# A COMPARISON OF DIOXIN LEVELS FOUND IN RESIDENTIAL SOILS OF DAVIS COUNTY UTAH WITH THOSE FOUND IN RESIDENTIAL SOILS IN THE DENVER FRONT RANGE

**Rocky Mountain Center for Occupational and Environmental Health**
**Department of Family and Preventive Medicine**
**University of Utah**

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## INTRODUCTION

### *1.1 Overview of the Issue*

Dioxins can be formed and released into the environment from multiple sources including, but not limited to, the combustion of municipal and medical waste, combustion of coal and wood from power plants, combustion of petroleum-based compounds, wood burning furnaces, uncontrolled burning of waste, forest and brush fires, structural fires, cement kilns, metals processing, and chemical manufacturing. Dioxins can be found in soils and other environmental media after atmospheric transport and deposition. Dioxins are a potential health concern because they may increase risk of cancer and other adverse health effects at very low exposure levels. Dioxins are persistent environmental chemicals that accumulate in the food chain because of their hydrophobic and lipophilic nature and resistance to metabolism.

It is desirable to measure ambient concentrations of dioxins in soil and other environmental media to allow comparison of these levels with dioxin levels from sites with regulatory or health concerns. A major effort to determine ambient levels of dioxins in soils was performed along the Denver, Colorado Front Range in 1999 to develop a baseline for comparison with soils collected from the Rocky Mountain Arsenal. This study was undertaken to compare the concentration of dioxins in the residential soils of Davis County, Utah to those found in the residential soils of the Denver Front Range.

### *1.2 Definition of Dioxins*

In this study the term "dioxins" is used to denote a set of 17 chemically related congeners in the dioxin/furan group that bind to the aryl hydrocarbon (Ah) receptor in some cells and possess toxic characteristics similar to 2,3,7,8 tetrachlorodibenzo-*p*-dioxin (TCDD), the most toxic of the dioxin congeners. TCDD and the other dioxins are a potential health concern because they may pose an increased risk of cancer and other adverse health effects at very low exposure levels.[1]

An additional 12 congeners from the polychlorinated biphenyl (PCB) group are often included with the 17 dioxin/furan congeners resulting in a total of 29 dioxin/furan/PCB congeners that are collectively referred to as "dioxins". This study does not include analysis of the PCB congeners because the current USEPA soil screening levels for dioxins are based only upon the 17 dioxin/furan congeners. [2]

### *1.3 Calculation of TCDD Equivalents in Soil*

Not all dioxin congeners are equally toxic. The relative toxicity of a congener, compared to that of TCDD is expressed in terms of Toxicity Equivalency Factor (TEF). Table 1 lists the consensus mammalian (including human) TEF values for the 17 dioxin/furan congeners, developed by a panel of experts assembled by the World Health Organization (WHO). Note that TEFs are often based on limited data, and so they are only an *order of magnitude* approximation of the relative toxicity of each congener.[3]

Table 1: List of Analytes and TEFs[3]

| Class | Target Analyte | TEF for Mammals |
|---|---|---|
| Dibenzo-*p*-dioxins (PCDDs) | 2,3,7,8-TCDD | 1 |
| | 1,2,3,7,8-PeCDD | 1 |
| | 1,2,3,4,7,8-HxCDD | 0.1 |
| | 1,2,3,6,7,8-HxCDD | 0.1 |
| | 1,2,3,7,8,9-HxCDD | 0.1 |
| | 1,2,3,4,6,7,8-HpCDD | 0.01 |
| | OCDD | 0.0001 |
| Dibenzofurans (PCDFs) | 2,3,7,8-TCDF | 0.1 |
| | 1,2,3,7,8-PeCDF | 0.05 |
| | 2,3,4,7,8-PeCDF | 0.5 |
| | 1,2,3,4,7,8-HxCDF | 0.1 |
| | 1,2,3,6,7,8-HxCDF | 0.1 |
| | 1,2,3,7,8,9-HxCDF | 0.1 |
| | 2,3,4,6,7,8-HxCDF | 0.1 |
| | 1,2,3,4,7,8,9-HpCDF | 0.01 |
| | 1,2,3,4,6,7,8-HpCDF | 0.01 |
| | OCDF | 0.0001 |

The aggregate toxicity of different dioxins in an exposure medium (soil, food, etc.) is a function of the concentration of each congener in the medium, the intake of the medium, the toxicokinetics (distribution, metabolism and elimination) of the congeners, the relative biological potency of the congeners, the absorption from the medium and the congener-specific TEF values. However, for the purposes of screening-level evaluations of dioxin concentrations in soil samples, it is usually most convenient to calculate the concentration of TCDD-Equivalents (TEQs) present in soil as shown below in eq 1:

(1) $$TEQ_{(D/F)} = \sum_{i=1}^{17} (C_i * TEF_i)$$

Where: $C_i$ is the concentration of the specific congener in the exposure medium and $TEF_i$ is the respective Toxicity Equivalency Factor for that congener.[3]

The application of TEF values to the calculation of soil TEQ values is only appropriately used for screening purposes. This is because TEFs are derived from, and thus should only be applied to, biological endpoints (e.g., embryotoxicity). The soil TEQ approach does not account for the potential influences of differential absorption, metabolism, distribution, and excretion of different congeners from soil, and risk assessors should account for these uncertainties in the interpretation of the soil TEQ values.[1]

### *1.4 Purpose of This Study*

The current study focuses on the concentration of the17 dioxin/furan congeners found in residential soils of Davis County. The results of 22 surface soil samples taken throughout the county are compared to the results of 38 samples that the United States Environmental Protection Agency (EPA) obtained in residential surface soils during their Denver Front Range study. Statistical analysis, consisting of a variance test followed by a two-tailed t-test to compare the means of the EPA data to the Davis County data, was performed to compare the residential surface soil dioxin levels in Davis County and those found in the Denver Front Range study.

