Exponent®
15375 SE 30th Place, Suite 250
Bellevue, WA 98007

Technical Memorandum
December 1, 2006

Comments on the Draft Remedial Investigation for the Uplands Environment of the Former Rayonier Mill Site

Exponent, at the request of the City of Port Angeles (the "City"), has reviewed the *Draft Remedial Investigation for the Uplands Environment of the Former Rayonier Mill Site* (remedial investigation report; Integral 2006). The following comments are given on behalf of the City.

The overall goal of the remedial investigation is to fully and accurately characterize the nature and extent of the impact of the site on the uplands environment. The City's purpose in making these comments is to help ensure that this goal is met. The City's interests are twofold 1) to protect the citizens of Port Angeles and to identify conditions that might be harmful to people or the environment; and 2) to ensure that the remedial investigation uses the appropriate and correct methods so that it does not unnecessarily alarm the public where the scientific evidence does not indicate health concerns. Remedial investigations should be inherently conservative (i.e., tending to be overly inclusive in delineating and identifying contamination) to ensure the protection of public health and environment; however, overly conservative assessments or interpretations can lead to unwarranted negative consequences for citizens including fear of hypothetical health effects, stigma for neighborhoods, and even difficulty in both obtaining mortgages and in real estate transactions. Thus, the City has requested that Exponent conduct a review of this document and associated materials (i.e., the Washington State Department of Ecology [Ecology] application of the draft rule amendment to dioxin cleanup levels) to evaluate whether the goals were met using appropriate and technically accurate methods and interpretations.

In our review, Exponent identified the following issues:

- Determining current and future risks to human health and the environment was mistakenly identified as a goal of the remedial investigation. This is the goal of a risk assessment not a remedial investigation. The text should be clarified to remove this goal.
- Future land uses at the site need to be defined as part of the remedial investigation in order to clearly understand the nature of impact from the site and whether all areas of future use have been adequately characterized for potential exposure.
- Current conditions at several onsite areas at which interim actions have been taken in the past may not be adequately characterized. These areas include the Ennis Creek/Finishing Room, the Fuel Oil Tank No. 2, the Hog Fuel Pile, the Machine Shop, and the Spent Sulfite Liquor Lagoon.
- The methods used to sample subsurface soils limit the ability to characterize the vertical extent of impact from the site.

- A discrepancy was noted in surface soil arsenic concentrations in the Bone Yard between samples collected during the remedial investigation and those collected during previous investigations. Additional focused sampling may be necessary to characterize current conditions.
- It is not possible to fully evaluate the nature and extent of impact on offsite residential areas based on the level of detail provided in the remedial investigation. Information from the sampling and modeling efforts must be integrated with each other to provide a complete understanding of the offsite area characterization. It appears that the remedial investigation concludes that no further offsite action is warranted. If so, the remedial investigation should expressly state and justify that conclusion.
- Ecology has proposed a draft rule amendment to Model Toxics Control Act (MTCA) that would revise the soil cleanup level for dioxin and dioxin-like compounds. It is our understanding that Ecology intends to apply the revised rule to the Rayonier site. Our analysis indicates that the current MTCA Method B cleanup level is adequately protective for unrestricted land use and the proposed revised level would potentially be impractical to implement.

These issues are more fully discussed below and represent our primary concerns. The parts of the remedial investigation report that we have not discussed appear to be appropriate or do not warrant comment during this review.

Section 1—Introduction

Page 1-1, third paragraph states, "The objective of the RI is to determine the nature and extent of chemicals of potential concern (COPCs) at the Site and determine the current and future risks to human health and the environment—focusing on collecting, developing, and evaluating enough information to select an appropriate cleanup action." The methods used in the remedial investigation report include comparison of chemical concentrations to cleanup levels. The remedial investigation primarily used MTCA Methods B and C cleanup levels. Method B cleanup levels are health risk-based concentrations calculated to be protective of exposures associated with unrestricted land use, including residential and recreational uses. Method C cleanup levels are also health risk-based, but are designed to be protective of the lower exposures and less sensitive receptors associated with industrial or commercial land use. In some cases where Methods B and C levels were not available, Method A cleanup levels were used. Method A levels may also be health risk-based, but also take into account other factors such as aesthetics (taste and smell) or potential to leach from soil to groundwater. Method A levels were used for petroleum mixtures and lead.

Comparison of chemical concentrations to cleanup levels is useful for identifying site CoPCs and delineating the nature and extent of impact on the site and surrounding areas. However, a risk assessment, including exposure assessment, toxicity assessment, and risk characterization, would need to be conducted to determine current and future risks to human health and the environment. A risk assessment has not been included in this remedial investigation. Thus, the

goals of the remedial investigation report have been misstated in the report. If the goal is to proceed directly from the remedial investigation report to development of a feasibility study and cleanup action plan, it is difficult to see what the cleanup plan will be based on without characterization of site risks.

Recommendation—Clarify the goals of the remedial investigation. A remedial investigation is not intended to determine risks to human health and the environment, and Rayonier mill site remedial investigation has not done so. Therefore, determining risks to human health and the environment should be removed as a stated goal of the remedial investigation.

Section 2—Site Background

The report synthesizes information about site setting and environment, historical and current land use and activities, and available data from previous studies. This provides a sense of current conditions and past exposure patterns. However, land uses at the site and in surrounding areas will likely change significantly in the near future, and exposure patterns will change along with land use. Potential future uses of the site need to be described to provide an understanding of the nature of the impact from the site in the future and whether areas of exposure in the future have been adequately characterized. This information would be best defined as part of a formal conceptual site model (CSM). A CSM describes the network of relationships between chemicals released from a site and the receptors that may be exposed to the chemicals through pathways such as ingestion of soil or water. An appropriate CSM for the Rayonier site would, at a minimum, identify chemical sources, describe potentially complete exposure pathways, and identify likely current and future land uses and potential human and ecological receptors.

Recommendation—Add a section describing a full CSM for the site, including current and potential future land uses and exposures.

Section 3—Interim Actions

Table 1 summarizes the interim cleanup and removal actions conducted at the site, as described in the remedial investigation report and the interim action report (Integral and Foster Wheeler 2003). From our review, the following issues should be further addressed to provide a more complete understanding of the nature and extent of impact at the site.

Recommendation—Include a table similar to Table 1 of this evaluation that summarizes the interim cleanup actions carried out at the site.

Ennis Creek/Finishing Room Area

Section 3.1.1 of the remedial investigation report notes that “many of the [sediment] confirmatory samples [in the 2002 interim action], which were collected from the walls and floor of the excavation prior to backfilling, were compromised by the presence of the sheen” from water infiltrating into the excavation. As discussed in the interim action report (Integral and Foster Wheeler 2003), several samples from the northern end of the excavation had TPH

concentrations that exceeded screening concentrations. This was attributed to the infiltration of water with a sheen into the excavation in this area, compromising the confirmatory sediment samples. Thus, the successful completion of the interim action was based on excavation to the pre-defined limits of excavation, determined through delineation samples collected prior to excavation. Further excavation was also constrained by concerns regarding the integrity of the bridge supports in this area.

