FINAL REPORT

Epidemiology
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Medical Department
3M Company
St. Paul, MN 55144

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Study
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Summary

A total of 36 subjects worked on the 3M Cottage Grove D1/D2 remediation project. Twenty-four (67%) subjects had baseline and end of project perfluorooctanoate (PFOA) and perfluorooctanesulfonate (PFOS) measurements. Twelve (33%) subjects had only end of project measurements. The 24 subjects' mean baseline PFOA concentration was 4.6 ng/mL (95% CI 3.6 – 5.5) and mean end of project PFOA concentration was 5.2 ng/mL (95 CI 3.8 – 6.6). Their mean baseline PFOS concentration was 15.6 ng/mL (95% CI 12.7 – 18.5) and mean end of project PFOS concentration was 17.2 ng/mL (95% CI 12.7 – 21.7). The mean paired concentration difference (baseline minus end of project) for PFOA was +0.7 ng/mL ($p = 0.17$). Likewise, the mean paired difference for PFOS was +1.6 ng/mL ($p = 0.32$). Of the 24 individuals with paired measurements, there was only 1 person who had a substantive increase in PFOA and PFOS concentrations at end of project (17.8 ng/mL and 56.0 ng/mL) over baseline (7.0 ng/mL and 19.6 ng/mL), respectively. Potential exposures for this individual may have come from the D1/D2 remediation site or an independent laboratory setting. Of the 12 individuals with only end of project measurements, their mean PFOA and PFOS concentrations were similar to those who also had a paired baseline measurement. Conclusion: Based on the paired biomonitoring data, and excluding 1 individual whose exposure could have occurred elsewhere, there were no substantive increases in PFOA or PFOS concentrations while working on the 3M Cottage Grove D1/D2 remediation project.

Introduction

Several remediation projects were launched in 2009 regarding legacy perfluorochemicals. These included the 3M Woodbury landfill remediation project, the 3M Cottage Grove Buildings 15 and 73 demolition and disposal project (hereafter referred to as only Building 15), the 3M Cottage Grove Building 25 re-roof project, the 3M Cottage Grove D1/D2 remediation project, and the 3M Decatur Building 2/49 demolition and disposal project. For each of these projects baseline and end-of-project assessments were required of 3M employees and contractor workers who entered specified work zones where potential exposure to legacy perfluorochemicals (e.g., PFOA (perfluorooctanoate) and PFOS (perfluorooctanesulfonate)) was possible, but due to the uniqueness of the work the magnitude was unknown. Both baseline and end of project assessments required a worker's response to a medical questionnaire and collection of blood for serum measurements of PFOA and PFOS, and analysis of several clinical chemistries. The purpose of this report is to provide a descriptive analysis of the PFOA and PFOS serum concentrations (ng/mL) at baseline and end of project time periods for the 3M Cottage Grove D1/D2 remediation project.

Methods

1. Informed consent

The purpose of the project was explained in an informed consent. Subjects read and signed this informed consent at both baseline and end of project assessments. Subjects were informed they could not work on this specific project without such compliance.

2. Clinical chemistries

Clinical chemistries included a lipid panel profile, blood glucose, BUN, creatinine, serum electrolytes, and liver enzyme tests (including alkaline phosphatase, AST, ALT, and total bilirubin). Fasting was not a requirement because of the logistics of collecting blood samples during various times of the day. Clinical chemistries were analyzed by Quest Diagnostics. Individual clinical chemistry analyses at baseline and at end of project were medically reviewed by Dr. Gibson. Subjects were informed in writing that this examination program was not a full medical 'check-up.' Values out of reference range were indicated with a notation for the subjects to follow up with their primary care physician if they had abnormal test results. However, questions could be directed to Dr. Gibson regarding their clinical chemistry test results should the subject so desire.

3. Analytical measurements of PFOA and PFOS

Serum samples were analyzed for PFOA and PFOS by state-of-the-art high performance liquid chromatography mass spectrometry methods by the 3M Medical Department's Toxicology Laboratory under the direction of Dave Ehresman. Medical Department personnel collected

blood samples that were processed to provide serum samples for analysis. These samples were assigned unique identification numbers and randomized prior to the samples being delivered for analysis. The 3M Medical Department's Toxicology Laboratory was "blinded" to the identity of all samples received for analysis.

