A STATISTICAL ANALYSIS OF ATTIC DUST AND BLOOD LIPID CONCENTRATIONS OF TETRACHLORO-P-DIBENZODIOXIN (TCDD) TOXICITY EQUIVALENCY QUOTIENTS (TEQ) IN TWO POPULATIONS NEAR WOOD TREATMENT FACILITIES

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INTRODUCTION

Colfax Creosoting Company and Durawood Treating Company are two wood treating companies operating in close proximity to one another in Louisiana. These facilities potentially released dioxins and other hazardous substances into the surrounding community. The facilities used pentachlorophenol (PCP), chromated copper arsenate (CCA), and creosote as insecticides to treat wood. Durawood is located within Alexandria and Colfax is located adjacent Pineville, LA. Colfax has been in operation since 1948 and Durawood has been in operation since 1926. Comparing the exposure of residents surrounding these similar sites gives insight into the pattern of exposure that communities adjacent to other wood treatment facilities might experience. Dioxins and furans are impurities found in PCP[1]. Attic dust and human blood sampling are useful tools for evaluating and assessing historical exposure to airborne dust contaminants. Once airborne dust infiltrates the attic, it settles and is protected from weathering, serving as a "time capsule" of contaminants associated with dust[2]. Dioxins and furans have relatively long half-lives in human blood, therefore, sampling human blood can also be used to assess historical exposure[3].

MATERIALS AND METHODS

Blood samples were collected from 22 current and past residents of the communities immediately surrounding the Durawood and Colfax facilities and analyzed to evaluate levels of dioxins and furans. There were 11 individuals in each group. The sampled individuals' ages ranged from 34 to 80 years with an average of 60 years. The 22 individuals were selected based on exhibited illnesses that could potentially have resulted from exposure to contaminants released by the facilities. Whole blood samples were collected in May 2007. Samples were then shipped overnight on ice to Severn Trent Laboratories (STL) in Sacramento, CA.

In accordance with USEPA Method 8290, STL used high resolution gas chromatography (HRGC)/mass spectrometry (HRMS) to analyze the blood samples. Each sample batch included a Method Blank (MB), a Laboratory Control Sample (LCS), and the unknown serum samples. Data was reviewed using comprehensive multi-tiered quality assurance and quality control procedures.

Attic sampling was performed in June 2004 in 13 buildings located within a one-mile radius of the Colfax wood treatment facility and in 15 buildings surrounding the Durawood wood treatment facilities.

The samples were collected using the High Volume Surface Sampler (HVS-3) forensic vacuum sampler developed by Environmetrics and Engineering Plus for the US Environmental Protection Agency. The target area for the samples was usually the attic at each residence since attic dust is typically undisturbed by residents and therefore provides sufficient volumes of dust for analysis. Sampling was performed in general accordance with American Society for Testing and Materials (ASTM) method D5438, "Standard Practice for Collection of Floor Dust for Chemical Analysis."

Sampling equipment was thoroughly decontaminated and Modified Level C Protection was followed. AXYS Analytical Laboratories was used for testing attic dust samples. PAHs were evaluated in general accordance with Modified USEPA Method 8270 using GC/HRMS. Dioxins/furans were analyzed in general accordance with USEPA Method 1613B using GC/HRMS. Each sample batch included a MB, a LCS, and the unknown attic dust sample. Quality assurance and quality control measures were taken similar to the blood sample analysis.

USEPA (1989)[4] Toxic Equivalency Factors (TEFs) were used to quantify and evaluate the levels of dioxins and furans in the attic dust and blood samples. TEFs were also used to quantify and evaluate the levels of PAHs in attic dust[4]. The USEPA has assigned TEFs to specific dioxin, furan, and PAH congeners, relating the toxicity of carcinogenic dioxins, furans, and PAHs to TCDD (dioxins and furans) and to benzo[a]pyrene (PAHs). To prevent an under-estimation of the actual levels of the target contaminants, non-detected target analytes in the blood and attic dust samples were addressed by considering the incidences as half the limit-of-detection in analysis of the data [3].

The 1999-2000 and 2001-2002 NHANES laboratory data for dioxins and furans were downloaded from the CDC website[5]. The data was downloaded in SAS format, but converted to Microsoft Excel format using SYSTAT 11.0 statistical software package. One-half the detection limit was substituted for concentrations below the detection limit in all calculations. TCDD TEQs were calculated for the data using the 1989 USEPA TEF values (Table 1) and total dioxin TEQs were summed for each individual. The data was then filtered for males and females 34 to 80 years of age to correspond with the data. TEQs were then used to calculate the sum, mean, maximum, minimum and other summary statistics for each congener in serum and in lipid-adjusted serum concentration data. NHANES TCDD TEQ data for individuals with ages ranging from 34 to 80 resulted in a population of 1729 individuals.

