TOXIC EQUIVALENT CONCENTRATIONS OF TCDD IN SOURCE SEDIMENTS AND STREET DIRT

INTRODUCTION

Archived sediment samples that had been collected by the City of Seattle in 2004 and 2005 from catch basins and maintenance holes, and street dirt collected from one location in 2005, were analyzed for dioxin and furan congeners in October 2005. The samples had been collected as part of routine source tracing for the Lower Duwamish Waterway (LDW) source control program, and were selected for analysis of dioxins and furans because they were from locations with relatively high polychlorinated biphenyl (PCB) concentrations among the source samples collected in 2004 and 2005. Analysis of the source samples for dioxins and furans was triggered by an interest in understanding background concentrations of these chemicals of interest for the LDW remedial investigation.

Results of the dioxin and furan analyses of the source sediment and street dirt samples are described below. Also included are summaries of concentrations in surface and subsurface sediments from the LDW, in surface sediments from the greater Seattle area, and in various media from background areas nationally. All of the data presented, except for the source sample dioxin and furan data, have been presented previously in documents generated for the LDW remedial investigation.

METHODS

Nine sediment samples from catch basins and maintenance holes, one sediment sample from a settling tank upstream of an oil-water separator at Basin Oil, and one street dirt sample from the right-of-way of 16th Avenue South were collected. Sediments from catch basins, which represent small drainage areas and are off the main storm water conveyance lines, were collected by accessing the catch basin interior through a manhole, and removing the top 3 to 4 inches of sediment from inside the catch basin sump. Individual aliquots were collected from at least three separate grab samples within a catch basin and composited to generate one sediment sample. Samples from maintenance holes, which access main storm water conveyance lines and represent much larger drainage areas, were also collected.

The street dirt sample was collected from the edge of the pavement on the west side of 16th Avenue South. It was analyzed for dioxins and furans because it contained elevated levels of PCBs. An approximately 12-ft-wide area of soil along the western edge of the roadway between the edge of the pavement and the fence line along the adjacent property, extending from Dallas Avenue South to South Cloverdale, was removed in June 2005 to a depth of 6 inches and covered with clean gravel. Four samples collected from the base of the

excavation contained very low concentrations of PCBs (< 0.04 mg/kg dw) (Hart Crowser 2005).

To summarize information on dioxin and furans, toxic equivalent (TEQ) concentrations of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) for each sediment and street dirt sample were calculated using the mammalian toxic equivalency factors (TEFs) for each dioxin and furan congener provided by van den Berg et al. (2006), except where noted. Concentrations of individual congeners that were not detected were estimated to be present at one-half the reported detection limit.

Laboratory analytical results were independently validated in 2008 (Integral 2008).

RESULTS

Maps 1, 2, and 3 show the locations and TCDD TEQ concentrations of the 49 surface sediment samples[1] tested for dioxins and furans in the LDW, and of the source samples. Locations of subsurface cores for which dioxin and furan concentrations are available are also shown. Table 1 provides summary statistics for the individual congeners and for TCDD TEQs in surface sediments of the LDW, and Table 2 provides the individual TCDD TEQ concentrations for catch basin and manhole sediments, and for the street dirt sample. Dioxin and furan concentrations were also measured in three sections from each of eight subsurface sediment cores as part of the LDW remedial investigation. Results of core samples (and any surface sediments near the cores) are provided in Table 3. The LDW surface sediment and core sample data sets were previously reported in the draft remedial investigation report (Windward 2007).

TCDD TEQ concentrations were also measured in surface sediments of water bodies in the greater Seattle area in 2005. Samples were primarily from freshwater habitats in the area, and included two samples from upstream of the LDW (note that the surface sediments for the LDW also include two upstream samples, on Map 3; a total of four locations upstream of the LDW site have been sampled). Greater Seattle area background data are provided in Table 4, and locations of the samples are shown in Map 7-3, which was excerpted from the draft LDW remedial investigation report (Windward 2007). The mean TCDD TEQ values presented in Table 4 were calculated after removing relatively high values and deriving the means for locations where two stations were close to one other, at the request of the U.S. Environmental Protection Agency (EPA). The locations and results of all samples from this sampling event are depicted on Map 7-3, and results are listed in Table 4.

Box plots showing the median, 25th, and 75th percentiles, one-and-a-half times the interquartile range, and outliers for TCDD TEQ concentrations of LDW surface sediments,

[1] Twenty-four of the surface sediment samples were collected by the U.S. Environmental Protection Agency in August and September 1998. Twenty-five were collected as part of the Phase 2 remedial investigation for the LDW.

the greater Seattle background area surface sediments, and the source sediments and street dirt sample are provided in Figure 1.