Sample extractions were performed using solid phase extraction (SPE) technique. The extraction and sample clean-up was based on a 100 uL sample size and utilized Waters (Milford, MA) Oasis® hydrophilic–lipophilic balance (HLB) 3.0mL cartridges (Ehresman et al. 2007).

The method used two stable labeled internal standards for quantitation. The internal standards used were a dual labeled PFOS where two ^{18}O molecules were included in the sulfonate group (internal standard, >99% purity, synthesized by Research Triangle Institute, Research Triangle Park, NC) and a dual labeled PFOA molecule, where the carboxyl and alpha carbons were labeled with ^{13}C stable isotope (greater than 97%, provided by DuPont, Wilmington, DE). All quantitations were based on matrix matched extracted standard curves.

A 5 uL injection of the sample eluate was introduced into the High Pressure Liquid Chromatograph (HPLC) which was directly interfaced into the triple quadrupole mass spectrometer (Applied Biosystems/MDS-Sciex Instrument Corporation, Forest City, CA). Standard curves covered the range from 1.0 - 150 ng/mL. Standard curves were evaluated using a quadratic regression model where the standards were weighted at 1/x, and each curve had an ''R'' value equal to or greater than 0.9998. Matrix spiked controls (QC samples) evaluated during this study all had acceptable results "with-in" their previously established ranges. Matrix-matched dilutions were used for samples requiring dilution to bring the samples into the linear range of the assay. Extracted serum and aqueous blanks remained below the lower limit of

quantitation established at 1.0 ng/mL (lowest standard fitted on the standard curve used for this project).

4. Communication

After each blood collection, individual letters were sent to the participants describing their results. In the baseline assessments, two letters were sent. One referred to the clinical chemistries and the other letter provided baseline PFOA and PFOS concentrations. At end of project, two letters were again sent to each participant. The first letter provided the individual's clinical chemistry results. The second letter compared baseline to end-of-project serum PFOA and PFOS concentrations.

Results

A total of 36 individuals participated in the D1/D2 remediation project: 24 (67%) had baseline and end of project assessments and 12 (33%) had only an end of project measurement performed. Of the 24 baseline assessments that were conducted, 17 (71%) used their 3M Woodbury end of project measurement (conducted on December 4, 2009) as their baseline assessment for the D1/D2 project. Five (21%) used their 3M Woodbury landfill remediation baseline assessment (conducted either on August 26, 2009 or September 14, 2009) as their baseline assessment for the D1/D2 project. These 5 individuals did not work on the 3M Woodbury landfill remediation project; thus their 3M Woodbury baseline assessment was sufficient for the 3M Cottage Grove D1/D2 project. Two (8%) individuals had an initial baseline assessment specific for the D1/D2 remediation project.

Table 1 provides the total number of individuals, by company, who were tested for PFOA and PFOS during the 3M Woodbury landfill remediation project.

Table 1. Distribution of Workers by Company

Company	Baseline	End-of-Project
Bolander	10	14
Metro Gravel	7	14
Weston	5	5
Other	2	3
Total	24	36

Figures 1 through 4 compare the baseline to end-of-project concentrations for PFOA and PFOS, respectively. [Note: These figures are graphed on a log scale.] A strong linear relation centered along the displayed diagonal line, termed the identity line where $y = x$, is indicative of no change between the paired measurements. For the 24 individuals with paired serum measurements for PFOA (Figure 1) and PFOS (Figure 3), it can be readily seen that only 1 individual had a substantive increase in serum PFOA and PFOS concentrations over baseline. The R^2 was 0.47 for PFOA (Figure 1) and 0.45 for PFOS (Figure 3). Because this individual was a Weston employee, it is not certain whether the exposure occurred at the D1/D2 excavation site or elsewhere (i.e., in the laboratory). Therefore, the following results will be analyzed by both including ($n = 24$) and excluding ($n = 23$) this individual. Removal of this individual, leaving 23 paired samples, resulted in R^2s of 0.90 for PFOA (Figure 2) and 0.91 for PFOS (Figure 4).

Tables 2a ($n = 24$) **and 2b** ($n = 23$) provide the measures of central tendency for the baseline and end-of-project PFOA concentrations for those subjects with paired measurements (baseline and end-of-project). Values are provided in ng/mL (parts-per-billion).