Statistical analyses were done on the datasets to determine if the cohorts' TCDD-TEQ blood lipid concentrations are statistically different and greater than the general US population of the same age range. The Statistics Online Computational Resource (SOCR) software developed by the University of California, Los Angeles was used for the analysis of the data. The results demonstrated that Colfax, Durawood, the meta-analysis and NHANES datasets are not normally distributed. Therefore, the Wilcoxon rank-sum test, a non-parametric test for assessing whether two samples of observations come from the same distribution, was used to evaluate the datasets. Non-detects were evaluated as the limit of detection divided by two. This is the most common method of evaluating non-detects since dioxin is assumed to be present in the samples at just below the analytical limit of detection. It is also possible to divide the non-detect by the square root of two. However, the results were found to be similar.

Initially, the Colfax and Durawood datasets were compared to the NHANES dataset individually. Then Colfax and Durawood datasets were combined and compared to the NHANES dataset in a meta-analysis. The Wilcoxon rank-sum tests the null hypothesis that the three samples are drawn from a single population, and therefore their probability distributions are equal. The samples must be independent, and the observations must be continuous measurements. The Wilcoxon rank-sum test generates a *p*-value for the datasets. If the probability distributions for the samples are equal, the Colfax and Durawood TCDD TEQ blood-lipid concentrations are not statistically different from the general US populations. The *p*-value represents the probability of error associated with rejecting the hypothesis of no difference between the two categories of observations (corresponding to the groups) in the population when, in fact, the hypothesis is true. A *p*-value of between 0.05 and 0.01 demonstrates that there is moderate evidence against the null hypothesis in favor of the alternative. A *p*-value of less than 0.001 indicates that there is strong evidence against the null hypothesis in favor of the alternative.

RESULTS AND DISCUSSION

The levels of dioxins, furans, and PAHs (i.e. total TEQ concentrations) in attic dust were compared to the United States Environmental Protection Agency's Preliminary Remediation Goals and found to far exceed the levels which are regarded as safe for the general population (Table 1).

The results of the statistical analysis of the TCDD TEQs in blood lipid demonstrate that the populations surrounding the Colfax and Durawood facilities have a statistically higher concentration of TCDD TEQs in blood lipid than the general population of the U.S. of the same age range. The means for datasets were 90.6, 40.1, 65.3 and 11.6 for Colfax, Durawood, meta-analysis, and NHANES (ages 34-80) respectively. When the Colfax and Durawood datasets were compared individually to the NHANES dataset using the Wilcoxon rank-sum test, there is sufficient evidence to indicate that the three cohorts are distinct ($p<0.001$). Table 2 presents the Colfax and Durawood TCDD TEQ concentration in blood lipid data. Table 3 presents data summary for the Colfax, Durawood, and meta-analysis TCDD TEQ blood lipid data. Table 4 presents the Wilcoxon rank-sum test data outputs comparing the NHANES dataset to the Colfax and Durawood TCDD TEQ blood lipid datasets individually and combined in the meta-analysis. The Colfax and Durawood TCDD TEQs values are statistically greater than the NHANEs TCDD TEQ values ($p<0.001$). The meta-analysis (combination of the Colfax and Durawood datasets) gives a more accurate representation of the study population and further confirms that the cohort surrounding the wood treatment facility has TCDD TEQ concentrations that are statistically greater than the general US population ($p<0.001$).

Similar to the blood levels, attic dust samples have significantly elevated OCDD and HpCDD levels. The elevated OCDD and HpCDD levels are consistent throughout the sampled homes. A similar pattern was also observed in Dahlgren *et al.*. (2003)[6], Dahlgren *et al.*. (2007)[2], and Hensley *et al.*. (2007)[3] studies. This pattern indicates that hazardous material originating from the wood-treatment facilities traveled off-site, impacting the surrounding residential areas. The elevated levels of dioxins, furans and PAHs in attic dust show that the residential areas surrounding both the Colfax and Durawood facilities have been exposed to dust that potentially contained unsafe levels of these contaminants.

Studies correlate exposure to chemicals such as dioxins, furans, and PAHs, with increased risk of developing a variety of diseases. Exposure to dioxins and furans can lead to endocrine disruption, reproductive & developmental defects, immunotoxicity, hepatotoxicity, neurotoxicity, and a variety of cancers[1]. Exposure to PAHs can increase the risk of developing breast, lung, and skin cancer, leukemia, respiratory toxicity, and reproductive toxicity[1]. Exposure to a mixture of dioxins, furans, and PAHs can significantly increase the risk of developing adverse health effects since these chemical may have additive and synergistic properties[3].

Similar to other studies that have investigated exposure from residing near wood treatment facilities, the levels of dioxins, furans, and PAHs found in attic dust and human blood in this study further demonstrate that the residential areas have been and are being exposed to potentially unsafe levels of these contaminants. Comparing the levels of dioxins, furans, and PAHs (i.e. total TEQ concentrations in attic dust) to the PRGs demonstrates that the levels found in the sampled homes are far above levels which are considered safe for the general population. The residents near the Colfax and Durawood facilities also have statistically higher concentrations of TCDD TEQs in blood lipid than the general population of the U.S. of the same age range. Furthermore, considering dioxin's long half-life in blood, these concentrations are even more significant. Comparing the exposure of residents around these similar sites gives insight into the pattern of exposure that communities adjacent to other wood treatment facilities might experience.