## MATERIALS AND METHODS

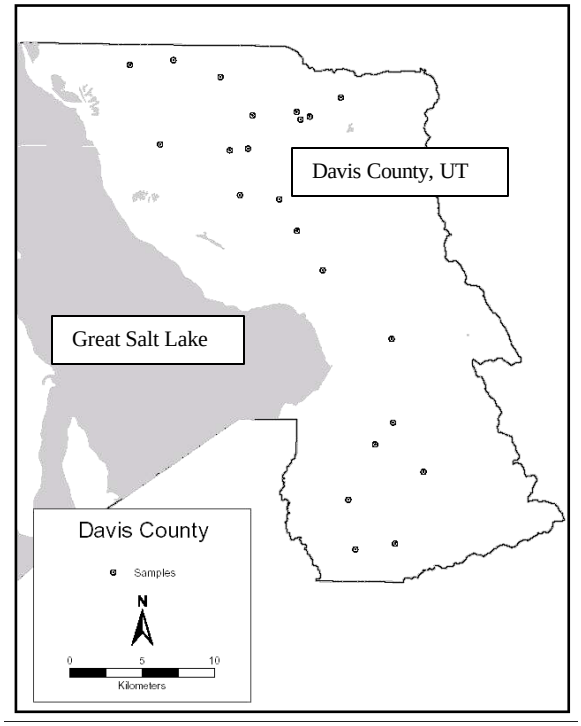
### *2.1 Study Area*

There has recently been much concern about dioxin in Davis County, UT due to the presence of a municipal waste combustor within the county. Davis County, UT is located between Salt Lake and Weber counties in the heart of the Salt Lake/Ogden metropolitan area and contains 15 cities. Davis County consists of 630 square miles and has the smallest land area of the 29 Utah counties. Only 223 square miles is actual developable land. The remainder is part of the Great Salt Lake. Fifteen cities are located in the county. The population of the county was 87,641 in 1990 and has increased to an estimated 2001 population of 250,000. Most of the population increase occupies land that was previously agricultural.[4]

Sample sites were chosen that met the EPA's definition of residential land use areas. The EPA defined residential land as land that is within 200 feet and adjacent to residential development. This land may include public parks, neighborhood greenbelts and trails, and street medians. Schools and playgrounds are not included.[1]

All of the soil samples were collected within the current boundaries of Davis County. A total of 22 sample locations in residential areas were designated and evenly distributed over the spatial area of the county. Figure 1 is a map of Davis County that contains the sampling locations.

Figure 1: Sampling Locations in Davis County




### *2.2 Sampling Procedure*

All efforts were taken to insure that the sample collection methods used for this study were equivalent to those used by the EPA during their study of the Denver Front Range. Samples were collected from relatively natural, undisturbed areas; away from potential contamination point sources not related to this investigation (i.e., railroad ties, residential shops and garages, industrial facilities, etc.); and from locations that are easily accessible and that can be readily identified in the future (i.e., near semi-permanent physical features). A global positioning satellite (GPS) device accurate to within ~ 30 feet was used to identify the UTM coordinates of each sampling location.

Thus, surface soil was the exposure medium of chief concern for human receptors and all soil samples collected for this study were grab samples collected at 0-2 inches in depth. Samples were collected as single point grab samples using a new, clean stainless steel trowel. The trowels were graduated in inches to ensure the proper sampling depth is obtained for each sample. All surface soil sampling equipment was disposed of following the collection of each sample, eliminating the need for equipment decontamination, and reducing the potential for cross-contamination. Each sample was collected in clean, laboratory supplied glass jars, labeled, and stored in a cooler with ice. Sample jars were completely filled and tightly capped. Two jars were filled at each of the locations so three random samples could be chosen for duplicates.

### *2.3 Sample Analysis*

All soil samples were submitted to Columbia Analytical Services (CAS) of Houston, TX for sample preparation. Each sample was air dried, weighed and coarse sieved

through a #10 (2 millimeter) stainless steel screen. The fraction passing through the screen is referred to as the "bulk" fraction. A portion of this fraction was stored in a clean amber glass jar for possible future use. The remainder of the bulk fraction was further sieved through a 60-mesh (250 micrometer) stainless steel screen to isolate the "fine" fraction. The fine sieved soils were placed in new clean amber jars each containing similar weights of soils that were intended to be as identical as possible.

The "fine" fraction was isolated for chemical analysis because it is believed that fine soil particles electrostatically adhere to skin, are more likely to be ingested by hand to mouth contact than course particles, and is the most relevant media for determining human health risks. In addition, the fines were analyzed during the Denver Front Range Study and similar sample handling methods were used to allow comparison of sample results.

After consultation with CAS samples were analyzed in accordance with EPA Method 1613 which could obtain a lower detection level and better resolution compared to EPA Method 8290. Method 1613 provides procedures for the detection and quantitative measurement of polychlorinated dibenzo-*p*-dioxins (tetra- through octachlorinated homologues; PCDDs), and polychlorinated dibenzofurans (tetra- through octachlorinated homologues; PCDFs) in a variety of environmental matrices and at part-per-trillion (ppt) to part-per-quadrillion (ppq) concentrations. The analytical method calls for the use of high-resolution gas chromatography and high resolution mass spectrometry (HRGC/HRMS) on purified sample extracts.

### *2.4 Quality Assurance*

Numerous steps were taken in this study to obtain data that would allow an assessment of the quality and reliability of the data collected. This was done so that the usability of the data could be defended.

