

The Practical Science of Bioremediation of Oiled Soil 2004

Dr. Harry L. Allen III, ERT
Vince Zenone, OSC

Bioremediation of Oil Spills

Something good is happening, but what is it and can we make it better?

PEPCO Spill Site Overview 4/15/00



PEPCO Spill Site Close-up 4/15/00



Flows within the Marsh



Control Area



Boardwalks in the Marsh



ESTIMATED NUTRIENT REQUIREMENTS FOR SWANSON CREEK MARSH CLEANUP ZONE W-1 AREA A - MAY 31, 2000

Area A - A 600' diameter circle within Work Area W-1

Oiled Area of Marsh	6.49	acres	282,744	sq. ft.
Depth (1")	0.08	feet	23,562	cu. ft.
Mass of Soil @108 lbs./cu.ft.	2,543,565	lbs.	1,156,166	kgs. soil
Estimated Oil Remaining	5,000	gals.	15,922	kgs. oil
Estimated % Oil	1.38%		14,000	mg/kg (ppm)
Weight of Oil @ 7 lbs./gal.	35,000	lbs	15,909	kgs. oil
Mass of Carbon @75%	26,250	lbs C	11,932	kgs. C

Application Rates

Oil to be Treated	15,909	kgs. oil	11,932	kgs. C	
Total Nutrient Needed	C:N:P Ratio	N (kgs.)	P (kgs.)	N (lbs.)	P (lbs.)
	60:1:0.2	199	40	438	88

Nutrient Application Rates

Weights of fertilizer based on C:N:P of 60:1:0.2 in lbs. for 6.49 acres of contaminated marsh.

	%N	Total Applied		Per Application		
		Wt. (lbs.)	lbs./acre	Wt. (lbs.)	lbs./acre	lbs./1000 sq.ft.
Diammonium Phosphate	21.21%	2,063	318	688	106	2

Applying Fertilizer



Area B after 6 Weeks Fertilization



Phases of Cleanup

Phase 1. Emergency - Primary Containment and Recovery

Phase 2. Removal - Secondary Recovery and Treatment

Phase 3. Long-term Removal - Tertiary Recovery,
Treatment and Natural Attenuation

Phase 3 Focuses on very low criteria for TPH and PAH (10 mg/kg)
Also on low ppm levels for specific PAH's through NOAA's
“SQuiRTs”

