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Title

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Abstract

A February 3, 2023 train derailment and subsequent burn released hazardous chemicals into East Palestine, Ohio. One potential exposure was polychlorinated dibenzo-p-dioxins, dibenzofurans, and coplanar polychlorinated biphenyls (cPCBs), collectively referred to as dioxins. Many studies have linked dioxins to numerous health effects. A pilot study was conducted July 17–18, 2023 to assess residents' serum dioxin levels. Eighteen persons who were White, nonsmokers with a mean age of 55, and 56% female, provided serum for analysis. Measurement of 20 dioxins, furans, and cPCBs congeners was conducted using gas chromatography, isotope dilution, and high-resolution mass spectrometry. A toxic equivalency (TEQ) value for each participant was calculated by multiplying the reported concentration of each congener by its toxic equivalency factor and summing the results. TEQs were compared to 2011–2012 National Health and Nutrition Examination Survey (NHANES) data by race/ethnicity, sex, and age group. All participants had serum TEQ values either below or within the range of NHANES values. Mean TEQ values were lower in younger age groups; we observed no sex-specific differences. These pilot data demonstrate that although dioxins may have formed during the derailment, exposures to participants did not increase their TEQ values compared with 2011–2012 NHANES.

Graphical Abstract
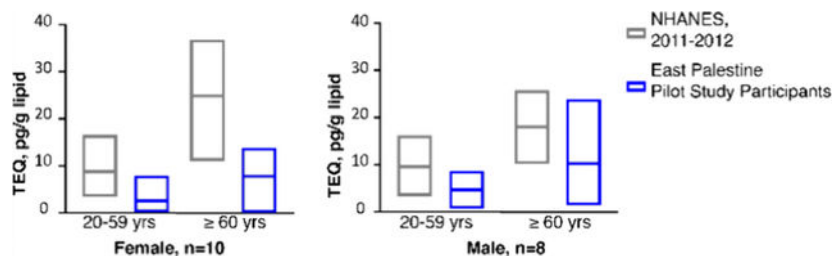
Keywords

disaster response research; community-engaged research; report-back; exposure; rural

INTRODUCTION

Around 9:50 PM on the evening of February 3, 2023, 52 out of 150 train cars derailed in East Palestine, Ohio.[1] According to the U.S. Environmental Protection Agency (EPA) Unilateral Administrative Order, 11 of the 52 cars contained hazardous materials, including vinyl chloride, ethylene glycol, ethylhexyl acrylate, and butyl acrylate.[1] At approximately 11:00 PM that evening, a shelter-in-place for the town of East Palestine was issued, and an evacuation was ordered for people living within one mile of the derailment. At 8:00PM on February 5, Governor DeWine issued an emergency evacuation for people living within one mile of the derailment site. On February 6, the five train cars containing vinyl chloride underwent a "vent and burn"[2] leading to strong concern about the formation of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F) and coplanar polychlorinated biphenyls (cPCBs), collectively referred to as dioxins.[3] Studies have demonstrated a link between dioxins, a group of persistent organic pollutants, and various health risks, including cancer, reproductive and developmental issues, immune system damage, and hormonal interference.[4,5] Dioxins have an estimated half-life, or the amount of time it takes for half of the chemical to be eliminated from the body, of 7 to 11 years which can vary based on a number of factors including age, body fat and smoking status.[6,7]

To evaluate the extent of possible dioxin contamination in East Palestine, the EPA collected soil and sediment samples in March and April 2023 at the derailment site for the measurements of dioxins among other chemicals. EPA results revealed that levels of dioxins fell within typical background ranges for rural and urban/suburban soil in the United States.[8] However, given the well-established associations between dioxin exposure and adverse health outcomes, investigating potential exposure in the community following the derailment became a priority.

In April 2023, the University of Kentucky (UK) launched the East Palestine Train Derailment Health Tracking Study (EP Health Tracking Study)[9] to assess and track residents' exposure and health concerns related to the derailment, evacuation, and following their return from evacuation or decision to not return. Residents were eligible if they were 18 years of age or older and lived in Columbiana County or one of the five surrounding counties. A community advisory board was established to provide guidance and recommendations for research. In this report, we provide the methods and results from a pilot study that was conducted to assess the dioxin serum levels in a subset of EP Health Tracking Study participants.