Although the practical limits of excavation because of the presence of the bridge are understandable, the limits of confirmation sampling leave the extent of the affected area unknown. The delineation samples from the northern edge of the excavation, where TPH concentrations remain elevated, were collected at depths no greater than 2 ft below ground surface. The excavation appears to have continued to a depth below the delineation samples. Thus, it is possible that the delineation samples do not adequately characterize the vertical OR horizontal extent of subsurface contamination.

Recommendation—Additional characterization at the northern edge of the excavation and beyond may be warranted, to fully understand the extent of affected soil.

Fuel Oil Tank No. 2 Area

Review of Table 3-2 and Figure 3-2 from the interim action report (Integral and Foster Wheeler 2003) indicates that most samples in the 1993 interim action were collected at depth in and around the Fuel Oil Tank No. 2 (FOT2) excavation area. The 2003 interim action at FOT2 was designed to address soil between FOT2 and the hog fuel pile to the east. It is not clear from the data presented or the description provided in either the remedial investigation report or the interim action report whether the extent of impact from FOT2 has been fully characterized.

Recommendation—The following issues should be addressed:

1. Surface soil in the area to the west and north of FOT2 does not appear to be adequately characterized. Surface soil confirmation samples were not collected outside the excavation area. If surface soil is not expected to be affected, this needs to be stated and supported.

2. Some subsurface samples outside the excavation area exceeded the TPH cleanup level after the 1993 interim action. These areas were subsequently addressed during the 2002 interim action. However, the interim action report indicates that some TPH-impacted soil remained after the 2002 action under a cement slab. The remedial investigation report confirms in Section 3.1.2 that pockets of TPH-impacted soil remain in the FOT2 area at concentrations above screening levels, but states “further excavation in these areas was deemed unjustified due to the extremely limited extent of this residual TPH.” The extent of residual is unclear from the available data because the residual is below a cement slab. At minimum, the remedial investigation report should make an attempt to better quantify the remaining TPH and discuss the potential impact should the slab be removed and expose the TPH-impacted soil.

3. The remedial investigation report states that "confirmation sampling demonstrated the cleanup action had achieved the removal of the vast majority of soils containing >500 ppm TPH." While it is true that the majority of confirmation samples had petroleum hydrocarbon concentrations that met cleanup levels, Table 5-5 of the interim action report indicates that five samples did not, with diesel-range organic (DRO) concentrations as high as 39,000 ppm. The ability to evaluate the implications of these five samples was limited by the absence of Figure 5-4 from the report. This figure is suppose to show the confirmation sample locations for the FOT2 area, is missing from the report. The implications of these elevated petroleum concentrations should be further discussed in the remedial investigation report.

Hog Fuel Pile Area

It is unclear from either the remedial investigation report or the interim action report whether confirmation samples were collected after the 2001 hog fuel pile excavation, or the 2002 excavation at the southwest corner of the hog fuel pile adjacent to FOT2. From the information provided, it is not possible to understand the nature and extent of impact in the area or to ascertain whether the cleanup goals were achieved by the interim actions.

Recommendation—Information about the above described confirmation samples should be added to the remedial investigation report. In addition, the basis for the delineation of 2001 and 2002 excavation areas should be included.

Machine Shop Area

Sidewall confirmation sample MCH0004 had a lead concentration of 1,100 ppm, well above the unrestricted cleanup level. Lead was not elevated in any other sample. This result was attributed to "the occasional presence of small pieces of metal included in the soil sample" in the interim action report, and follow-up sampling was deemed unnecessary. However, without further analysis this explanation is only supposition. While the lack of elevated lead concentrations in adjacent samples is consistent with this explanation, the fact that this sample was collected at the southern edge of the excavation with no additional samples outside the excavation to provide confirmation that MCH0004 is anomalous, a certain amount of uncertainty remains as to the nature of impact in this area.

As noted in the interim action report, an approximately 5-ft wide concrete support structure was left in place during the excavation and backfill that took place as part of the interim action. As a result, the soil below the concrete was not characterized.

Recommendation—Provide further information about analyses that were completed, if any, to support the explanation given for the elevated lead concentration in MCH0004. At a minimum, the uncertainty associated with the lead concentration in this sample should be more fully discussed in the remedial investigation report, and may need more investigation. In addition, the decision to leave the concrete support structure in place without characterization of the soil

below it should be more clearly described in the remedial investigation report and the potential implications (e.g., whether contaminated soils remain and the fate of this contamination) discussed.

Spent Sulfite Liquor Lagoon

Section 3.1.5 of the remedial investigation report states that no chemicals were above MTCA Method B levels, or in the case of arsenic the MTCA Method A cleanup level for industrial sites based on background. Currently, both the unrestricted and industrial cleanup levels for arsenic are 20 ppm, based on background.

It is unclear from the remedial investigation report whether confirmation samples were collected from the spent sulfite liquor lagoon prior to backfill. Similarly, the locations and depths of samples are unclear. Were samples collected from below the clay liner? The sampling protocol indicates that samples were collected only from the berm and the liner, and that none were collected from below.

Recommendation—The remedial investigation report should clarify the basis for arsenic cleanup level for the spent sulfite liquor lagoon interim action, and indicate whether or not it meets the unrestricted criteria. The remedial investigation report should also clarify the number, locations, and types of samples collected in this area. In addition, the implications of the lack of confirmation samples below and around the perimeter of the lagoon (e.g., whether contaminated soils remain and the fate of this contamination) should be discussed.

Section 4—Field Sampling

According to Section 4.1, subsurface soil samples were collected at a depth of 3 in. to groundwater (ranging from 3.5 to 16 ft below ground surface). The entire subsurface soil horizon was then homogenized prior to analysis. Using this method it is not possible to determine the vertical extent of contamination. This would be a particular issue where surface soil concentration exceeded a cleanup level, but the co-located subsurface sample did not. This method of sampling limits the ability to evaluate the nature and extent of impact on subsurface soil.

Recommendation—The limitations associated with the sampling method should be discussed in the remedial investigation report and results evaluated to determine whether focused sampling is necessary at specific locations using a method that is able to discern differences in chemical concentrations at different soil horizons.

Section 5—Nature and Extent of CoPCs in Soil and Sediment

Bone Yard

The third paragraph of Section 5.1.2.2 states, "ESI sampling at the bone yard evaluated five locations (E&E 1998). Four locations were sampled at 0- to 2-ft intervals and 2- to 4-ft intervals for a total of eight samples. At one additional location, samples were collected from 0 to 10 ft in 2-ft intervals for a total of five samples. Groundwater was detected at 10 ft bgs. All of these samples were analyzed for a suite of chemicals." A surface soil sample that combines the 0- to 2-ft horizon potentially dilutes the concentrations of chemicals that may be present at higher concentration near the top 0 to 3 cm, where direct exposure to soil is most likely.

As discussed in Section 5.1.2.2, the arsenic concentration in sample BY02 collected during the remedial investigation was significantly lower than the arsenic concentration from a co-located sample collected during the ESI. In fact, the former was below background and the latter above. Several possible explanations were presented. The best way to address the discrepancy would be to collect additional confirmation samples in the area.

Recommendation—The limitations associated with the sampling method should be discussed in the remedial investigation report and results evaluated to determine whether focused sampling is necessary at specific locations to evaluate chemical concentrations at the top 0 to 3 cm of soil. This could be used to address the arsenic concentration discrepancy as well.

