TerraTherm, Inc.
10 Stevens Road
Fitchburg, MA 01420
Phone: (978) 343-0300
Fax: (978) 343-2727

September 30, 2009

Bruce Tsutsui
Site Discovery, Assessment and Remediation
Hazard Evaluation and Emergency Response Office
Hawaii State Department of Health

Via e-mail: bruce.tsutsui@doh.hawaii.gov

Re: Results of Thermal Treatability Test for Oahu, Hawaii Site

Dear Bruce,

TerraTherm, Inc. (TerraTherm) is pleased to present DHHL with the results of the laboratory treatability test of thermal remediation for your site in Oahu. The testing was completed by KEMRON, our selected treatability laboratory in Atlanta, GA.

Thank you very much for the opportunity to assist you with the evaluation of thermal treatment options for your dioxin sites. Please feel free to contact us if you have any questions or comments on this proposal and cost estimate.

Sincerely,

TerraTherm, Inc.

Gorm Heron

Gorm Heron, PhD.
Vice President and Senior Engineer

Attachment: Final Treatability Study Report with Appendices.

122020

TerraTherm®

EXECUTIVE SUMMARY

Laboratory Testing for OAHU Dioxin Project

The treatability study was performed to:

(1) Determine whether thermal treatment is capable of desorbing, vaporizing and removing both dioxins and herbicides from site materials in order to meet the Target Criteria for each contaminant;

(2) Evaluate necessary treatment temperature and duration to achieve acceptable soil contaminant concentrations.

Testing was performed on two different samples from the site:

Boiler Room sample
Spill Area sample

Testing was done at three temperatures (250°C, 325°C and 400°C) for the Spill Area sample, and at one temperature (325°C) for the Boiler Room sample. The samples were treated for a period of seven days. All thermal tests were conducted to TerraTherm's satisfaction, and the data were collected as planned. Therefore, the tests are believed to represent a fair evaluation of thermal treatment of these samples.

The samples contained very high concentrations of dioxin constituents, and few pesticides and semi-volatile compounds. All pesticides and semi-volatile constituents were absent in all treated soils at temperatures of 325°C and 400°C. Only trace amounts were found in the sample treated at 250°C. The following paragraphs summarize the dioxin results.

The results for the Boiler Room sample treated at 325°C is shown in Table A. The untreated sample had high concentrations of many of the dioxin congeners, and a 2,3,7,8-tetrachloro-dibenzodioxin (2,3,7,8-TCDD) toxicity equivalent (TEQ) of 1,043,000 ng-TEQ/kg. Treatment efficiencies for each congener were 99.7% or higher. Based on the calculated TEQ, the treatment efficiency was 99.993%, with a post-treatment concentration of 75 ng-TEQ/kg.

Tables B, C, and D show the results for the Spill Area samples tested at 250°C, 325°C and 400°C, respectively. Treatment efficiency increased with increasing temperature, as follows:

TerraTherm®

250°C: 68%
325°C: 99.9%
400°C: 99.9995%

Note that for the 400°C treatment, the post-treatment concentration was 2.3 ng-TEQ/kg.

Table B shows an increase in the concentration of several congeners from starting concentrations, most notably 2,3,7,8-TCDD and 1,2,3,7,8-PeCDD. These data indicate transformation of other congeners into these during heating at 250°C. However, the total TEQ decreased from 460,000 to 149,000 ng-TEQ/kg, indicating that the toxicity of the soil was not increased. Please note that the treatments at 325 and 400°C showed that any congeners which accumulated at 250°C were effectively removed at the higher temperatures.

For field-scale treatment of soils from this site, the following conclusions appear:

- The treatment efficiency increases significantly with treatment temperature.
- During treatment, some temporary intermediates may be formed, leading to accumulation of some congeners in the range of 250°C. However, the data suggest that the 2,3,7,8-TEQ decreases during thermal treatment at 325 and 400°C.
- Treatment for seven days at 325°C reduced concentrations to the range of 75-450 ng-TEQ/kg.
- Treatment for seven days at 400°C reduced concentrations to the range of 2 ng-TEQ/kg.