METHODS AND MATERIALS

Twenty (20) EP Health Tracking Study participants living within a radius of approximately one mile from the derailment site who were nonsmokers living in nonsmoking homes were invited to participate in the Biological Pilot Study.[9] This study was approved by the University of Kentucky (UK) Institutional Review Board (IRB, #86158). Of the 19 participants who consented, 18 provided enough blood serum for measurement of dioxins. On July 17–18, 2023, whole blood was collected and processed to obtain serum using

methods previously described.[10–12] Serum was transported on ice to the UK Center for Clinical and Translational Science Biomarker Analysis Lab (CCTS-BAL) for transport to the UK Health-Care Laboratory Services for nonfasting lipid measurement and for storage at −80 °C. Samples were then shipped overnight on dry ice to the Division of Laboratory Sciences, which is part of the National Center for Environmental Health of the Centers for Disease Control and Prevention (CDC).[13] CDC's Human Research Protection Office determined that the analysis of deidentified specimens at the CDC laboratory did not constitute engagement in human subjects' research. Briefly, sera (9.3–15 g) were extracted and dioxins were isolated from biological material and concentrated according to standard operating procedures.[14] Quantification of 20 PCDD/F and cPCBs congeners was conducted by using gas chromatography isotope dilution high-resolution mass spectrometry; all analytical data were adjusted by subtracting the median blank value. The limits of detection (LOD) were determined as the higher value calculated by two methods: 1) three times the standard deviation of the quantity found in blanks; or 2) the lowest point of the calibration curve having a signal-to-noise ratio of >10:1. The 20 dioxins, furans, and cPCBs were assigned international toxic equivalency factors (TEFs).[15] A toxic equivalency (TEQ) value for each participant was calculated by multiplying the reported concentration of each dioxin congener by its corresponding TEF and summing the results.[16] Serum dioxin TEQ was compared to the CDC's National Health and Nutrition Examination Survey (NHANES) 2011–2012 data by race/ethnicity, sex, and age group. Of note, these 2011–2012 NHANES dioxin data were generated from an analysis of pooled samples.

Individual and group-level summary data were shared with participants in the form of a letter. To develop effective report-back communication strategies, representative data were used to create a draft letter which was reviewed by members of the research study's Community Advisory Board (CAB). The CAB provided feedback and recommendations on the content and flow of the data communication strategies.

RESULTS

Table 1 describes the characteristics of the pilot study cohort. The mean age of the participants at enrollment was 55 years (standard deviation (SD) of 15 years). All participants were White, had at least completed high school, did not currently smoke or vape, and had no smokers or vapers in their home. The participants' race and ethnicity were representative of the East Palestine community. Two-thirds (67%) of the participants had a body mass index (BMI) greater than 30 kg/m^2. Approximately 20% of the participants had an annual household income of less than $50,000 and over half (56%) of the participants were female. The mean residential distance from the derailment site was 0.9 miles (SD, 0.4miles). One participant did not evacuate from their home after the derailment, but nine evacuated shortly after the derailment (February 3–4) and eight evacuated February 5–6 prior to the vinyl chloride vent and burn. There was also a range of dates when participants returned home with the first participants returning home on February 8 with the majority returning by February 13 (Table 1).

The serum dioxin TEQ values of the participants (all of whom were White) were compared to those of White participants of the 2011–2012 NHANES by sex, and age group. All study

participants had serum TEQ values below or within the mean or the 95% confidence interval (95% CI) of pooled samples from NHANES 2011–2012 (Figure 1). We did not have any participants in the 12–19 years age group. The mean TEQ values were lower in younger age groups; we observed no sex-specific differences.

Individual result letters provided a brief description of serum TEQ and how it was calculated, the participant's individual serum TEQ value, how their level compared to the mean values from NHANES, and a brief summary of how other participants in the pilot study compared to NHANES values. Information was also provided about dioxins, how people are exposed to dioxins, resources, and contact information for the study lead (EH) if participants had any questions. An example illustration of individual serum dioxin TEQ in participant's letters is provided in Figure 2. A representative individual result letter is provided as Supporting Information (Figure S1).