Offsite Residential Areas

The nature and extent of impact on residential areas downwind of the site does not appear to be adequately characterized according to the information presented in the main text. The remedial investigation relies primarily on modeling to characterize the nature and extent of offsite residential areas. While modeling is a useful tool for predicting fate and transport characteristics for the purpose of designing a better, more efficient sampling plan, it is not a replacement for sampling. The existing offsite data available from the expanded site inspection (ESI) may be adequate to characterize current conditions in conjunction with modeling, but the level of detail provided in the remedial investigation report does not provide enough information to fully evaluate the situation. Atmospheric deposition modeling of particulates was compared to surface soil sampling data in onsite and offsite soil via cluster analysis and regression, as discussed briefly in Section 5.2.1 of the remedial investigation. However, the results of this analysis and conclusions based on these results are not stated. Further details are provided in Appendix H regarding the methods and assumptions used in the model, but there is still no clear statement of results and conclusions.

A congener analysis was also conducted, comparing the patterns of dioxins and furans in offsite soil samples with the pattern from one source sample of stack particulates from the hog fuel boiler, and with the patterns from typical urban background samples (Malcolm Pirnie 2005). But this analysis is only mentioned in passing at the end of Section 5.2.2 of the remedial investigation without any discussion of scope, methods, results, or conclusions.

Recommendation—One of the goals of the remedial investigation was to evaluate what effects, if any, the Mill had on surrounding areas. From the remedial investigation report, it appears that no further investigation is being recommended to characterize the impact of the Mill on offsite areas. If this is so, the report should more clearly state this conclusion and provide clear supporting rationale. Information from the sampling and modeling efforts must be integrated with each other to provide a complete understanding of the offsite area characterization. In particular, the remedial investigation should 1) provide an analysis of how well the sampling and modeling efforts complement and validate each other, 2) provide a clear statement of the methods, results and conclusions for both the atmospheric deposition modeling and the dioxins and furans pattern analysis, and 3) describe data gaps and their significance in characterizing offsite areas.

Ecology's Proposed Soil Cleanup Levels for Dioxins/Furans

Ecology has proposed a draft rule amendment to MTCA that would revise the soil cleanup level for dioxin and dioxin-like compounds. It is our understanding that Ecology intends to apply the revised rule to the Rayonier site. Because of this, we have attached our technical evaluation of the proposed draft rule amendment (Attachment A). In our evaluation we review the overall basis of health risk assessment for dioxins, present the change in the dioxin cleanup level that would result from the draft rule amendment, and discuss the scientific evidence on the health protectiveness of this level. We also provide perspective on national cleanup levels set by the federal government and on how the revised MTCA cleanup level would compare to background levels to which much of the population is exposed.

Under the draft rule amendment, the MTCA cleanup level for toxicity equivalent (TEQ) mixtures of dioxin and furan congeners (i.e., chemically similar compounds that differ in numbers and position of chlorine atoms in molecular structure) would be 10 times lower than the current value. Dioxin and furans are assessed as a combined mixture of similar compounds called congeners. Because these congeners differ in toxicity relative to the most toxic congener (2,3,7,8-tetrachlorodibenzo-*p*-dioxin [TCDD]), the concentration of each congener is multiplied by a toxic equivalency factor (TEF) that relates its toxicity to that of TCDD before adding the concentrations to yield the total TEQ. Scientific evidence, however, indicates considerable protectiveness in how risks and cleanup levels are developed for these compounds, and does not support the necessity of a more stringent level for protection of human health (see Attachment A).

A recent publication by Sutter et al. (2006) provides additional evidence to that presented in Attachment A that the TEF method used to assess the toxicity of different dioxin congeners is highly uncertain and likely to overestimate the toxicity of dioxin mixtures to humans. Specifically, one of the more common and most persistent dioxin congeners in environmental samples, 1,2,3,4,6,7,8,9-octachlorodibenzo-*p*-dioxin (OCDD), is likely to compete with the most toxic of the congeners, TCDD, for binding to key metabolic enzymes in the body that results in the formation of compounds responsible for toxicity. Because OCDD is many times less toxic than TCDD, this compound may be an antagonist to TCDD and actually reduce TCDD toxicity. Dioxin congeners are also less potent in causing toxicity in human cell models than in rodent cell models, from which the TEF values for individual dioxin congeners have

been estimated, and this difference is even more pronounced for the congeners of weaker potency such as OCDD. Lastly, Sutter et al. (2006) note that the TEF values are based on studies conducted in rodents using concentrations much higher than commonly found in the environment. Whether this mechanism is even relevant at lower exposure concentrations is unclear. Thus, given the highly conservative (i.e., overestimating risk) nature of the current methods for calculating the risk of dioxin congener mixtures, additional stringency in the target risk level for the total mixture is unwarranted for the protection of public health.

Nationwide cleanup levels considered health protective by the U.S. Environmental Protection Agency and Agency for Toxic Substances and Disease Registry are orders of magnitude higher than the cleanup level that would result from the draft rule amendment. Moreover, the lower Method B cleanup level in the draft rule amendment is within background levels in populated areas of Washington, and near analytical detection limits. While comparison to urban background may not be appropriate for Port Angeles, the proposed cleanup level of 6.67 ppt TEQ is not far from the sum of half the analytical limits of detection of each of the 17 congeners. Thus, because the toxicity equivalence factor concentrations of even undetected congeners are assumed to be present and added together, barely detectable dioxin concentrations could exceed the proposed Method B cleanup level. Therefore, this draft rule amendment is not necessary to protect public health and will potentially be impractical to implement.

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Table 1. Rayonier Port Angeles upland interim cleanup and removal actions

Area	Chemicals Present	Soil/Sediment Cleanup Level (ppm)	Materials Left in Place	Cleanup Achieved (Y/N)	Basis of Cleanup Levels	Notes
Finishing Room – Ennis Creek 1998 Interim Action	TPH PCBs	1,000 10	All samples below PCB cleanup level; 45 of 47 below TPH cleanup level; 2 slightly above.	No.	MTCA Method B, Unrestricted.	Groundwater pump and treat yielded undetected results for TPH and PCBs.
Finishing Room – Ennis Creek 2002 Interim Action	TPH diesel TPH heavy oil PCBs	100 200 0.021	TPH concentrations above cleanup levels remain at northern edge of excavation; attributed to infiltration of water with sheen into excavation, compromising sediment samples.	Yes, based on excavation to limits of pre-delineated area. But some exceedances remain.	MTCA Method B, Unrestricted and protection of aquatic organisms for PCBs.	Groundwater pump and treat yielded undetected results for TPH and PCBs.
Former Fuel Oil Tank No. 2 1993 Interim Action	TPH PCBs (Aroclor® 1254)	1,000 1	Some elevated TPH concentrations remaining outside excavation area.	No.	MTCA Method B, Unrestricted for PCBs and Residual Saturation Level for TPH.	
Former Fuel Oil Tank No. 2 2002 Interim Action	TPH diesel TPH heavy oil PCBs	2,000 2,000 0.5	Some elevated TPH concentrations remaining outside excavation area under a cement slab.	Yes, according to report, but some elevated concentrations remain under cement slab.	MTCA Method B, Unrestricted for PCBs and Residual Saturation Level for TPH.	Metals and VOCs were also evaluated.
Hog Fuel Pile	TPH diesel TPH heavy oil PCBs	2,000 2,000 0.5	Unclear.	Unclear. Location, nature and extent of confirmation samples unknown.	MTCA Method B, Unrestricted for PCBs and Residual Saturation Level for TPH.	Metals and VOCs were also evaluated.
Former Machine shop	TPH diesel TPH heavy oil PCBs	2,000 2,000 0.5	One high lead concentration.	Yes, according to report, but one elevated soil lead concentration remains.	MTCA Method B, Unrestricted for PCBs and Residual Saturation Level for TPH.	Metals and VOCs were also evaluated.