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Table 1: The levels of dioxins, furans, and PAHs (i.e. total TEQ concentrations) in attic dust were compared to the United States Environmental Protection Agency's Preliminary Remediation Goals and found to far exceed the levels whic are regarded as safe for the general population.

COLFAX			DURAWOOD		
Site Number	Total B[a]P TEQ Concentration (mg/kg)	Total Dioxin TEQ Concentration (ng/kg)	Site Number	Total B[a]P TEQ Concentration (mg/kg)	Total Dioxin TEQ Concentration (ng/kg)
1	0.97	264	**14**	0.19	768
2	0.95	326	**15**	1.06	198
3	2.58	331	**16**	0.83	241
4	0.08	1062	**17**	0.76	35
5	0.37	30	**18**	2.61	383
6	0.44	206	**19**	119.88	151
7	0.14	360	**20**	2.35	202
8	0.56	4596	**21**	0.22	29
9	0.11	870	**22**		82
10	0.1	123	**23**	0.56	331
11	0.47	61	**24**	6.09	488
12	0.05	343	**25**	0.38	112
13	0.08	11	**26**		41
			27	0.85	47
			28	1.37	831
95% UCL	0.99	1436	**95% UCL**	43.6	432
Mean	0.73	660	**Mean**	10.55	263
Median	0.44	326	**Median**	0.85	198
US EPA Preliminary Remediation Goals (PRGs) for combined soil exposure routes					
Compound	*Benzo[a]pyrene (PAH)*	*Dixoin*	**Compound**	*Benzo[a]pyrene (PAH)*	*Dixoin*
	0.062	3.9		0.062	3.9

Table 2: Colfax and Durawood TCDD TEQ concentration in blood lipid data

	Client ID:	Age	TCDD TEQs
COLFAX	1	34	19.9
	2	63	292.4
	3	54	28.3
	4	50	63.0
	5	48	42.7
	6	67	69.4
	7	43	74.6
	8	72	112.7
	9	63	83.7
	10	72	45.7
	11	80	164.4
DURAWOOD	12	59	53.1
	13	70	81.4
	14	69	26.9
	15	59	46.8
	16	37	38.2
	17	66	19.1
	18	79	26.5
	19	66	55.6
	20	59	20.4
	21	59	36.1
	22	58	36.6
	95% UCL	--	86.7
	Minimum	34.0	19.1
	Maximum	80.0	292.4
	Mean	**60.3**	**65.3**

Table 3: Data summary for the Colfax, Durawood, and meta-analysis TCDD TEQ concentration in blood lipid data.

Statistical Parameter	Colfax (Ages 34-80)	NHANES (Ages 34-80)	Durawood (Ages 37-70)	NHANES (Ages 37-70)	Meta-Analysis (Ages 34-80)	NHANES (Ages 34-80)
Number	11	1729	11	1312	22	1729
Mean	90.6	11.6	40.1	11.1	65.3	11.6
Median	69.4	9.1	36.6	8.9	46.3	9.1
Minimum	19.9	0.1	19.1	0.1	19.1	0.1
Maximum	292.4	108.8	81.4	108.8	292.4	108.8
Lower Quartile	44.2	6.1	26.7	6.1	30.3	6.1
Upper Quartile	98.2	13.8	50.0	13.3	292.4	13.8
Percentile 10.00000	28.3	4.2	20.4	4.2	21.0	4.2
Percentile 90.00000	164.4	21.9	55.6	19.9	109.8	21.9
Variance	6136.0	82.0	338.0	73.0	3752.8	82.0
Std.Dev.	78.3	9.1	18.4	8.5	61.3	9.1
Skewness	2.0	3.3	1.1	3.5	2.8	3.3
Kurtosis	2.0	20.4	1.3	22.6	9.0	20.4

Table 4: The Wilcoxon rank-sum test data comparing the NHANES dataset to the Colfax and Durawood TCDD TEQ blood lipid datasets individually and combined in the meta-analysis.

	Colfax TCDD TEQs (Ages 34-80)	*NHANES TCDD TEQ (Ages 34-80)*	*Durawood TCDD TEQs (Ages 37-70)*	*NHANES TCDD TEQ (Ages 37-70)*	*Meta-analysis TCDD TEQs (Ages 34-80)*	*NHANES TCDD TEQ (Ages 34-80)*
Sample Size	11	1729	11	1729	22	1729
Mean	90.62	0.97	90.62	0.97	65.30	9.18
Rank Sum	18724	1495946	18724	1495946	37140.0	1501500.5
Test Statistics	361	18658	361	18658	151.0	13103.5
P(T<=t) one-tail	0.000		0.000		0.000	
P(T<=t) two-tail	0.000		0.000		0.000	