DISCUSSION

The train derailment in East Palestine, Ohio, brought a high level of concern regarding the potential for dioxin exposure and subsequent elevated serum dioxin TEQ levels. In samples collected 5 months after the disaster, we found that all East Palestine resident participants had serum dioxin TEQ values either below or within the range of values in the 2011–2012 NHANES (Figure 1). Our data demonstrate that participant exposure was not high enough to elevate serum TEQ levels above those observed in the general U.S. population. It is possible that the vent and burn of the five railcars containing vinyl chloride that occurred on February 6th would have been the most likely time for the highest levels of dioxin exposure, and only one of our participants was in the community during this event. Although collection and analyses of serum dioxin in the weeks following the disaster would have provided much needed guidance for the public health response, the 5 month lag provided time for accumulation, if any, and given the long half-life of dioxin in the body (7–11 years),[6,7] the time frame of collection does not diminish the validity of these findings.

It is also important to note that dioxin levels in the environment and humans have declined over time.[17–20] A population study using serum dioxin data from three NHANES time periods (1999–2004) identified a decrease in serum dioxin levels by 56% for the 12 to 19 years old group and by 38% for the 20 to 39 years old group in the U.S. population; this is consistent with international trends.[17] In addition, Fang et al. observed significant decline in dioxins in mothers' milk samples from Sweden, with steeper rate of decline (9.2–11% per year) over the most recent years (2002–2011), than for the full study period (5.8–6.8% per year) (1972–2011).[20]

We also observed lower mean TEQ values in the younger age groups (Figure 1), consistent with NHANES values (mean TEQ values in 60 years male: 18.1, female: 25; 20–39 years male: 8, female: 5.7).[21] This finding may partially be attributed to the decline in exposure to dioxin of the general population over recent decades[17–20] and they have had less time to bioaccumulate these chemicals.[6,22–24] Furthermore, we observed a stronger correlation between BMI and TEQ values in females than in males (data not shown). Although this observation aligns with women generally having a higher percentage of body fat than

men,[25,26] a study observed no significant differences in the levels of dioxin-like chemicals between sexes, but higher levels of dioxin-like chemicals were observed in women in the >60 years age group.[27]

Although any exposures related to this disaster did not increase serum dioxin levels above those found in the U.S. general population in 2011–2012, other community studies have shown significant impacts of community exposure to dioxin. A study on adolescents exposed in the aftermath of the World Trade Center collapse revealed dioxin levels surpassing those reported among similarly aged children in the 2003–2004 NHANES cycle.[28] The median TEQ for these participants was 25.3, exceeding the 95th percentile of total TEQ concentration among individuals aged 12–29 based on 2003–2004 NHANES data (14.0).[29] Also, in 1976, a devastating explosion at a chemical factory occurred near Seveso, Italy, resulting in exposure of residents to elevated levels of dioxin.[30,31] Two decades after the explosion, a historical cohort study was initiated, focusing on female residents who were newborns to 40 years old at the time of explosion, and total TEQ were measured in a subset of this cohort.[15] Notably, this subset comprised individuals who were younger at the time of exposure, a mean age of 10.2 years, and the median TEQ values for these participants was 25.7 parts per trillion (ppt), indicating markedly elevated levels relative to those measured from unexposed female residents during the period of 1998–2000, where the median TEQ stood at 18.1 ppt.[32] It is noteworthy to highlight that all TEQ values within our cohort fell below the reported values calculated in these studies (Figure 1 and Table S1).

This pilot study has limitations. One limitation is the small sample size; however, this was a pilot study to compare levels of dioxins in residents living near the derailment site to national dioxin levels. In addition, all participants were White and nonsmokers thereby limiting the generalizability to all members of the community; however, based on U.S. Census data, 94% of East Palestine is White.[33] Another limitation is that prederailment dioxin values were not available for comparison; thus, our comparison is only to national pooled samples by age group, race/ethnicity, and sex categories in 2011–2012. Unfortunately, at the writing of this manuscript, no contemporary dioxin values were available from NHANES and studies show a decreasing trend in the U.S. and worldwide.[10,17–19] When more recent background data become available, these data need to be compared with our pilot study cohort's values.