Please note that treatment durations longer than 7 days may further reduce the dioxin concentrations, as shown in related studies of organic compounds.[1,2] Also, it is likely that soils with lower starting concentrations will achieve lower final concentrations after seven days of thermal treatment. As an example, the TerraTherm technology has treated less contaminated soils to post-treatment concentration levels of <0.1 ng-TEQ/kg at 325°C.[3]

[1] Uzgiris, E.E., Edelstein, W.A., Philipp, H.R., and Iben, I.E.T. 1995. "Complex Thermal Desorption of PCBs from Soil." *Chemosphere*, 30(2):377–387.
[2] Hansen, K.S., D.M. Conley, H.J. Vinegar, J.M. Coles, J.L. Menotti, and G.L. Stegemeier. 1998. "In Situ Thermal Desorption of Coal Tar." Proceedings of the Institute of Gas Technology/Gas Research Institute International Symposium on Environmental Biotechnologies and Site Remediation Technologies. Orlando, FL, December 7-9, 1998.
[3] Baker, R.S., Smith, G.J., and H. Braatz. 2009. "In-Pile Thermal Desorption of Dioxin Contaminated Soil and Sediment." In: Proceedings of the 29rd International Symposium on Halogenated Persistent Organic Pollutants (Dioxin 2009), Beijing, China, Aug. 23-28, 2009.

The laboratory tests showed that thermal treatment can reduce the dioxin concentrations dramatically. The treatment temperature and duration must therefore be selected on a site-specific basis. The treatment temperature and/or duration would increase with the starting dioxin concentrations, and will depend on the target concentrations required. However, this testing and past experience indicate that even extremely high starting concentrations can be effectively lowered to acceptable levels.

TerraTherm®

Table A. Results for Dioxins: Boiler Room sample treated at 325°C.

BOILER ROOM SAMPLES 325 C	Analytical results (ng/kg)			TEQ calculation (ng/kg-TEQ)			
PARAMETER	Average Untreated Boiler Room	Average 325 C Boiler Room	% reduction at 325 C	PARAMETER	Average TEQ Untreated Boiler Room	TEQ 325 C Boiler Room	% reduction at 325 C
2,3,7,8-TCDF	9,100	3.6	99.96	2,3,7,8-TCDF	910	0.36	99.96
Total TCDF	310,000	110	99.96				
2,3,7,8-TCDD	6,500	22	99.66	2,3,7,8-TCDD	6,500	22	99.66
Total TCDD	31,333	430	98.63				
1,2,3,7,8-PeCDF	32,333	3.90 J	100.00	1,2,3,7,8-PeCDF	970	0.00	100.00
2,3,4,7,8-PeCDF	107,667	5.5	99.99	2,3,4,7,8-PeCDF	32,300	1.65	99.99
Total PeCDF	1,533,333	130	99.99				
1,2,3,7,8-PeCDD	52,333	34	99.94	1,2,3,7,8-PeCDD	52,333	34	99.94
Total PeCDD	223,333	400	99.82				
1,2,3,4,7,8-HxCDF	390,000	8.5	100.00	1,2,3,4,7,8-HxCDF	39,000	0.85	100.00
1,2,3,6,7,8-HxCDF	593,333	11.0	100.00	1,2,3,6,7,8-HxCDF	18	1.10	94.00
2,3,4,6,7,8-HxCDF	316,667	7.5	100.00	2,3,4,6,7,8-HxCDF	31,667	0.75	100.00
1,2,3,7,8,9-HxCDF	108,000	1.60 BJ	100.00	1,2,3,7,8,9-HxCDF	10,800	0.00	100.00
Total HxCDF	11,700,000	170	100.00				
1,2,3,4,7,8-HxCDD	168,333	21	99.99	1,2,3,4,7,8-HxCDD	16,833	2.1	99.99
1,2,3,6,7,8-HxCDD	996,667	44	100.00	1,2,3,6,7,8-HxCDD	99,667	4.4	100.00
1,2,3,7,8,9-HxCDD	370,000	55	99.99	1,2,3,7,8,9-HxCDD	37,000	5.5	99.99
Total HxCDD	5,433,333	630	99.99				
1,2,3,4,6,7,8-HpCDF	15,466,667	42	100.00	1,2,3,4,6,7,8-HpCDF	154,667	0.42	100.00
1,2,3,4,7,8,9-HpCDF	510,000	0.56 J	100.00	1,2,3,4,7,8,9-HpCDF	5,100	0.00	100.00
Total HpCDF	21,000,000	51	100.00				
1,2,3,4,6,7,8-HpCDD	47,000,000	220	100.00	1,2,3,4,6,7,8-HpCDD	470,000	2.2	100.00
Total HpCDD	55,500,000	570	100.00				
OCDF	98,666,667	4.4 I*	100.00	OCDF	29,600	0.00	100.00
OCDD	186,333,333	270	100.00	OCDD	55,900	0.08	100.00
				Sum TEQ	1,043,265	75.41	99.993