Table 1. (cont.)

Area	Chemicals Present	Soil/Sediment Cleanup Level (ppm)	Materials Left in Place	Cleanup Achieved (Y/N)	Basis of Cleanup Levels	Notes
Spent Sulfite Liquor Lagoon	TPH diesel TPH heavy oil PCBs	2,000 2,000 0.5	Unclear.	Yes.	MTCA Methods A and B , Unrestricted.	PCDD/Fs and metals were also evaluated.

Note: MTCA - Model Toxics Control Act
PCB - polychlorinated biphenyl
PCDD/F - polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran
TPH - total petroleum hydrocarbon

Attachment A

Evaluation of the Effect of the Model Toxics Control Act Draft Rule Amendment for Dioxins in Soil

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Technical Memorandum

Evaluation of the Effect of the Model Toxics Control Act Draft Rule Amendment for Dioxins in Soil

Prepared for

City of Port Angeles
Port Angeles, Washington

Prepared by

Exponent

15375 SE 30 Place, Suite 250
Bellevue, WA 98007

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Evaluation of the Effect of the Model Toxics Control Act Draft Rule Amendment for Dioxins in Soil

This memorandum evaluates cleanup level revisions for dioxin and dioxin-like compounds (a.k.a. dioxins) that would result from the Washington State Department of Ecology's (Ecology's) July 2006 Draft Rule Amendment for their Model Toxics Control Act (MTCA). The focus of this evaluation is the health protectiveness of the Method B cleanup level for unrestricted land use and the risk assessment methodology that forms the basis of this cleanup level.[1] In particular, this memorandum evaluates whether the revised cleanup level is necessary for the protection of health.

The following sections review the overall basis of health risk assessment for dioxins, present the change in the dioxin cleanup level that would result from the draft rule amendment, and discuss the scientific evidence on the health protectiveness of this level. Perspective is also provided on national cleanup levels set by the federal government and on how the revised cleanup level would compare to background levels to which much of the population is exposed.

This evaluation finds that the proposed Method B cleanup level is unnecessarily stringent. In addition, because this proposed cleanup level is likely to be below background concentrations in many areas in the state, implementing this stringent cleanup level would be impractical.

Background on Dioxin Risk Assessment

Risk assessment is a regulatory tool that provides information about hypothetical risks under assumed exposure conditions. Because risk assessment is conducted to protect public health even for the maximum reasonably exposed individual, it is likely to overestimate risks for many individuals.

Dioxin is the common term for polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDDs/Fs), a group of two structurally similar families of chlorinated chemicals that differ in their number and position of chlorine atoms in each congener. Dioxin congeners are ubiquitous in the environment. Industrial sources of PCDDs/Fs include incineration of municipal and certain industrial wastes, chlorination processes used in pulp and paper manufacturing and other water treatment systems, and the production and use of certain chlorinated pesticides. Residential sources are also common, such as wood and trash burning, fossil fuel combustion emissions, and other combustion sources. PCDDs/Fs are typically present in the environment as a mixture of many individual compounds. One member of a group of PCDD/F congeners, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) is the most extensively studied and is thought to be the most toxic compound within this chemical class. As a result, the toxicity and

[1] The less-used Method C cleanup level for industrial land use has a risk assessment basis similar to the Method B level, but is ten times higher because a ten times higher risk goal is applied. Thus, comments regarding the risk assessment basis of the Method B cleanup level are also applicable to the Method C cleanup level.

other data for this chemical frequently provide the foundation for assessing the hazard associated with related congeners that are less well studied. In particular, some of these congeners, especially those with chlorine at the 2, 3, 7, and 8 positions, have shown effects similar to those of 2,3,7,8-TCDD and thus are included in dioxin risk assessments.

The U.S. Environmental Protection Agency (EPA) has classified 2,3,7,8-TCDD as a probable human carcinogen (i.e., Group B2 carcinogen) based on inadequate data in human populations, but sufficient evidence in laboratory animals. Although numerous epidemiological studies have been undertaken to assess the potential carcinogenicity of 2,3,7,8-TCDD and related compounds in humans, such studies have not shown strong evidence of carcinogenicity in humans and generally suffer from several limitations. In particular, accurate exposure data typically have been lacking and the studied individuals have frequently had potentially confounding exposures to other chemicals. The toxicity of dioxins has been shown to vary greatly among animal species. Humans do not appear to be the most sensitive, but use of animal data including the most sensitive species is part of health-protective regulatory policy.

EPA is in the midst of re-evaluating the toxicity of PCDD/Fs, but most risk assessments of dioxin compounds in soil are still evaluated based on a prior carcinogenic slope factor for ingestion or inhalation of 2,3,7,8-TCDD of 1.5×10^5 $(\text{mg/kg-day})^{-1}$ (U.S. EPA 1985). This value was derived on the basis of data indicating an increased incidence of tumors of the liver, lung, and nasal turbinates observed in female rats in a chronic feeding study conducted by Kociba et al. (1978). This toxicity value was derived through application of doses much higher than those experienced by people in the workplace or the environment, and assumes that there is no threshold below which a carcinogenic risk for PCDD/Fs is zero.

EPA has not developed quantitative toxicity factors for any other specific PCDD/F congeners because of the limited toxicological information available for these compounds.[2] Instead, EPA applies a toxicity equivalence factor (TEF) approach for quantitatively estimating the toxicity of 16 other congeners (with chlorine substitutions in the 2,3,7,8 positions) that is based on their likely toxicity relative to that of 2,3,7,8-TCDD (van den Berg et al. 1998). These TEFs were recently re-evaluated by a World Health Organization (WHO) expert panel (van den Berg et al. 2006). The TEF approach was developed under the assumption that dioxin-like chemicals exert their carcinogenic effect via a similar mechanism of action in the body. In the TEF approach, 2,3,7,8-TCDD is assigned a weighting factor, or TEF, of 1. The other 16 PCDD/F congeners are assigned weighting factors based on their toxicity relative to 2,3,7,8-TCDD. To apply the TEF approach to a PCDD/F mixture, the concentrations of the 17 congeners (including 2,3,7,8-TCDD) are multiplied by their respective TEFs and are then summed to yield the equivalent concentration of 2,3,7,8-TCDD. This sum is termed the 2,3,7,8-TCDD toxic equivalent (TEQ). Individual congeners differ greatly in toxicity (e.g., TEFs range from 1 to 0.00001 times the toxicity of 2,3,7,8-TCDD). There is considerable uncertainty related to the

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[2] EPA has developed a cancer slope factor for use in estimating risks associated with ingestion and inhalation exposures to mixtures of hexachlorodibenzo-*p*-dioxins (U.S. EPA 2006). Risk assessments for PCDDs/Fs, however, typically use the TEF approach to estimate the carcinogenic risks associated with these compounds. The TEF approach yields more conservative risk estimates.