#### Duplicates

A duplicate is a second sample of soil that is collected simultaneously and with the same sampling method as with the first sample at the same location.

#### Independent Data Validation

## RESULTS AND DISCUSSION

Detailed analytical results for each field sample are presented in Appendix A1. The results are summarized below.

### *3.1 Data Validation Results*

Full validation of the data collected during this study found the analytical results for all samples to be usable, as qualified with the appropriate data quality flags.

### *3.2 TEQ Values in Field Sample and Comparison to Denver Front Range*

The analytical results obtained were treated in the same manner as the results that the EPA determined in their Denver Front Range study. The data flags from the two respective labs were compared and the data was treated accordingly. Most of the data points were used as reported; the exception would be those analytes for which the lab reported "nondetects". For those analytes a concentration of ½ the method detection limit was applied. The results for each of the 17 analytes (congeners) for each sample were multiplied by their respective TEF value to obtain a TEQ value for the congener. The individual congener TEQs were then summed to obtain the sample TEQ. The sample results for both Davis County and the Denver Front Range were then rank ordered. This data is presented below in Table 2, with concentrations in parts per trillion (ppt).

Table 2: Davis County and Denver Front Range Residential Soil Dioxin Concentrations

| **Sample** | **Davis County Concentration (ppt)** | **Denver Front Range Concentration (ppt)** |
|---|---|---|
| 1 | 0.323 | 0.213 |
| 2 | 0.399 | 0.525 |
| 3 | 0.425 | 0.879 |
| 4 | 0.436 | 0.885 |
| 5 | 0.490 | 1.103 |
| 6 | 0.575 | 1.112 |
| 7 | 0.601 | 1.148 |
| 8 | 0.615 | 1.273 |
| 9 | 0.673 | 1.275 |
| 10 | 0.687 | 1.283 |
| 11 | 0.727 | 1.425 |
| 12 | 1.067 | 1.507 |
| 13 | 1.140 | 1.571 |
| 14 | 1.177 | 1.749 |
| 15 | 1.241 | 1.779 |
| 16 | 1.396 | 1.797 |
| 17 | 1.833 | 1.871 |
| 18 | 2.223 | 1.994 |
| 19 | 2.445 | 2.114 |

| | | |
|---|---|---|
| 20 | 2.819 | 2.290 |
| 21 | 3.727 | 2.328 |
| 22 | 4.466 | 3.054 |
| 23 | | 3.578 |
| 24 | | 3.817 |
| 25 | | 4.420 |
| 26 | | 5.634 |
| 27 | | 6.714 |
| 28 | | 7.540 |
| 29 | | 7.984 |
| 30 | | 8.340 |
| 31 | | 9.371 |
| 32 | | 11.340 |
| 33 | | 16.806 |
| 34 | | 22.478 |
| 35 | | 26.929 |
| 36 | | 27.956 |
| 37 | | 30.254 |
| 38 | | 42.880 |

The data in Table 2 was then plotted. Both sets of data appeared to be logarithmically distributed so logarithmic regression was applied to each data set. The graph for the Denver Front Range is presented as Figure 2 and the graph for Davis County is presented as Figure 3.

Figure 2: Denver Front Range Data Plot

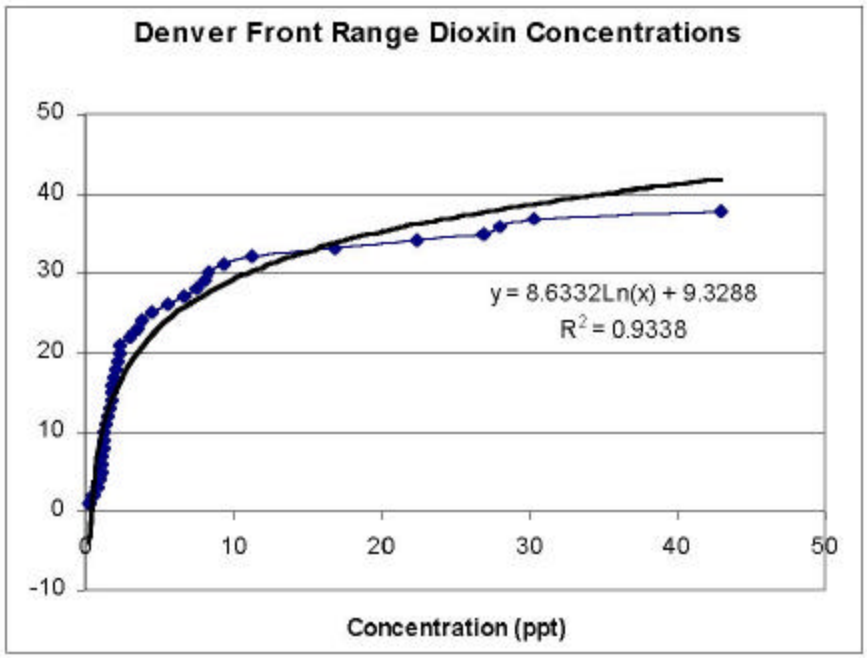
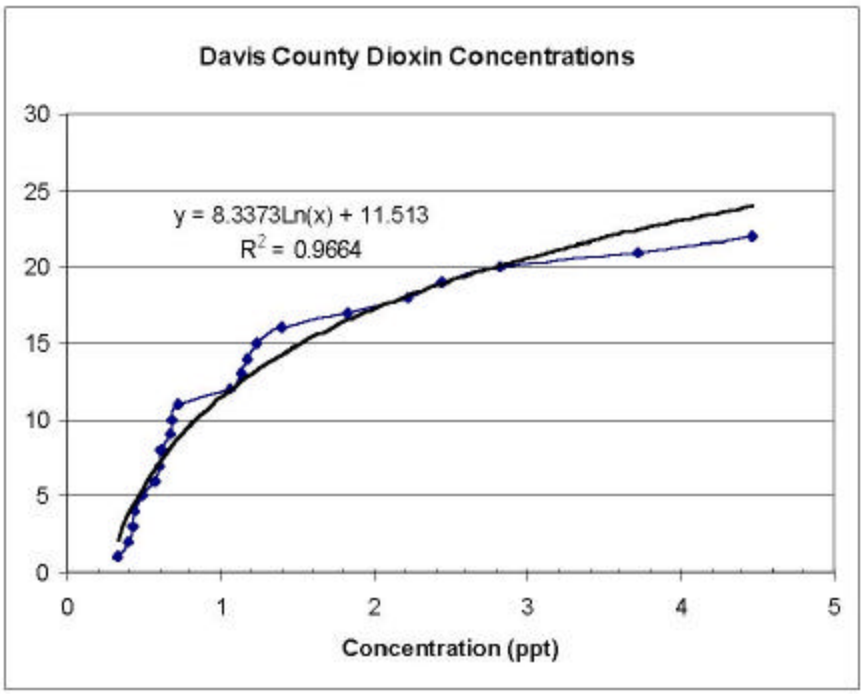


