UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION 5

77 W. Jackson Boulevard

Chicago, Illinois 60604

<u>MEMORANDUM</u>

SUBJECT: Summary of Phase 1 Dioxin Results for the East Palestine Derailment Incident

FROM: Mike Devito, Keith Fusinski, Michelle Kerr, Mark Durno

On behalf of the Environmental Unit for the East Palestine Train Derailment

TO: Ralph Dollhopf, Incident Commander

DATE: 9/14/2023

Dioxins are a class of toxicants that consist of polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, and polychlorinated biphenyls. These chemicals act through similar mechanisms of action and induce a broad spectrum of toxic responses in both humans and wildlife. Human exposure comes predominately through the diet with animal-based foods as the main source of these contaminants. These chemicals are unwanted contaminants in a variety of industrial processes as well as combustion processes. The most potent and well-studied dioxin is 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Because there is limited toxicity data on the individual chlorinated dioxins, dibenzofurans and biphenyls, the USEPA and other international regulatory bodies have agreed to use the Toxic Equivalency Factor (TEF) method to assess risks from dioxin exposures. This method assigns a relative potency or TEF of each congener to TCDD. In a mixture of dioxins, the concentration of the individual dioxins is multiplied by their TEF to come up with a TCDD equivalents (TEQ). The individual TEQs are summed and the total TEQ value in the sample is assumed to behave as TCDD. The following sections review the dioxin and TEQ soil concentration data from the East Palestine Train Derailment.

Background Dioxin Soil Concentrations

Our initial challenge in this analysis is determining background dioxin and TEQ soil concentrations. Urban et al. (2014[1]) evaluated 14 rural and 12 urban/suburban background D/F TEQ studies. Of the 26 studies presented in Urban et al. (2014), the studies were divided into rural and urban/suburban land use. The studies were also evaluated for consistency with the methods being used at EPTD for the criteria (in order):

1) Land use/land cover.

2) Reporting of detection limits.

3) Reporting of congener data.

4) Use of non-detect values.

5) Use or correction to 2005-WHO TEFs.

Of the 26 studies reported in Urban et al (2014), data sets from four studies that presented four rural and three suburban/urban sites that met the criteria and the extracted data from these studies is presented in Table 1. The urban/suburban soil samples tend to have higher soil dioxin concentrations than the rural soil samples (Table 1).

Table 1. Sural and Suburban/Urban Dioxin Soil Concentrations from Urban et al (2014).

Rural Studies									
	Land Use/Land Cover	DL Congener Reported	ND value	2005 TEF	Number of Samples	Mean TEQ (pg/g soil)	Median TEQ (pg/g soil)	Minimum TEQ (pg/g soil)	Maximum TEQ (pg/g soil)
USEPA Columbus Ohio (USEPA, 1996)	Suburban or ex urban non-Ag	yes	DL/2	yes	3	1	1.2	1	1.8
Denver, Colorado Urban and Rural Soil Survey (USEPA, 2002)	Partial mix of AG and open space	yes	DL/2	yes	64	2.2	1.1	0.1	20.2
WA State Dept of Ecology Study (WDE, 2010)	Non-AG and open space	yes	DL/2	yes	16	2.5	1.9	0.7	6.6

[1] Jonathan D Urban , Daniele S Wikoff, Alea T G Bunch, Mark A Harris, Laurie C Haws A review of background dioxin concentrations in urban/suburban and rural soils across the United States: implications for site assessments and the establishment of soil cleanup levels. *Science of the Total Environment,* Volumes 466–467, January 2014, Pages 586-597. DOI: 10.1016/j.scitotenv.2013.07.065

WA State Dept of Ecology Study (WDE, 2011)	Rural but non-agricultural and some areas were forested	yes	DL/2	yes	41	1.7	0.6	0.1	9.4
Urban/Suburban Studies									
	Land Use/Land Cover	DL Congener Reported	ND value	2005 TEF	Number of Samples	Mean TEQ (pg/g soil)	Median TEQ (pg/g soil)	Minimum TEQ (pg/g soil)	Maximum TEQ (pg/g soil)
Denver, Colorado Urban and Rural Soil Survey (USEP, 2002)	Urban/Suburban but impacted by arsenal or hazardous waste site	yes	DL/2	yes	98	13.1	4.4	0.2	145.7
WA State Dept of Ecology Study (WDE, 2010)	Suburban/ Urban	yes	DL/2	yes	14	4.2	2	0.7	21
WA State Dept of Ecology Study (WDE, 2011)	Suburban/ Urban	yes	DL/2	yes	120	19.2	12	1.9	120