Finally, TCDD TEQ concentrations in a variety of environmental media including lake sediments, compiled by Windward (2005) from EPA sources, are summarized in Table 5. The sediments came from lakes at which there were no known sources of dioxins and furans. TCDD TEQ concentrations in this data set were calculated using a set of TEFs (van den Berg et al. 1998) that are different from the TEFs used to calculate the TCDD TEQ concentrations for the remainder of the sediment data presented in this memorandum, and are therefore not directly comparable to the more local TCDD TEQ data.

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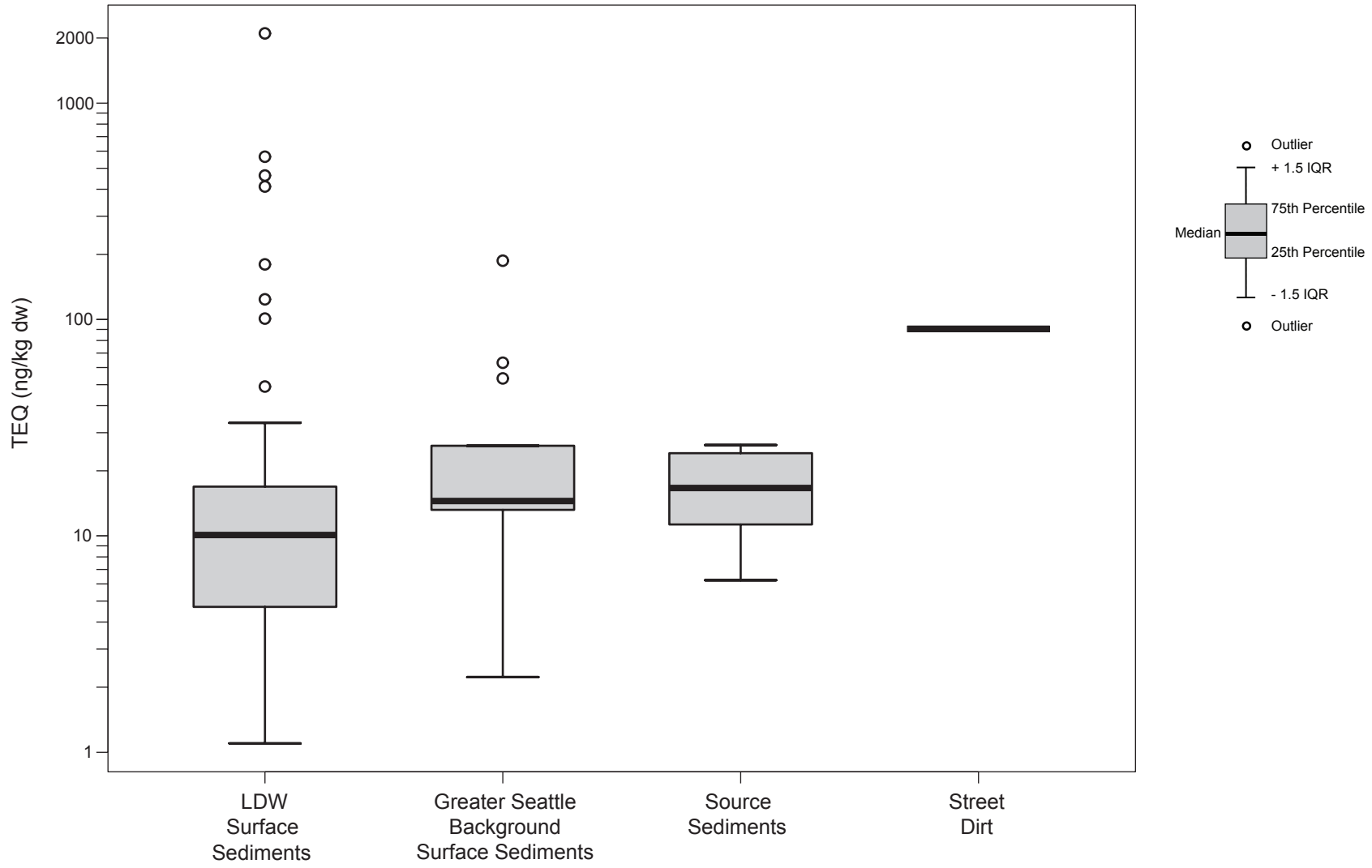

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Figure 1.
Box-Whisker Plots of TEQ Concentrations in Sediment Samples from the LDW, the Greater Seattle Area, Source Sediments, and Street Dirt.

