APPENDIX B

PASSIVE SAMPLER STUDY RESULTS

2023 DMMP MONITORING OF THE ELLIOTT BAY NON-DISPERSIVE UNCONFINED OPEN-WATER DREDGED MATERIAL DISPOSAL SITE

DRAFT REPORT - REV. 1

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LIST OF ACRONYMS AND ABBREVIATIONS

DMMP	Dredged Material Management Program
DF	dibenzofuran
DU	decision unit
LOC	level of chlorination
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzodioxin
PDMS	polydimethylsiloxane
PE	polyethylene
PRC	performance reference compounds
SPME	Solid-phase microextraction

1.0 INTRODUCTION

As part of the 2023 Dredged Material Management Program (DMMP) monitoring of the Elliott Bay disposal site, an *ex-situ* sediment exposure study was conducted using passive samplers to evaluate concentrations of polychlorinated dibenzodioxin and dibenzofurans (PCDDs/DFs) and polychlorinated biphenyls (PCBs) in sediment porewater from the Disposal Site decision unit (DU) and the Environs DU. *Ex-situ* tests were conducted by tumbling composite sediments from each surface DU (0-10 cm) with "SP3™" polyethylene (PE) passive samplers prepared by SiREM at their laboratory in Guelph, Ontario Canada[1]. Following the *ex-situ* test, the PE passive samplers were extracted and analyzed for PCDDs/DFs and PCBs at Eurofins TestAmerica in Knoxville, Tennessee, and the resultant data were used to calculate the freely dissolved concentrations, correcting for non-equilibrium conditions using performance reference compounds (PRCs) (Attachment A).

Separately, test species (*Macoma nasuta* and *Alitta virens*) were subjected to 45-day bioaccumulation tests with sediment from each DU to evaluate the uptake of PCDDs/DFs and PCB congeners (NewFields 2024). Measured tissue concentrations after exposure were compared to concentrations measured in the PE passive samplers to assess the ability of passive samplers to serve as a proxy for determining bioavailability.

2.0 METHODS

2.1 *Ex-situ* Experiments

PE passive samplers prepared by SiREM were used to evaluate dissolved concentrations of PCDDs/DFs and PCB congeners in porewater of the onsite (EB-DU) and offsite (EBE-DU) surface (0-10 cm) sediments. The PE samplers were exposed to the EB-DU and EBE-DU composite samples in the laboratory approximately one month after sample collection. The *ex-situ* tests continuously mixed the test sediment around the passive sampler by tumbling to optimize conditions for analyte partitioning into the sampler. The passive samplers were mixed with composite sediment samples for 45 days. For each test sediment, separate containers were used to tumble passive samplers for PCDDs/DFs versus PCB congeners.

PRCs were used to evaluate the uptake kinetics of the samplers during the exposure period and to correct for non-equilibrium conditions. Ten individual PCB congeners, not typically found in high concentration in the environment and representing different levels of chlorination, were spiked into the PE samplers prior to initiation of the *ex-situ* tests. PRCs included PCB-14, PCB-36, PCB-78, PCB-104, PCB-121, PCB-142, PCB-155, PCB-184, PCB-192, and PCB-204.

[1] The SP3™ passive sampler is a commercially available PE passive sampler provided by SiREM for measuring freely dissolved organic compounds in porewater (sediment and soil), surface water, and stormwater. The solid-phase microextraction (SPME) fiber is the other commonly used passive sampler, which was tested during the 2020 pilot study for DMMP monitoring at the Port Gardner disposal site (NewFields 2021).

2.2 PE Sampler Data Calculations

Concentrations of PCDDs/DFs and PCBs congeners measured in the PE passive samplers (reported by the laboratory in units of ng/g PE) were used to calculate 1) PRC-normalized PE concentration and b) dissolved porewater concentrations. These equations use the loss of PRCs from the PE sampler to correct for potential non-equilibrium conditions at the termination of the *ex-situ* tests (i.e., insufficient time for the contaminant partitioning between the porewater and PE to come to equilibration).

2.2.1 PRC-Normalized PE Concentration Calculation

Contaminant concentration in the PE sampler (C_{PE}) and the PRC-normalized concentration in the PE sampler ($C_{PE\text{-}corrected}$) are related as follows:

$$C_{PE-corrected} = \frac{C_{PE}}{1-e^{k_e t}} \quad (1)$$

and

$$k_e = \ln\left(\frac{C_{PRC-t}}{C_{PRC-0}}\right) \div t \quad (2)$$

where t is the deployment time (in days), $C_{PRC\text{-}0}$ is the concentration of PRC before deployment, and $C_{PRC\text{-}t}$ is the concentration of PRC after deployment. These equations use the loss of PRCs from the PE sampler to correct for potential non-equilibrium conditions at the termination of the *ex-situ* tests (i.e., insufficient time for the contaminant partitioning between the porewater and PE to come to equilibration).

For the PCB data, data for the PRCs in each sample is used to create a plot of logk_e versus logK_{PE}, where K_{PE} is the passive sampler-dissolved phase partition coefficient (in L/kg). Using K_{PE} values for each PCB congener, provided by the analytical laboratory, a k_e value for each PCB congener in each sample was calculated and used in Equation 1 to calculate $C_{PE\text{-}corrected}$.

2.2.2 Dissolved Porewater Concentration Calculation

Contaminant concentration in the PE sampler (C_{PE}) and the dissolved concentration (C_{free}) are related as follows:

$$C_{free} = \frac{C_{PE}}{(1-e^{k_e t})\times K_{PE}} \quad (3)$$

This equation is similar to Equation 1, above, but uses K_{PE} to convert the value to a dissolved concentration.

2.3 Sediment Concentrations of PCDDs/DFs and PCB Congeners

Sediment concentrations of PCDDs/DFs and PCB congeners were measured in surface sediment (0-10 cm depth) at both ED-DU and EDE-DU locations. Sediment concentrations were reported by the laboratory SGS-Wilmington in pg/g.

2.4 *Macoma nasuta* and *Alitta virens* Bioaccumulation Tests

Bioaccumulation tests of ED-DU and EDE-DU sediments were conducted following DMMP guidance (DMMP 2021) with modifications as outlined below. Adult *Macoma nasuta* (clam) and *Alitta virens* (worm) were exposed to sediment in separate exposure tanks for a 45-day period. Five replicates for each species were generated for each DU test, as well as three pretest replicates for each species for a total of 26 tissue samples. The exposure tanks maintained constant flow-through conditions and daily water quality measurements were taken on each tank. Water circulation did not exceed four exchanges per 24-hour period. On day 45 of the test, the sediment was sieved to collect the worms and clams. Surviving animals were placed in clean flow-through tanks to purge their gut contents for 24 hours, after which the tissues were placed into certified clean glass sample jars, frozen, and sent to the chemistry laboratory for compositing and chemical analysis. Tissue concentrations of PCDDs/DFs and PCB congeners were reported by the laboratory SGS-Wilmington in ng/kg wet weight.

3.0 RESULTS

3.1 Loss of PRCs

Concentrations of the ten PRCs measured in the PE samplers tumbled with sediment in *ex situ* experiments decreased compared to those in blank PE samplers, which were not tumbled with sediment. The tables below list the relative amount of each PRC that was lost in each of the triplicate exposures with Disposal Site DU (EB-DU-P-1, EB-DU-P-2, and EB-DU-P-3) and Environs DU (EBE-DU-P-1, EBE-DU-P-2, and EBE-DU-P-3). Table 1 lists the relative amount of PRC lost in the samplers used to measure PCBs and Table 2 lists the relative amount of PRC lost in the samplers used to measure PCDDs/DFs. In the PE samplers used to measure PCBs, PRC loss ranged from 2 to 88 percent. In the PE samplers used to measure PCDDs/DFs, PRC loss ranged from 14 to 96 percent. The closer the loss of PRC is to 100 percent, the closer the PRC is to reaching equilibrium between the sampler and the porewater. Lower level of chlorination [LOC] PRCs, such as PCB-14 and PCB-36 (LOC 1 and 2, respectively) were closer to equilibrium than the higher LOC PCBs (e.g. PCB-192 and PCB-204) owing to the faster partitioning kinetics of lower LOC PCBs. Three instances occurred where the calculated loss of PRC was slightly less than zero, where the concentration in the deployed sample was slightly more than the concentration in the blank sample. These instances were considered outliers and included PCB-184 in EB-DU-P-2.PCBs, PCB-184 in EB-DU-P-3.PCBs, and PCB-204 in EB-DU-P-2.PCBs. In each case, the PRC had a high LOC and the amount of PRC measured after the *ex-situ* experiment was only slightly above the initial concentration, likely due to analytical variability.

Table 1. Loss of PRCs in PE passive samplers used for PCB measurements

PRC	LOC	EB-DU-P-1.PCBs	EB-DU-P-2.PCBs	EB-DU-P-3.PCBs	EBE-DU-P-1.PCBs	EBE-DU-P-2.PCBs	EBE-DU-P-3.PCBs
PCB-14	1	85%	88%	87%	86%	84%	85%
PCB-36	2	56%	60%	60%	60%	62%	56%
PCB-78	3	39%	41%	41%	45%	48%	35%
PCB-104	4	30%	35%	35%	35%	45%	30%
PCB-121	5	14%	18%	20%	20%	29%	16%
PCB-142	6	23%	25%	23%	23%	30%	19%
PCB-155	7	10%	7%	13%	14%	21%	11%
PCB-184	8	5%	OUTLIER	OUTLIER	11%	15%	9%
PCB-192	9	2%	2%	6%	11%	15%	6%
PCB-204	10	3%	OUTLIER	3%	9%	15%	9%

OUTLIER = calculated loss of PRC was slightly less than zero, see text
LOC = level of chlorination

Table 2. Loss of PRCs in PE passive samplers used for PCDD/DF measurements

PRC	LOC	EB-DU-P-1.DF	EB-DU-P-2.DF	EB-DU-P-3.DF	EBE-DU-P-1.DF	EBE-DU-P-2.DF	EBE-DU-P-3.DF
PCB-14	1	96%	94%	93%	87%	86%	87%
PCB-36	2	74%	69%	21%	58%	47%	56%
PCB-78	3	71%	71%	76%	48%	53%	44%
PCB-104	4	74%	74%	83%	48%	55%	43%
PCB-121	5	55%	56%	29%	21%	30%	19%
PCB-142	6	66%	64%	27%	31%	39%	27%
PCB-155	7	61%	61%	57%	23%	33%	20%
PCB-184	8	53%	53%	16%	15%	23%	15%
PCB-192	9	56%	56%	77%	16%	23%	12%
PCB-204	10	55%	54%	34%	14%	19%	14%

LOC = level of chlorination

3.2 Relationship Between k_e and K_{PE}

Figure 1 shows the relationship between k_e and K_{PE} in each of the PE ex-situ experiments for PCB measurements, and Figure 2 shows the same relationship in each of the PE ex-situ experiments for PCDD/DF measurements. The equations for the linear regressions were used to calculate $C_{PE\text{-}corrected}$ and C_{free}.