Sorbents



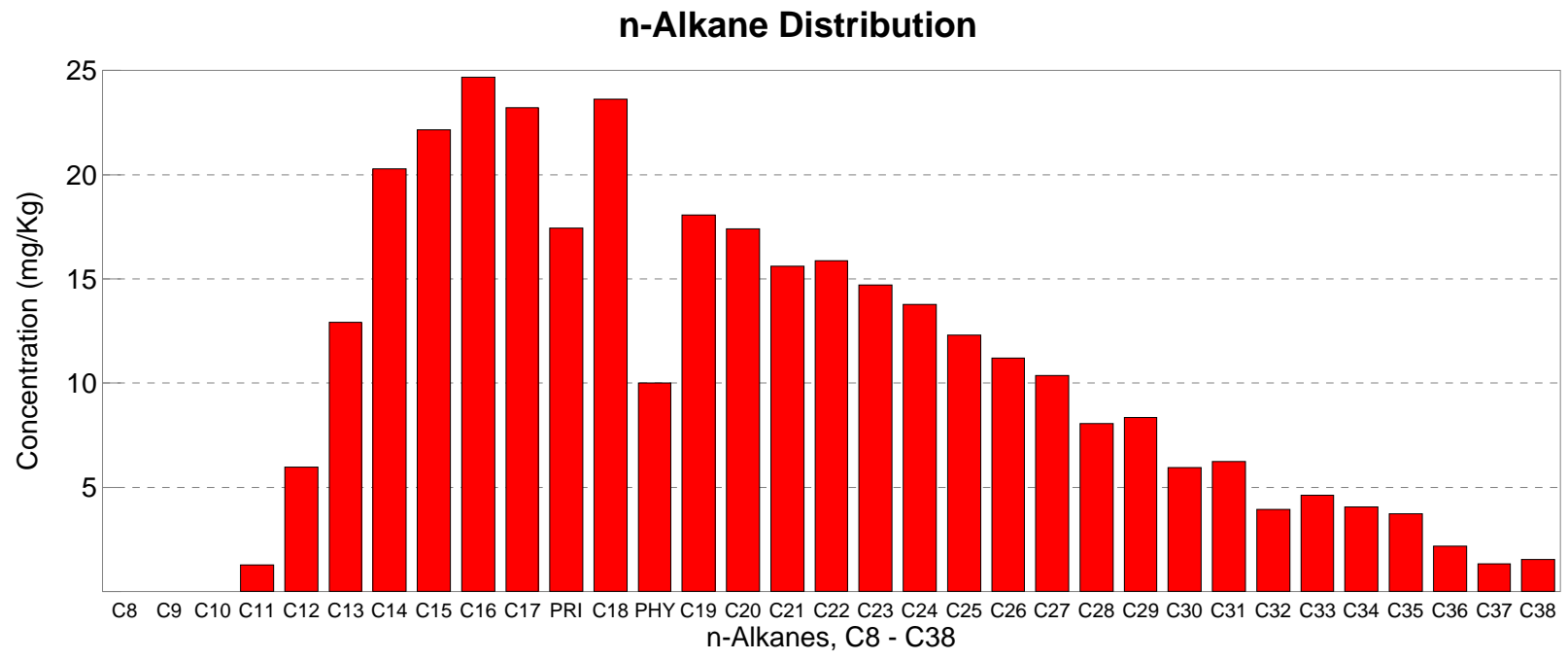
Berming & Diking



Vacuuming



W1BS05 Alkanes in Oil



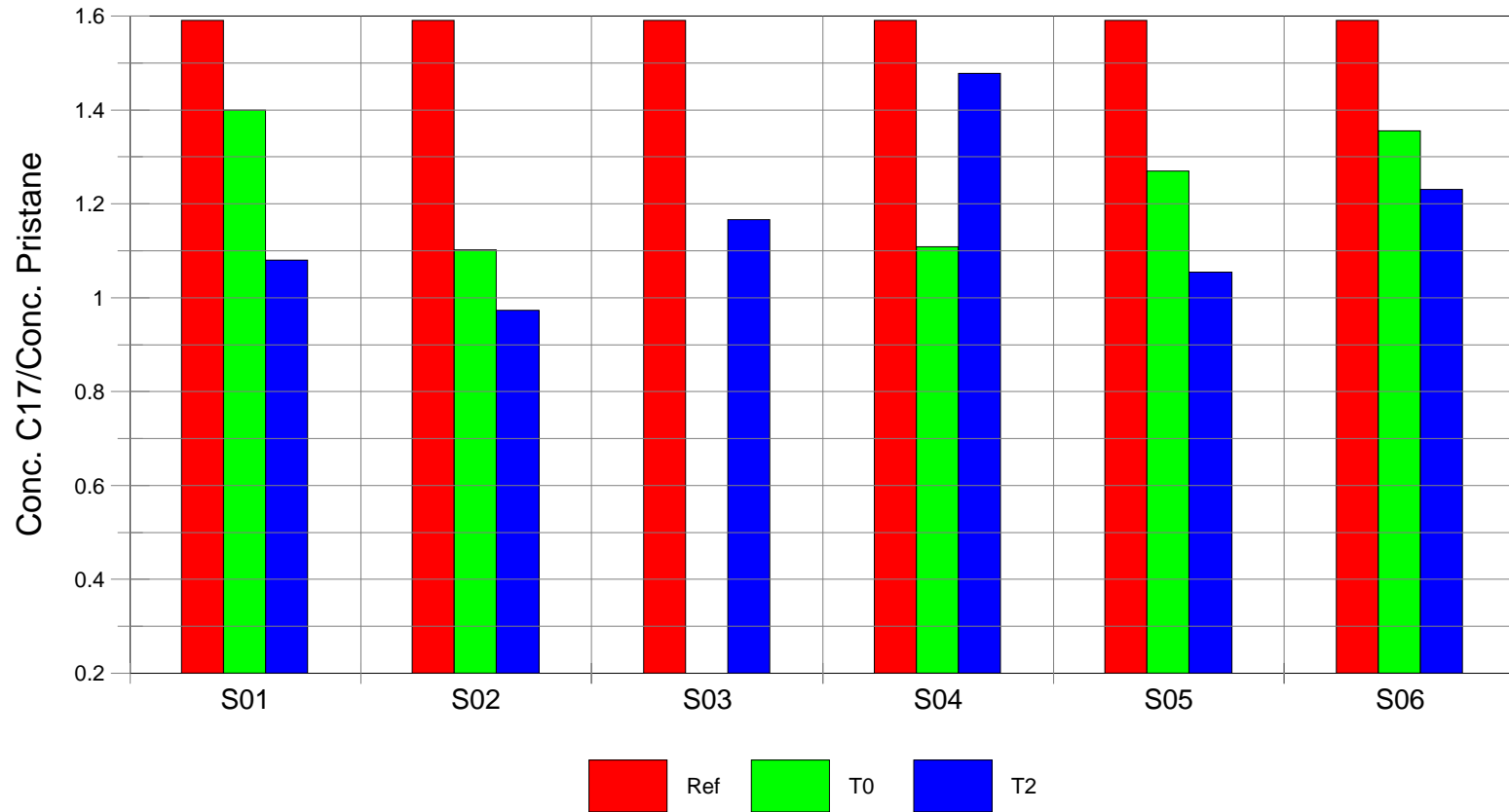
Marsh Sampling Station



Biodegradation in Mechanical Removal Area

C17/Pristane Ratio: Area A

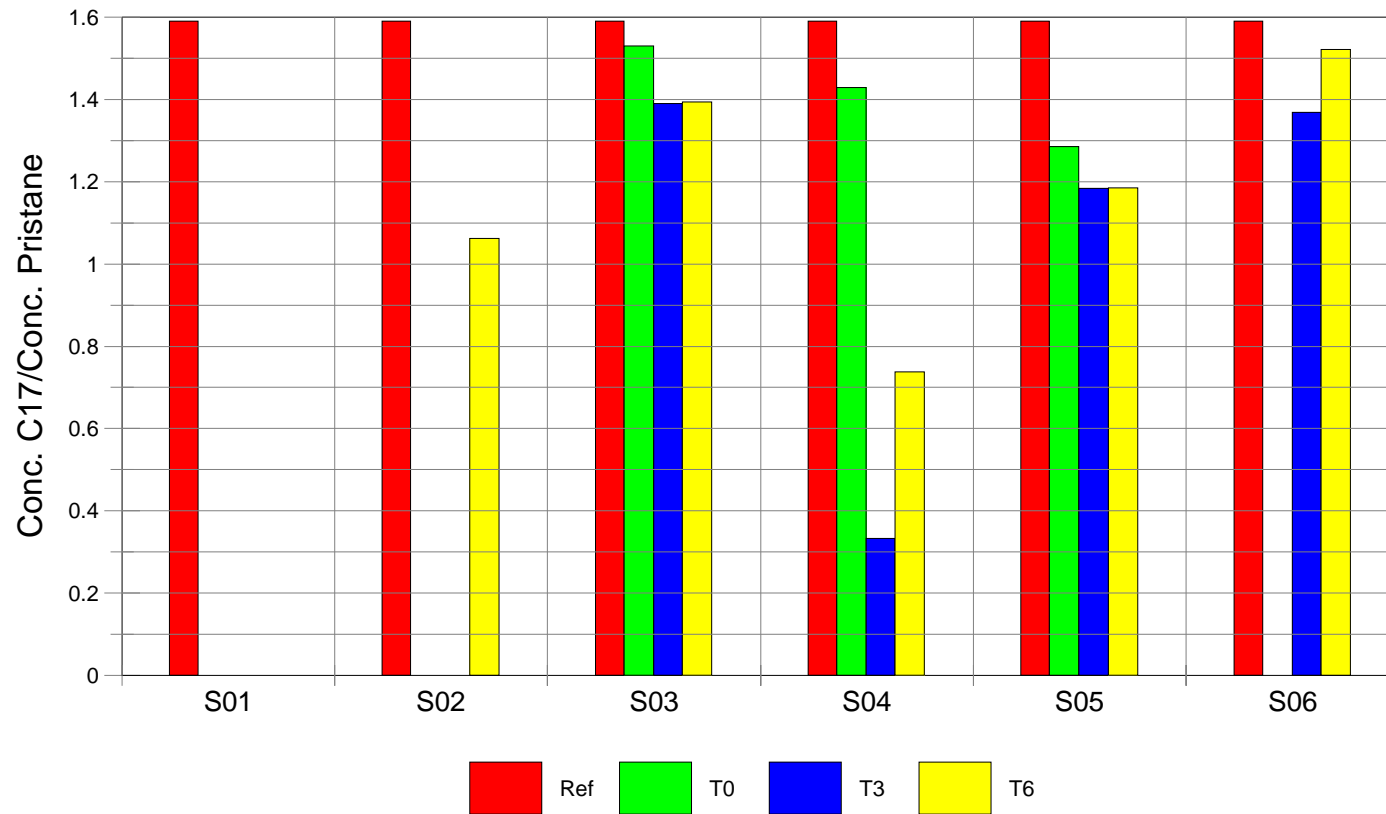
Based on GC/MS Concentrations



Biodegradation in Treated Area

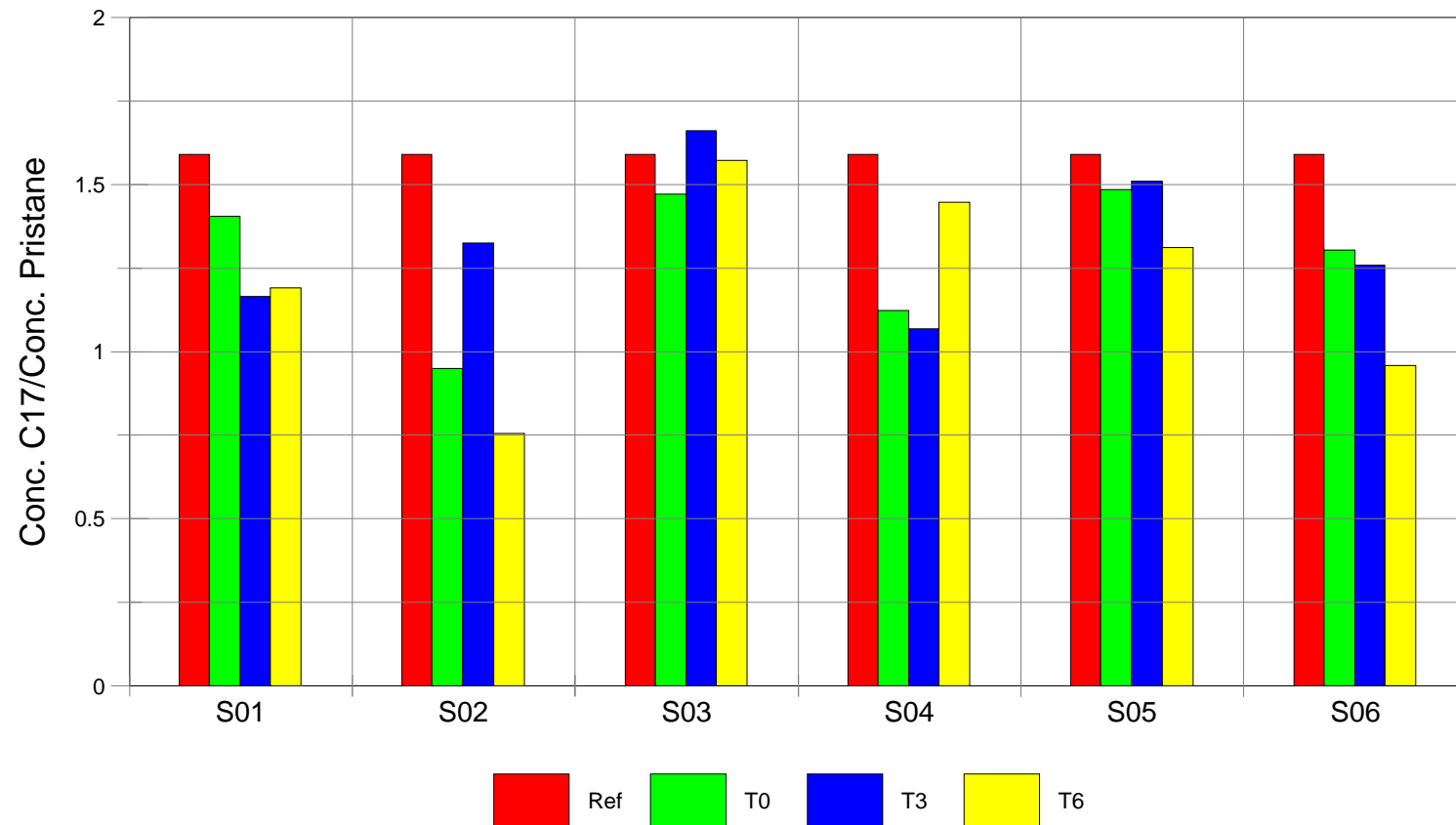
C17/Pristane Ratio: Area B

Based on GC/MS Concentrations

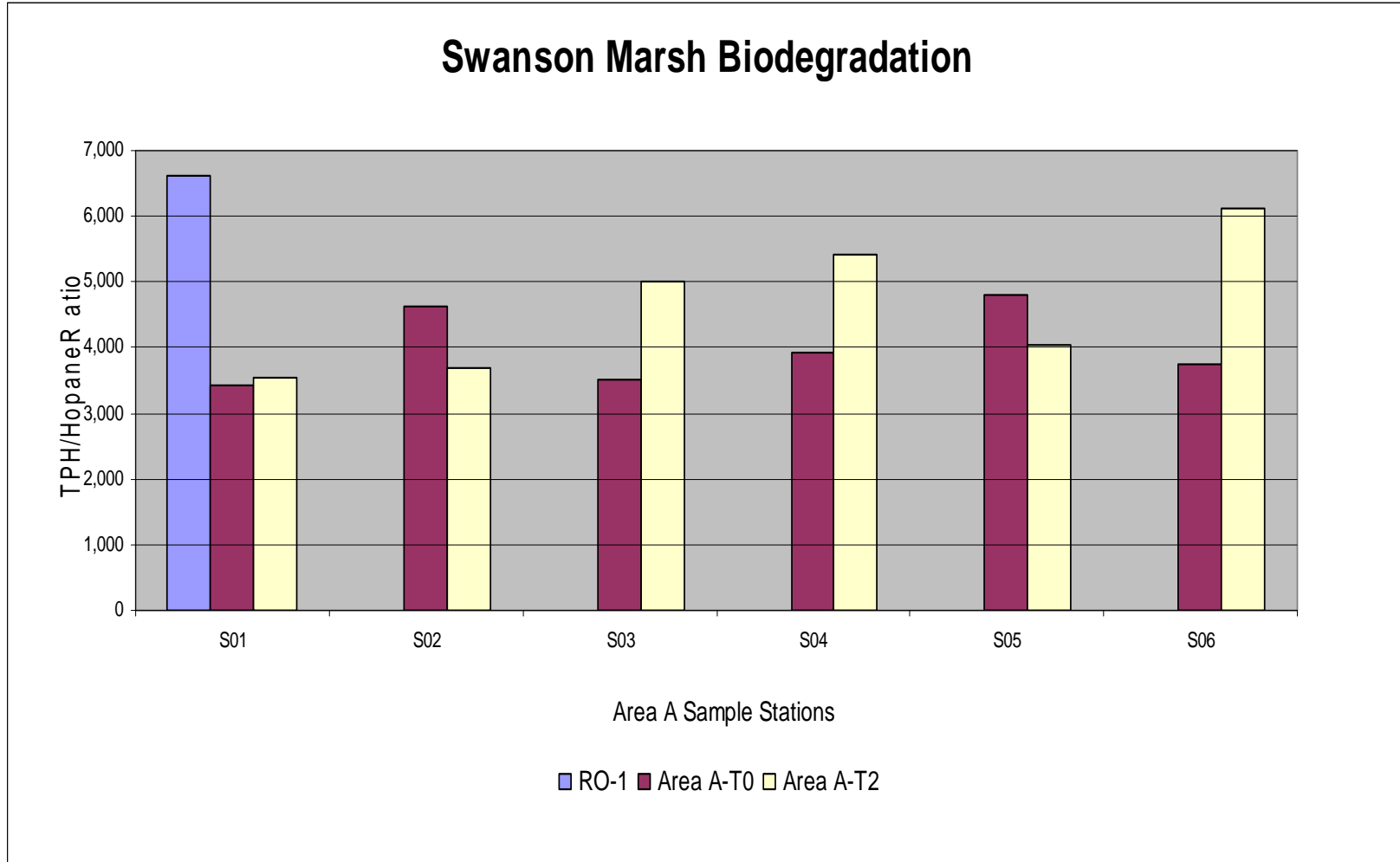


Biodegradation in Non-Treated Area

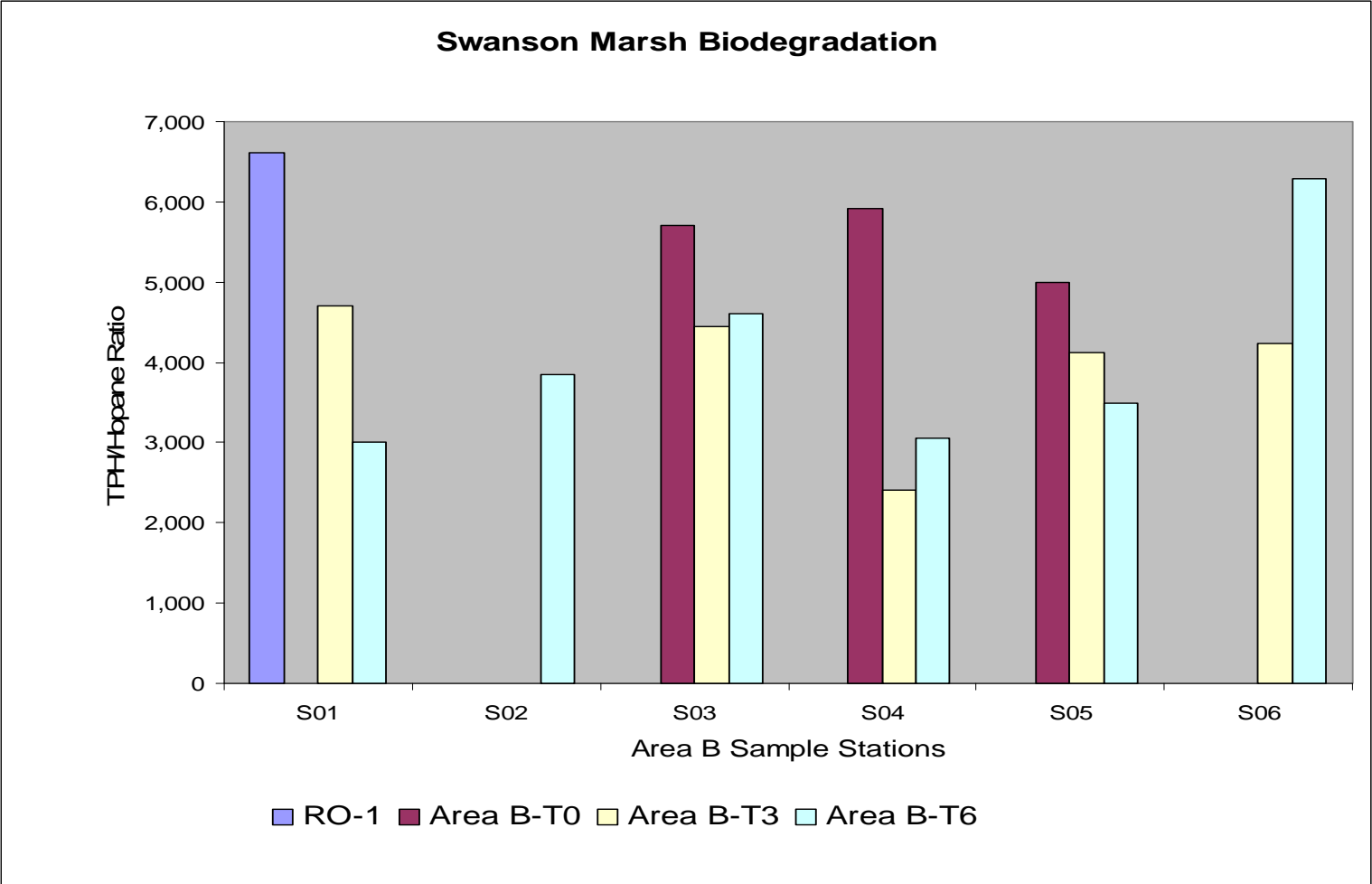
C17/Pristane Ratio: Area C Based on GC/MS Concentrations