Together, our study demonstrates that although dioxins may have been generated during the derailment and subsequent burning of chemicals, any exposure experienced by our participants was not significantly elevated relative to historical serum dioxin levels in the United States. We recognize that there were many other chemicals released or formed during the derailment and subsequent burning of vinyl chloride in the railcars and that dioxins are just one type of chemical of concern. Due to the half-life of PCDD/F being measured in years to decades,[34] a follow-up dioxin measurement 1 to 3 years postderailment may provide useful information to exclude that other potential ongoing exposures do not lead to increases in body burden compared with the NHANES data, especially for subjects living in areas with known or suspected increased soil dioxin concentration.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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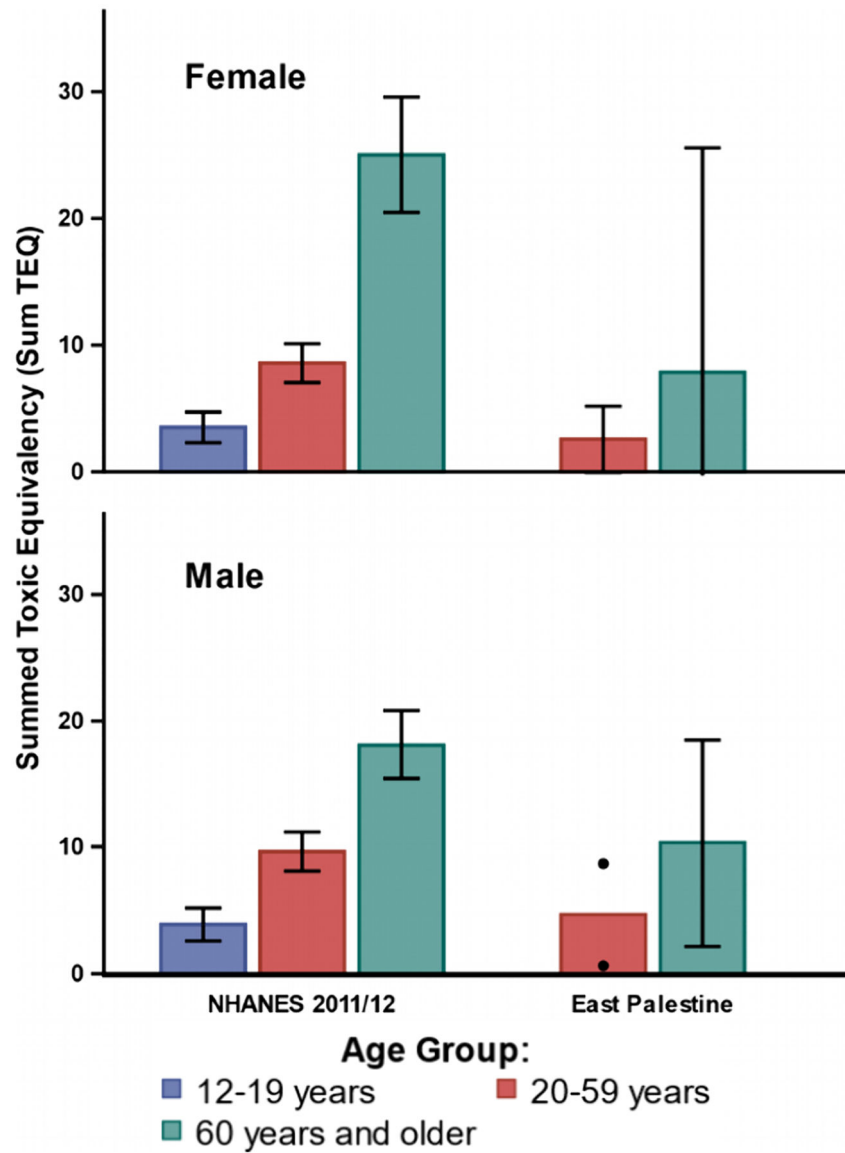
Figure 1.
Mean and 95% confidence interval (CI) of the serum dioxin TEQ concentration (pg/g lipid) of the study participants, compared to the CDC's National Health and Nutrition Examination Survey (NHANES) 2011–2012 study by sex and age. All study participants were white (*n* = 18) and are compared to white participants of the NHANES. The 95% CI is indicated for groups with 5 or more subjects. The age group 20–59 years for East Palestine residents included 2 subjects, and their measurement results are indicated with dots without a 95% CI.
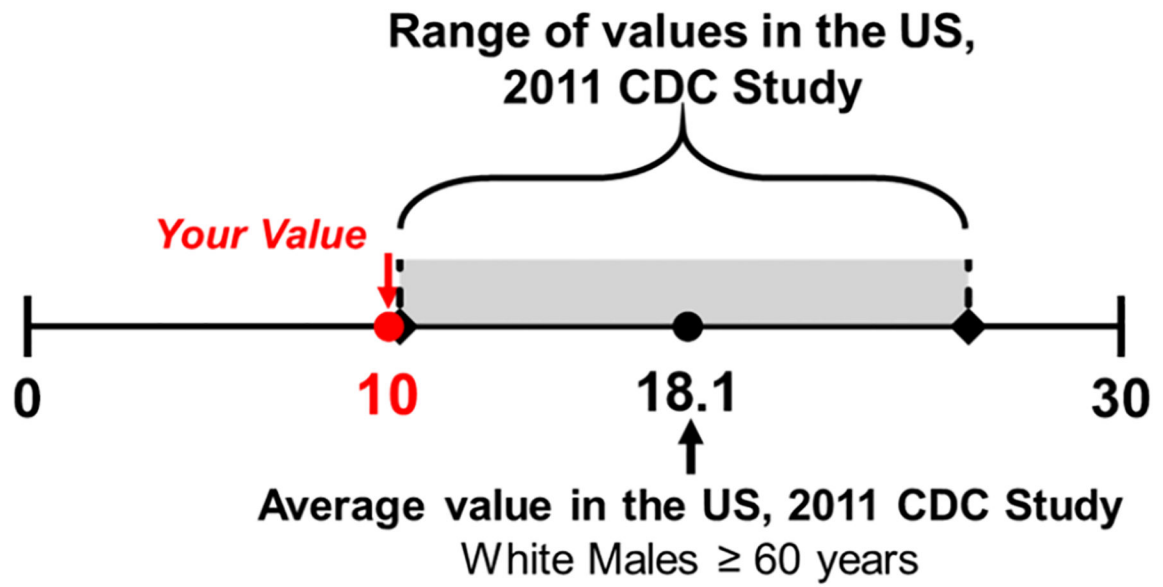
Figure 2.
Example of individual serum TEQ value illustration.