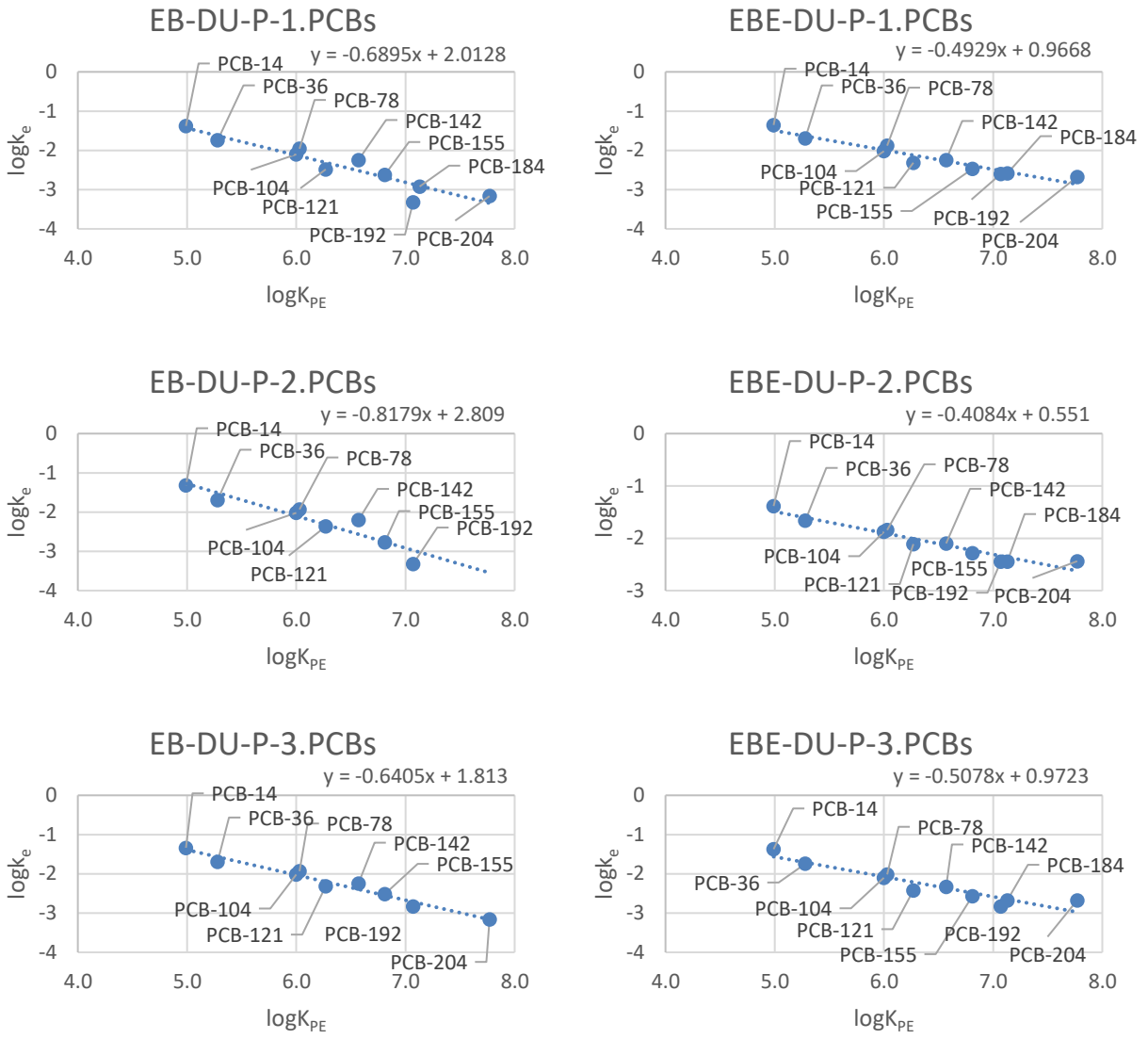

Figure 1. Relationship between k_e and K_{PE} in each of the PE ex-situ experiments for PCB measurements

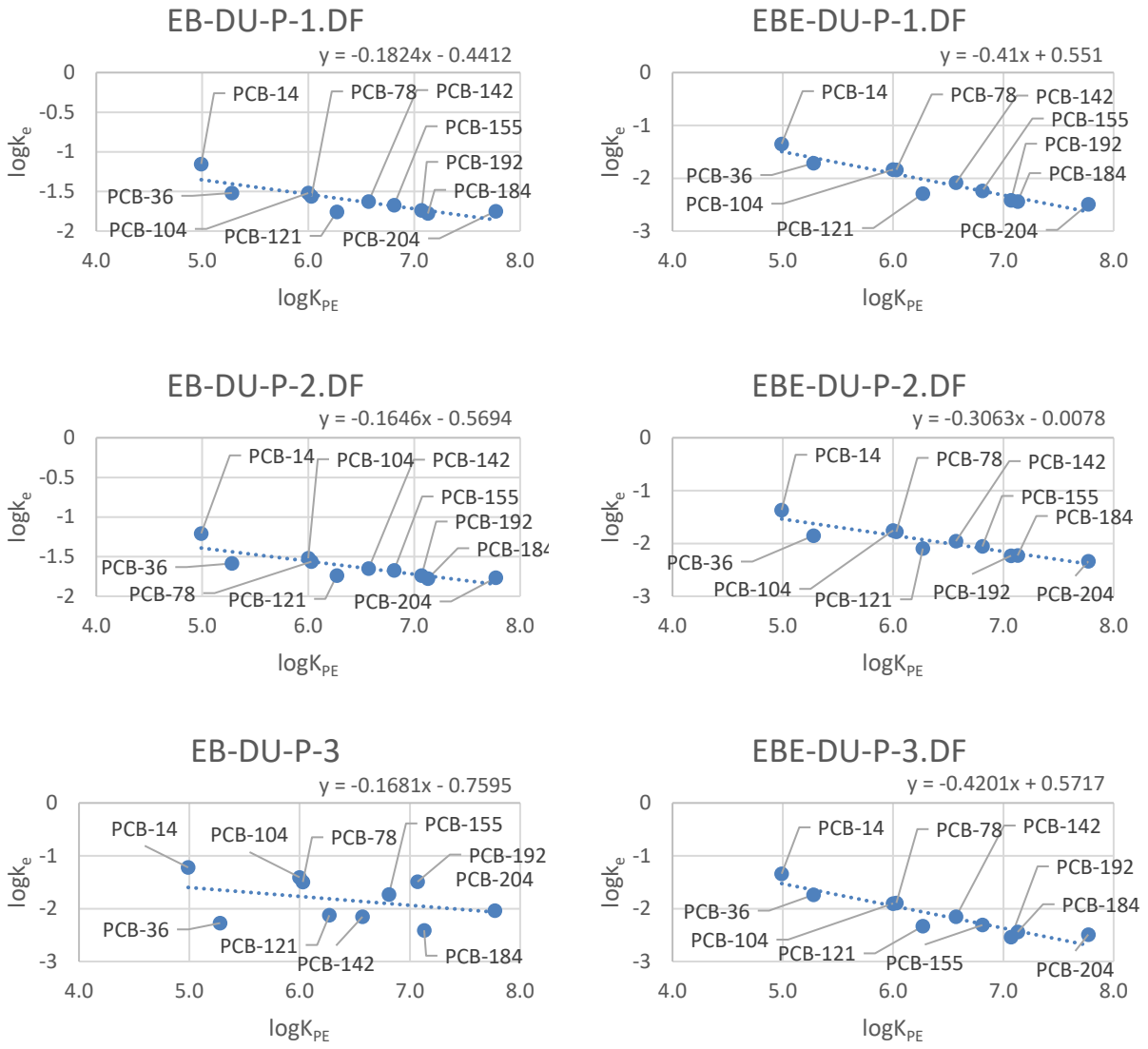

Figure 2. Relationship between k_e and K_{PE} in each of the PE ex-situ experiments for PCDD/DF measurements

3.3 PRC-Normalized PE Concentrations of PCDDs/DFs and PCBs

PRC-corrected PE concentrations ($C_{PE\text{-}corrected}$) were calculated from PE sampler data using the approach described in Section 2.0. $C_{PE\text{-}corrected}$ from triplicate *ex-situ* experiments for PCCDs/DFs are shown in Figure 3 and those for PCBs are shown in Figure 4. Tabular $C_{PE\text{-}corrected}$ data each sampler is listed in Attachments B (PCB congeners) and C (PDCC/DF congeners).