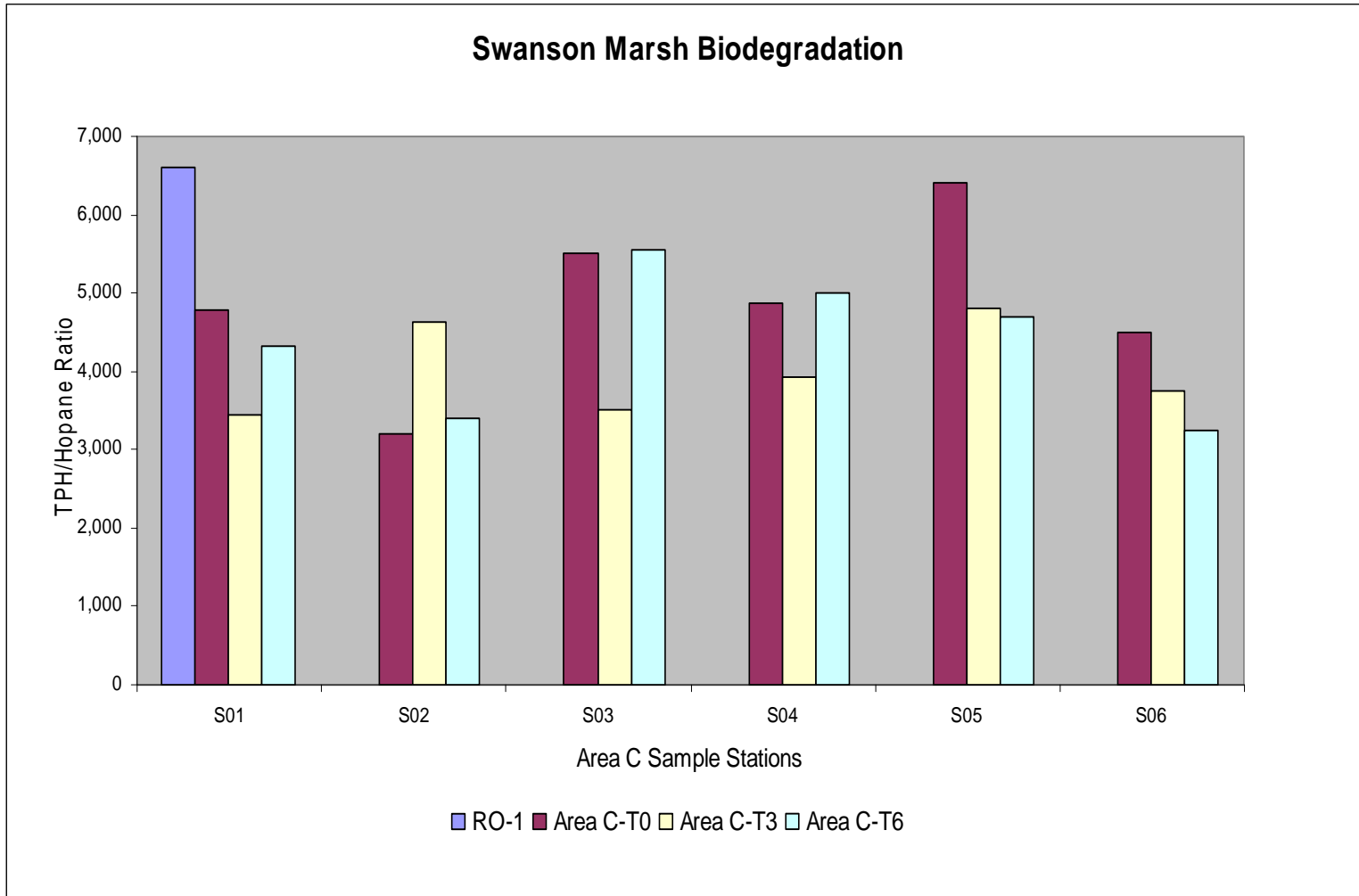
Area A –TPH/Hopanes



Area B –TPH/Hopanes

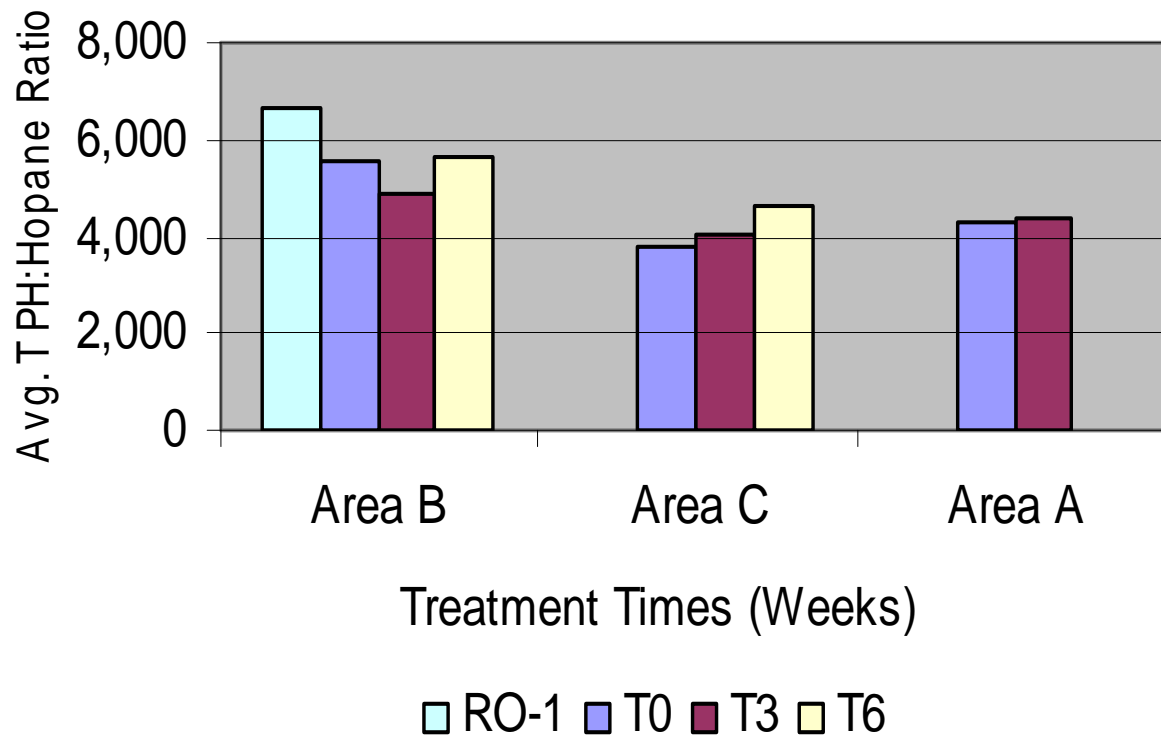


Area C – TPH/Hopanes



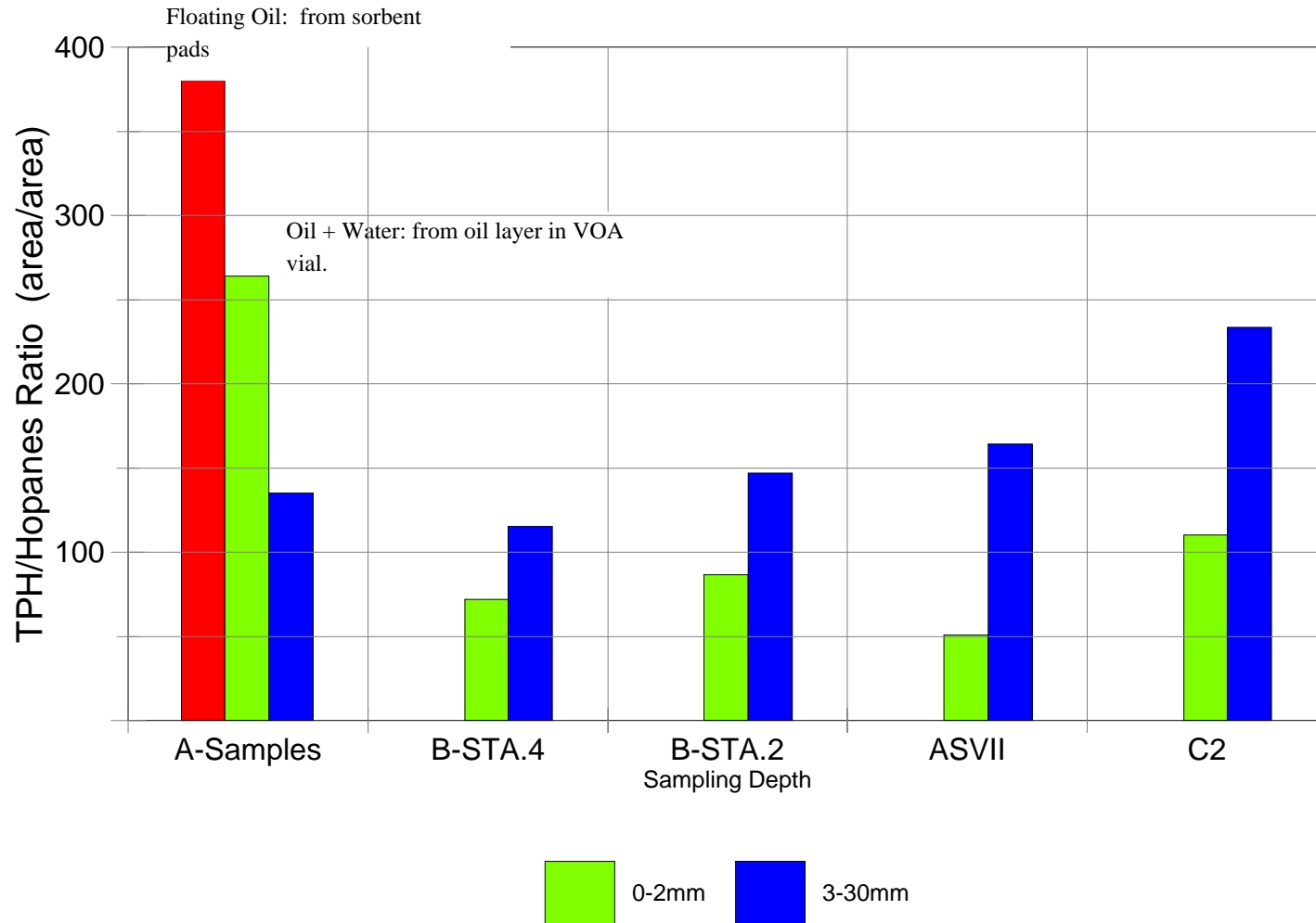
Summary Areas A, B, C

Swanson Creek Bioremediation



Depth Study – Oxygen Limitation

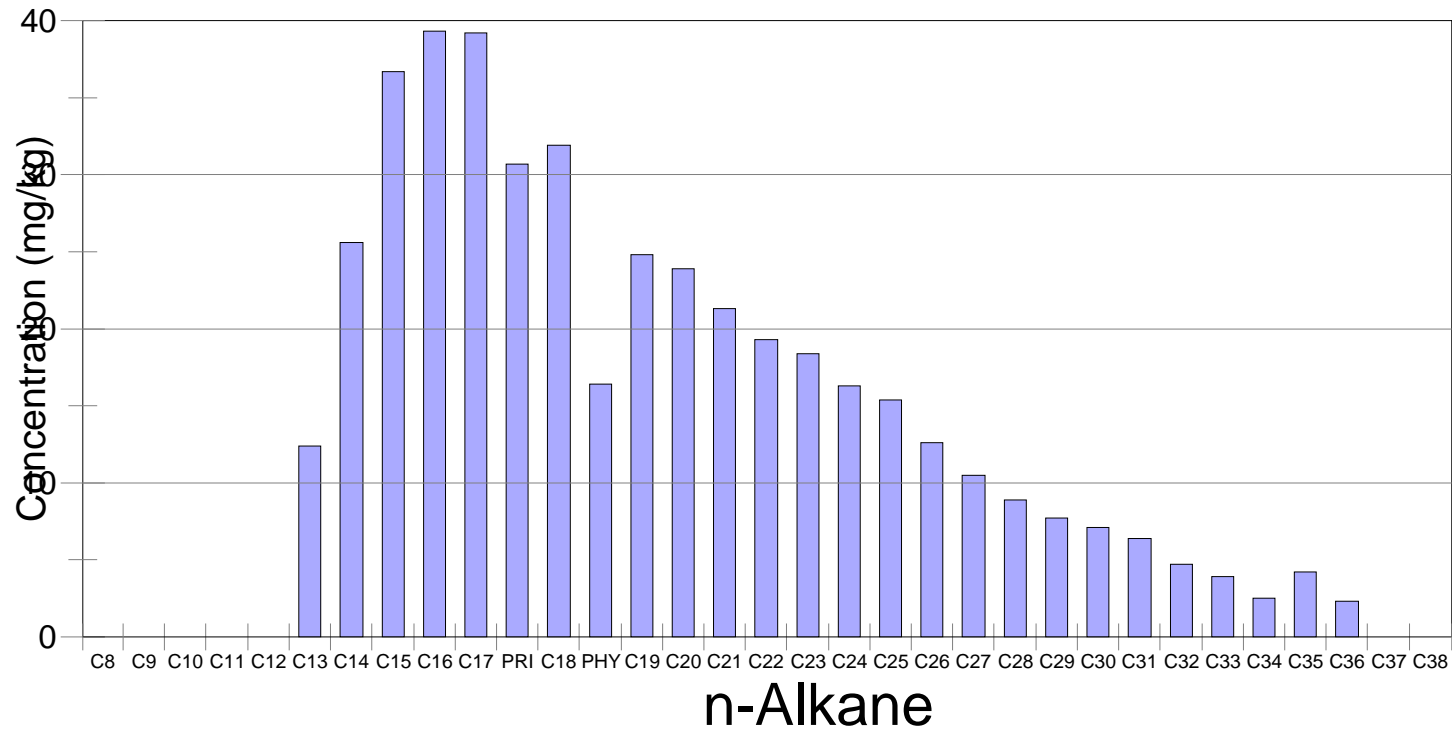
Swanson Creek TPH/Hopanes Ratios Sediment Layer Study