Figure 3: Davis County Data Plot




The logarithmic regressions yielded $R^2$ values of 0.934 for the Denver Front Range data and 0.966 for the Davis County data. These $R^2$ values demonstrate a nearly linear relationship for the log-transformed data. Figures 4 and 5 are graphs of the logarithmically transformed data.

Figure 4: Log Transformed Plot of Denver Front Range Data

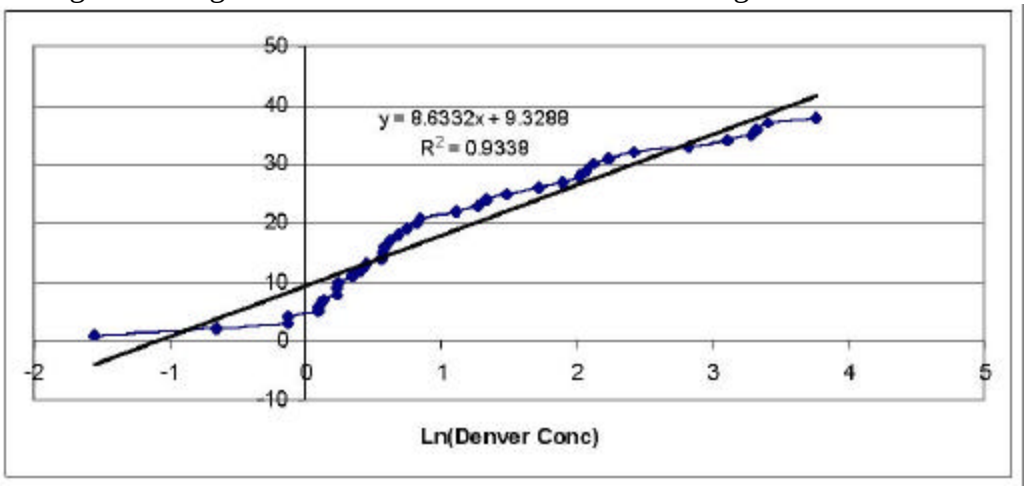
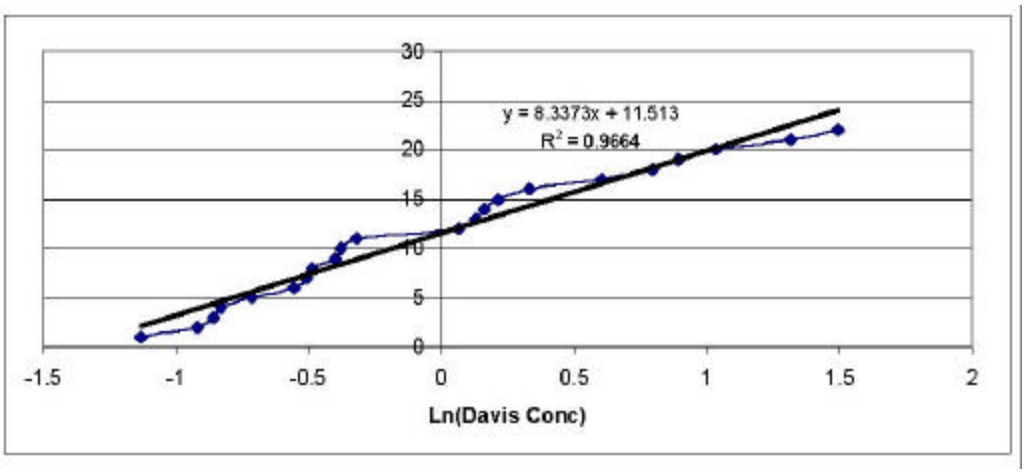



Figure 5: Log Transformed Plot of Davis County Data




Geometric numerical summary measures were then computed for each of the two data sets presented in Table 2. Those results are shown below in Table 3.