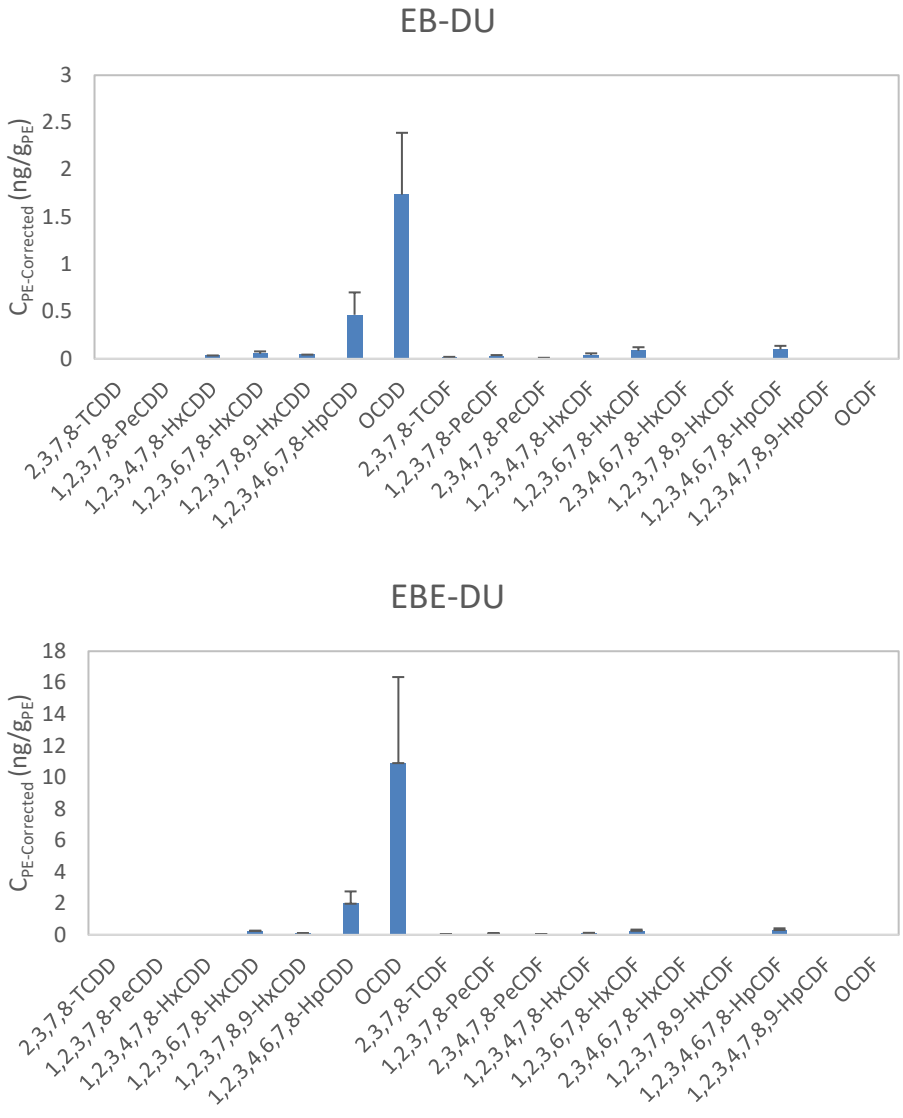

Figure 3. PRC-Corrected PE Concentrations ($C_{PE\text{-}corrected}$) of PCDDs/DFs Calculated from *ex-situ* experiments with PE passive samplers

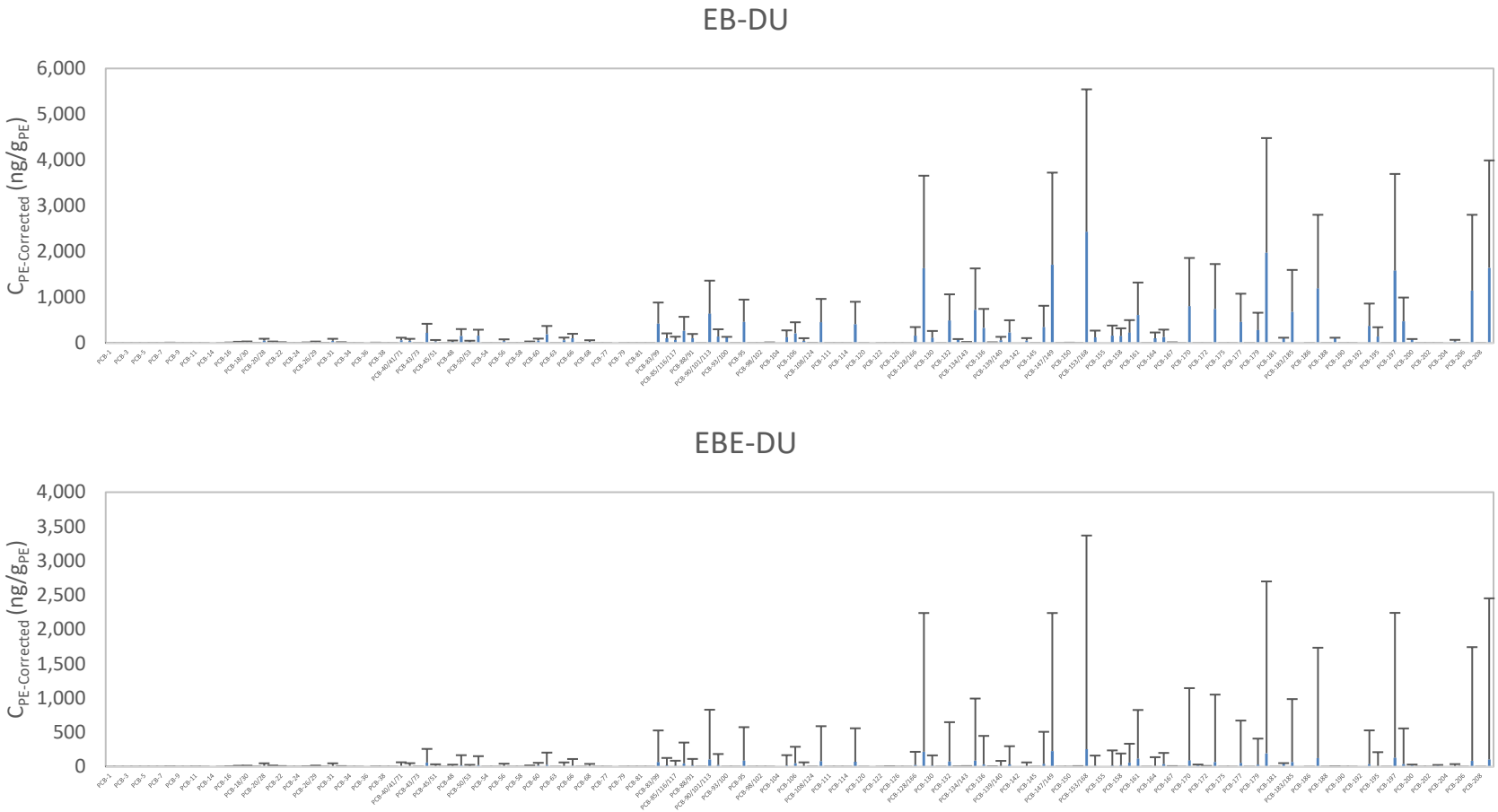

Figure 4. PRC-Corrected PE Concentrations ($C_{PE\text{-}corrected}$) of PCBs Calculated from *ex-situ* experiments with PE passive samplers

3.4 Dissolved Porewater Concentrations of PCDDs/DFs and PCBs

Dissolved porewater concentrations were calculated from PE sampler data using the approach described in Section 2.0. Average calculated dissolved porewater concentrations from triplicate *ex-situ* experiments for PCCDs/DFs are shown in Figure 5 and those for PCBs are shown in Figure 6. Tabular data showing the calculated porewater concentrations for each sampler are listed in Attachments D (PCB congeners) and E (PDCC/DF congeners).

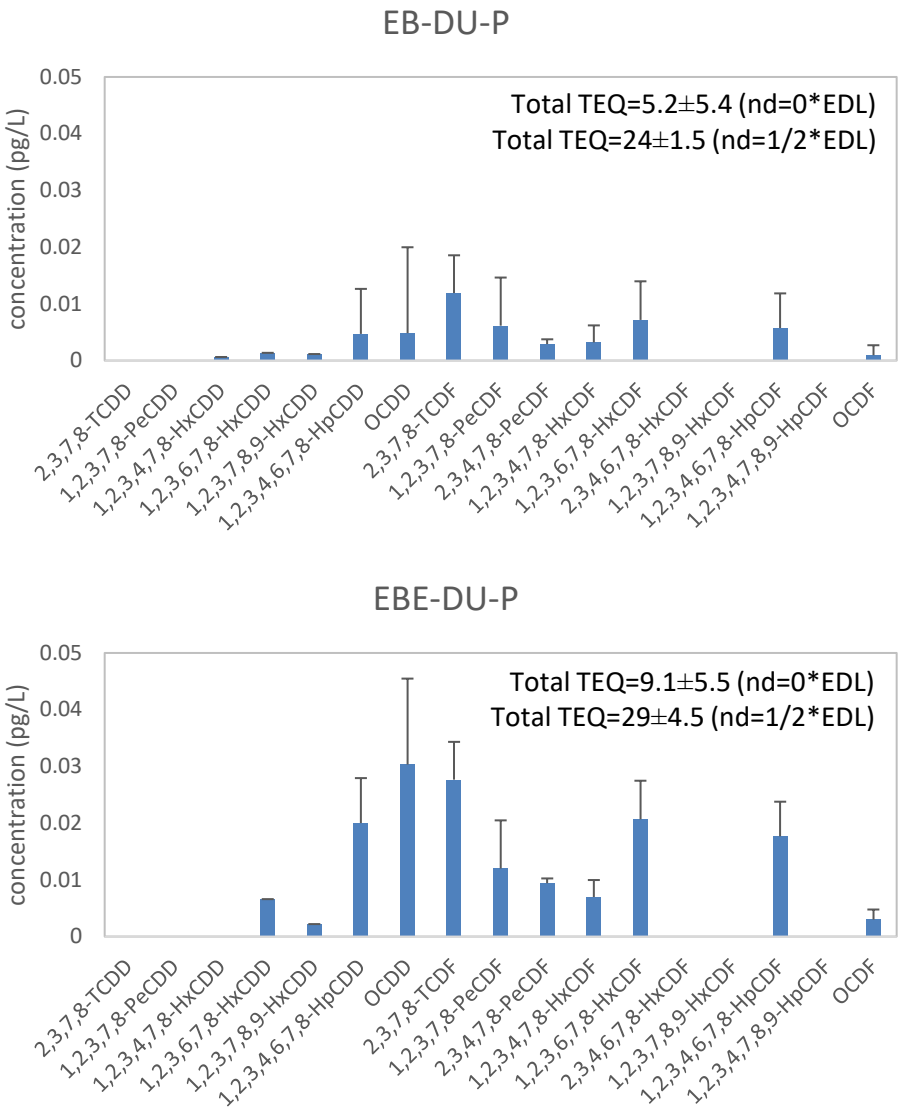

Figure 5. Porewater Concentrations of PCDDs/DFs Calculated from *ex-situ* experiments with PE passive samplers