- Not Detected
J - Value below calibration range
B - Less than 10x higher than method blank level
I - Interference present
* - Estimated Maximum Possible Concentration
E - PCDE Interference
S - Peak Saturation

TerraTherm®

Table B. Results for Dioxins: Spill Area sample treated at 250°C.

SPILL AREA SAMPLES 250 C PARAMETER	Analytical results (ng/kg) Average Untreated Spill Area	Average 250 C Spill Area	% reduction at 250 C	TEQ calculation (ng/kg-TEQ) PARAMETER	Average TEQ Untreated Spill Area	TEQ 250 C Spill Area	% reduction at 250 C
2,3,7,8-TCDF	7,300	2,500	66	2,3,7,8-TCDF	730	250	65.75
Total TCDF	81,667	74,000	9				
2,3,7,8-TCDD	2,233	12,000	(437)	2,3,7,8-TCDD	2,233	12,000	(437.31)
Total TCDD	5,000	150,000	(2,900)				
1,2,3,7,8-PeCDF	40,000	13,000	68	1,2,3,7,8-PeCDF	1,200	390	67.50
2,3,4,7,8-PeCDF	126,667	18,000	86	2,3,4,7,8-PeCDF	38,000	5,400	85.79
Total PeCDF	966,667	250,000	74				
1,2,3,7,8-PeCDD	17,667	38,000	(115)	1,2,3,7,8-PeCDD	17,667	38,000	(115.09)
Total PeCDD	67,333	360,000	(435)				
1,2,3,4,7,8-HxCDF	446,667	68,000	85	1,2,3,4,7,8-HxCDF	44,667	6,800	84.78
1,2,3,6,7,8-HxCDF	663,333 E	32,000	NA	1,2,3,6,7,8-HxCDF	-	3,200	NA
2,3,4,6,7,8-HxCDF	196,667	43,000	78	2,3,4,6,7,8-HxCDF	19,667	4,300	78.14
1,2,3,7,8,9-HxCDF	156,667	16,000	90	1,2,3,7,8,9-HxCDF	15,667	1,600	89.79
Total HxCDF	7,066,667	940,000	87				
1,2,3,4,7,8-HxCDD	53,667	55,000	(2)	1,2,3,4,7,8-HxCDD	5,367	5,500	(2.48)
1,2,3,6,7,8-HxCDD	440,000	120,000	73	1,2,3,6,7,8-HxCDD	44,000	12,000	72.73
1,2,3,7,8,9-HxCDD	126,667	160,000	(26)	1,2,3,7,8,9-HxCDD	12,667	16,000	(26.32)
Total HxCDD	1,533,333	1,300,000	15				
1,2,3,4,6,7,8-HpCDF	4,233,333	710,000	83	1,2,3,4,6,7,8-HpCDF	42,333	7,100	83.23
1,2,3,4,7,8,9-HpCDF	306,667	54,000	82	1,2,3,4,7,8,9-HpCDF	3,067	540	82.39
Total HpCDF	21,000,000	1,800,000	91				
1,2,3,4,6,7,8-HpCDD	17,333,333	2,800,000	84	1,2,3,4,6,7,8-HpCDD	173,333	28,000	83.85
Total HpCDD	27,000,000	5,300,000	80				
OCDF	21,966,667	1,200,000	95	OCDF	6,590	360	94.54
OCDD	110,000,000	25,000,000	77	OCDD	33,000	7,500	77.27
				Sum TEQ	460,187	148,940	67.63