TEFs used in these calculations as noted by Ecology in their documentation and as discussed further below.

Impact of Draft MTCA Rule Amendment for Dioxins

In response to ambiguity in the MTCA rule, the draft rule amendment clarifies Ecology's policy on how TEF values should be used in establishing MTCA Method B and Method C cleanup levels. Under Method B (unrestricted land use), the total site risk for carcinogenic substances cannot exceed 1 in 100,000 (10^{-5}) and the cancer risk for individual substances cannot exceed 1 in a million (10^{-6}). Under Method C (industrial land use), these target risk levels are ten times higher. MTCA allows the use of TEF values to assess the potential cancer risk and develop cleanup levels for dioxin and furan mixtures. The draft rule amendment specifies that mixtures of dioxin and furan congeners, however, be considered a single hazardous substance rather than multiple hazardous substances in determining compliance with MTCA cleanup levels and remediation levels. Accordingly, a cancer risk of 10^{-6} would be applied to the TEQ for the mixture (sum of the 17 individual TEQs) under Method B and a risk of 10^{-5} will be applied under Method C. The allowable risk level and associated cleanup level for dioxin and furan mixtures is thus ten times lower than the risk for other mixtures of hazardous substances.

In support of their draft rule amendment, Ecology notes that dioxin and furan congeners, although chemically distinct, have similar mechanisms of action and consequently behave as similar chemicals in the body. Ecology also cites the widespread practice by other environmental agencies of summing TEF concentrations in assessing risks and cleanup levels. Nevertheless, not all agencies, including the federal government, require that the sum of TEF concentrations meet a stringent total risk of no more than 10^{-6}. Nevertheless, Ecology should consider whether more stringent cleanup levels are necessary to protect health and or are even feasible.

Necessity of the Draft Rule Amendment for Dioxins to Protect Health

Many conservative assumptions that drive estimated risks upward and cleanup levels lower are inherent in risk assessment of dioxins. As a result, a stringent Method B cleanup level using a lower risk goal of 10^{-6} for the TEQ sum of dioxin and furan mixtures is unnecessary and is likely to result in a target concentration lower than background levels in many developed areas.

Current scientific evidence indicates that the cancer risk associated with lower dioxin TEQ doses in the extrapolated low risk range (e.g., associated with a 10^{-4} risk and lower) is likely negligible. Specifically, although the EPA cancer slope factor for assessing health risks of dioxins assumes a linear dose-response relationship at low doses, current science (reviewed by NAS 2006) indicates that the relationship at low doses is likely non-linear, and that risks are actually lower than predicted based on a linear relationship. The recent National Academy of Sciences (NAS) expert panel (NAS 2006) that reviewed the EPA dioxin reassessment noted that

a non-linear model was more supported by the scientific evidence than the existing linear approach.

Evidence cited by NAS (2006) as supporting a lower risk at low doses or even a practical threshold for risk from dioxins includes its mechanism of action, lack of direct genotoxicity, and results from animal bioassay studies. The mechanism of toxic action at high doses leading to cancer is likely not applicable at low doses. For example, because liver toxicity is a likely precursor to liver cancer, exposures below levels causing liver toxicity would not be expected to lead to cancer. Dioxins are not direct genotoxic carcinogens (e.g., substances that cause point mutations on DNA leading to cancer). Rather, they cause toxicity and potential tumor formation by means that require sufficiently high concentration in the body to bind with receptors and cause activation or to result in accumulation of a sufficient amount of stress or damage to overwhelm the body's defenses. Such mechanisms would have little, if any, contribution to cancer risk at low doses. As a result, the current cancer slope factor is very protective for estimating risks and cleanup levels. Moreover, because the dose-response relationship is likely sublinear, TEQ mixture concentrations associated with a 10^{-5} risk are already within the low dose range in which toxicity and cancer risks are negligible. Lowering of concentrations to meet a 10^{-6} risk level would have no actual benefit for reduced cancer risk.

The cancer slope factor for 2,3,7,8-TCDD (and applied in the TEF approach to the other 16 related congeners) is also based on exposure to dioxins in well-absorbed media such as food or corn oil. As noted by the WHO expert panel (van den Berg et al. 2006), chemical differences among dioxin-like compounds greatly affect lipid and water solubility, which in turn affects their environmental transport and fate and gastrointestinal bioavailability.[3] A recent paper by Warmerdam et al. (2006) reports on the results of simulated gastrointestinal bioaccessibility measurements for different congeners of dioxins and furans in soil at an industrial site (Attachment 1). Bioaccessibility for most congeners ranged from approximately 10 to 25 percent, with two congeners (1,2,3,7,8,9-HxCDF and 2,3,4,6,7,8-HxCDF) showing much higher bioaccessibility of approximately 55 and 48 percent, respectively.

Thus, adding all TEQ concentrations without correction for differences in bioavailability, for example, is scientifically inaccurate because it assumes equal exposure to all congeners despite their great differences in bioavailability and actual absorbed dose in the body. For this reason, the WHO expert panel (van den Berg et al. 2006) recommendations indicate that the use of separate risk assessment equations for each congener would be appropriate. These differences among compounds reinforce that dioxins should be evaluated as a mixture of chemicals that have different environmental and biological behavior rather than as a single substance.

Adding TEF concentrations together also compounds the health protective bias in each TEF. The individual TEFs for the congeners are based on upper percentile estimates (e.g., above the 75th, 90th percentile) of toxicity from the existing studies (van den Berg et al. 2006; Haws et al. 2006). As a result, as noted by the WHO expert panel (van den Berg et al. 2006), probabilistic modeling approaches (e.g., Haws et al. 2006), which estimate TEFs for individual congeners

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[3] Comments by Dr. Jeff Louch (National Council for Air and Stream Improvement, Inc.) provide additional details on studies that have reported differences in bioavailability of congeners.

based on the full range of the data from different studies, are able to incorporate the effect of potential uncertainties in TEFs with less bias.

Additional work not reviewed by the NAS panel includes recent National Toxicology Program cancer bioassays for 2,3,7,8-TCDD and 2,3,4,7,8-pentachlorodibenzofuran (4-PeCDF) (reviewed by Budinsky et al. 2006). These studies provide better pharmacokinetic data than was previously available. Using these data, Budinsky et al. (2006) estimated that the TEF for 4-PeCDF of 0.5 identified in van den Berg et al. (1998) is likely overestimated and that instead the data support an administered dose TEF no greater than 0.25 and a TEF in the 0.05–0.1 range "for internal dose metrics such as lifetime average liver concentration or body burden."

Perspective from National Cleanup Levels

National soil cleanup levels for dioxins as identified by EPA and dioxin soil screening guidelines identified by the Agency for Toxic Substances and Disease Control (ATSDR) are considerably higher than the cleanup level for dioxins that would result from the draft rule amendment. Although Ecology correctly notes that ATSDR and EPA both use a total TEQ approach as the basis for comparing site-specific data to cleanup levels, the target cleanup levels identified by the references cited are much higher than the values that would result from the proposed Ecology methods.