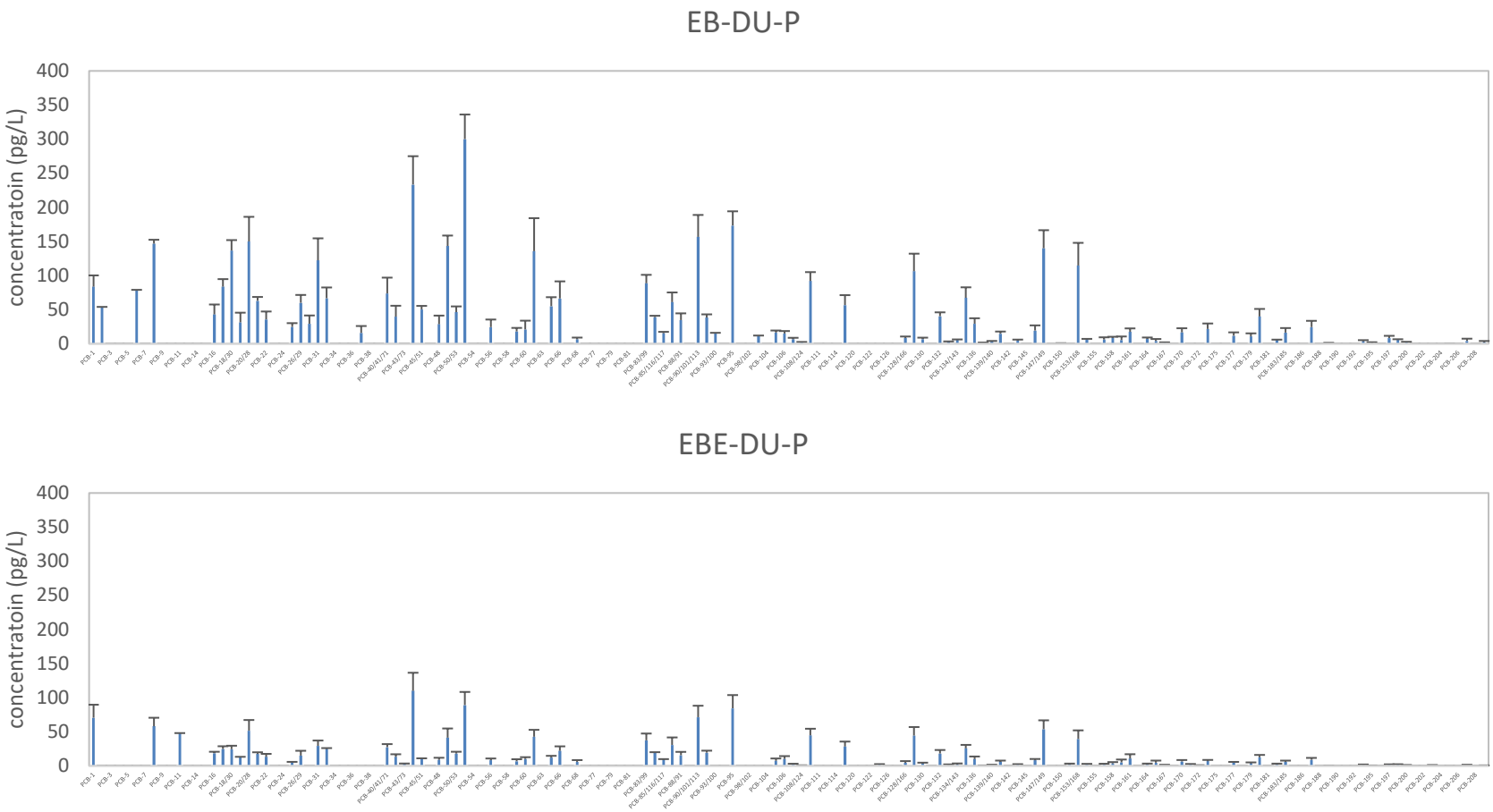

Figure 6. Porewater Concentrations of PCBs Calculated from *ex-situ* experiments with PE passive samplers

3.5 Sediment Concentrations of PCDDs/DFs and PCBs

Concentrations of PCDDs/DFs and PCBs were measured in surface sediment (0-10cm) collected from EB-DU and EBE-DU. Figure 7 shows the concentrations of PCDDs/DFs in EB-DU and EBE-DU sediment, and Figure 8 shows the concentrations of PCB congeners in EB-DU and EBE-DU sediment.

The concentrations and patterns of measured PCDD/DF concentrations were similar in the sediment samples (Figure 7). OCDD was the most abundant congener, followed by other highly chlorinated congeners (e.g., OCDF, 1,2,3,4,6,7,8-HpCDD, and 1,2,3,4,6,7,8-HpCDF). The concentrations of total PCBs in the sediment samples were comparable, particularly after TOC-normalization. Total PCBs for EB-DU was 78,323 pg/g dry weight (dw) (and 6.42 mg/kg TOC normalized) versus 53,139 pg/g dw for EBE-DU (and 5.59 mg/kg TOC normalized) (Figure 8). However, the patterns of measured PCB congeners were slightly different among the sediments. EB-DU had a greater relative abundance of lower molecular weight PCB congeners compared to EBE-DU (Figure 8).

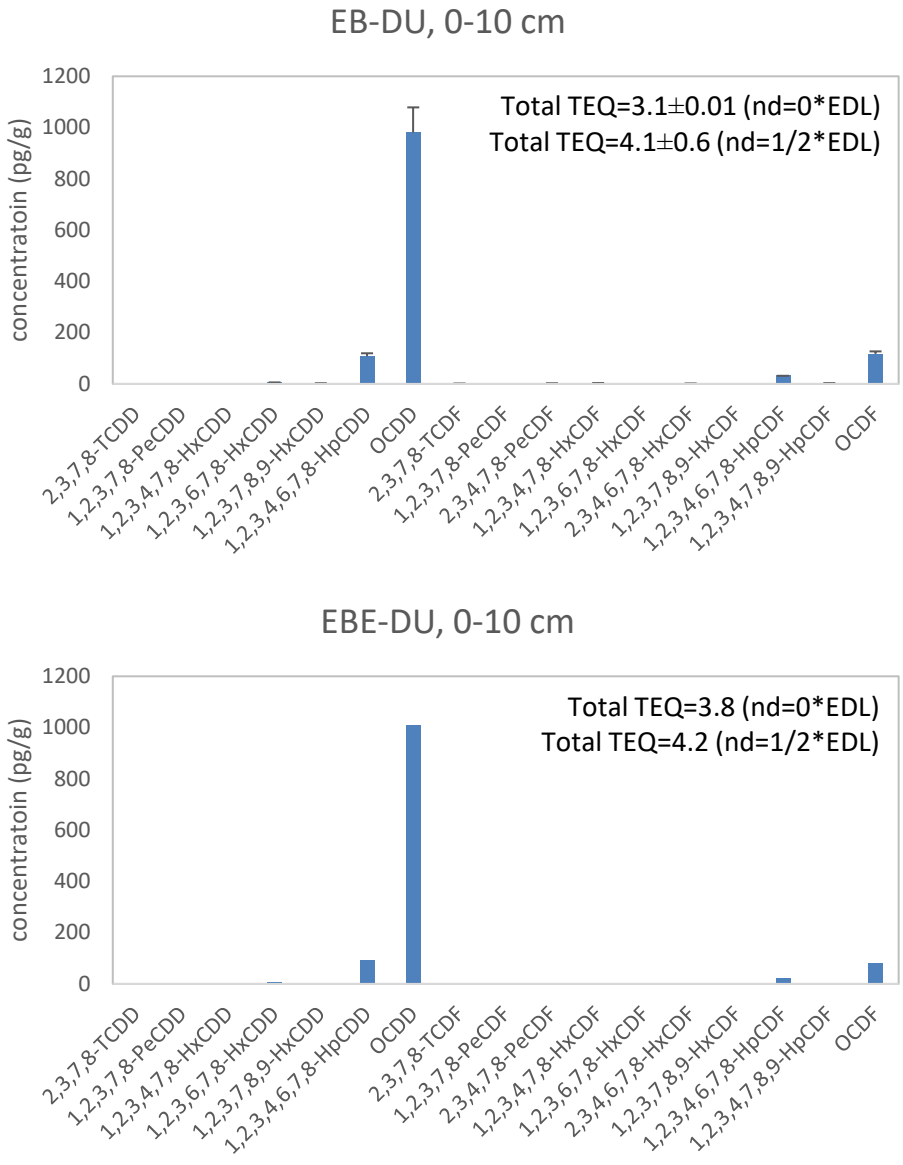

Figure 7. Concentrations of PCDDs/DFs in EB-DU and EBE-DU surface sediment, 0-10 cm. Note: the EB-DU figure (top) represents the average (plus standard deviation) of duplicate measurements, whereas the EBE-DU figure (bottom) represents a single measurement.