Table 1.

Characteristics of the Pilot Study Participants

	Total (*N* = 18)	Male (*N* = 8)	Female (*N* = 10)
Age, n	18	8	10
Mean (SD), years	55 (15)	63 (12)	49 (15)
Range, years	31–76	38–76	31–67
Age Group, n (%)			
20–39 years	5 (28)	1 (13)	4 (40)
40–59 years	4 (22)	1 (13)	3 (30)
60 years	9 (50)	6 (75)	3 (30)
Race, n (%)			
White	18 (100)	8 (100)	10 (100)
Ethnicity, n (%)			
Not Hispanic or Latino	17 (95)	7 (88)	10 (100)
Unknown	1 (6)	1 (13)	0 (0)
Income, n (%)			
Under $20,000	1 (6)	0 (0)	1 (10)
$20,000 – $49,999	2 (11)	1 (13)	1 (10)
$50,000 – $74,999	3 (17)	2 (25)	1 (10)
$75,000 and above	8 (44)	3 (38)	5 (50)
Prefer not to answer	4 (22)	2 (25)	2 (20)
Education, n (%)			
High school	4 (22)	3 (38)	1 (10)
Some college/associate degree	8 (44)	4 (50)	4 (40)
Bachelor or Graduate degree	6 (33)	1 (13)	5 (50)
Body Mass Index (BMI), n (%)			
Less than 25 kg/m^2	1 (5)	0	1 (10)
25–30 kg/m^2	5 (28)	2 (25)	3 (30)
Higher than 30 kg/m^2	12 (67)	6 (75)	6 (60)
Current Smoking or Vaping Status, n			
Currently smoke or vape	0	0	0
Residential distance from derailment site (miles)			
Mean (SD)	0.9 (0.4)	0.9 (0.4)	0.8 (0.3)
Range	0.3–1.6	0.4–1.6	0.3–1.0
Evacuation date, n (%)			
February 3–4	9 (50)	2 (25)	7 (70)
February 5–6	8 (44)	5 (63)	3 (30)
Did not evacuate	1 (6)	1 (12)	0 (0)
Return date, n (%)			
February 8–9	6 (35)	2 (29)	4 (40)
February 10–13	7 (41)	3 (43)	4 (40)
February 26	1 (6)	1 (14)	0 (0)

	Total (N = 18)	Male (N = 8)	Female (N = 10)
Did not return as of July 17, 2023	3 (18)	1 (14)	2 (20)