Free Oil Chromatogram

PEPCO Bioremediation

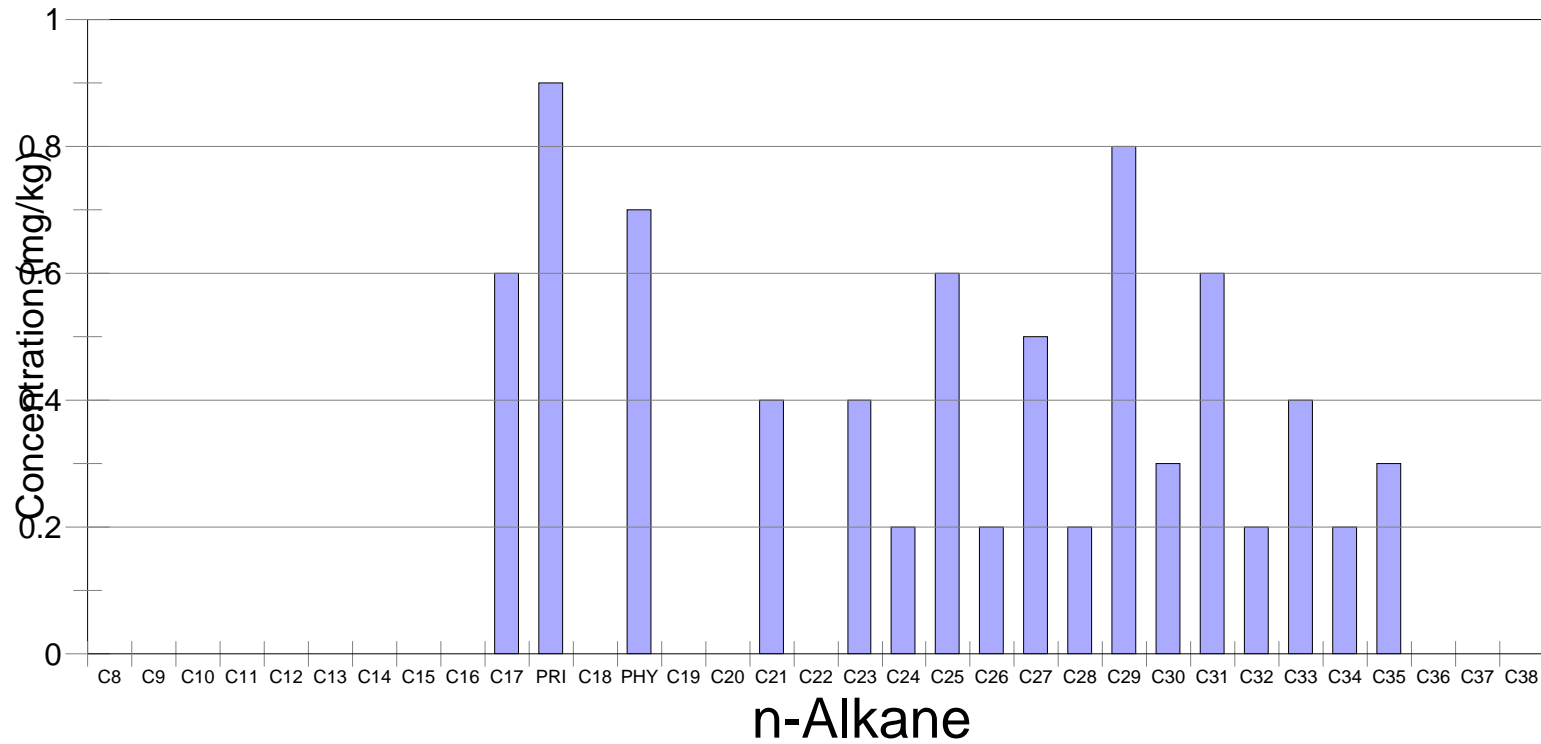
Free Surface Oil, 9/24/00



Weathering in Treated Area

PEPCO Bioremediation

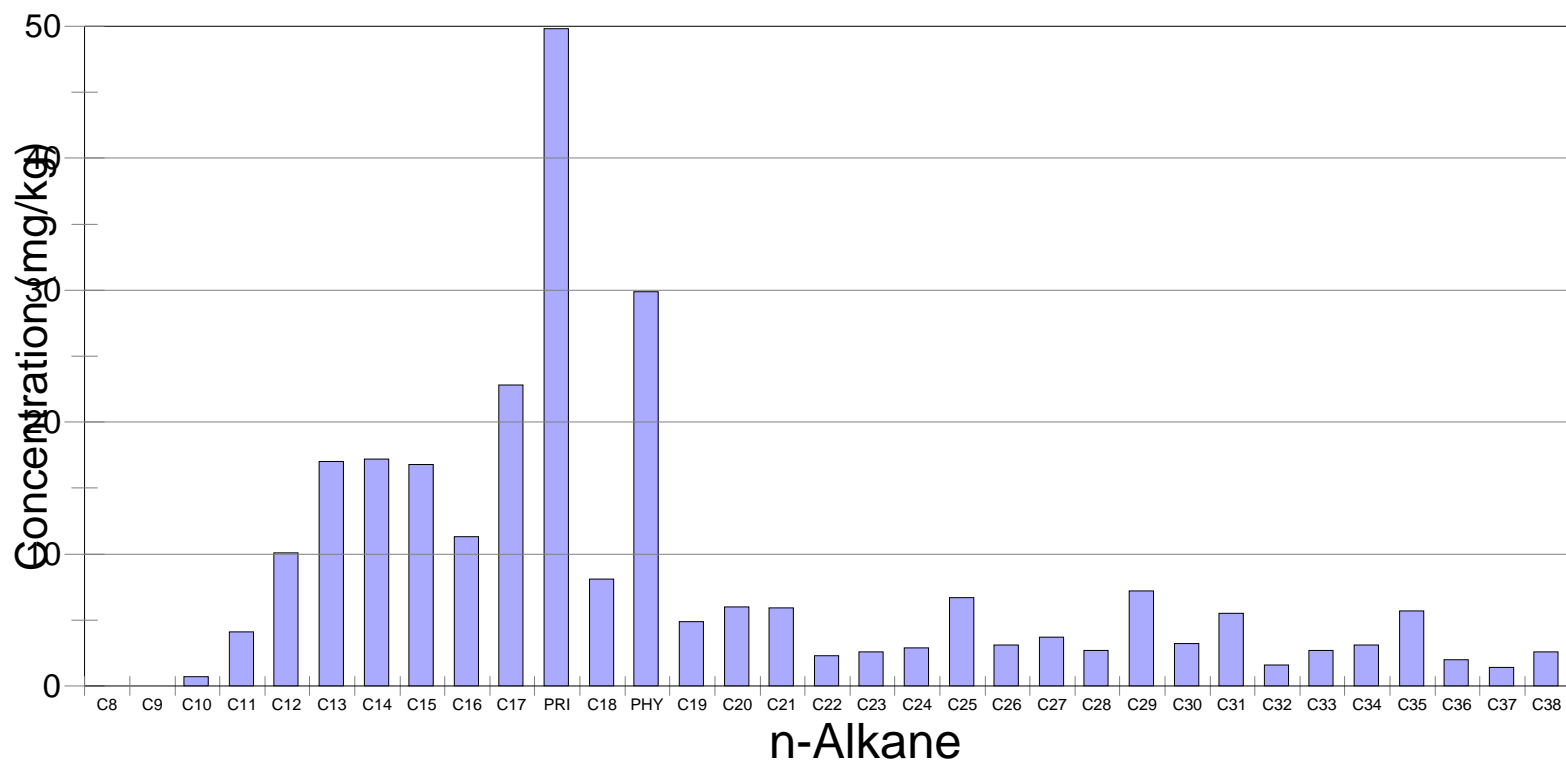
Area B 0-3 mm, 9/24/00



Weathering in Untreated Area

PEPCO Bioremediation

Area C, 0-3mm, 9/24/00



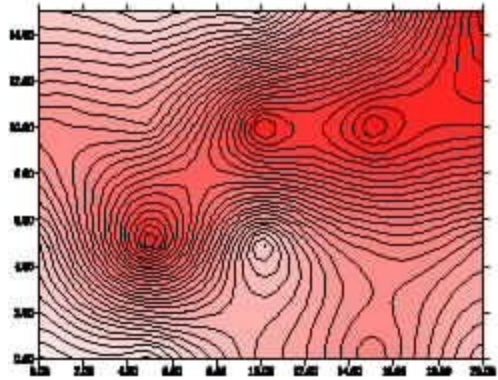
Oil in the Sands



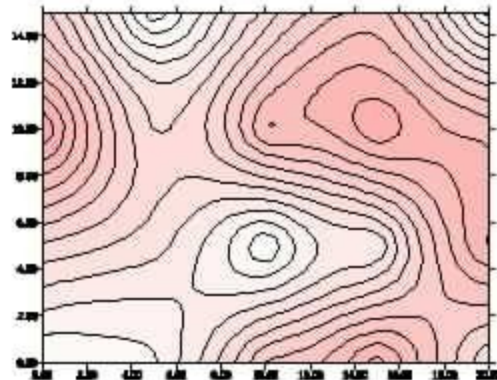
Allegheny Forest Sites - McCracken Farm Loading the Biopod



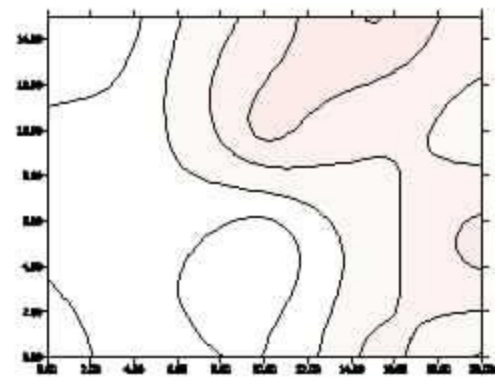
TPH at McCracken #2 Effect of Soil Mixing



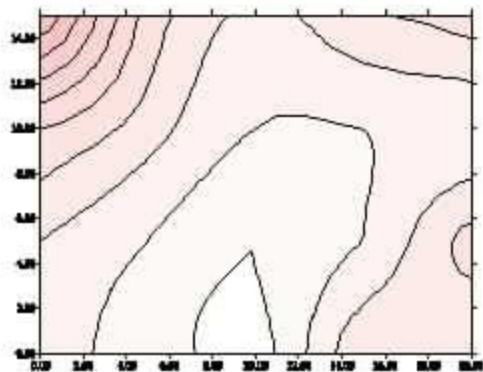
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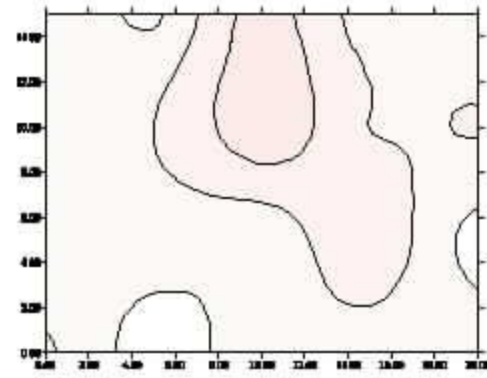
8-8-01



9-14-01



10-26-01



11-30-01

Conclusion

- Biodegradation of Oiled Soil is an Effective Removal Technology if the Soil can be Worked.
- Biostimulation is Effective only at Surface Because of Oxygen Limitations.
- Gross Measurements of Oil Loss Have Limited Usefulness in Measuring Biodegradation
- Sophisticated Analytical Techniques are Needed
- Sampling is Key to Interpreting the Process.