The literature survey provides a starting point in understanding background dioxin soil concentrations. In order to better characterize background dioxin concentrations, twenty-five (25) sites in the East Palestine area were designated as representative of background soil in the East Palestine area. Soil samples were collected from these sites at two different depths, 0-1 inch and at 1-6 inches below the surface, to identify contamination from the vent and burn compared to historic deposition of dioxins. It is assumed that if the 0–1-inch sample is significantly higher than the 1–6-inch sample, then it is likely due to recent deposition from the vent and burn of vinyl chloride. The mean ratio of the 0-1 inch/1-6-inch soil dioxin concentration data for each congener for each sample pair was 1.15 ± 0.2, indicating little difference in dioxin concentrations at different soil depths and limited deposition of dioxins from the vent and burn of vinyl chloride at these sites. Since there were no significant differences between the 0-1 inch and 1-6-inch samples, these measurements were treated as duplicate samples and averaged for each sampling site. Summary statistics are shown in Table 2. For most of these samples, many of the dioxins were below the limits of quantitation and many were below the limits of detection. One half the detection limit was reported and used for congeners where the data was below detection limits. The octa- and heptachlorinated dioxins were the most frequently quantitated congeners. The mean TEQ concentration in the background soil samples was 6.7 ± 8.0 pg TEQ/g soil with a high of 40 pg TEQ/g. These data are consistent with the few studies summarized by Urban et al (2014) presented in Table 1.

Risk Screening Levels (RSLs) and Regional Removal Management Levels (RMLs)

The USEPA uses several approaches to aid decision makers in assessing a potential Superfund site. One approach employs Regional Screening Levels or RSLs. The USEPA describes RSLs as

"*They are risk-based concentrations derived from standardized equations combining exposure information assumptions with EPA toxicity data. SLs are considered by the Agency to be protective for humans (including sensitive groups) over a lifetime; however, SLs are not always applicable to a particular site and do not address non-human health endpoints, such as ecological impacts.*"

They are used for site "screening" to help identify areas, contaminants, and conditions that require further attention at a particular site. SLs are not de facto cleanup standards and should not be applied as such. Generally, at sites where contaminant concentrations fall below SLs, no further action or study is warranted under the Superfund program, so long as the exposure assumptions at a site match those considered by the SL calculations. Chemical concentrations above the SL would not automatically trigger a response action; however, exceeding a SL suggests that further evaluation of the potential risks by site contaminants is appropriate. RSLs are based upon a 1 in 1 million excess lifetime cancer risk or a non-cancer Hazard Quotient of 1 (whichever is most protective). The **cancer** RSL for dioxin for residential exposure (24 hour a day exposure for 350 days a year for 26 years) is 4.8 pg TEQ/g soil. The **noncancer** RSL for residential exposure to dioxin is 51 pg TEQ/g soil. These values were generated by the USEPA and are available at https://semspub.epa.gov/work/HQ/404061.pdf and a more detailed discussion of RSLs and their applications can be found at https://www.epa.gov/risk/regional-screening-levels-rsls.

A second approach used by the USEPA is the Regional Removal Management Levels or RMLs. The USEPA describes RMLs as:

"RMLs help identify areas, contaminants, and conditions where a removal action may be appropriate. Sites where contaminant concentrations fall below RMLs, are not necessarily "clean," and further action or study may be warranted under the Federal Superfund program. In addition, sites with contaminant concentrations above the RMLs may not necessarily warrant a removal action dependent upon such factors as background concentrations, the use of site-specific exposure scenarios or other program considerations."

RMLs are based upon a 1 in 10,000 excess lifetime cancer risk or an HQ of 3, whichever is most protective. Thus, the RMLs are less protective than the RSLs. RMLs are not de facto cleanup levels. The **cancer** RML for dioxin residential exposure is 480 pg TEQ/g soil and the **noncancer** RML for residential exposure to dioxins in soil is 150 pg TEQ/g soil. A more detailed discussion of RMLs and their application can be found at https://www.epa.gov/risk/regional-removal-management-levels-rmls-frequent-questions#FAQ4.