Specifically, ATSDR provides a screening level of 50 ng/kg (ppt) TEQ as the starting point in considering whether some evaluation is needed for residential sites in its publication titled *Dioxin and Dioxin-like Compounds in Soil: Part I. ATSDR Interim Policy Guideline* and *Part II: Technical Support Document for ATSDR Interim Policy Guideline* (ATSDR 1997). In their evaluation, ATSDR considered all toxicological data available at that time and concluded that, for residential soils, concentrations up to 50 ng/kg TEQ would be protective for all potential adverse effects. ATSDR also identified an "evaluation level" for PCDD/Fs in the range of 50 ng/kg TEQ to 1,000 ng/kg TEQ, where ATSDR recommends that site-specific factors such as bioavailability, climate, community concerns, and other factors be considered in determining whether any additional evaluation or further protective measures are needed. Levels above 1,000 ng/kg TEQ were identified by ATSDR as an "action level," above which potential public health measures should be considered (Table 1).

Table 1. Comparison of MTCA draft TEQ cleanup levels with screening values and cleanup values for TEQs in soil

Source	PCDDs/Fs TEQ (ng/kg)
MTCA draft Method B cleanup level	6.67
MTCA draft Method C cleanup level	66.7
ATSDR screening level (ATSDR 1997)	Less than or equal to 50
ATSDR evaluation levels (ATSDR 1997)	Greater than 50 but less than 1,000
ATSDR action level (ATSDR 1997)	Greater than or equal to 1,000
EPA action level for residential soil (U.S. EPA 1998)	1,000
EPA action levels for industrial soils (U.S. EPA 1998)	5,000–20,000

Note: ATSDR - Agency for Toxic Substances and Disease Registry
EPA - U.S. Environmental Protection Agency
MTCA - Model Toxics Control Act
PCDD/F - polychlorinated dibenzo-*p*-dioxin and polychlorinated dibenzofuran
TEQ - toxicity equivalent based on data for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin

U.S. EPA (1998) outlines these levels in their 1998 Superfund directive as follows:

> One ppb (TEQs, or toxicity equivalents) is to be generally used as a starting point for setting cleanup levels for CERCLA removal sites and as a PRG for remedial sites for dioxin in surface soil involving a residential exposure scenario. For commercial / industrial exposure scenarios, a soil level within the range of 5 ppb to 20 ppb (TEQs) should generally be used as a starting point for setting cleanup levels at CERCLA removal sites and as a PRG for remedial sites for dioxin in surface soil. These levels are recommended unless extenuating site-specific circumstances warrant a different level.[4] (www.epa.gov/superfund/resources/remedy/pdf/92-00426-s.pdf)

EPA goes on to indicate that these levels are derived based on direct contact with soils, rather than bioaccumulation into the food chain. EPA indicates that, where states take the lead in cleanups, more stringent levels may be applied, but EPA indicates that this should only occur "where evidence exists that risks posed by the site differ from risks estimated using standard national default guidance values."

Thus, the EPA default cleanup levels are clearly intended to be applied in most cases. The guidance document identifies these values as both cleanup levels and preliminary remediation goals. The cleanup levels that would result from the draft rule amendment are much lower than dioxin cleanup levels as currently applied by EPA.

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[4] One "ppb" is 1,000 ng/kg. "Dioxin" is PCDD/F expressed on a TEQ basis. A "PRG" is a preliminary remediation goal. "CERCLA" is the Comprehensive Environmental Response, Compensation and Liability Act, 42 U.S.C. § 9601 *et seq*.

A brief review of online abstracts of EPA records of decision for various sites in the western U.S. revealed several sites with a soil cleanup level of 1,000 ng/kg TEQ and a range from 6.7 to 1,000 ng/kg TEQ, and sediment cleanup levels ranging from 1,000 to 8,000 ng/kg TEQ within EPA Regions 9 and 10.

Perspective from Background Concentrations

The Method B cleanup level that would result from the draft rule amendment (6.67 ng/kg) falls within background levels in developed areas and possibly even some rural residential areas and would thus be impractical to enforce (see Table 1). Background soil sampling for developed ("urban") areas in Washington state had TEQ concentrations that ranged from 0.13 to 19.5 ng/kg, assuming that undetected concentrations of congeners were zero (Attachment 2; Rogowski et al. 1999). If half the detection limit is used instead for undetected concentrations, as is the common practice in calculating the TEQ, this range increases to 0.64 to 21.9 ng/kg (Attachment 2). Use of the detection limit rather than half the detection limit would result in even higher TEQ concentrations (Attachment 2).

Background soil levels sampled in British Columbia indicated that TEQ concentrations ranged up to about 50 ng/kg (Van Oostdam and Ward 1995). A summary of studies on TEQ levels in soil in North America (NAS 2006; U.S. EPA 2003) reported an overall mean of 2.7 ng/kg and a range of study means of 0.11 to 5.7 ng/kg for rural soils. For developed ("urban") areas, a mean of 9.3 ng/kg with a range of survey means of 2 to 21 ng/kg was reported. These levels for soil were calculated assuming that undetected concentrations were zero and included only 11 of the 17 congeners. TEQ concentrations would be higher if half the detection limit was assumed for undetected concentrations and all 17 congeners were included.

These data indicate that if Ecology adopted a 6.67 ng/kg TEQ cleanup level, it is possible that a number of samples from developed areas in the state would have dioxin concentrations that exceed this level.

Although increases in TEQ concentrations resulting from inclusion of undetected congeners and changes in TEF methods are relatively small, these changes can result in exceeding the low cleanup level that would result by the draft rule amendment. This cleanup level is not far from the sum of half the analytical limits of detection of each of the 17 congeners. Thus, because the TEF concentrations of even undetected congeners are assumed to be present and added together, barely detectable dioxin concentrations could exceed the proposed Method B cleanup level. The NAS panel (see page 15; NAS 2006) stressed the importance of properly considering the influence of undetected congeners as well.

Conclusions

Under the draft rule amendment, the MTCA cleanup level for TEQ mixtures of dioxin and furan congeners would be ten times lower than the current value. Scientific evidence, however, indicates considerable protectiveness in how risks and cleanup levels are developed for these compounds and does not support the necessity of a more stringent level for protection of human

health. Nationwide cleanup levels considered health protective by EPA and ATSDR are orders of magnitude higher than the cleanup level that would result from the draft rule amendment. Moreover, the lower Method B cleanup level in the draft rule amendment is within background levels in populated areas of Washington, and near analytical detection limits. Therefore, this draft rule amendment is not necessary to protect public health and potentially will be impractical to implement.