CB65
25.6
7.2
5.9
CB52
18.1
1.59
180
16
7.8
11.7
10.2
8.9
16.9
27.1
10.6
124
16.4
14.4
13
18.2
2,100
463
565
49.0
8.1
10.1
2.2
12
13.0

City Source Sample Stations
TCDD TEQ Concentrations in Surface Sediment (ng/kg dw; Windward 2007)
Locations of Sediment Cores with Dioxin and Furan Data
City of Seattle Stormwater System Mainlines
City of Seattle Boundary

MH100 Location ID and
26.3 TCDD TEQ Concentration (ng/kg dw)

Background imagery is for reference purposes only, is courtesy of the USGS and is dated 2002.

MH - Manhole
CB - Catch Basin
TP - Test Pit

0 0.125 0.25 0.5
Miles

N

Location on Jerry's Computer: C:\Jerry\SPU_DIOXIN\SPU_Dioxin_Sampling_11X17_1.mxd JP @ 04.17.2008

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Map 1.
TCDD TEQ Concentrations (ng/kg dw) in LDW Surface Sediments and Selected Source Samples from the Lower LDW

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Map 2.
TCDD TEQ Concentrations (ng/kg dw) in LDW Surface Sediments and Selected Source Samples from the Middle LDW

SD52
90.5
2.6
10.1
CB41
15.2
5.22
4.92
13.5
2.9
22.7
8.29
8.4
1.7
4.7
4.69
MH3
24.1
1.1
1.2

City Source Sample Stations

TCDD TEQ Concentrations in Surface Sediment (ng/kg dw; Windward 2007)

Locations of Sediment Cores with Dioxin and Furan Data

City of Seattle Stormwater System Mainlines

City of Seattle Boundary

MH100 Location ID and
26.3 TCDD TEQ Concentration (ng/kg dw)

Background imagery is for reference purposes only, is courtesy of the USGS and is dated 2002.

MH - Manhole
CB - Catch Basin
TP - Test Pit

0 0.125 0.25 0.5
Miles

N

Location on Jerry's Computer: C:\Jerry\SPU_DIOXIN\SPU_Dioxin_Sampling_11X17_1.mxd JP @ 04.16.2008

integral consulting inc.

Map 3.
TCDD TEQ Concentrations (ng/kg dw) in LDW Surface Sediments and Selected Source Samples from the Upper LDW

Centroid location number
Dioxin and furan TEQ value (ng/kg dw)**
J: estimated

3 13.4 J*

* Value is average of the original sample value and the field duplicate sample value
** Dioxin and furan TEQ values were calculated from individual dioxin and furan concentrations with mammalian TEFs, using ½ the reporting limit for undetected dioxin and furan congeners.

Puget Sound
Sammamish R.
Lake Union
Elliott Bay
Seattle
Lake Washington
Mercer Island
Lower Duwamish Waterway
Cedar R.

3 13.2 J*
1 1a 187 J, 1b 63.1 J
9 9a 5.46 J, 9b 26.1 J
8 53.4 J
2 2a 13.7 J, 2b 18.9 J
4 14.7 J
7 2.59 J
5 5a 14.1 J, 5b 14.5 J
6 2.23 J

Wind Ward environmental LLC

N

0 1 2 3 4 Miles
0 1 2 3 4 Kilometers

Map 7-3. Dioxin and furan TEQs in surface sediment samples from the greater Seattle area

DRAFT

Prepared by CEH, 10/29/07, MAP #2307, W:\Projects\00-08-06 Duwamish_RI\data\gis\Phase2 RI\Background

Table 1. Summary Statistics for Dioxins, Furans, and TCDD TEQ Concentrations in LDW Surface Sediments