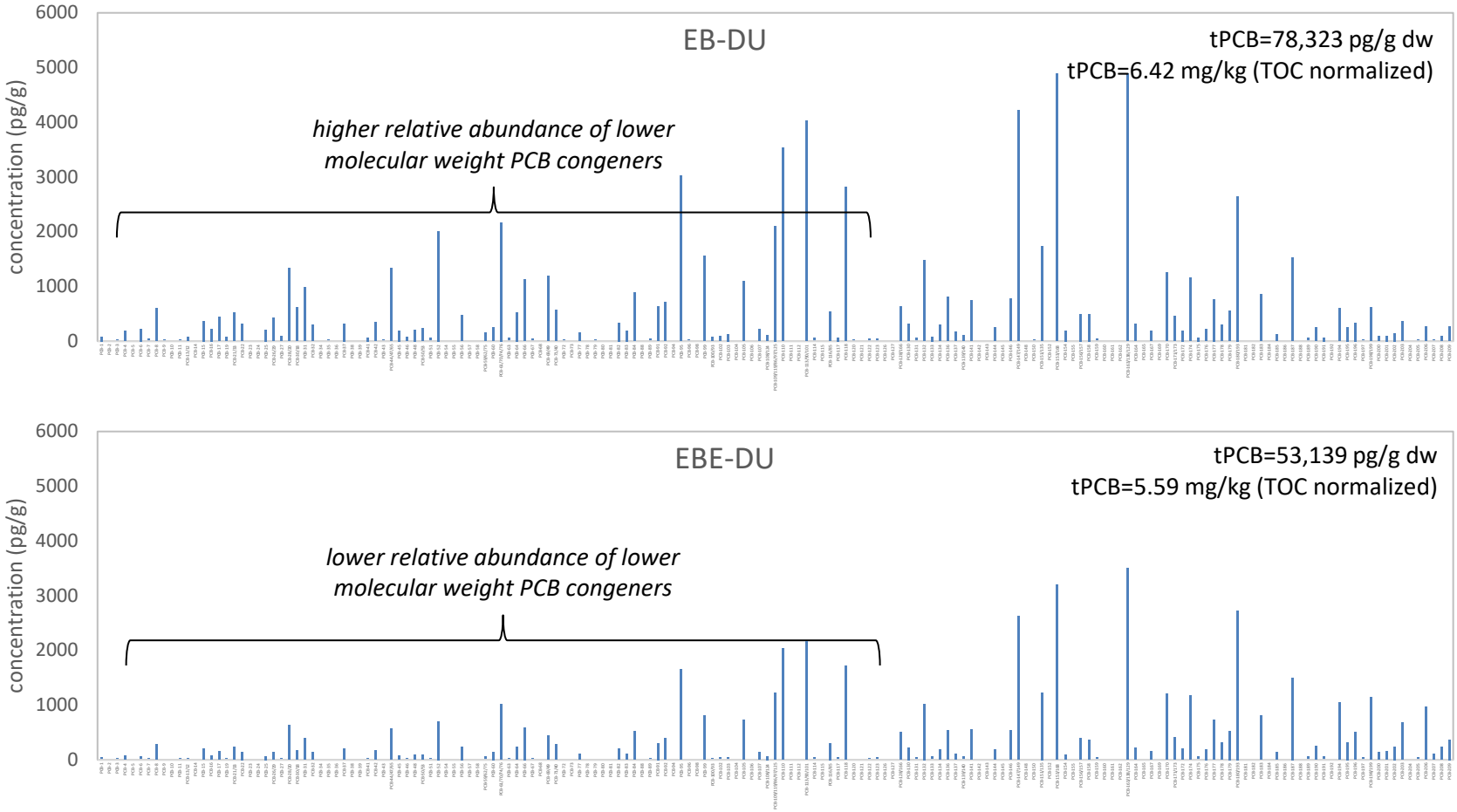

Figure 8. Concentrations of PCB congeners in EB-DU and EBE-DU surface sediment, 0-10 cm.

3.6 Tissue Concentrations of PCDDs/DFs and PCBs following 45-Day Bioaccumulation Tests

Concentrations of PCDDs/DFs and PCBs were measured in *Macoma nasuta* and *Alitta virens* following 45-day bioaccumulation tests. The following subsections describe the results for each of these test species separately.

3.6.1 Concentrations of PCDDs/DFs and PCBs in Macoma nasuta

PCDDs/DFs and PCB congeners were measured in *M. nasuta* pre-test tissues and in tissues after 45-day bioaccumulation tests with EB-DU and EBE-DU sediment. Figures 9 and 10 show the concentrations of PCDDs/DFs and PCBs, respectively, in *M. nasuta* following 45-day bioaccumulation tests with EB-DU and EBE-DU sediment.

The changes in tissue concentrations of PCDDs/DFs and PCB congeners in *M. nasuta* following 45-day bioaccumulation tests varied. For example, only a slight increase in tissue concentrations of the most abundant PCDDs/DFs in *M. nasuta* was observed following exposure to EB-DU or EBE-DU sediment, though there was no increase in TEQ. Conversely, there was a large increase in *M. nasuta* tissue concentrations of PCB congeners following 45-day bioaccumulation tests with both EB-DU and EBE-DU sediments. *M. nasuta* exposed to EB-DU sediment exhibited the highest tissue concentrations of PCB congeners (Figures 10).

The uptake of PCB congeners by *M. nasuta* reflected the subtle differences in sediment chemistry. The profile of PCB congeners in *M. nasuta* tissue after exposure contained relatively more lower molecular weight congeners in the organisms exposed to EB-DU sediment compared to those exposed to EBE-DU sediment. This is consistent with the profiles of PCB congeners measured in sediment samples (see Section 3.5).

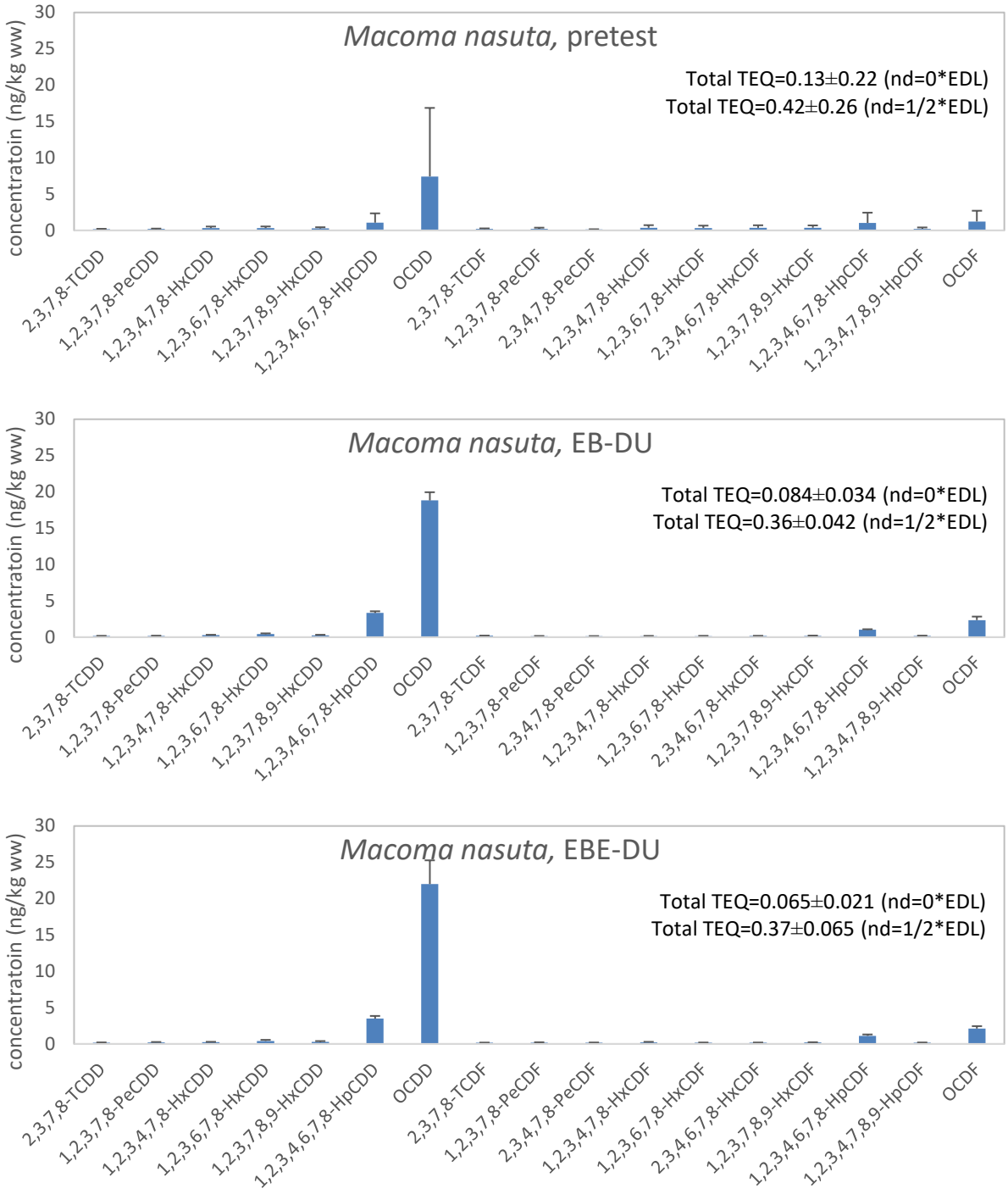

Figure 9. Concentrations of PCDDs/DFs in *Macoma nasuta* following 45-day bioaccumulation tests with EB-DU and EBE-DU sediment. Figures represent average (plus standard deviation) of n=3 measurements for the pretest and n=5 samples each for the EB-DU and EBE-DU bioaccumulation tests. Data are shown on the same scale for comparison.