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Attachment 1

Oral Bioaccessibility of Dioxins/Furans from Industrial Soils Using a Simulated Human G.I. Tract (Warmerdam et al. 2006)

ORAL BIOACCESSIBILITY OF DIOXINS/FURANS FROM INDUSTRIAL SOILS USING A SIMULATED HUMAN G.I. TRACT

Warmerdam J, Finley B, Fehling K, Morinello E

ChemRisk, 25 Jessie St., Ste. 1800, San Francisco, CA 94105

Introduction

Polychlorinated dibenzo-*p*-dioxins and furans (PCDD/Fs) are common environmental contaminants with very high soil binding coefficients. Laboratory experiments with test animals indicate that the oral systemic absorption (bioavailability) of PCDD/Fs from soil is lower than for PCDD/Fs in lipophilic vehicles such as corn oil or other oil-based delivery media used in animal-feeding studies. For example, administration of tetrachlorodibenzo-*p*-dioxin (TCDD) in commonly used vehicles typically yields oral bioavailabilities ranging from 70%-90%[1-3], while the reported oral bioavailability of TCDD in soils ranges from 0.5-60% relative to reference oral formulations[4-8].

The relative bioavailability of soil-bound chemicals can be determined directly from feeding studies in which the concentration of the parent chemical or a metabolite is measured in tissues and/or via a "mass-balance" analysis involving measurements of chemicals excreted in the feces. However, there are anatomic and physiological differences between humans and common animal test species, which may confound the applicability of the results for human risk assessment purposes[9,10].

An *in vitro* bioaccessibility study permits derivation of a conservative estimate of the *in vivo* oral bioavailability of soil-bound chemicals in humans that can be used as an alternative or supplement to animal studies. In a bioaccessibility study, the soil is extracted with fluids that simulate the stomach and small intestine segments of the human GI tract. The amount of chemical present in the liquid phase following the extraction is used to determine the bioaccessible fraction. Because the extraction conditions are believed to be at least as harsh as those present *in vivo*, presumption of 100% absorption of the bioaccessible fraction yields a conservative estimate of bioavailability. The *in vitro* approach avoids animal use, has the advantages of simplicity and lower cost, and permits evaluation of many different variables (effect of soil type, soil particle size, chemical concentration, etc.) that simply is not practical with the more costly and time-consuming *in vivo* studies.

To date, there are no published bioccessibility measurements of PCDD/Fs in industrial soils. In this paper, we describe the bioaccessibility results for PCDD/Fs in soils near an operating facility in the U.S. The measured TEQ in the soils ranges from 0.7 µg/kg to 23.6 µg/kg and OCDF is the primary congener, comprising approximately 90% of the total PCDD/F mass. The purpose of this study is to supplement the existing bioaccessibility and bioavailability data for PCDD/Fs in contaminated media.

Materials and Methods

A total of eight surface soil samples (0-3 inches depth) were collected from an industrial site with historical PCDD/F discharges. The soils were analyzed for 17 polychlorinated dibenzo-*p*-dioxins and furans with EPA method SW 8290 using high resolution gas chromatography / high resolution mass spectrometry.

The soil samples were air dried and sieved in an attempt to isolate the fraction less than 250 microns in diameter. Two samples (#4 and #5) were coarse grained and could only be sieved to a < 500 micron fraction. One sample (#3) was coarse grained and gummy and was used unsieved.

The sieved fraction of each sample was subjected to the following *in vitro* extraction method:

The extractions were conducted in 1-liter Teflon bottles, which were immersed in a water bath at 37° C. Mixing was accomplished with a stir table oscillating at 30 revolutions per minute. A buffered solution was prepared by adding 60 grams of glycine (0.2 M; Sigma UltraPure®) to 4 L of Type II deionized (DI) water, and adjust to pH 1.5 with concentrated HCl (~240 mL). To this, 32.5 g of sodium chloride (NaCl, concentration of 150 mM in stomach fluid), 4.00 g of pepsin (activity of 800-2,500 units/mg, final concentration of 1.00 g/L in stomach fluid), 20 g bovine serum albumin (minimum 98 percent, final concentration of 5 g/L in stomach fluid), and 10 g mucine (Type III, purified from porcine stomach; final concentration of 2.5 g/L in stomach fluid) were added. Eight hundred mL of the gastric solution were placed in each Teflon bottle, and 4.8 mL of oleic acid (90%; Aldrich Chemical) were added. Eight grams of test soil were added, and the resulting mixture was stirred at 30 rpm on the mixing table for one hour.

After the 1-hour simulated gastric portion of the test, the solution in each bottle was adjusted to pH 7.2 using sodium hydroxide (50 percent w/w, approximately 10 mL). Finally, 480 mg pancreatin (activity equivalent to 8 × U.S.P. specifications) and 3.2 mg bovine bile (50 percent bile acids, mixture of free and conjugated acids) were added to each reaction vessel and stirred at 30 rpm for 4 hours to simulate small intestinal-phase extraction.

Each reaction vessel was centrifuged at 5000 ×*g* for 10 minutes. The supernatant was decanted into a graduated cylinder and total volume was measured. All eight samples were analyzed for 17 PCDD/F congeners at Alta Analytical Laboratories, Inc. (Alta) in El Dorado Hills, CA. Quality assurance samples included an extraction blank, a spiked extraction blank, and a triplicate analysis of one sample (#2) to assess reproducibility.

Results and Discussion

A majority of the soil TEQ concentration and extractant resulted from four congeners: 2,3,4,7,8-PeCDF, 1,2,3,4,7,8-HxCDF, 1,2,3,6,7,8-HxCDF, and 1,2,3,4,6,7,8-HpCDF. As shown in Figure 1, the average % congener contribution to total TEQ was very similar for soils vs. extractants.

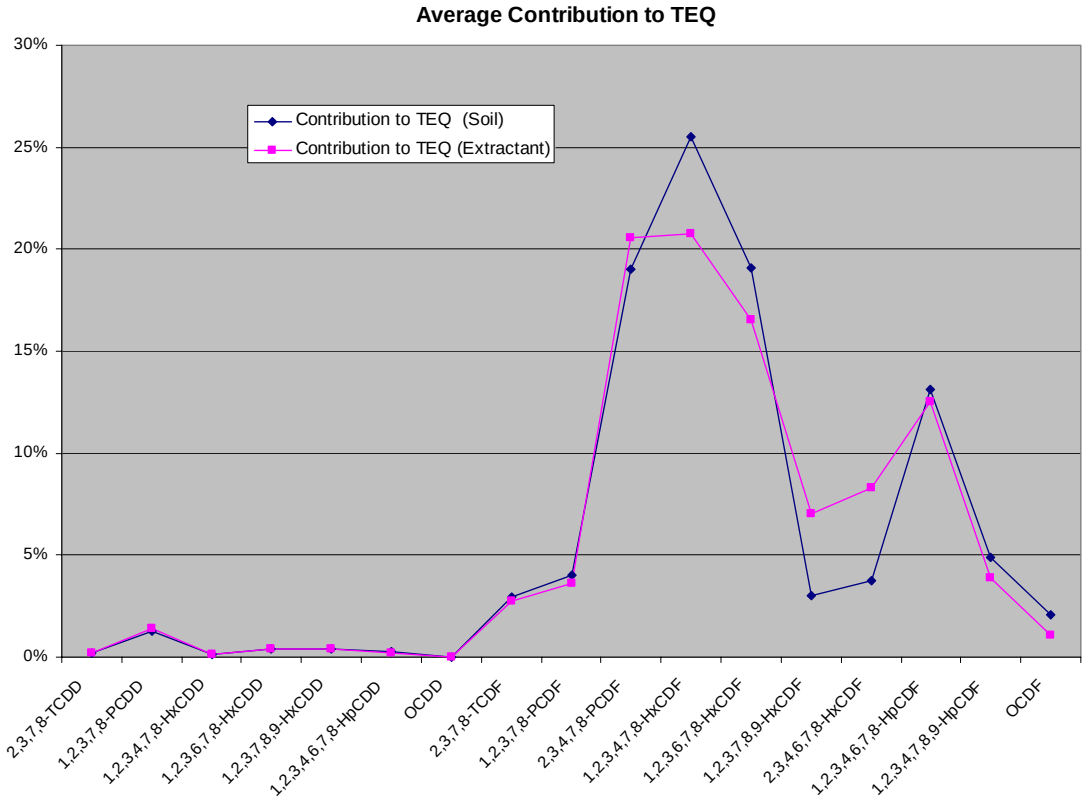

Figure 1 – Average contribution to TEQ (Soil and Extractant)