Cutoff for Outlier Determination

Based on the definitions of RSLs and RMLs, a **cutoff of 51 pg TEQ/g soil** will be used to identify outlier samples sites that may require further investigation. The RSL is approximately 10 times that of the mean and median dioxin concentration in background soil samples surrounding East Palestine and is slightly higher than the highest TEQ soil sample measured as part of the background samples (Table 2).

Site Analysis

In late February 2023, US EPA directed Norfolk Southern Railroad (NS) to sample for dioxin which may have been associated with soot deposition from the vent and burn of vinyl chloride on February 6, 2023. On March 7, 2023, US EPA approved a plan from NSR to do so. Norfolk Southern Railroad's sampling consisted of 8 categories of sites, in addition to background. The categories were Residential, Commercial, Agricultural, and Other for each of Ohio and Pennsylvania. The results of the group statistics are shown in Table 1. A one-way Analysis of Variance was performed on the data with all site categories compared to background. No significant differences were observed between the site group means and the background samples [p=0.80; F (9, 146)]. Similar to the samples designated as background, for many of the sites sampled, only the octa- and hepatchlorinated dioxins were found above the limits of quantitation and many compounds were below the limits of detection. Using 51 pg TEQ/g soil as the cutoff to identify outlier sample sites, then there are highest background TEQ soil concentrations are outliers, then there are 6 outlier sample sites out of 146 sites sampled or approximately 4% of the sites sampled. These sites are described in Table 3. Note that all outliers were in public-right-of way (not on private property) or at a commercial/industrial property.

Table 2: Summary Statistics of Background and Sampling Sites

	Background	**OH Res**	**OH Other**	**OH Com**	**OH Ag**	**PA Com**	**PA Other**	**PA AG**	**PA Res**
Number of sample sites	**25**	**25**	**17**	**9**	**16**	**7**	**12**	**21**	**14**
Median (pg TEQ/g soil)	**3.7**	**11**	**4.1**	**16**	**4.2**	**8.6**	**4.3**	**3.8**	**4.5**
Mean (pg TEQ/g soil)	**6.7**	**14.0**	**4.6**	**21.0**	**8.1**	**21.0**	**31.0**	**32.0**	**8.8**
Std. Deviation (pg TEQ/g soil)	**8.0**	**18.0**	**2.0**	**19.0**	**11.0**	**39.0**	**88.0**	**101**	**9.7**

Table 3. Outlier Sites

Sample number	**Site**	**TEQ pg TEQ/g**	**Comments**
OH-Res	F10-1	96 (0-1 inch) 90 (1-6 inch) **Avg 93**	Located on the public right-of-way approximately 1-mile due north of the incident
OH-Com	K11-5	59 (0-1 inch) 49 (1-6 inch) **Avg 54**	Located on Norfolk Southern property just north of the incident
OH-Com	K11-6	70 (0-1 inch) 34 (1-6 inch) **Avg 52**	Located on Norfolk Southern property just north of the incident
PA-Com	Q14	110 (0-1 inch) 110 (1-6 inch) **Avg 110**	Located on the public right-of-way approximately 1.5 miles south/southeast of the incident
PA-Other	O15	480 (0-1 inch) 140 (1-6 inch) **Avg 310**	Located on the public right-of-way

			approximately 1.3 miles southeast of the incident
PA-Agr	H15-2	520 (0-1 inch) 670 (1-6 inch) 630 (1-6 inch) **Avg 607**	Located on the public right-of-way on SR51 approximately 1 mile northeast of the incident

Relationship between Total TEQ and Total Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic Aromatic Hydrocarbons (PAHs) may also have been associated with soot deposition and the plan called for analyzing samples for this group of compounds as well. Polycyclic aromatic hydrocarbons naturally occur in coal, crude oil, and gasoline. When coal, oil, gas, wood, garbage, and tobacco are burned they are produced. PAH are also known carcinogens. The total TEQ and total PAH concentrations were evaluated using Pearson Correlation analysis to determine if there was a relationship between TEQ and PAH concentrations in the soil samples. The data analyzed was from NS sampling from Phase 1 Soil Sampling Plan of 146 locations at two depths for a total of 292 samples. PAHs included are listed in Table 4. There was no significant relationship between total PAH and total TEQ (see Table 5 for statistics and Figure 2A). Similar results were observed for TCDD alone and total PAHs (see Table 5 for statistics and Figure 2B).