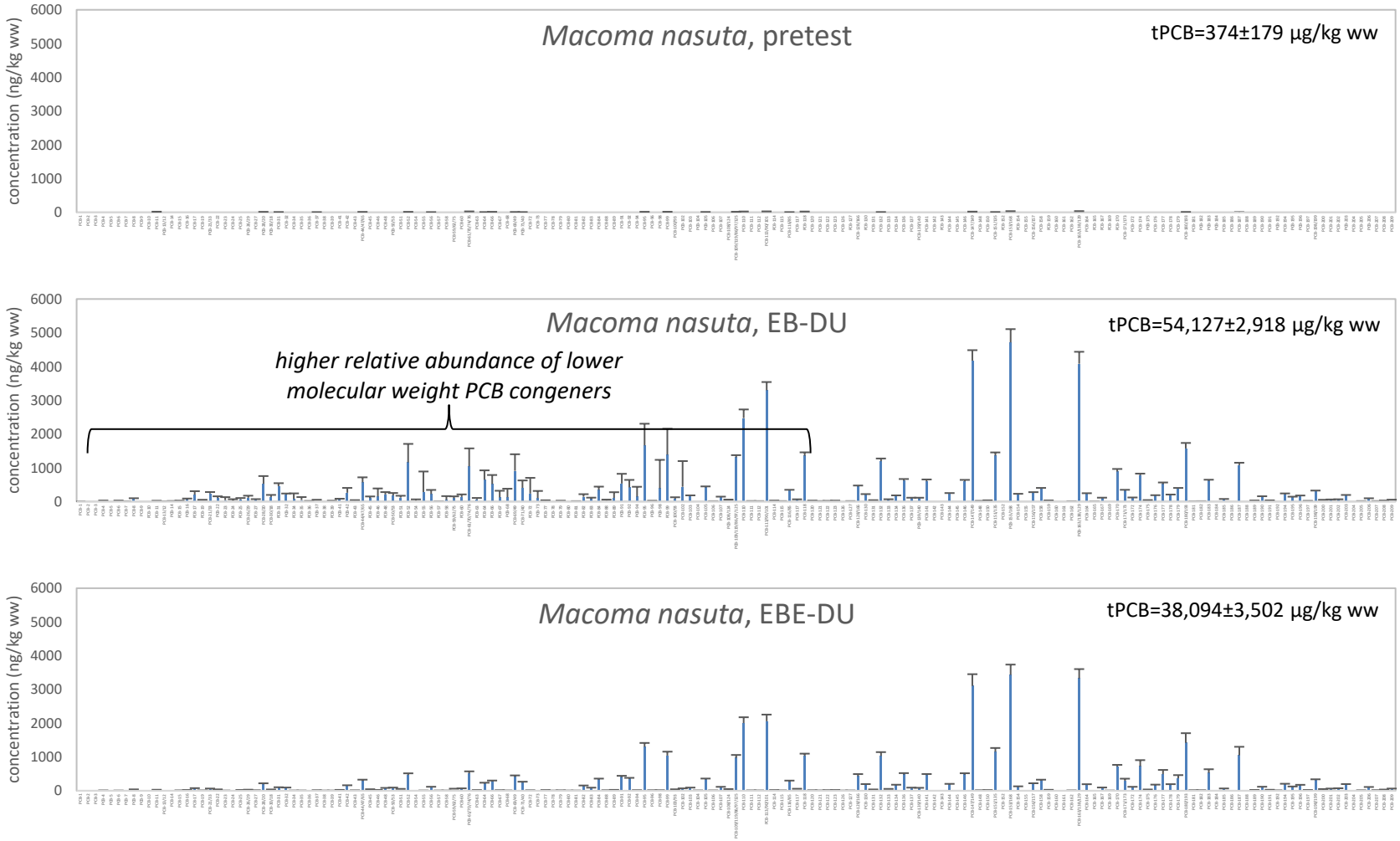

Figure 10. Concentrations of PCB congeners in *Macoma nasuta* following 45-day bioaccumulation tests with EB-DU and EBE-DU sediment. Figures represent average (plus standard deviation) of n=3 measurements for the pretest and n=5 samples each for the EB-DU and EBE-DU bioaccumulation tests. Data are shown on the same scale for comparison.

3.6.2 Concentrations of PCDDs/DFs and PCBs in Alitta virens

PCDDs/DFs and PCB congeners were measured in *A. virens* worm pretest tissues and in tissues after 45-day bioaccumulation tests with EB-DU and EBE-DU sediment. Figures 11 and 12 show the concentrations of PCDDs/DFs and PCBs, respectively, in *A. virens* following 45-day bioaccumulation tests with EB-DU and EBE-DU sediment.

The changes in tissue concentrations of PCDDs/DFs and PCB congeners in *A. virens* following 45-day bioaccumulation tests also varied. Unlike *M. nasuta*, a slight decrease in tissue concentrations of the most abundant PCDDs/DFs was observed in *A. virens* following exposure to EB-DU or EBE-DU sediment. Conversely, there was a large increase in *A. virens* tissue concentrations of PCB congeners following 45-day bioaccumulation tests with both EB-DU and EBE-DU sediments (Figures 11 and 12).

The uptake of PCB congeners by *A. virens* did not reflect the subtle differences in sediment chemistry in the same manner as the uptake of PCB congeners by *M. nasuta* (see Section 3.6.1). The profiles of PCB congeners in *A. virens* tissue after exposure have similar profiles of PCB congeners in organisms exposed to both EB-DU and EBE-DU sediments, even though the EB-DU sediment contained more lower molecular weight congeners relative to EBE-DU sediment (see Section 3.5).

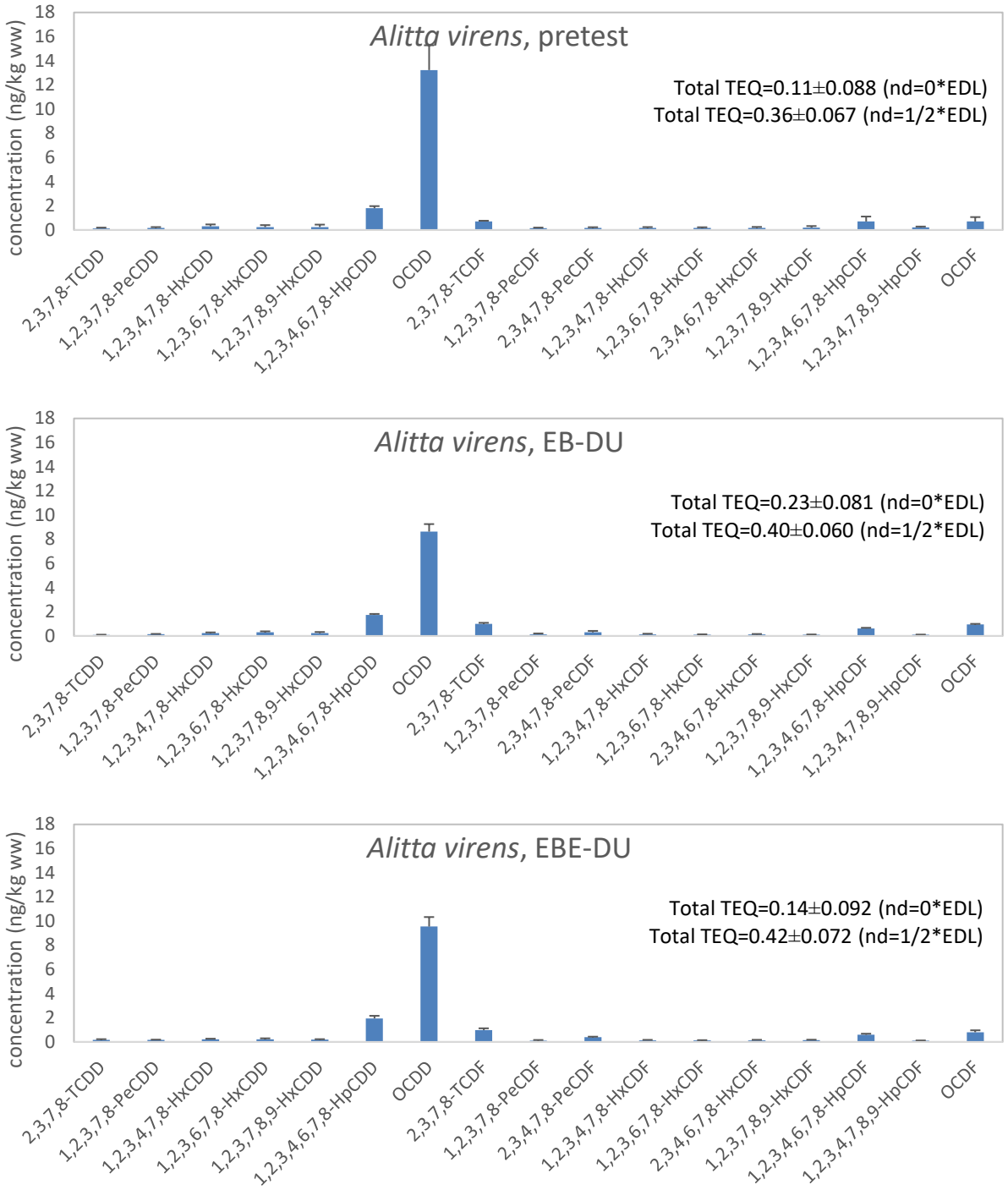

Figure 11. Concentrations of PCDDs/DFs in *Alitta virens* following 45-day bioaccumulation tests with EB-DU and EBE-DU sediment. Figures represent average (plus standard deviation) of n=3 measurements for the pretest and n=5 samples each for the EB-DU and EBE-DU bioaccumulation tests. Data are shown on the same scale for comparison.