Table 3: Summary of Statistical Data

| Data Set | Observations | Range | Geometric Mean | 95% Confidence Interval |
|---|---|---|---|---|
| Davis County | 22 | 0.323-4.466 | 0.998 | 0.711-1.402 |
| Denver Front Range | 38 | 0.213-42.88 | 3.248 | 2.158-4.889 |

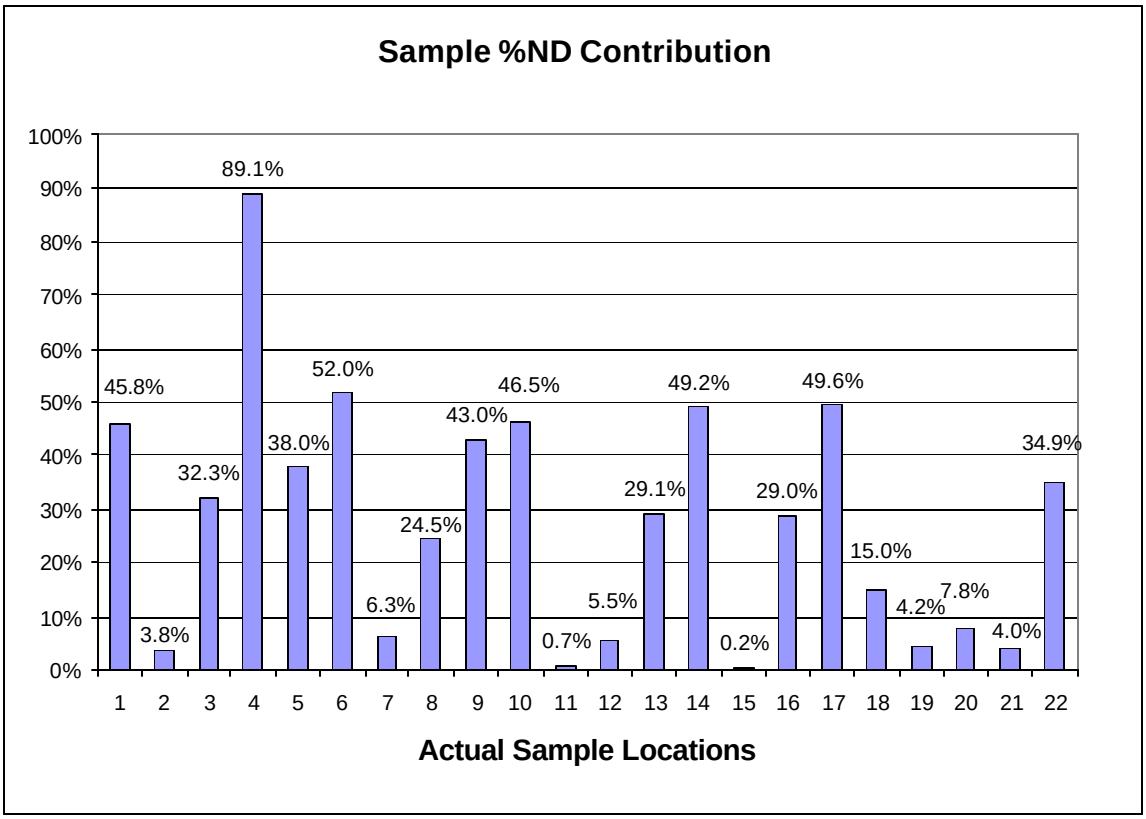
The logarithmically transformed data for Davis County and the Denver Front Range were then subjected to an equal variance test to determine which type of t-test was required to compare the means of the two data sets. The test yielded $p$=0.0152, which demonstrates that the two data sets have unequal variances. An unequal variances, unpaired two-sample t-test was then applied to the two data sets to compare the means of those sets. The results of the test were $p$=0.0000, therefore the hypothesis was rejected which leads to the conclusion that the geometric means of the data sets are not equal.

### *3.3 Contribution of Congeners Below the Quantitation Limit (Non-Detects)*

As noted above, in the calculation of the TEQ value for a sample, all congeners that were below the MDL (signal/noise ratio < 2.5) were assumed to have a concentration equal to ½ the detection limit. All other results were used as reported by CAS. This is the same method that the EPA used in their study.

Figure 6 is a graphical representation of the contribution of non-detected congeners at each sample location.

Figure 6: Contribution of Non-Detected Congeners




Treatment of non-detected congeners in a sample is an important consideration when comparing dioxin concentrations. In this study non-detects contributed between 0.2-89.1% of the overall sample concentration, with the largest contributions occurring on the samples with the lowest concentrations. Therefore, in order to compare dioxin concentrations between studies, treatment of the non-detects must be identical.

### *3.4 Contribution of Specific Congeners*

The contribution of individual congeners may provide information that would lead to the source of the dioxin contamination. It can also reveal which congeners are contributing the majority of the risk. Table 4 presents the overall congener contribution for Davis County and the Denver Front Range reported mean contribution. It should be noted that the top five contributors in each case are the same.