Conclusion (Cont.)

- Statistics are Necessary, but Should be Used With Caution.
- Natural Attenuation of Oiled Soil will Probably be a Very Long Process.
- Plant Root Growth may Accelerate Biodegradation, but More Work is Needed and the Jury is Still Out.

Acknowledgements

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FIELD-SCALE STUDIES ON REMOVAL OF CREOSOTE FROM CONTAMINATED SOIL

Harry L. Allen, U.S.EPA

Leo Francendese, U.S.EPA

Greg Harper, PRC Environmental Management

T. Ferrell Miller, Lockheed Martin/REAC

Superfund Site

Walker Springs Wood Treating Site



Abandoned Equipment at Walker Springs Site



TABLE 1. Target Creosote Components Evaluated in Bioremediation Studies

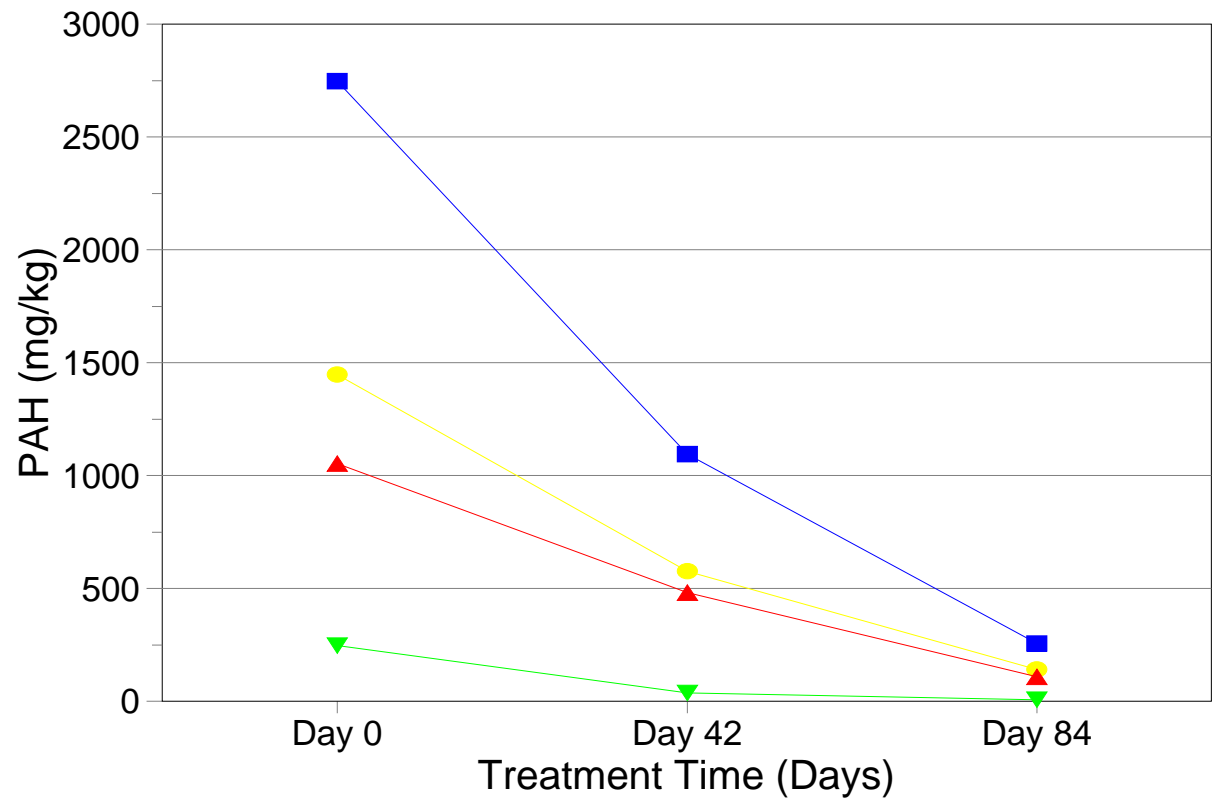
Analyte Group	Creosote Compound
Group 1 PAHs	Naphthalene, 1-Methylnaphthalene, 2-Methylnaphthalene, 2,6-Dimethylnaphthalene, Biphenyl
Group 2 PAHs	Acenaphthalene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, 2-Methylanthracene
Group 3 PAHs	Fluoranthene, Pyrene, Chrysene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-c,d)pyrene
Phenolics	o-Cresol, m-Cresol, p-Cresol, Pentachlorophenol (PCP)
Heterocycles	Dibenzofuran, Carbazole

Old Wood Chip Pile



PAH Degradation in Bench-Scale Solid Phase Amended with Limestone, Sawdust and Nutrients

Bench-Scale #4

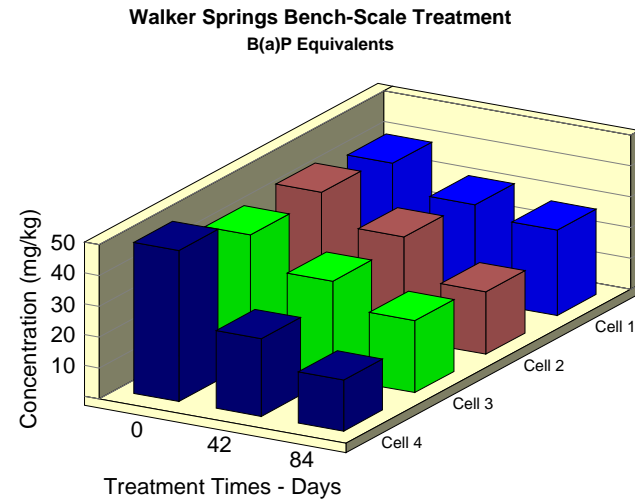
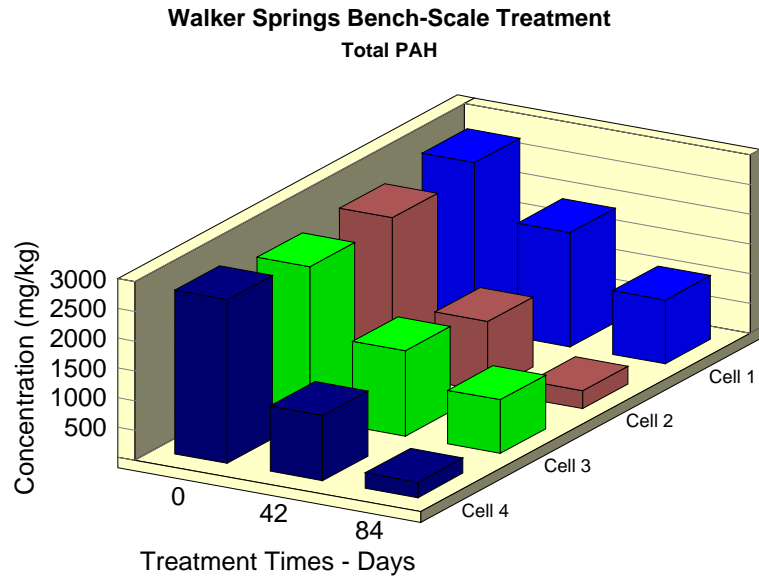


■ Total PAH ▼ Group 1 PAH ● Group 2 PAH ▲ Group 3 PAH

B(a)P Toxic Equivalency Factors

PAH	TEF
acenaphthylene	N
acenaphthene	6.5E-06
fluorene	9.5E-06
phenanthrene	N
anthracene	1.3E-06
pyrene	1.3E-05
chrysene*	0.001
benzo(a)pyrene*	1
benz(a)anthracene*	0.1
benzo(b)fluoranthene*	0.1
benzo(k)fluoranthene*	0.01
indeno(c,d-1,2,3)pyrene*	0.1
1,2-dibenz(a,h)anthracene*	1
*Carcinogen	

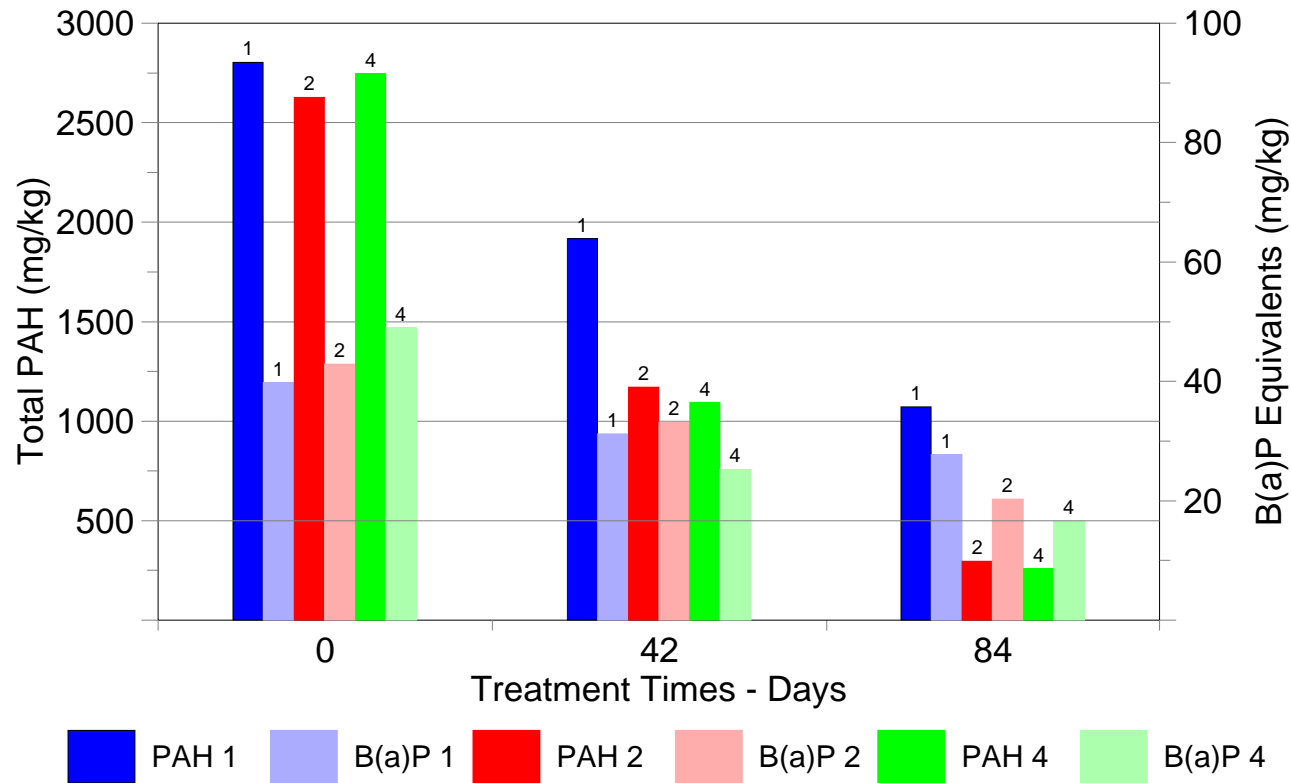
Bench-Scale Results Showing Effect of Recipe



- Recipe 1: Limestone
- Recipe 2: LS & Nutrient
- Recipe 3: LS & Sawdust
- Recipe 4: LS & Nut.& SD