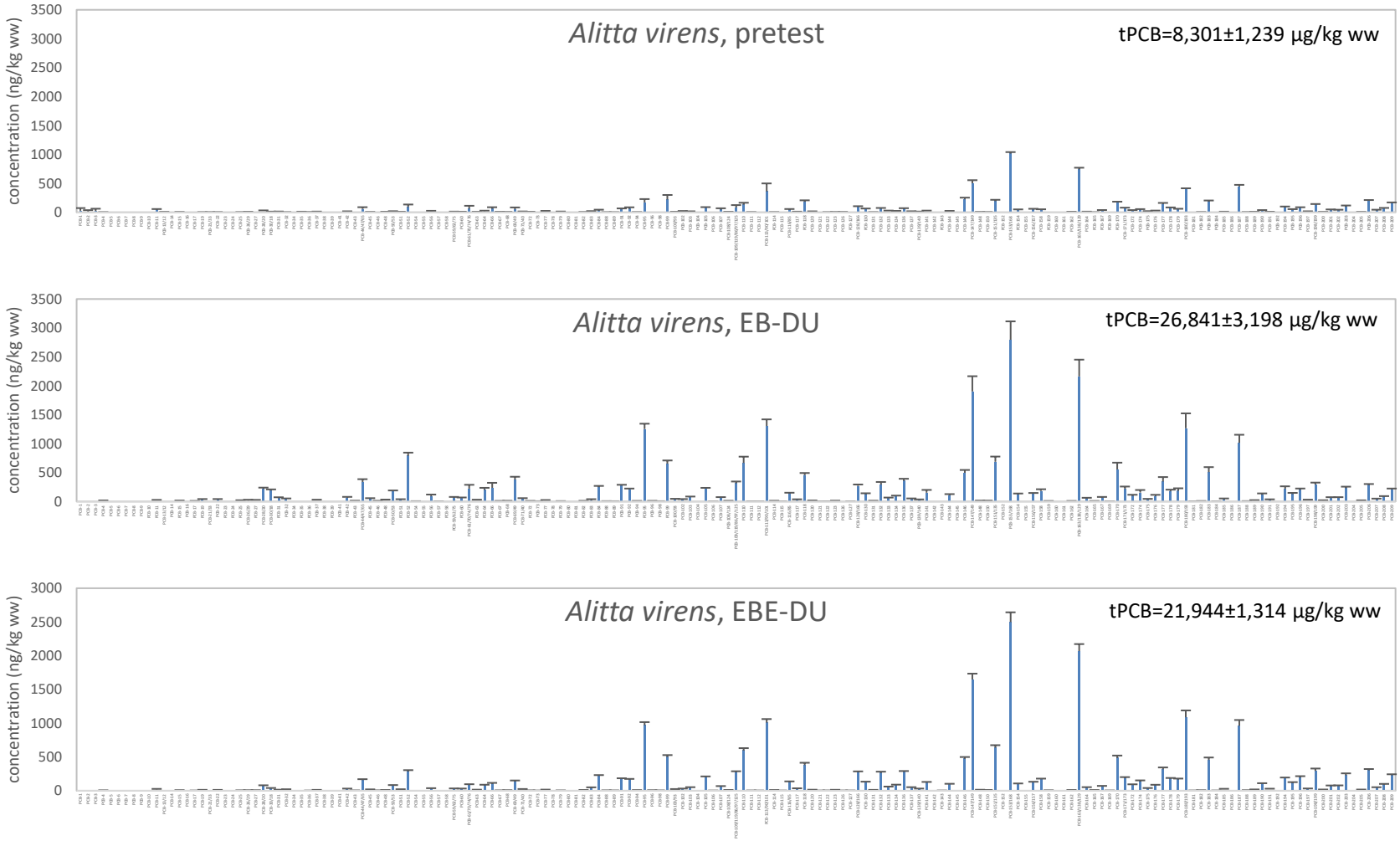

Figure 12. Concentrations of PCB congeners in *Alitta virens* following 45-day bioaccumulation tests with EB-DU and EBE-DU sediment. Figures represent average (plus standard deviation) of n=3 measurements for the pretest and n=5 samples each for the EB-DU and EBE-DU bioaccumulation tests. Data are shown on the same scale for comparison.

3.7 Comparison of PCDD/DF and PCB Congener Data in *M. nasuta* Tissue and Passive Samplers

This section describes the relationship between PCDD/DF and PCB congener concentrations measured in PE samplers and *M. nasuta* tissues after exposure to EB-DU and EBE-DU sediments. Figure 13 shows the PRC-normalized concentration in the PE sampler ($C_{PE\text{-}corrected}$) versus the lipid-normalized *M. nasuta* tissue concentrations of PCDDs/DFs and PCB congeners. For the PCB congener data, the low molecular weight PCB congeners (i.e., LOC1-5) are shown in different symbols from high molecular weight congeners (i.e., LOC6-10). A correlation was observed between both PCDD/DF and PCB congener concentrations in tissues and passive samplers after exposure to sediments.

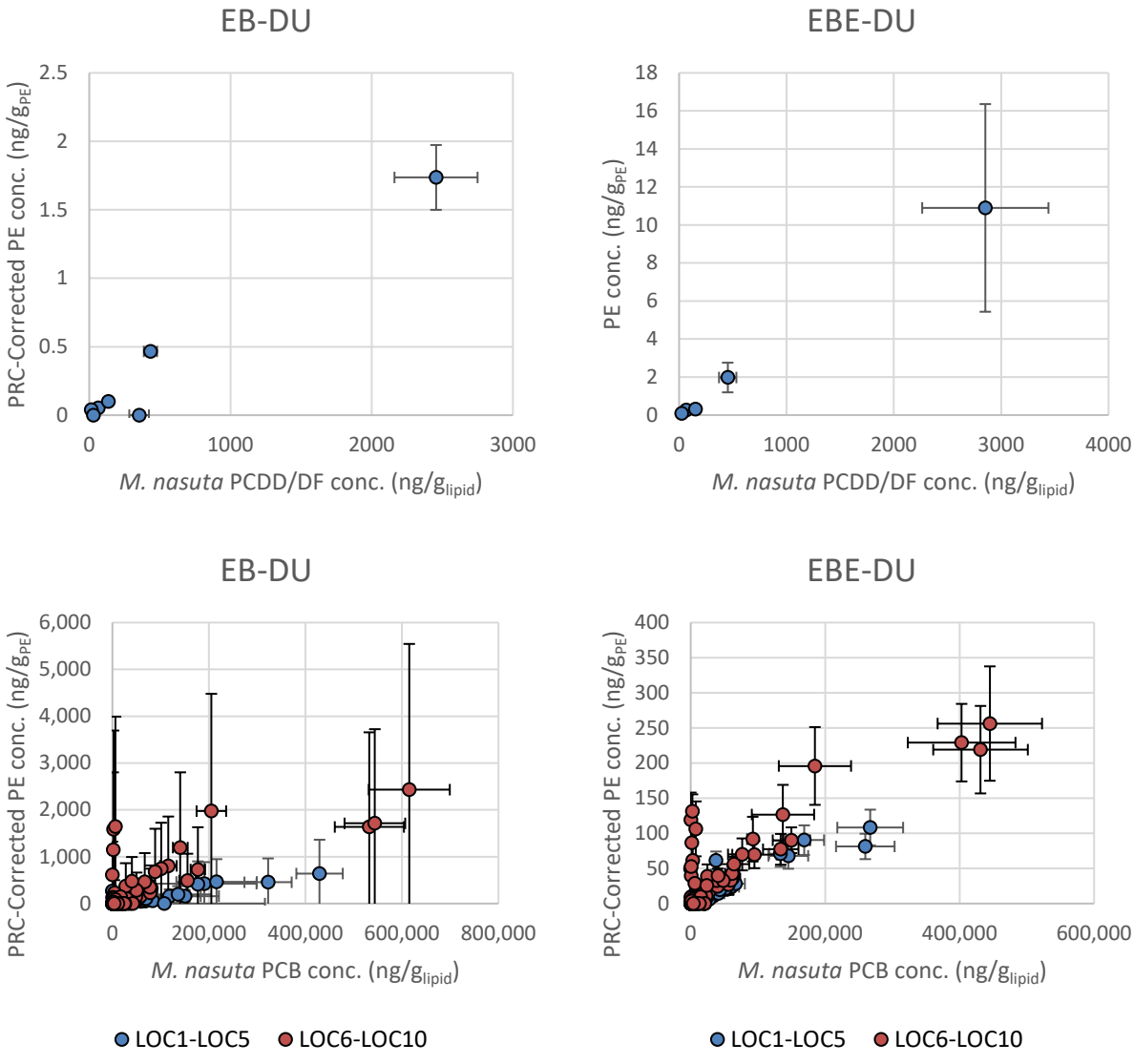

Figure 13. $C_{PE\text{-}corrected}$ **versus** *M. nasuta* **tissue concentrations of PCDDs/DFs and PCB congeners versus PE samplers following exposure to EB-DU and EBE-DU sediment.**

3.8 Comparison of PCDD/DF and PCB Congener Data in *A. virens* Tissue and Passive Samplers

This section describes the relationship between PCDD/DF and PCB congener concentrations measured in PE samplers and *A. virens* tissues after exposure to EB-DU and EBE-DU sediments. Figure 14 shows the PRC-normalized concentration in the PE sampler ($C_{PE\text{-}corrected}$) versus the lipid-normalized *A. virens* tissue concentrations of PCDDs/DFs and PCB congeners. For the PCB congener data, the low molecular weight PCB congeners (i.e., LOC1-5) are shown in different symbols from high molecular weight congeners (i.e., LOC6-10). Similar to *M. nasuta*, a correlation was observed between both PCDD/DF and PCB congener concentrations in *A. virens* tissues and passive samplers after exposure to sediments.