Table 2a. PFOA Baseline and End of Project Concentrations (ng/mL), N = 24 Paired Samples

						Arithmetic		Geometric	
	Min	Q1	Median	Q3	Max	Mean	95% CI	Mean	95% CI
Baseline	2.0	3.0	4.2	5.5	11.2	4.6	3.6 – 5.5	4.1	3.4 – 5.0
End of Project	2.0	3.5	4.3	5.9	17.8	5.2	3.8 – 6.6	4.6	3.8 – 5.6

Table 2b. PFOA Baseline and End of Project Concentrations (ng/mL), N = 23 Paired Samples

						Arithmetic		Geometric	
	Min	Q1	Median	Q3	Max	Mean	95% CI	Mean	95% CI
Baseline	2.0	2.9	4.1	5.5	11.2	4.4	3.5 – 5.4	4.0	3.4 – 4.9
End of Project	2.0	3.5	4.3	5.6	10.1	4.7	3.9 – 5.5	4.3	3.7 – 5.1

Tables 3a (n = 24) **and 3b** (n = 23) provide the measures of central tendency for the baseline and end of project PFOS concentrations for those subjects with paired measurements (baseline and end-of-project).

Table 3a. PFOS Baseline and End of Project Concentrations (ng/mL), N = 24 Paired Samples

						Arithmetic		Geometric	
	Min	Q1	Median	Q3	Max	Mean	95% CI	Mean	95% CI
Baseline	4.2	9.9	15.6	20.0	29.8	15.6	12.7 – 18.5	14.1	11.5 – 17.3
End of Project	4.7	9.8	16.1	22.0	56.0	17.2	12.7 – 21.7	14.8	11.6 – 18.7

Table 3b. PFOS Baseline and End of Project Concentrations (ng/mL), N = 23 Paired Samples

						Arithmetic		Geometric	
	Min	Q1	Median	Q3	Max	Mean	95% CI	Mean	95% CI
Baseline	4.2	7.2	15.0	20.1	29.8	15.4	12.4 – 18.5	13.9	11.2 – 17.2
End of Project	4.7	9.6	15.9	20.6	30.3	15.5	12.5 – 18.5	13.9	11.3 – 17.3

Because the data were paired samples, a matched-paired statistical analysis was performed where the mean difference is the average of the sum of the individual differences for the 24 (or 23) subjects . See Equation 1.

Equation 1.

$$\text{Mean Difference} = \sum_{i=1}^{24}(\text{end of project} - \text{baseline})/24$$

Because of the skewed PFOS distribution, in particular, as seen in Table 3, the mean differences of the natural logs of the paired values were also determined. See Equation 2.

Equation 2.

$$\text{Mean} = [\sum_{i=1}^{24}[(\ln(\text{end of project value})) - (\ln(\text{baseline value}))/24]$$

Results for *Equation 1 and Equation 2*, and associated statistics of the mean differences of the paired comparisons, are provided in **Tables 4a and 4b** for both PFOA and PFOS.

Table 4a. Matched-pair Analysis Comparing Baseline to End of Project PFOA and PFOS Concentration (ng/mL), N = 24 Paired Samples

Mean Paired Difference	PFOA (ng/mL)	t-ratio	p value	PFOS (ng/mL)	t-ratio	p value
Equation 1	+0.7	1.40	0.17	+1.6	1.01	0.32
Equation 2	+0.11	2.19	0.04	+0.05	0.83	0.41

Table 4b. Matched-pair Analysis Comparing Baseline to End of Project PFOA and PFOS Concentration (ng/mL), N = 23 Paired Samples

Mean Paired Difference	PFOA (ng/mL)	t-ratio	p value	PFOS (ng/mL)	t-ratio	p value
Equation 1	+0.2	1.41	0.17	0.0	0.17	0.87
Equation 2	-0.07	2.05	0.05	-0.04	0.10	0.92

Only when the logs of PFOA were taken limited for the n = 23 subjects was there a statistically significant increase in the mean of the paired differences as seen in Equation 2 in **Table 4b**. The difference between end of project and baseline PFOA log concentrations was negative (-0.07) indicating a decrease in concentrations from baseline to end of project. However, the difference is slight given the analytical variability of the measurements. A similar situation was seen for PFOS in **Table 4b** but this finding was not statistically significant

There 12 individuals who only had an end of project assessments. Their mean PFOA and PFOS concentrations were compared to the 24 (and 23) subjects who had both baseline and end of project measurements to determine if they had different concentrations at end of project. The mean serum PFOA and PFOS concentrations at end of project were not statistically significantly different between these two groups although the 12 individuals, who did not have baseline

assessments, had higher mean values for both PFOA **(Tables 5a and 5b)** and PFOS **(Tables 6a and 6b)** at end of project.