Effect of Recipe on PAH Removal

Walker Springs Bench-Scale Treatment



Walker Springs Pilot Units



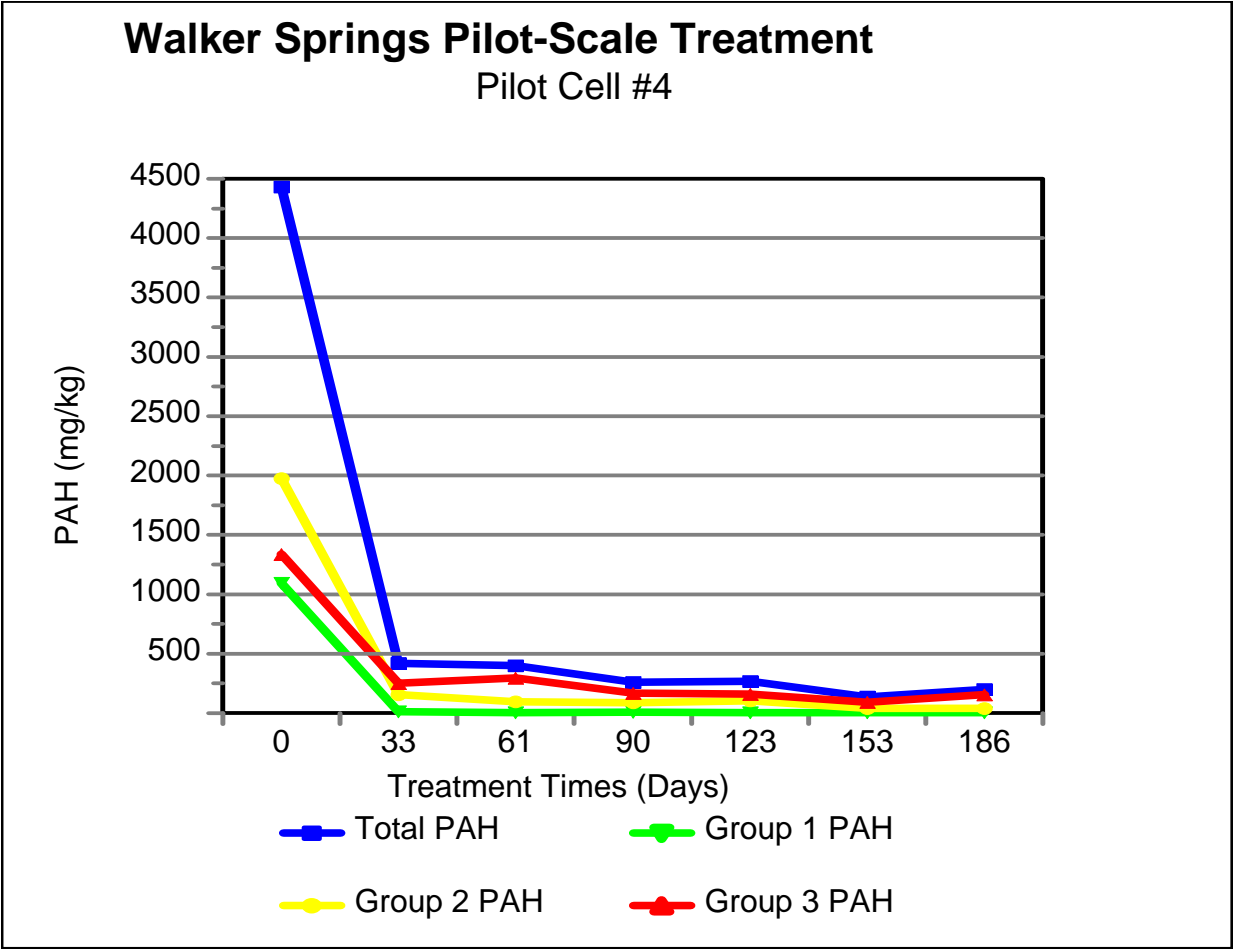
Tilling Pilot Units



Sampling Locations in Pilot Units

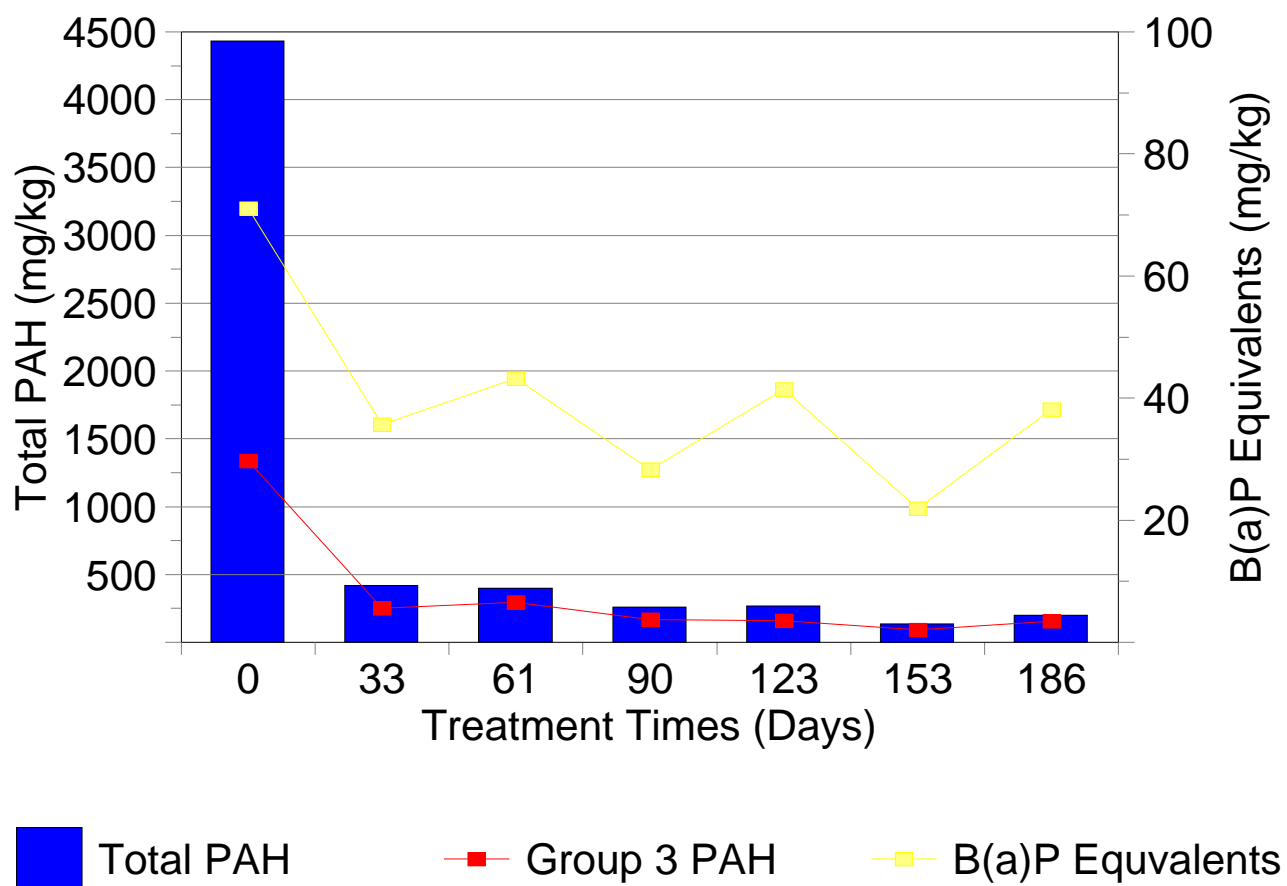


PAH Degradation in Field-Scale Solid Phase Studies Using Recipe 4



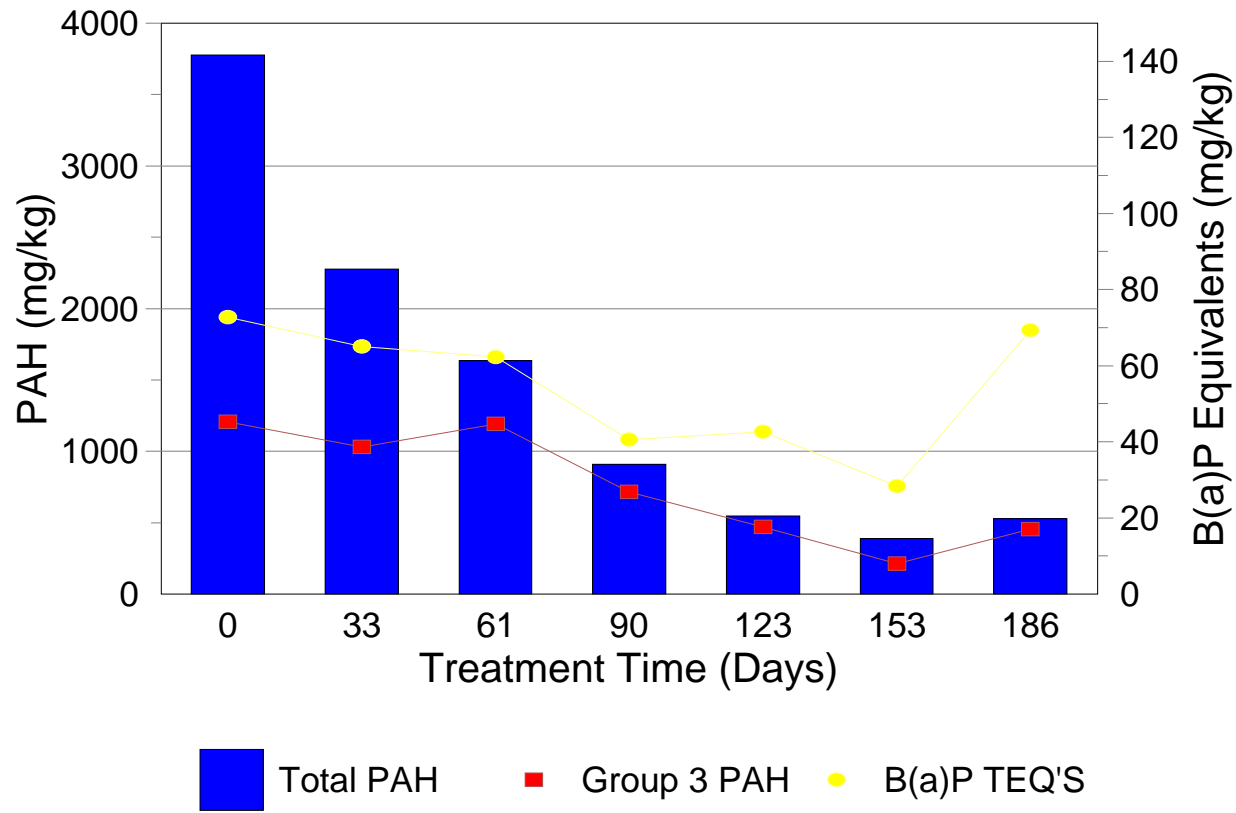
PAH Degradation in Field-Scale Pilot Unit Using Recipe 4 – Added Limestone, Sawdust, Nutrients

Walker Springs Pilot-Scale Treatment Pilot Cell #4



PAH Degradation in Field-Scale Pilot Unit Using Recipe 3 –No Added Nutrients

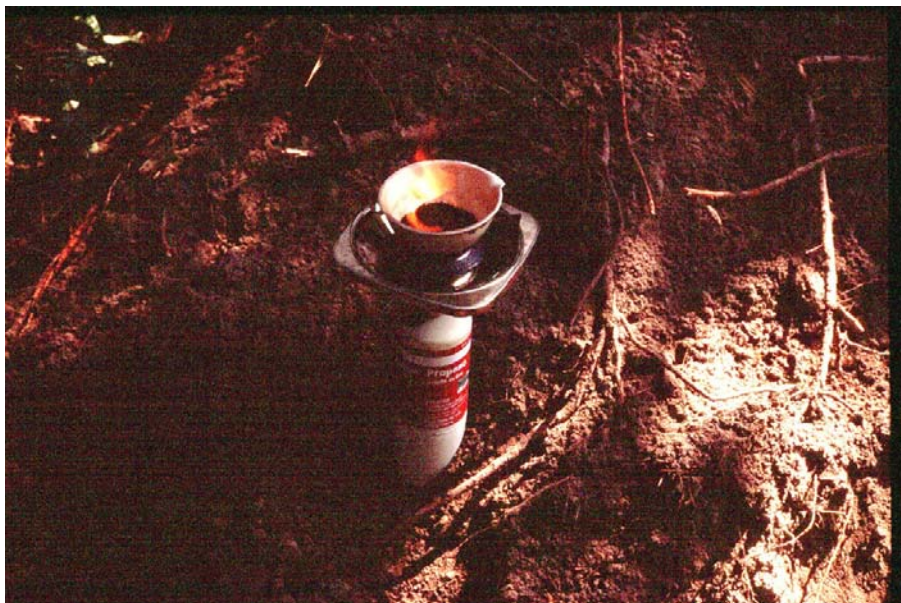
Walker Springs Wood Treating Site Pilot-Scale Treatment Unit #3