	Detection Frequency		Concentration (ng/kg dry weight)			
Chemical	Ratio	%	Minimum Detected Concentration	Maximum Detected Concentration	Calculated Mean[a]	Range of Reporting Limits[b]
2,3,7,8-TCDD	22/47	47.00	0.0890 *J*	30.6	1.6	0.27–1.1
1,2,3,7,8-PeCDD	24/47	51.00	0.284 *J*	57.1	4.7	0.53–4.1
1,2,3,4,7,8-HxCDD	24/47	51.00	0.382 *J*	124	9.2	0.72–5.4
1,2,3,6,7,8-HxCDD	39/47	83.00	1.73 *J*	3,400	120	0.74–4.1
1,2,3,7,8,9-HxCDD	35/47	74.00	1.19 *J*	315	27	0.84–4.8
1,2,3,4,6,7,8-HpCDD	45/47	96.00	41.4 *J*	73,700	2,800	0.99–1.1
OCDD	47/47	100.00	7.8 *J*	241,000	18,000	na
2,3,7,8-TCDF	38/47	81.00	0.426 *J*	397	14	0.18–1.4
1,2,3,7,8-PeCDF	23/47	49.00	0.214 *J*	69.3	5.02	0.28–5.0
2,3,4,7,8-PeCDF	24/47	51.00	0.392 *J*	230	17	0.44–5.4
1,2,3,4,7,8-HxCDF	34/47	72.00	0.694 *J*	2,530	130	0.29–4.2
1,2,3,6,7,8-HxCDF	24/47	51.00	0.335 *J*	365	23	0.22–4.3
1,2,3,7,8,9-HxCDF	22/47	47.00	0.0730 *J*	33.8 *J*	1.97	0.12–2.4
2,3,4,6,7,8-HxCDF	24/47	51.00	0.307 *J*	302 *J*	14	0.29–2.5
1,2,3,4,6,7,8-HpCDF	44/47	94.00	6.71	40,300	1,200	0.62–7.7
1,2,3,4,7,8,9-HpCDF	31/47	66.00	0.421 *J*	3,720	120	0.77–4.2
OCDF	46/47	98.00	12.5	93,700	3,000	0.74–0.74
TCDD TEQ	47/47	100.00	1.1 *J*	2,100 *J*	na	na

Source: Windward (2007)

Notes:

TCDD TEQs were calculated using mammalian TEFs from Van den Berg et al. (2006).

LDW = Lower Duwamish Waterway

J = estimated

TCDD TEQ = toxic equivalent concentration of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

TEF = toxic equivalency factor

[a] Calculated mean concentration is the average of detected concentrations and one-half the reporting limit for nondetected results.

[b] Reporting limits are based only on nondetect samples.

Table 2. TCDD TEQ Concentrations (ng/kg dw) in Source Sediment and Street Dirt Samples

Sample Station	Sample ID	Sample Type	TEQ	Location
Catch Basins				
CB40	CB40-080404[a]	Sediment	11.3 *J*	7585 Perimeter Rd
CB41[b]	CB41-081904[a]	Sediment	15.2 *J*	8661 Dallas Ave S
CB52	CB52-020405	Sediment	18.1 *J*	SW Idaho St and W Marginal Wy SW
CB65	CB65-032205	Sediment	25.6 *J*	3419 11th Ave SW
Maintenance Holes				
MH100	MH100-021605	Sediment	26.3	MH100 on flume at NBF
MH20	MH20-041305	Sediment	22.3 *J*	MH at S Riverside and S Holden St
MH221A	MH221A-021605	Sediment	6.2 *J*	King County Airport SD3-east line
MH229A	MH229A-021605	Sediment	7.6 *J*	Sediment trap T4 upstream of Boeing
MH3	MH3-031605	Sediment	24.1 *J*	MH adjacent to Hyster washpad
MH363	MH363-021605	Sediment	11.6 *J*	King County Airport SD3-north line
Street Dirt Sample				
SD52	TP52-031605	Street dirt	90.5	16th Ave S, 60' from Dallas

Notes:
TCDD TEQs were calculated using TEFs from Van den Berg et al. (2006), and assuming ND = 1/2 DL.

DL = detection limit
J = estimated
MH = maintenance hole
NBF = North Boeing Field
ND = nondetect
S = south
TCDD TEQ = toxic equivalent concentration of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEF = toxic equivalency factor
W = west

[a] This sample was collected in 2004. All other samples were collected in 2005.
The period between collection and extraction of these two samples exceeded standard holding times.

[b] CB41 is from a settling tank immediately upstream of an oil-water separator at Basin Oil

Table 3. TCDD TEQ Concentrations in LDW Subsurface Cores and in Associated Surface Sediment Samples