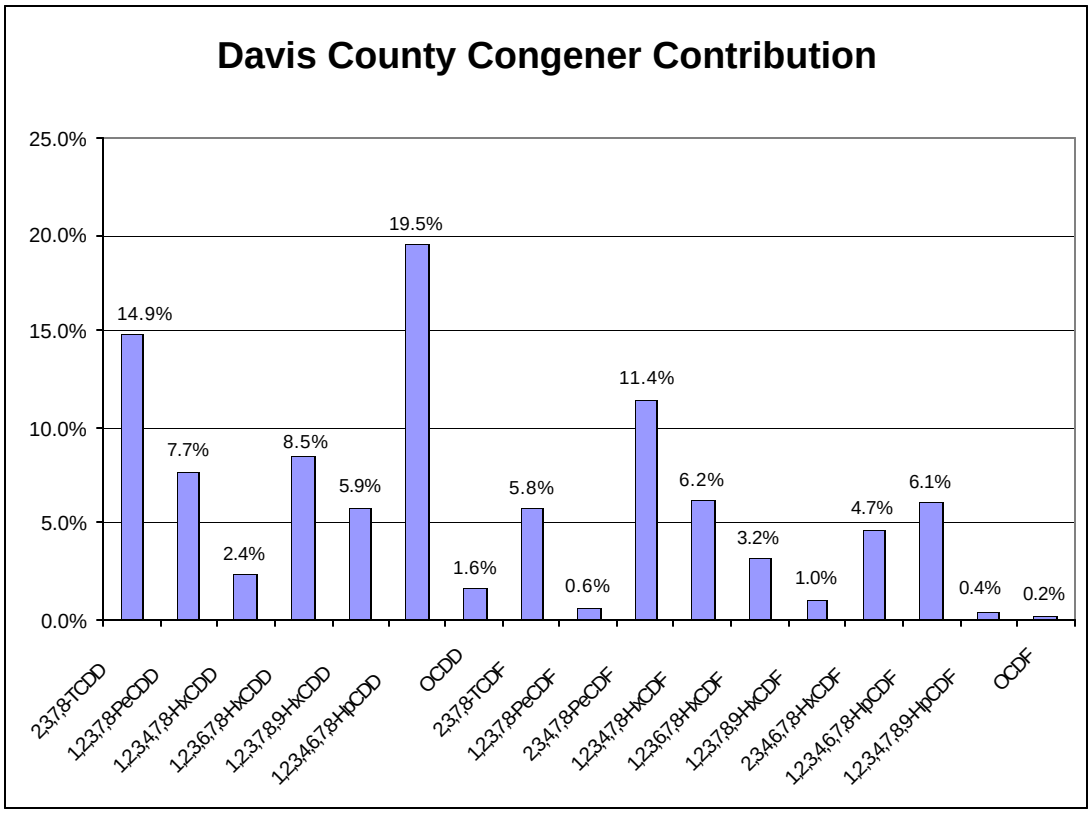
Table 4: Davis County and Denver Front Range % Contribution by Congener

| Congener | Davis County Overall % Contribution | Denver Front Range EPA Reported Mean % Contribution |
|---|---|---|
| 2,3,7,8-TCDD | 14.9% | 9.0% |
| 1,2,3,7,8-PeCDD | 7.7% | 23.9% |
| 1,2,3,4,7,8-HxCDD | 2.4% | 3.7% |
| 1,2,3,6,7,8-HxCDD | 8.5% | 7.9% |
| 1,2,3,7,8,9-HxCDD | 5.9% | 5.0% |
| 1,2,3,4,6,7,8-HpCDD | 19.5% | 21.7% |
| OCDD | 1.6% | 1.5% |
| 2,3,7,8-TCDF | 5.8% | 0.6% |
| 1,2,3,7,8-PeCDF | 0.6% | 0.6% |
| 2,3,4,7,8-PeCDF | 11.4% | 10.7% |
| 1,2,3,4,7,8-HxCDF | 6.2% | 2.7% |
| 1,2,3,6,7,8-HxCDF | 3.2% | 2.3% |
| 1,2,3,7,8,9-HxCDF | 1.0% | 2.6% |
| 2,3,4,6,7,8-HxCDF | 4.7% | 3.4% |
| 1,2,3,4,6,7,8-HpCDF | 6.1% | 3.7% |
| 1,2,3,4,7,8,9-HpCDF | 0.4% | 0.4% |
| OCDF | 0.2% | 0.1% |

*NOTE: Shaded denotes top five

The data in Table 4 are also presented graphically in Figure 7.

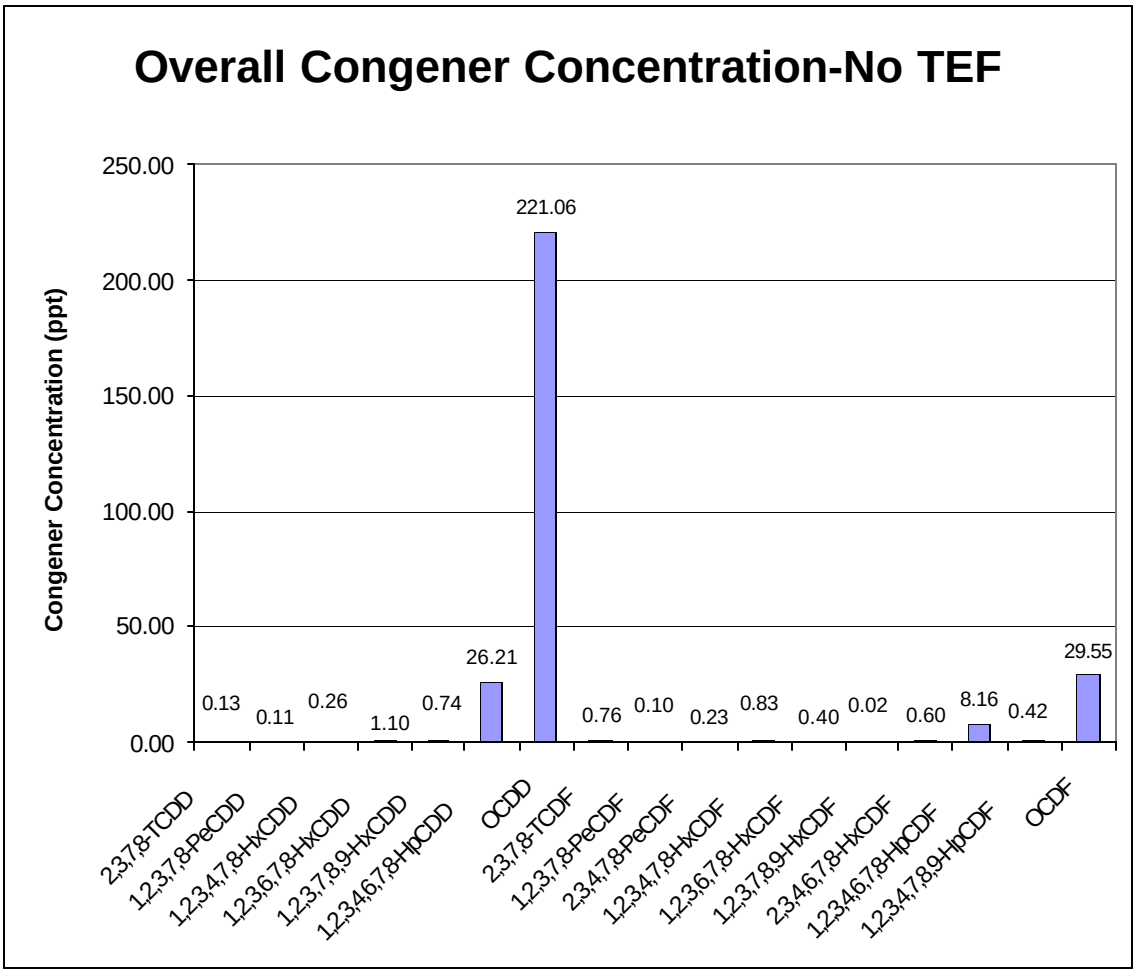
Figure 7: Overall Contribution by Congener in Davis County




