
Furans	Total TEQ for furan congeners	"Chlorinated dibenzofurans (total)"
Dioxin-like PCBs	Total TEQ for dioxin-like PCB congeners **AND**	"Chlorinated dibenzo-p-dioxins (total)" **AND**
Total PCBs	Total PCB Congener Analysis (no adjustments using TEFs)	"PCB mixtures (total)"

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6.0 What method do I use to analyze PCBs?

Overview:

Reference Implementation Memo No. 12, *When to Use EPA Method 1668 for PCB Congener Analyses for a summary of PCB Analyses* (Ecology 2015b).

There are two basic approaches for evaluating the ecological risks associated with environmental concentrations of PCBs:

- Total PCB Concentration using EPA Method 8082 and
- Congener Specific Analyses using EPA Method 1668.

Step 1. Are dioxin-like congeners NOT suspected at a site? Use Total PCB Concentration EPA Method 8082.

See **Section 7.0** for the procedure. **NOTE:** The determination that EPA Method 8082 will sufficiently test for PCBs at your site should be discussed with your Ecology Cleanup Project Manager.

BACKGROUND: Under the MTCA Cleanup Regulation, site contaminant concentrations for comparing to screening levels (Table 749-2 and Table 749-3) for PCB mixtures can be calculated using measurements of total PCB concentrations in environmental media. This can be done using standard methods involving gas chromatography/electron capture detection systems. Specifically, total PCB concentrations are estimated by comparing the chromatographic pattern of peaks in the environmental sample to the pattern or number of peaks in a commercial Aroclor sample. With this approach, the total of all Aroclors reported for the sample would be compared to the WAC 173-340-900 (Table 749-2 or 749-3) screening level for "PCB mixtures (total)," to determine if PCBs are a contaminant of ecological concern.

Step 2. Are dioxin-like congeners suspected at a site? Use Congener Specific Analyses EPA Method 1668.

See **Section 7.0** for the procedure.

BACKGROUND: PCB mixtures may include up to 209 individual congeners that differ in the number and location of chlorine atoms. Over the last 30 years, the standard approach for estimating PCB environmental concentrations has begun to shift from the analysis of commercial mixtures (Aroclors, identified above) to congener-based analyses. Dioxins and furans are generally present in the environment as complex mixtures of chemical "congeners" that differ in the number and location of chlorine atoms. Using this approach, the total PCB concentrations are compared to the WAC 173-340-900 (Table 749-2 or 749-3) screening level for "PCB mixtures (total)." The summed dioxin-like TEQ calculation are compared to the WAC 173-340-900 (Table 749-2 or 749-3) screening level for "Chlorinated dibenzo-p-dioxins (total)" to determine if dioxin-like PCBs are a contaminant of ecological concern:

7.0 Step-by-Step Procedure for Determining Compliance for Mixtures of PCBs Using the Tables in WAC 173-340-900 and EPA Method 8082 or EPA Method 1668

Overview:

When establishing and determining compliance using screening level tables in WAC 173-340-900, PCBs shall be considered a single hazardous substance.

Which screening level should be used to determine compliance?

- **Use the Simplified TEE screening levels (MTCA Table 749-2)** only at sites where it has been determined that a Simplified TEE (WAC 173-340-7492) will meet the Ecological Risk Assessment requirements of WAC 173-340.

- **Use the Site-Specific TEE (MTCA Table 749-3)** at any site.

EPA Method 8082:

Step 1: Calculate total PCBs by summing Total Aroclors as listed in Table 1 of Implementation Memo No. 12, *When to Use EPA Method 1668 for PCB Congener Analyses.*

Step 2: Determine if PCBs are a contaminant of ecological concern:
Reference the procedures found in Table 3, Section 3.0 of this memo.
Use Procedure No. 3 to compare Total Aroclors (from Step 1 above) to the appropriate WAC 173-340-900 screening level in Table 749-2 or 749-3 for "PCB mixtures (total)" to determine if PCBs are a contaminant of ecological concern.

EPA Method 1668:

Step 1: Calculate total PCBs by summing EPA Method 1668 total PCB Congener Analysis (209 congeners).

Step 2: Determine if PCBs are a contaminant of ecological concern: Reference the procedures found in Table 3, Section 3.0 of this memo and compare Total PCB concentrations to the appropriate WAC 173-340-900 screening level (Table 749-2 or 749-3) for "PCB mixtures (total)" to determine if PCBs are a contaminant of ecological concern.

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8.0 Step-by-Step Procedure for Calculating Site-Specific Dioxin, Furan, and PCB Ecologically Protective Cleanup Levels and Determining Compliance (When Using Methods other than MTCA Tables 749-2 or Table 749-3)

Overview:

When it has been determined to use protective cleanup levels other than Tables 749-2 and 749-3, the seven (7) PCDD congeners, ten (10) PCDF congeners, and twelve (12) dioxin-like PCB congeners should be considered a single hazardous substance.

- Multiply the concentration of each congener by its TEF to calculate the congener-specific TEQ.
- Sum the congener-specific TEQs to calculate the total TEQ.
- Compare the total TEQ with a 2,3,7,8-TCDD contaminant level that has been determined to be protective of ecological receptors (plants, soil biota, wildlife).

Step 1. Calculate the total TEQ for the congeners using Equation 1 (see equation following these steps).

Calculate the TEQ of each of the seven (7) dioxin, ten (10) furan, and twelve (12) PCB congeners by multiplying the individual congener analytical results by the appropriate TEF, as seen in Table 2 of this document. Sum the resulting calculations to determine the total TEQ.

Step 2. Compare PQL/EQLs for each dioxin-like congener to quantitation limits found in Implementation Memo No. 11.

Review the QAPP to verify that the Laboratory Quantitation Limit (PQL/EQL) for each dioxin-like congener (PCDD, PCDF, PCB) is at (or lower than) the Quantitation Limit established for each congener listed in Ecology Implementation Memo No. 11, *Dioxins, Furans, and Dioxin-Like PCB Congeners: Addressing Non-Detects and Establishing PQLs for Ecological Risk Assessments in Upland Soil* (Ecology 2015a).

Step 3a. If the following four criteria have been met, assign non-detected congeners a value of one-half (1/2) the detection limit for compliance calculations:

- Congener has been detected at the site (EDL);
- Congener is not detected in the sample of concern (EDL);
- Lab PQL/EQL detection limits are no greater than the PQL/EQL established in Ecology Implementation Memo No. 11; and
- The department does not require a lower quantitation limit as per WAC 173-340-830(2) (e).

Step 3b. If the following three criteria have been met, assign non-detected congeners a value of zero (0) for compliance calculations:

- Congener is not detected in any sample at the site (EDL);
- Lab PQL/EQL detection limits are no greater than the PQL/EQL established in Ecology Implementation Memo No. 11; and
- The department does not require a lower quantitation limit as per WAC 173-340-830(2) (e).

Step 3c. If the following conditions apply, other approved statistical procedures can be used (such as the Kaplan-Meier (KM) Product Limit Estimator for the treatment of non-detected congeners, USEPA 2011) (Ecology 2015a):

- If some of the congeners are non-detect; and
- There are at least three detected congeners.

Step 4. Compare total TEQ calculation to 2,3,7,8-TCDD contaminant level.

Compare the total TEQ calculation with a 2,3,7,8-TCDD contaminant level that has been determined to be protective of ecological receptors (plants, soil biota, wildlife) through methods listed in WAC 173-340-7493(3)(a) through (g) [Selection of appropriate terrestrial ecological evaluation methods].

Equation 1: Calculating TEQ concentrations in samples. (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

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9.0 References

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