Table 4. PAHs Used as Markers of Particle Deposition

2-Methylnaphthalene	Acenaphthene	Acenaphthylene	Anthracene	Benzo(a)anthracene
Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene
Dibenzo(a,h)anthracene	Fluorene	Fluoranthene	Indeno(1,2,3-cd)pyrene	Naphthalene
Phenanthrene	Pyrene			

Table 5. Pearson Correlation between Total TEQ and PAHs

Pearson r	Total TEQ vs Total PAH	2,3,7,8-TCDD vs Total PAH
r	0.077	0.071
R squared	0.0059	0.005
P value		
P (two-tailed)	0.19	0.23
P value summary	Not significant	Not Significant
Significant? (alpha = 0.05)		
Number of XY Pairs	292	292

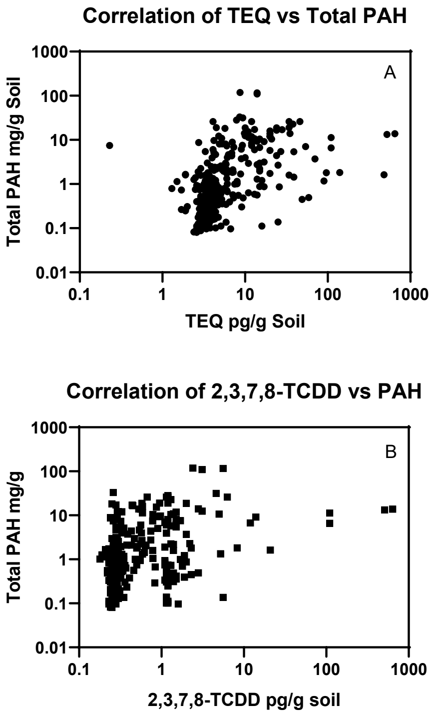

Figure 2. Relationship Between PAH and TEQ (A) and 2,3,7,8-TCDD (B) Concentrations.

Relationship Between 2,3,7,8-TCDD and Total TEQ

The relationship between soil concentration of 2,3,7,8-TCDD, the most potent dioxin, and Total TEQ was evaluated for all data. There was a statistically significant relationship between total TEQ and 2,3,7,8-TCDD soil concentrations (See Table 6 and Figure 3).

Table 6. Pearson Correlation Between Total TEQ and TCDD

Pearson r	
r	0.86
R squared	0.73
P value (two-tailed)	<0.0001
P value summary	
Significant? (alpha = 0.05)	Yes
Number of XY Pairs	292

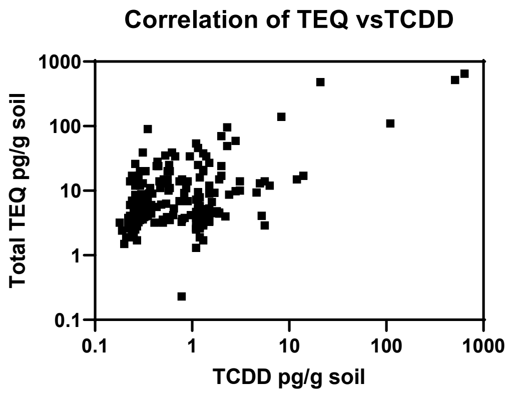

Figure 3. Relationship between 2,3,7,8-TCDD and TEQ Soil Concentrations.

Relationship Between NS Samples and EPA Samples

Soil was collected at 1 inch and at 6 inches and samples were split for analysis for dioxins by both NS and US EPA for forty-three (43) locations. A correlation analysis was performed on the NS and EPA data based on the concentration of all dioxins expressed as pg TEQ/g soil (Table 8 and Figure 5). In theory, the NS and EPA data should be equivalent, and this this equivalence is represented by a "unity line" in the figure. Data points above the unity line indicate that the NS samples are greater than the EPA samples and data points below the line indicate the EPA samples are greater than the NS samples. The TEQ sample measurements from NS at location F10 at a sample depth of 1 inch were almost 40 times higher compared to the EPA, measurements and the samples from this location were removed from the analysis as outliers. Examination of the F10 samples indicate that all dioxins were higher by factors of 2 to over 100 times in the NS analysis compared to the USEPA analysis. The reason for this large difference is uncertain. However, after the removal of this location, the ratio of the paired NS data to the EPA data averaged 1.50 ± 0.85 with a median value of 1.37. These results indicate that in general, NS TEQ soil measurements were slightly higher than the EPA split samples. When the two data sets are compared there is a statistically significant correlation between the two data sets when expressed as pg TEQ/g soil (Table 8 and Figure 4). It appears that much of the deviation between the two data sets is associated with differences in the limits of detection and reporting values. The NS data tends to report greater amounts of dioxins compared to the EPA data from the split samples. EPA's and NS's contracted laboratories passed a performance evaluation sample for dioxins in soil, verifying accuracy of results. To put the differences between the NS and EPA results in context, EPA incorporated nine duplicate samples for dioxin measurements and these paired data averaged 1.75 ± 1.60. This is consistent to the ratio between the NS and EPA samples indicating that the difference between the two data sets is consistent with EPA's variability in sample measurements.