Table 5a. End of Project Arithmetic Means of Serum PFOA Concentrations (ng/mL) Among D1/D2 Subjects With and Without Baseline Assessments, N = 24 Paired Samples

Had baseline assessment?	N	Mean	95% CI	t-statistic	p value
Yes	24	5.2	3.8 – 6.6	-0.52	0.61
No	12	6.5	1.3 – 11.6		

Table 5b. End of Project Arithmetic Means of Serum PFOA Concentrations (ng/mL) Among D1/D2 Subjects With and Without Baseline Assessments, N = 23 Paired Samples

Had baseline assessment?	N	Mean	95% CI	t-statistic	p value
Yes	23	4.7	3.9 – 5.5	-0.76	0.46
No	12	6.5	1.3 – 11.6		

Table 6a. End of Project Arithmetic Means of Serum PFOS Concentrations (ng/mL) Among D1/D2 Subjects With and Without Baseline Assessments, N = 24 Paired Samples

Had baseline assessment?	N	Mean	95% CI	t-statistic	p value
Yes	24	17.2	12.5 – 18.6	-0.40	0.69
No	12	18.8	12.7 – 21.7		

Table 6b. End of Project Arithmetic Means of Serum PFOS Concentrations (ng/mL) Among D1/D2 Subjects With and Without Baseline Assessments, N = 23 Paired Samples

Had baseline assessment?	N	Mean	95% CI	t-statistic	p value
Yes	23	15.5	12.5 – 18.6	-0.91	0.37
No	12	18.8	11.6 – 26.0		

Discussion

Comparison of baseline and end of project serum concentrations of PFOA and PFOS provided each worker an excellent method to assess his/her exposure experience for the 3M Cottage Grove D1/D2 remediation project. Given the fact that exposure potential during the course of the remediation project was unknown, the use of biomonitoring data allowed for an assessment of the actual, yet unknown, exposure to PFOA or PFOS, or to materials that may degrade to them. Only 1 of the 24 D1/D2 remediation subjects had a substantive increase in serum concentrations over baseline. Because this individual was a Weston employee, it is not known where the increased exposure to PFOA and PFOS might have occurred. Because of minimum differences between baseline and end of project PFOA and PFOS measurements for 23 of the 24 subjects with paired measuremetns, the clinical chemistry data were therefore not analyzed by paired statistics.

Conclusion

Based on paired biomonitoring data, there was no substantive change in PFOA or PFOS serum concentrations for those workers involved with the 3M Cottage Grove D1/D2 remediation project except for 1 worker whose source of exposure could have been either at the site and/or at other employer-related locations.

References

Ehresman DJ, Froehlich JW, Olsen GW, Chang SC, Butenhoff JL. 2007. Comparison of human whole blood, plasma, and serum matrices for the determination of perfluorooctanesulfonate (PFOS), perfluorooctanoate (PFOA), and other fluorochemicals. Environ Res 103:176-184.

Figure 1. 3M Cottage Grove D1/D2 Remediation Project:
Baseline vs. End of Project PFOA Concentrations (ng/mL) for N = 24 Paired Samples

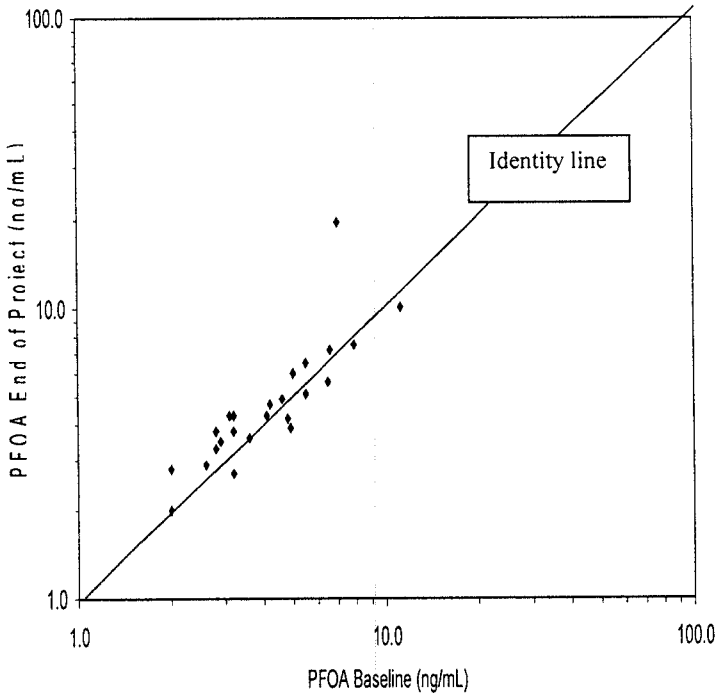

Figure 2. 3M Cottage Grove D1/D2 Remediation Project:
Baseline vs. End of Project PFOA Concentrations (ng/mL) for N = 23 Paired Samples