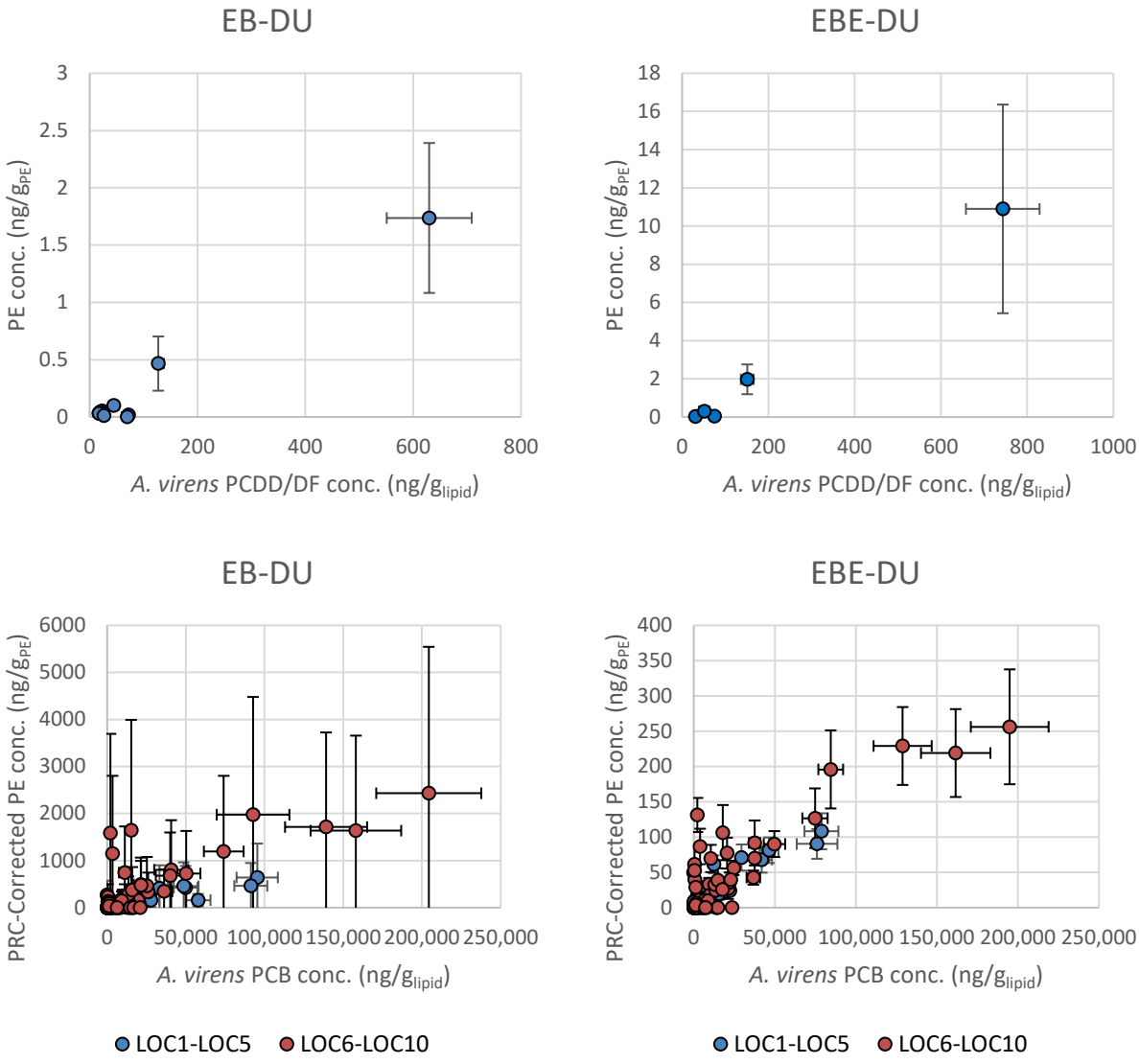

Figure 14. $C_{PE\text{-}corrected}$ versus *A. virens* tissue concentrations of PCDDs/DFs and PCB congeners versus PE samplers following exposure to EB-DU and EBE-DU sediment.

4.0 DISCUSSION

This report provides results of an *ex-situ* sediment exposure study that used PE passive samplers to evaluate concentrations of PCDDs/DFs and PCBs in sediment porewater from the Disposal Site DU and Environs DU at the Elliott Bay disposal site. Additionally, the report describes comparisons of the passive sampler results to *M. nasuta* and *A. virens* tissues following bioaccumulation studies and highlights the use of PE passive samplers for modelling or predicting uptake of PCDDs/DFs and PCBs by benthic organisms.

The use of PRCs allowed for correction for non-equilibrium conditions and a more accurate calculation of dissolved porewater concentrations of PCDDs/DFs and PCBs. A total of ten (10) PRCs were used. Each being a specific PCB congener not typically found in high concentrations in the environment and representing a different LOC. Concentrations of the PRCs measured in the PE samplers after sediment *ex-situ* experiments decreased compared to those in blank samplers, and the loss of PRC ranged from 3-88% in the PCB experiments and 14 to 96% in the PCDD/DF experiments with lower LOC PRCs exhibiting the greatest loss. The wide range of PRC losses suggests that the 45-day exposure time was appropriate for this analysis.

Dissolved porewater concentrations were calculated from PE passive sampler data using PRCs to correct for non-equilibrium conditions. Average dissolved PCB porewater concentrations calculated from triplicate PE *ex-situ* experiments for PCBs were in the low pg/L range (up to 300 pg/L, PCB-52 in EB-DU-P) and dissolved PCDD/DF concentrations were in the sub pg/L range (up to 0.03 pg/L, OCDD in EBE-DU-P). These low concentrations illustrate one of the benefits of passive samplers, specifically the ability to calculate dissolved concentrations at levels far lower than what is afforded by analytical measurements.

Concentrations of PCBs increased in *M. nasuta* and *A. virens* tissues following bioaccumulation tests, whereas the concentrations of PCDDs/DFs were similar or slightly decreased. The increase in PCB concentrations was particularly notable, as concentrations increased by approximately three orders of magnitude. The profile of PCBs in *M. nasuta* generally reflected the differences in PCB sediment chemistry. Specifically, sediment from EB-DU contained a higher relative abundance of lower molecular weight PCB congeners compared to sediment from EBE-DU. Consequently, *M. nasuta* exposed to EB-DU sediment exhibited tissue PCB concentrations containing a higher relative abundance of lower molecular weight PCB congeners compared to organisms exposed to EBE-DU sediment.

Following exposure to EB-DU or EBE-DU sediment, the PE passive sampler data compared favorably to *M. nasuta* and *A. virens* tissue concentrations of PCBs and PCDDs/DFs. A direct comparison was made using the passive sampler concentrations, and not the dissolved concentrations calculated from the passive sampler data, as the passive sampler material (in this case polyethylene) mimics lipids and is therefore a favorable sink for hydrophobic organic contaminants. Additionally, the lipid-normalized tissue concentration was used for the comparison for the same reason. Comparison of PE passive sampler concentrations and lipid-normalized tissue concentrations showed a good correlation for both PCBs and PCDDs/DFs. In both cases, the lipid-normalized tissue concentrations were higher than the passive sampler concentrations, though there was a linear relationship between concentrations suggesting that modelling can be used to predict biological uptake from passive sampler data. However, some lower LOCs are subject to biotransformation, so more information is needed to understand these relationships, particularly for those PCB congeners which can transform.

In the future, the DMMP may adopt the use of passive sampler testing to support a Tier 1 analysis for evaluating bioaccumulative risk of chemicals of concern to on-site resources under Part 1, Goal C of the

DMMP monitoring plan framework (DMMP 2023), or to support development of reference values for each DMMP site.

5.0 REFERENCES

Adams, R.G., R. Lohmann, L.A. Fernandez, J.K. MacFarlane, and P.M. Gschwend. 2007. Polyethylene Devices: Passive Samplers for Measuring Dissolved Hydrophobic Organic Compounds in Aquatic Environments. *Environ. Sci. Technol*. 2007, 41, 4, 1317–1323. Publication Date: January 13, 2007.

DMMP. 2021. Dredged Material Evaluation and Disposal Procedures. USER MANUAL. July 2021. Dredged Material Management Program. Prepared by the Dredged Material Management Office, U.S. Army Corps of Engineers, Seattle District.

DMMP. 2023. In prep. Disposal Site Monitoring Plan: Unconfined Open-Water, Non-Dispersive Dredged Material Disposal Sites in Puget Sound. In preparation for the DMMP Agencies.

NewFields. 2021. SPME Special Study Results. Appendix B to 2020 Pilot Study: DMMP Monitoring of the Port Gardner Non-Dispersive Unconfined Open-Water Dredged Material Disposal Site. July 12, 2021. Submitted to Washington State Department of Natural Resources, Aquatic Resources Division, Olympia, WA. Submitted by NewFields, Edmonds, WA.

NewFields. 2024. 2023 DMMP Monitoring of the Elliott Bay Non-Dispersive Unconfined Open-Water Dredged Material Disposal Site. Final Report. July 11, 2024. Submitted to Washington State Department of Natural Resources, Aquatic Resources Division, Olympia, WA. Submitted by NewFields, Edmonds, WA.

Attachment A

SiREM Passive Sampler Analytical Report (Electronic Copy Only)

Attachment B

PRC-normalized PE concentration ($C_{PE\text{-}corrected}$) of PCBs

Attachment C

PRC-normalized PE concentration ($C_{PE\text{-}corrected}$) of PCDDs/DFs

Attachment D

Dissolved porewater concentration (C_{free}) of PCBs calculated from PE data

Attachment E

Dissolved porewater concentration (C_{free}) of PCDDs/DFs calculated from PE data