	Subsurface Sediment		Surface Sediment	
Subsurface Core Sampling Location	Sampling Interval (ft)	TCDD TEQ (ng/kg dry weight)	Sampling Location Closest to Subsurface Core	TCDD TEQ (ng/kg dry weight)
LDW-SC19	0–1	22.8 *J*	LDW-SS36	27.1 *J*
(RM 1.0 south of Kellogg Island)	1–2	20.1 *J*		
	2–4	20.5 *J*		
LDW-SC20	0–2	38.7 *J*	LDW-SS37	124 *J*
(RM 1.0 in the navigation channel)	2–4	27.1		
	4–6	194 *J*		
	8–10	5.60 *J*		
LDW-SC26	0–1	15.9 *J*	none[a]	no data
(RM 1.4 on the west side of the navigation channel)	1–2	13.1 *J*		
	2–4	22.4 *J*		
	6–8	136 *J*		
LDW-SC28	0–1	19.9 *J*	none[a]	no data
(RM 1.4 on the west side of the navigation channel)	1–2	14.8		
	2–4	18.5 *J*		
LDW-SC29	0–1	54.1 *J*	LDW-SS56	2,100 *J*
(RM 1.4 west of the Glacier northwest dock)	1–2	1.03 *J*		
	2–4	0.147 *J*		
LDW-SC39	0–1	7.91 *J*	none[a]	no data
(between RM 2.1 and RM 2.2 on the western	1–2	12.4 *J*		
shoreline)	2–4	13.1 *J*		
LDW-SC40	0–1	6.71 *J*	none[a]	no data
(near RM 2.3 on the western shoreline)	1–2	0.485 *J*		
	2–4	0.355 *J*		
LDW-SC41	0–1	13.8	LDW-SS83	33.3 *J*
(near RM 2.4 on the east side in the Myrtle Street	1–2	12.5 *J*		
Embayment)	2–4	14.0 *J*		

Source: Windward (2007)

Notes:

TCDD TEQs were calculated using mammalian TEFs from in Van den Berg et al. (2006).

J = estimated

TCDD TEQ = toxic equivalent concentration of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

TEF = toxic equivalency factor

[a] No surface samples were collected near subsurface cores.

Table 4. TCDD TEQ Concentrations in Surface Sediments from Locations in the Greater Seattle Area

Location	Sampling Location	TCDD TEQ (ng/kg dry weight)	Included in Mean (ng/kg dry weight)
Elliott Bay (Terminal 91)[a]	EB-SS2a	13.7 *J*	16.3
	EB-SS2b	18.9 *J*	
Lake Union (I-5 bridge)[a]	LU-SS9a	5.46 *J*	15.8
	LU-SS9b	26.1 *J*	
Lake Washington (Bothell)	LW-SS3	13.2 *J*[b]	13.2
Lake Washington (Bellevue)	LW-SS4	14.7 *J*	14.7
Lake Washington (Renton)	LW-SS5a	14.1 *J*	14.3
	LW-SS5b	14.5 *J*	
Ship Canal (Salmon Bay)[a]	SC-SS1a	187 *J*	
	SC-SS1b	63.1 *J*	
Union Bay (Laurelhurst)	UB-SS8	53.4 *J*	
Mean for greater Seattle area locations (excluding samples from the Ship Canal and Union Bay)			**14.9**
Springbrook Creek (Tukwila)	SB-SS6	2.23 *J*	2.23
Duwamish River (Tukwila)	DRD-SS7	2.59 *J*	2.59
Mean for upstream locations			**2.41**

Source: Windward (2007)

Notes:
TCDD TEQs were calculated using mammalian TEFs from Van den Berg et al. (2006).

J = estimated
TCDD TEQ = toxic equivalent concentration of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEF = toxic equivalency factor

[a] Two samples were collected, one approximately 30 to 50 ft from the outfall and the other approximately 100 to 120 ft from the outfall.

[b] Reported concentration is the average of two field samples.

Table 5. TCDD TEQ Concentrations in Various Media from Throughout the U.S. (National Background)

Media	Arithmetic Mean of TCDD TEQ[a]	TCDD TEQ Range	Number of Samples
Urban soils[a]	9.4 ng/kg	2–21 ng/kg	171
Rural soils[a]	2.5 ng/kg	0.1–6 ng/kg	292
Urban air[b]	0.12 pg/m^3	0.03–0.2 pg/m^3	106
Rural air[a]	0.017 pg/m^3	0.01–0.02 pg/m^3	7
Sediment[b,c]	5.3 ng/kg	< 1–16.3 ng/kg	11

Source: Windward (2005)

Notes:
TCDD TEQs were calculated using mammalian TEFs from Van den Berg et al. (1998).

TCDD TEQ = toxic equivalent concentration of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin
TEF = toxic equivalency factor

[a] Undetected congener concentrations set equal to zero.

[b] Undetected congener concentrations set equal to half the detection limits.

[c] Urban and rural sediment; all data from lakes not known to be influenced by dioxin/furan sources.