Appendix B presents each sample with graphs illustrating each congener's contribution to the overall concentration for that sample. These graphs vary greatly and this data does not lead to the conclusion that "fingerprinting" a source would be possible in this case.

An analysis of the individual congener contribution to the overall concentration without applying the TEF multipliers was also performed. The results are presented in Figure 8. This analysis was performed to determine which congener contributed most to concentration on a weight basis. As can be seen from the figure, OCDD is by far the most prevalent congener.

Figure 8: Overall Congener Contribution, No TEFs Applied




### *3.5 Quality Control Samples*

Quality control samples that were analyzed as part of this study indicate that the data are reliable and accurate, as described below.

Method Blanks

Duplicates

At every sample location a field duplicate was taken. Of the 22, three were randomly chosen to be analyzed. These samples were compared to the samples from the same site. As in the EPA's study, the Method Quantification Limit (MQL) was used to compare the sample pairs. The MQL is defined as ten times the signal noise. The MQL is a unique value for each of the congeners in each of the samples. The individual

congener MQLs were then summed to obtain the overall sample MQL or $MQL_{TEF}$ . The overall difference between the sample pairs is compared to the lowest $MQL_{TEF}$ of the pair. These results are presented in Table 5.

Table 5 : Analysis of Duplicates

| | $C_{sample}$ | $C_{duplicate}$ | ? $_{(sample-duplicate)}$ | Lowest $MQL_{TEF}$ |
|---|---|---|---|---|
| Sample Location 3: | 0.490 | 0.327 | 0.163 | 1.216 |
| Sample Location 9: | 0.687 | 0.471 | 0.216 | 1.153 |
| Sample Location 18: | 1.396 | 0.536 | 0.860 | 0.891 |

All differences were within on $MQL_{TEF}$, therefore CAS met initial QC requirements that the EPA used in their study.

Performance Evaluation Samples

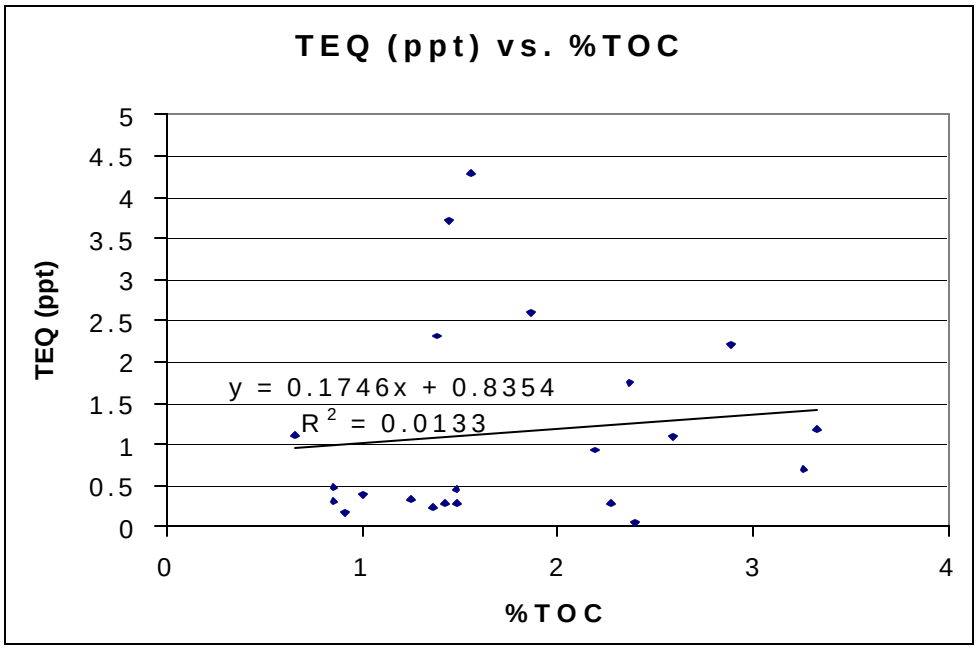
Laboratory Spikes

### *3.6 Evaluation of Potential Confounders*

Binding of dioxins to soil particles is a physical process that might be expected to depend on the total organic carbon (TOC) content of the soil due to the chemical properties of dioxins. This data was found to be somewhat limited, which may be due to the use of TEQ values calculated from congener contributions that were below the MDL.

Figure 8 shows the relationship between TOC and TEQ. The TOC levels in the samples ranged from 0.66% to 3.33%. The slope of the best fit is different from zero, but the coefficient of determination is low ($R^2$ = 0.013). This suggest that the TEQ value for a sample my depend in part on the TOC of the soil, but that it is not the main determinant of the TEQ value.