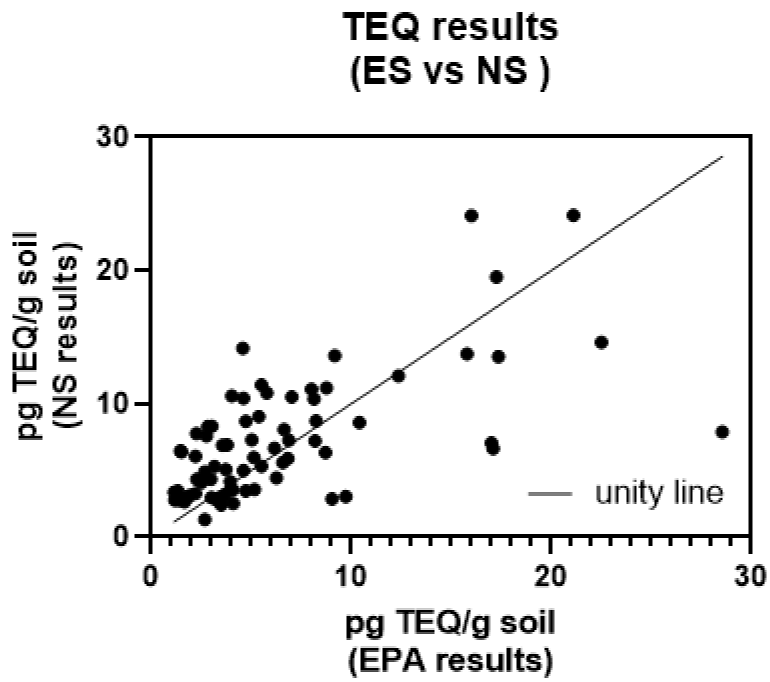

Figure 4. The relationship between NS and EPA dioxin soil measurements from paired samples.

Table 8. Pearson Correlation Between NS and EPA pg Dioxin/g Soil Data

Pearson r	
r	0.65
R squared	0.42
P value	
P (two-tailed)	<0.0001
P value summary	
Significant? (alpha = 0.05)	Yes
Number of XY Pairs	84

Summary

The sampling plan provided sufficient samples to assess background dioxin concentrations in the soil around East Palestine and this allows for a better understanding of the contribution of the vent and burn to dioxin soil concentrations in the area. The data from the background soil samples in East Palestine is consistent with background soil dioxin concentrations, as reviewed in Urban et al. (2014). The vast majority of the non-background samples had dioxin concentrations that were consistent with the background samples. Only 6 sample sites appear to be outside of background concentrations and these samples were in the public right-of-way or on commercial/industrial properties. One challenge in the interpretation of these outlier samples is that there does not appear to be a clear connection of these higher samples to the vent and burn. They are dispersed across the region and samples located near these outlier sites generally are no higher than background concentrations. It appears that the vent and burn did not significantly contribute to background dioxin deposition in the area. In addition, most of the dioxins were below the quantitation and detection limits in the samples and the TEQ values are driven in part by the reporting limits. The exception to this finding is that for the six outlier samples, the TEQ is driven by 2,3,7,8-TCDD. Given that the outlier samples are geographically distinct from each other, that other samples sites near the outliers are at background TEQ concentrations, and that only 6 of 146 location samples (≈4%) are considered outliers it is recommended that the outlier data be reviewed for data transposition and other possible data errors. There is not a clear basis to recommend re-sampling and analysis other than to investigate the outliers, which is beyond the scope of the question at hand about impacts from the derailment.