- Not Detected
J - Value below calibration range
B - Less than 10x higher than method blank level
I - Interference present
* - Estimated Maximum Possible Concentration
E - PCDE Interference
S - Peak Saturation
NA - not available due to qualifiers

TerraTherm®

Table C. Results for Dioxins: Spill Area sample treated at 325°C.

SPILL AREA SAMPLES 325 C PARAMETER	Analytical results (ng/kg) Average Untreated Spill Area	Average 325 C Spill Area	% reduction at 325 C	PARAMETER	TEQ calculation (ng/kg-TEQ) Average TEQ Untreated Spill Area	TEQ 325 C Spill Area	% reduction at 325 C
2,3,7,8-TCDF	7,300	14	99.81	2,3,7,8-TCDF	730	1.4	99.81
Total TCDF	81,667	570	99.30				
2,3,7,8-TCDD	2,233	87	96.10	2,3,7,8-TCDD	2,233	87	96.10
Total TCDD	5,000	2,700	46.00				
1,2,3,7,8-PeCDF	40,000	29	99.93	1,2,3,7,8-PeCDF	1,200	0.87	99.93
2,3,4,7,8-PeCDF	126,667	43	99.97	2,3,4,7,8-PeCDF	38,000	12.9	99.97
Total PeCDF	966,667	800	99.92				
1,2,3,7,8-PeCDD	17,667	240	98.64	1,2,3,7,8-PeCDD	17,667	240	98.64
Total PeCDD	67,333	3,700	94.50				
1,2,3,4,7,8-HxCDF	446,667	70	99.98	1,2,3,4,7,8-HxCDF	44,667	7.0	99.98
1,2,3,6,7,8-HxCDF	663,333 E	54	NA	1,2,3,6,7,8-HxCDF	-	5.4	NA
2,3,4,6,7,8-HxCDF	196,667	46	99.98	2,3,4,6,7,8-HxCDF	19,667	4.6	99.98
1,2,3,7,8,9-HxCDF	156,667	21	99.99	1,2,3,7,8,9-HxCDF	15,667	2.1	99.99
Total HxCDF	7,066,667	1,100	99.98				
1,2,3,4,7,8-HxCDD	53,667	140	99.74	1,2,3,4,7,8-HxCDD	5,367	14	99.74
1,2,3,6,7,8-HxCDD	440,000	230	99.95	1,2,3,6,7,8-HxCDD	44,000	23	99.95
1,2,3,7,8,9-HxCDD	126,667	360	99.72	1,2,3,7,8,9-HxCDD	12,667	36	99.72
Total HxCDD	1,533,333	4,100	99.73				
1,2,3,4,6,7,8-HpCDF	4,233,333	310	99.99	1,2,3,4,6,7,8-HpCDF	42,333	3.10	99.99
1,2,3,4,7,8,9-HpCDF	306,667	23	99.99	1,2,3,4,7,8,9-HpCDF	3,067	0.23	99.99
Total HpCDF	21,000,000	660	100.00				
1,2,3,4,6,7,8-HpCDD	17,333,333	1,500	99.99	1,2,3,4,6,7,8-HpCDD	173,333	15	99.99
Total HpCDD	27,000,000	3,400	99.99				
OCDF	21,966,667	220	100.00	OCDF	6,590	0.07	100.00
OCDD	110,000,000	4,200	100.00	OCDD	33,000	1.26	100.00
				Sum TEQ	460,187	454	99.90

- Not Detected
J - Value below calibration range
B - Less than 10x higher than method blank level
I - Interference present
* - Estimated Maximum Possible Concentration
E - PCDE Interference
S - Peak Saturation
NA - not available due to qualifiers

TerraTherm®

Table D. Results for Dioxins: Spill Area sample treated at 400°C.