Preparation and Management of Soil Treatment



Field Testing for Moisture Content

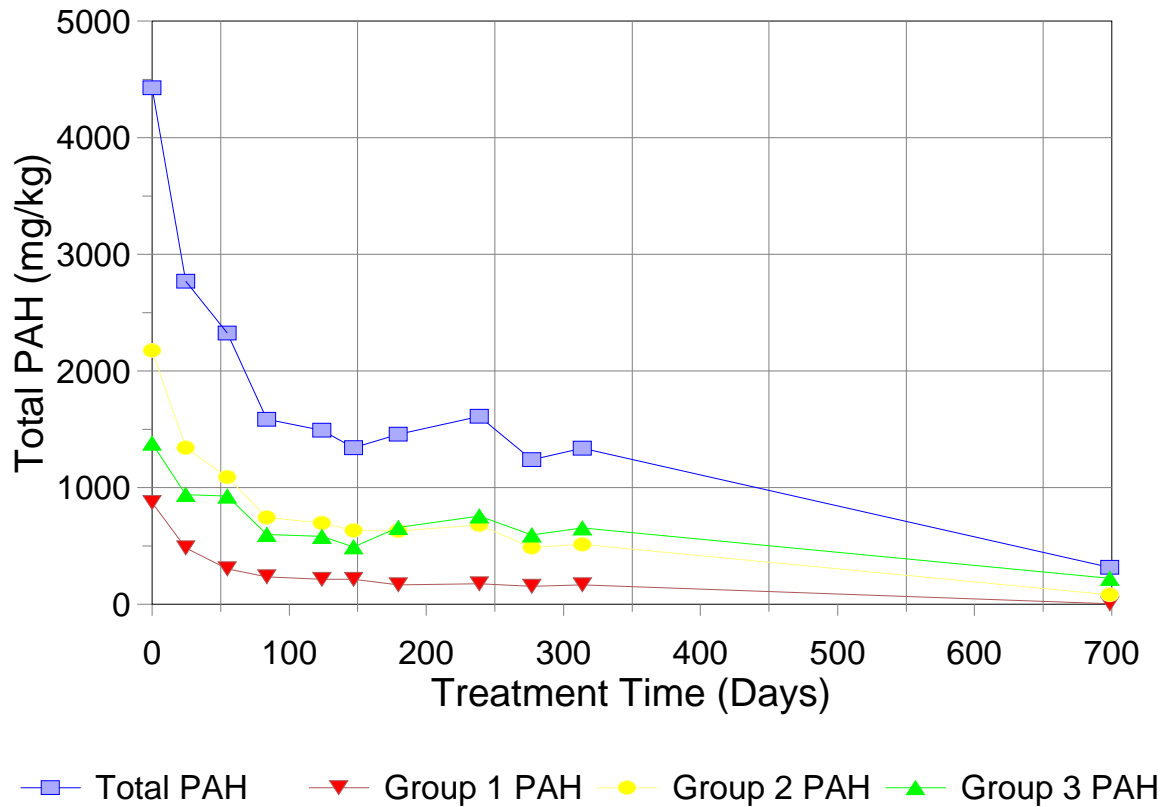


Covering to Control Moisture

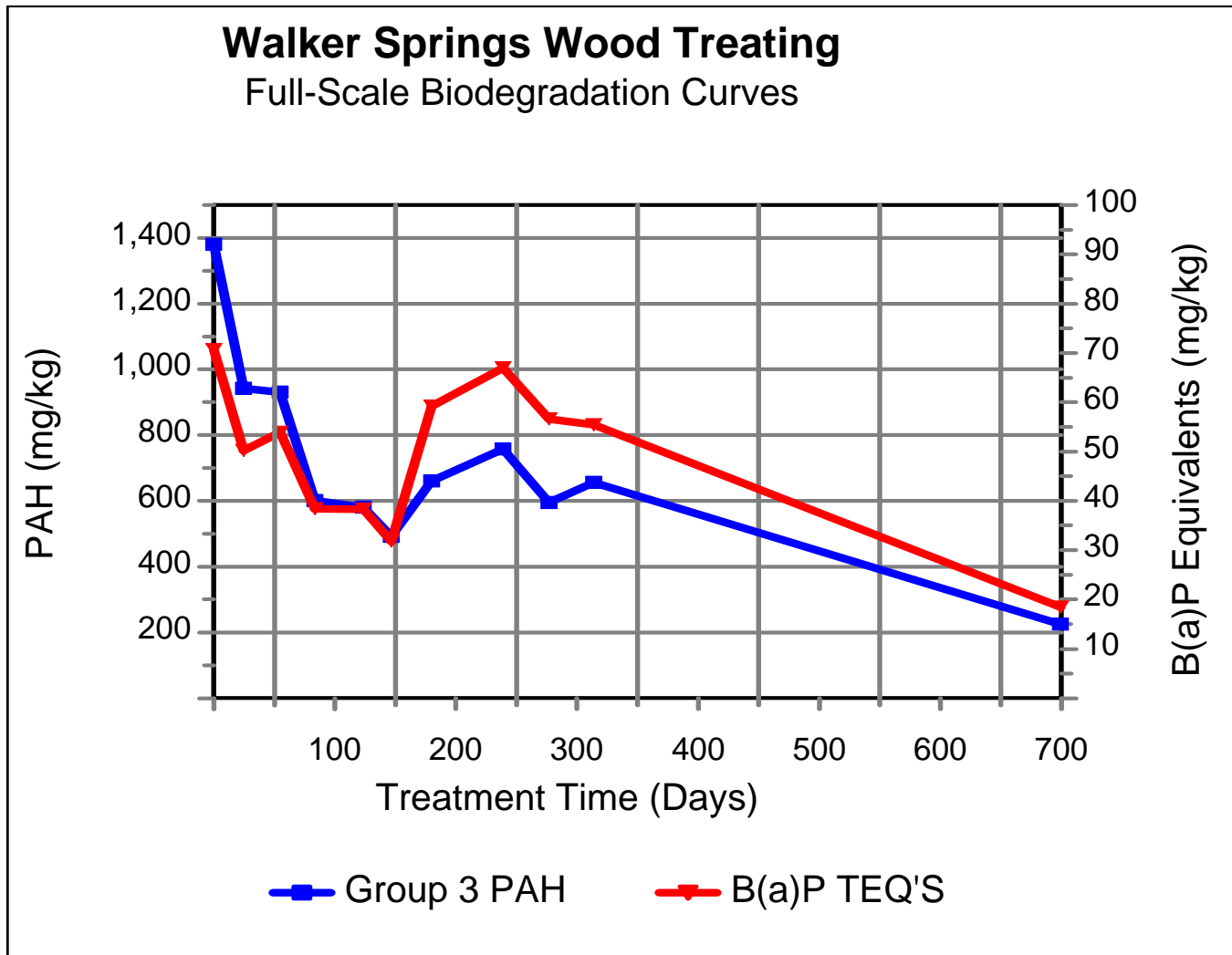


PAH Degradation in Full-Scale Treatment

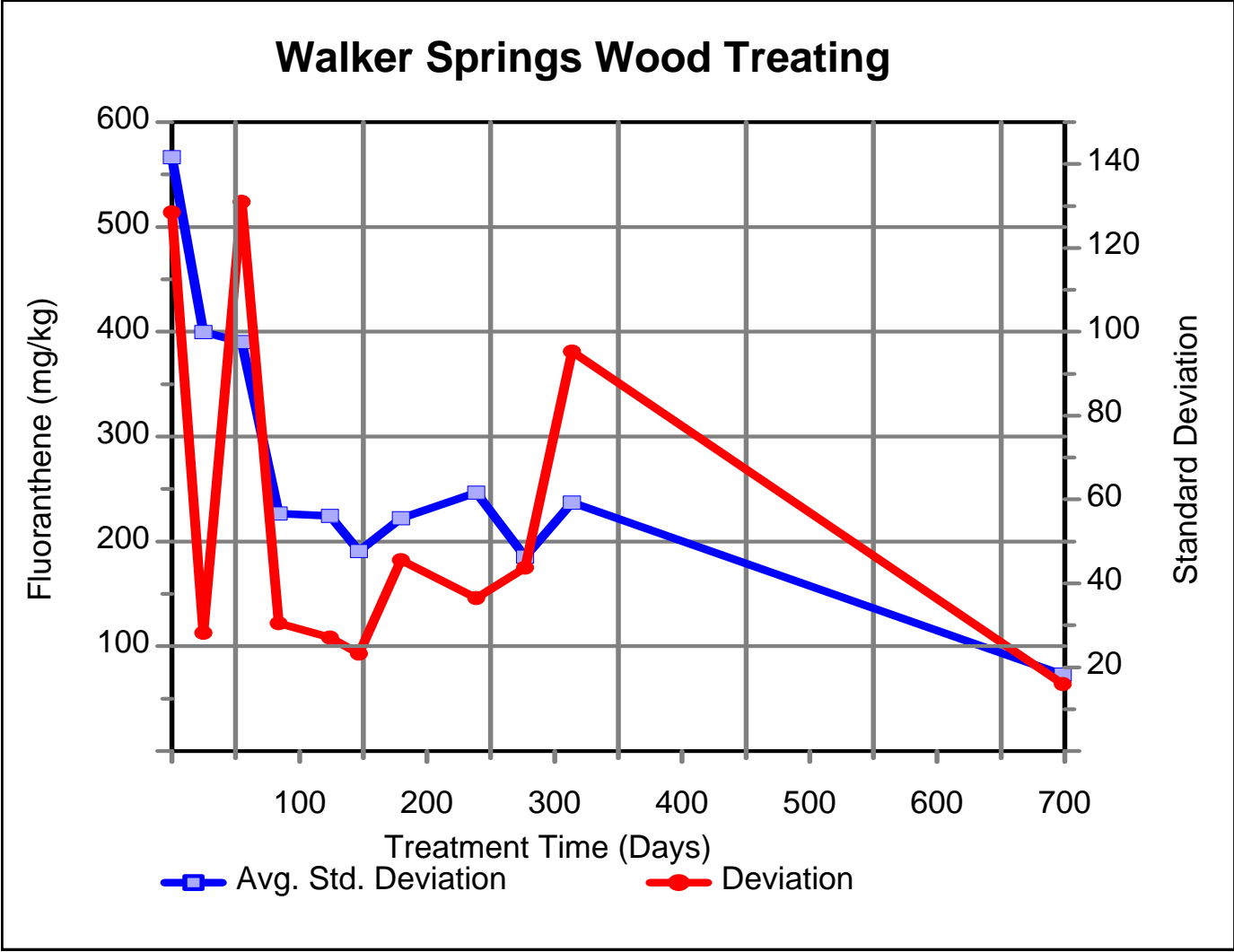
Walker Springs Wood Treating Full-Scale Biodegradation Results