Figure 8: Graph of TOC vs. TEQ



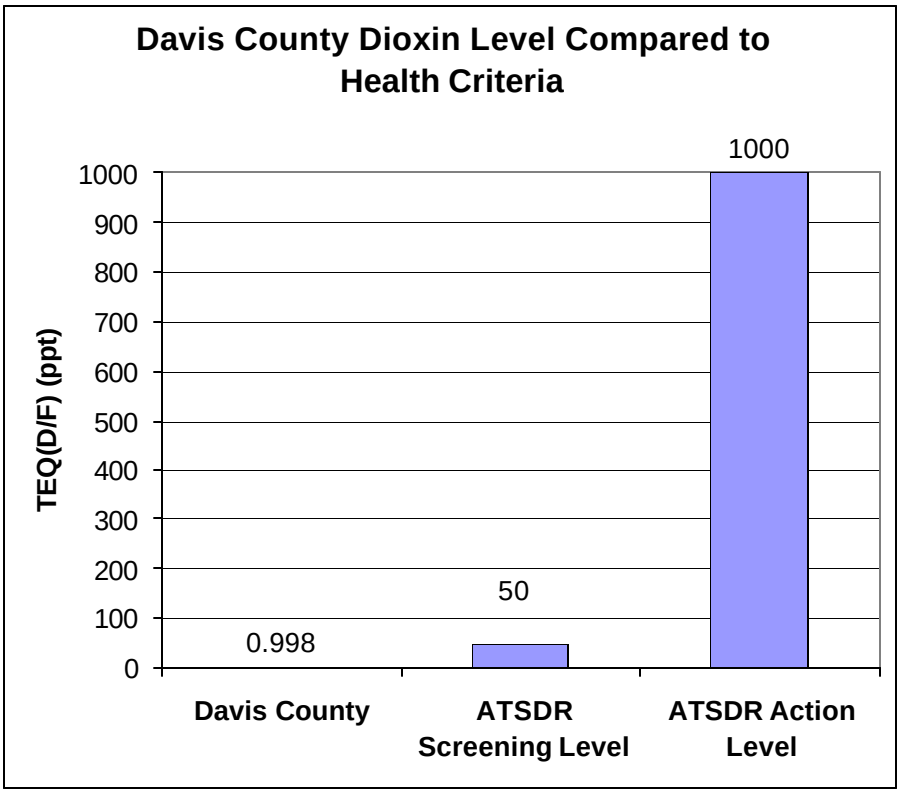

### *3.7 Comparison to Human Health-Based Guidelines*

Although the basic purpose of this study was to characterize the distribution of dioxins in soils of residential areas of Davis County and compare them to the Denver Front Range, it may be of some use to provide a health-based frame of reference by which the distributions may be placed in context.

The EPA has currently established a default concentration value of 1,000 parts per trillion (ppt) TEQ in surface soil as a concentration that is not of cancer or non-cancer concern for lifetime exposure of residents.[1] These concentrations are based only upon the 17 TCDD-like PCDDs and PCDFs (which were evaluated in this study), calculated using the TEFs for mammals recommended by WHO.[3]

The Agency for Toxic Substances and Disease Registry (ATSDR) has also established a guideline for human exposure (residential) to dioxins in soil.[5] ATSDR identifies a concentration of 50 ppt TEQ in soil as a "screening level," below which no further investigation will usually be required. ATSDR identifies 1000 ppt TEQ as an "action level," which indicates that public heath actions should be considered. These actions include surveillance, research, health studies, community education or exposure investigations. Figure 9 compares these levels to the level of dioxin that was found in Davis County. None of the individual soil samples in Davis County exceeded the ATSDR's screening level (or even approached it). In consideration of these factors it can be determined that the dioxin levels in Davis County residential soil samples taken during this study are not of significant human health concern.

Figure 9: Davis County Dioxin Level Compared to Health Criteria




## CONCLUSIONS

This study compares the concentration of dioxin in residential soils of Davis County to those found by the EPA in the Denver Front Range. All efforts were made to duplicate the sampling methodology and treatment of the analytical data used by the EPA in their study. The hypothesis of this study was not supported by the data. The geometric mean concentration of dioxin in Davis County soil was found to be 0.998 ppt and in the Denver Front Range it was found to be 3.248 ppt.

The levels of dioxin found in the residential soils of Davis County are far below the 50 ppt screening level established by the Agency for Toxic Substance and Disease Registry (ATSDR). The screening level defines chemicals of concern to human health which are then taken forward in the health assessment process for further evaluation. These levels are also substantially lower than the ATSDR's action level of 1000 part per trillion. The action level is defined as the concentration at which consideration of action to interdict exposure occurs.[5] The dioxin levels in Davis County residential soil samples taken during this study are not of significant human health concern.

There are numerous factors that could contribute to the difference in the soil dioxin levels found in Davis County as compared to those found in the Denver Front Range. Geographical features may play a role. Davis County has a mountain range directly to its

east and the Denver Front Range has a mountain range to its west. Differences in weather patterns would also play a role in deposition of dioxins from the atmosphere. One significant source of dioxin is from uncontrolled combustion of biomass (i.e. forest fires). The Denver Front Range may be downwind from more forest fires and thus may be subjected to more significant dioxin deposition. Davis County has historically been the "bread basket" of Utah and has only recently seen a significant increase in population. There are only limited areas of the county that could be considered industrial. Most of the county is residential or agricultural.

Other studies could be undertaken to investigate the dioxin concentrations found in other land-use area types or other Utah counties to compare to the results of this study.

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