Bioaccessibility total TEQ results for the eight samples ranged from 9 to 46%, with an overall average of 22%. There did not appear to be any trends with respect to degree of bioaccessibility vs. initial soil concentration. The bioaccessibility values for TCDD ranged from 2 to 75%, (average of 24%). Bioaccessibility was lowest in samples #3, #4, and #5; these samples were either sieved to below the 500-micron particle-size level, rather than the 250-micron level (#4 and #5), or not seived at all (#3). This result suggests that, at least with the soils used in this study, bioaccessibility may decrease with increasing particle size. As indicated in Figure 2, the bioaccessibility of the two congeners 1,2,3,7,8,9-HxCDF and 1,2,3,4,6,7,8-HxCDF was clearly elevated relative to the other congeners

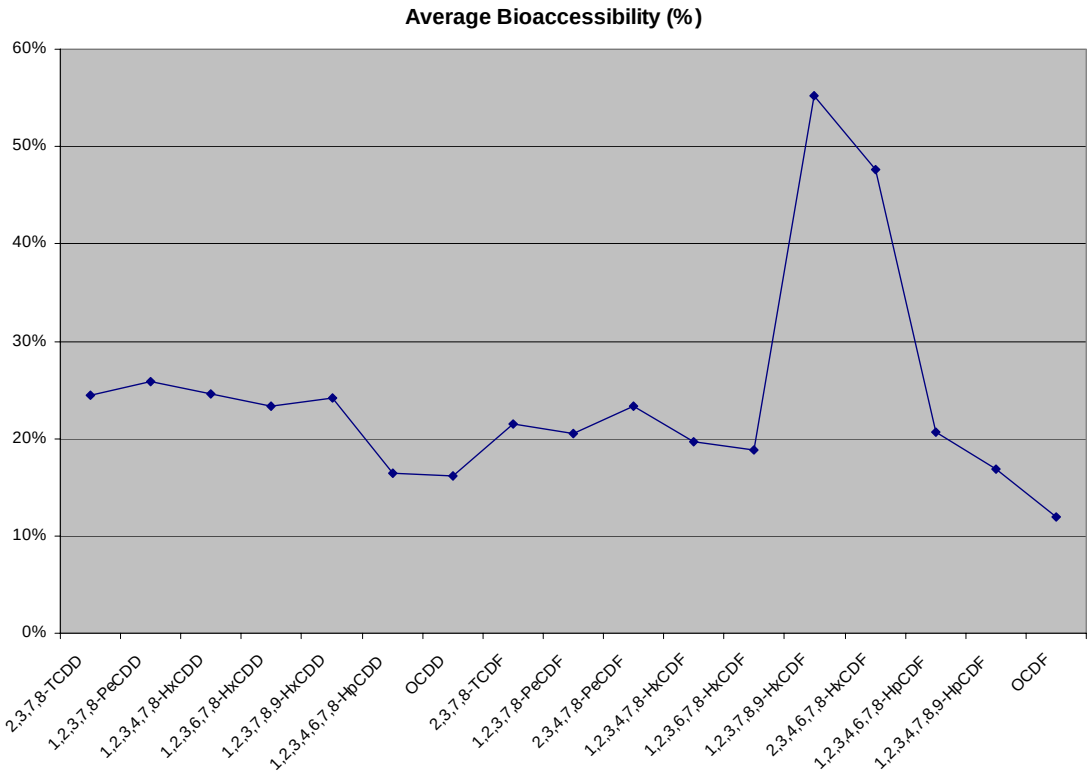

Figure 2 – Average Bioaccessibility of 17 PCDD/F congeners

The mean bioaccessibility measured in this study (22%) is within the range determined from *in vivo* TCDD bioavailability studies (0.5%-60%). This value agrees with values from other, similar studies and likely represents an upper bound estimate of oral bioavailability for these soils[1,11].

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Attachment 2

TEQ Values of Soil Samples Collected from Selected Washington State Land Use Areas (Rogowski et al. 1999)

Appendix 3-G. TEQ values of soil samples collected from selected Washington State land use areas (ng/kg)

Land Use	TEQ ND = 0	TEQ ND = 1/2 DL	TEQ ND = DL	Lab #
Forested Lands				
East non-commercial	5.16	5.57	6.04	328341
East non-commercial	0.449	1.60	2.76	338331
West non-commercial	4.93	5.69	6.46	308000
West non-commercial	2.57	4.86	7.15	318241
East commercial	0.0330	1.05	2.06	338330
East commercial	0.914	3.84	6.76	318243
West commercial	2.02	2.70	3.38	328332
West commercial	2.42	2.80	3.17	338333
Open Areas				
East rangeland grazed	0.0431	0.891	1.74	338332
East rangeland grazed	0.0400	1.31	2.59	328336
West rangeland grazed	0.617	1.40	2.19	308004
West rangeland grazed	4.59	5.87	7.15	328331
East non-grazed	0.0460	0.631	1.22	328335
East non-grazed	0.0834	1.36	2.64	328340
West non-grazed	2.37	2.87	3.37	328330
West non-grazed	0.330	1.09	1.84	318242
Urban Areas				
Richland	4.75	7.09	9.44	328337
Kennewick	1.08	1.92	2.76	328339
Spokane	0.984	3.00	5.01	328333
Tacoma 1	19.5	21.9	24.4	318239
Tacoma 2	9.47	11.7	13.9	318240
Seattle 1	0.313	0.699	1.08	318230
Seattle 2	5.13	5.47	5.81	318238
Seattle 3	4.72	5.78	6.84	318236
Seattle 4	0.133	0.639	1.14	318231
Seattle 5	0.804	1.21	1.62	318235
Seattle 6	2.10	3.02	3.94	318232
Seattle 7	0.729	1.52	2.30	318233
Seattle 8	5.96	6.31	6.66	318234
Seattle 9	1.36	2.81	4.26	318237
Duplicate Samples				
Spokane	0.326	4.36	8.39	328334
Richland	4.50	8.26	12.0	328338

ND = Non-detect
DL = Detection limit
ND = 0: if congener not detected, concentration assumed = 0
ND = ½ DL: if congener not detected, concentration assumed = ½ detection limit
ND = DL: if congener not detected, concentration assumed = detection limit