Group 3 and B(a)P Equivalents Degradation in Full-Scale Treatment

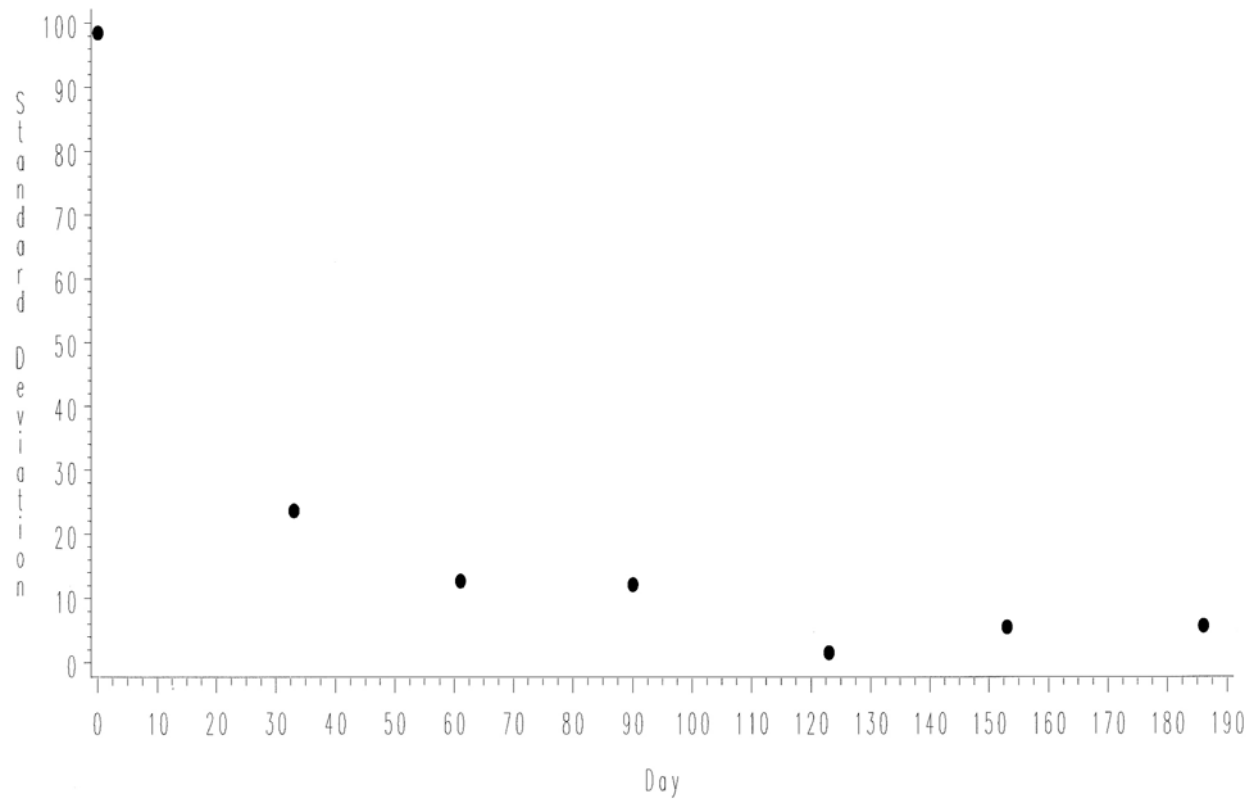


Change in Data Variation With Time for Fluoranthene in Full-Scale Treatment

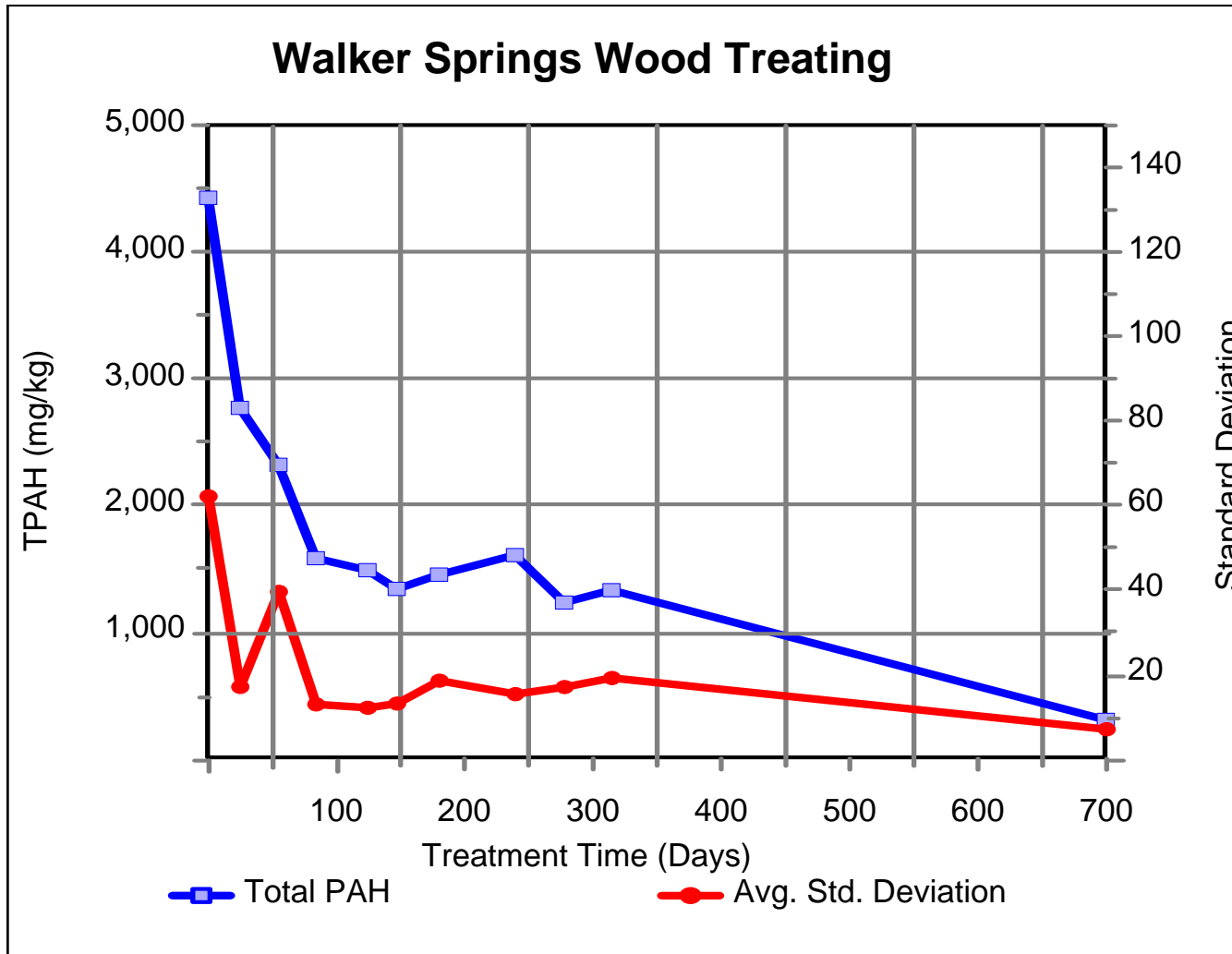


Plot of Standard Deviation vs. Day

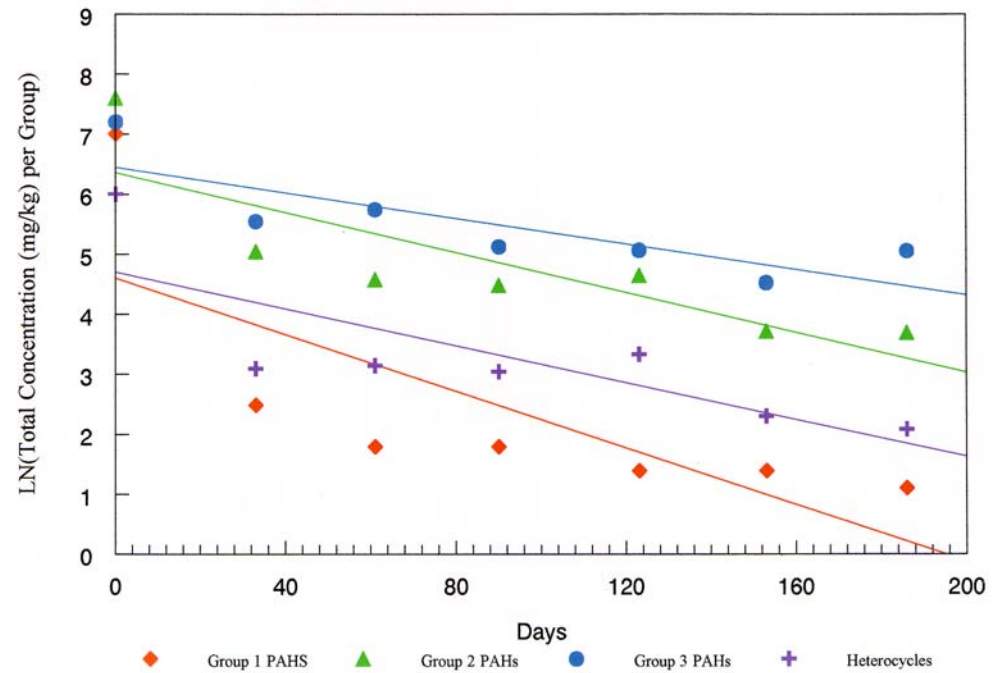
Walker Springs Pilot Study - Unit #4
COMPOUND=fluoranthene



Change in Data Variation With Time for TPAH in Full-Scale Treatment

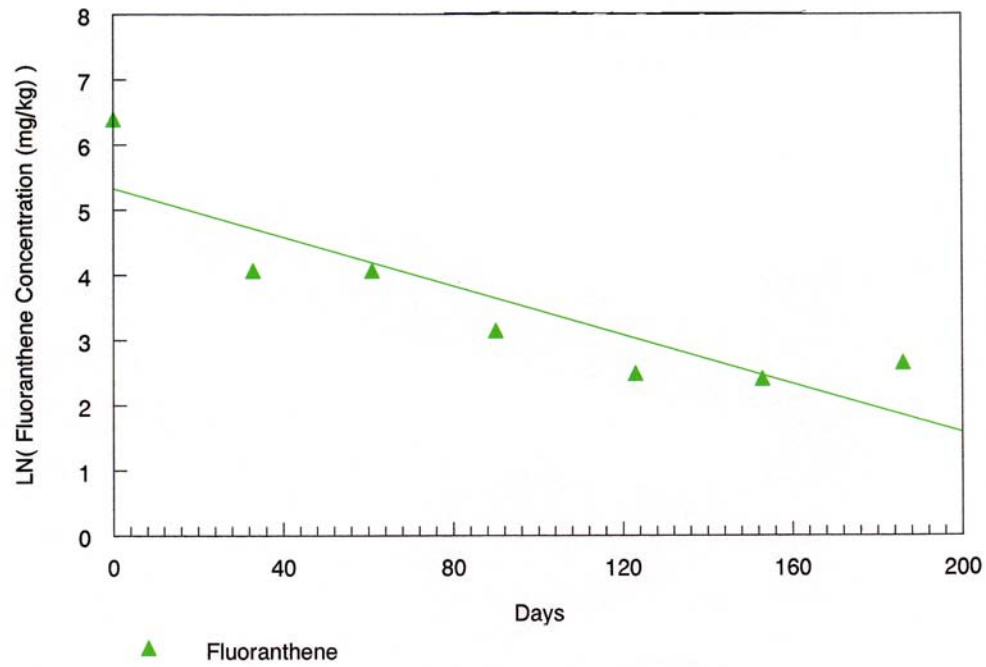


Regression of Total Concentration Per Group vs. Time Walker Springs Pilot Study - Unit #4

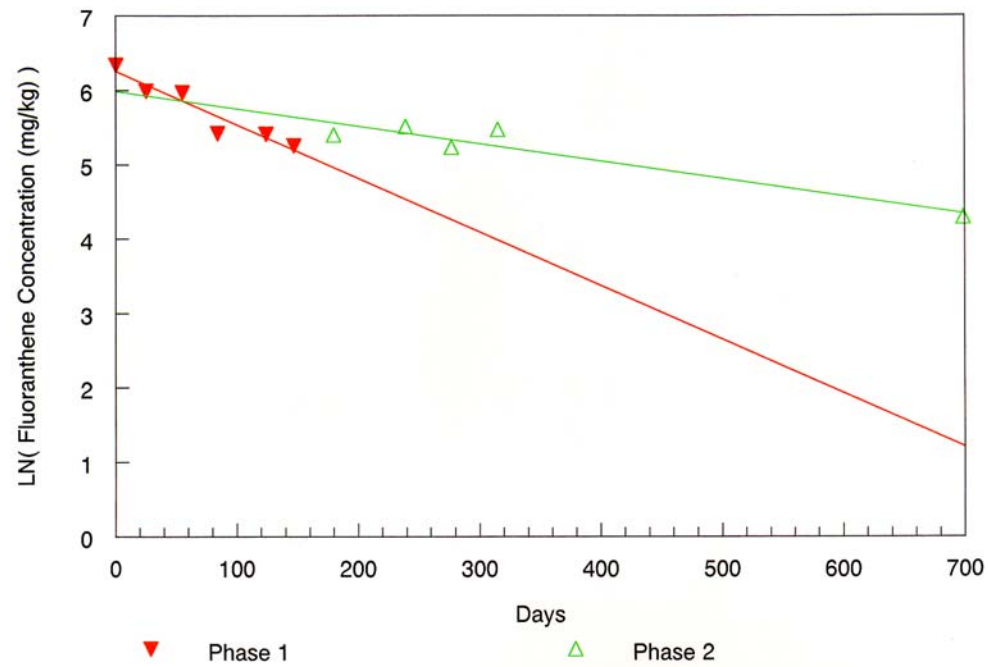


Regression of Fluoranthene vs. Time

Walker Springs Pilot Study - Unit #4



Regression of Fluoranthene vs. Time Walker Springs Field Unit



**Walker Springs Field Treatment Unit Bioremediation
Calculation of Half-Life Based on Semi-Logarithmic Regression Studies**

Compound	Days 0 to 147		Days 180 to 699	
	Half-life (days)	R-Squared	Half-life (days)	R-Squared
Group 1 PAHs	78	0.8251	102	0.9583
Group 2 PAHs	88	0.9004	165	0.9720
Group 3 PAHs	107	0.9162	301	0.9352
Heterocycles	82	0.8115	169	0.9640
Phenanthrene	80	0.9388	133	0.9769
Fluoranthene	96	0.9096	295	0.9062
Pyrene	99	0.8892	330	0.9329
Chrysene	114	0.9120	257	0.9372
Benz(a)anthracene	110	0.9564	267	0.8768
	Days 0 to 699			
Fluoranthene	289	0.7929		

Conclusions

- Walker Springs Cleaned Up
- PAH Degraded or Immobilized in a Reasonable Timeframe
- Addition of Bulking Agent and Nutrients Effective
- Bioaugmentation with Active Soil is Effective
- Destruction of Carcinogenic PAH Can Be Done But Special Care May Be Necessary
- Sampling May Be a Problem in Interpreting Results