SPILL AREA SAMPLES 400 C	Analytical results (ng/kg)			TEQ calculation (ng/kg-TEQ)			
PARAMETER	Average Untreated Spill Area	Average 400 C Spill Area	% reduction at 400 C	PARAMETER	Average TEQ Untreated Spill Area	TEQ 400 C Spill Area	% reduction at 400 C
2,3,7,8-TCDF	7,300	-	100.00	2,3,7,8-TCDF	730	0.00	100.00
Total TCDF	81,667	1	100.00				
2,3,7,8-TCDD	2,233	0.24 I*	100.00	2,3,7,8-TCDD	2,233	0.00	100.00
Total TCDD	5,000	8	99.84				
1,2,3,7,8-PeCDF	40,000	-	100.00	1,2,3,7,8-PeCDF	1,200	0.00	100.00
2,3,4,7,8-PeCDF	126,667	0.36 I*	100.00	2,3,4,7,8-PeCDF	38,000	0.00	100.00
Total PeCDF	966,667	2.80 J	100.00				
1,2,3,7,8-PeCDD	17,667	1	100.00	1,2,3,7,8-PeCDD	17,667	0.74	100.00
Total PeCDD	67,333	9	99.99				
1,2,3,4,7,8-HxCDF	446,667	1	100.00	1,2,3,4,7,8-HxCDF	44,667	0.11	100.00
1,2,3,6,7,8-HxCDF	663,333 E	1	NA	1,2,3,6,7,8-HxCDF	-	0.11	NA
2,3,4,6,7,8-HxCDF	196,667	1	100.00	2,3,4,6,7,8-HxCDF	19,667	0.06	100.00
1,2,3,7,8,9-HxCDF	156,667	0	100.00	1,2,3,7,8,9-HxCDF	15,667	0.05	100.00
Total HxCDF	7,066,667	16	100.00				
1,2,3,4,7,8-HxCDD	53,667	2	100.00	1,2,3,4,7,8-HxCDD	5,367	0.15	100.00
1,2,3,6,7,8-HxCDD	440,000	3	100.00	1,2,3,6,7,8-HxCDD	44,000	0.26	100.00
1,2,3,7,8,9-HxCDD	126,667	3	100.00	1,2,3,7,8,9-HxCDD	12,667	0.28	100.00
Total HxCDD	1,533,333	28	100.00				
1,2,3,4,6,7,8-HpCDF	4,233,333	8	100.00	1,2,3,4,6,7,8-HpCDF	42,333	0.08	100.00
1,2,3,4,7,8,9-HpCDF	306,667	1	100.00	1,2,3,4,7,8,9-HpCDF	3,067	0.01	100.00
Total HpCDF	21,000,000	26	100.00				
1,2,3,4,6,7,8-HpCDD	17,333,333	39	100.00	1,2,3,4,6,7,8-HpCDD	173,333	0.39	100.00
Total HpCDD	27,000,000	79	100.00				
OCDF	21,966,667	25	100.00	OCDF	6,590	0.01	100.00
OCDD	110,000,000	240	100.00	OCDD	33,000	0.07	100.00
				Sum TEQ	460,187	2.32	99.9995

- Not Detected
J - Value below calibration range
B - Less than 10x higher than method blank level
I - Interference present
* - *Estimated Maximum* Possible Concentration
E - PCDE Interference
S - Peak Saturation
NA - not available due to qualifiers