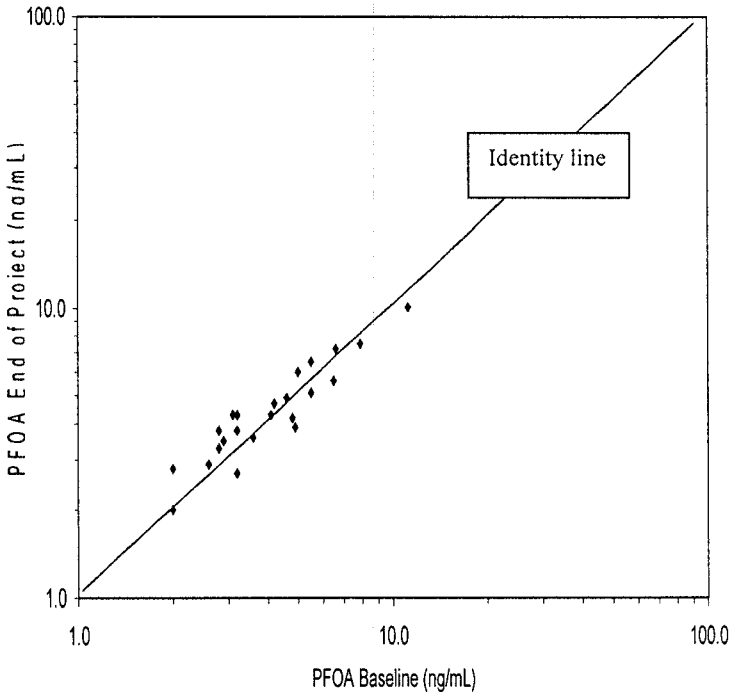

Figure 3. 3M Cottage Grove D1/D2 Remediation Project:
Baseline vs. End of Project PFOS Concentrations (ng/mL) for N = 24 Paired Samples

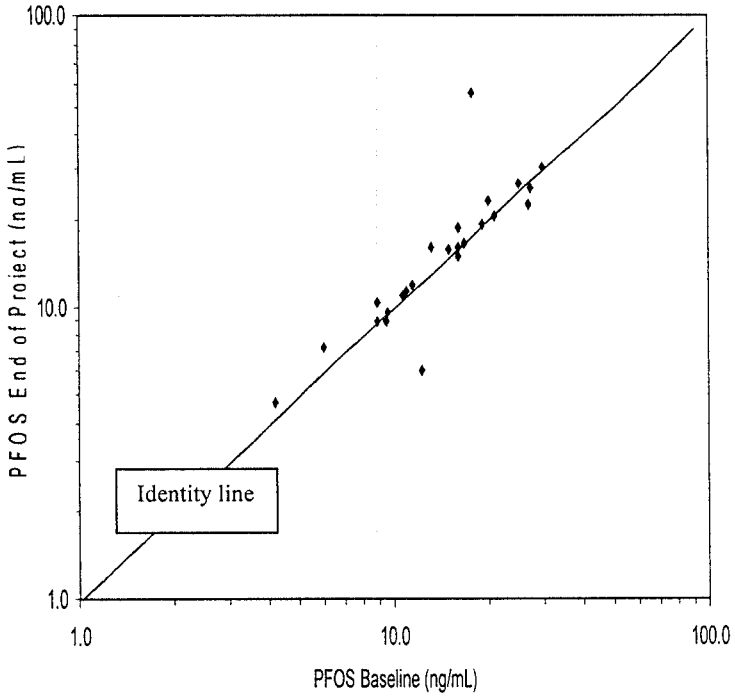

Figure 4. 3M Cottage Grove D1/D2 Remediation Project:
Baseline vs. End of Project PFOS Concentrations (ng/mL) N = 23 Paired Samples