Composting Considerations for TNTA and TNTC Plum Brook Ordnance Works Sandusky, Ohio

Presented To:
Restoration Advisory Board
September 11, 2002

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What is Composting?

Ex-situ bioremediation of contaminated soil in piles

Agricultural amendments such as manure and straw added to contaminated soil (compost mix typically 25% soil by volume)

Manure added to provide a nutrient source to promote biodegradation

Straw or wood chips added as a bulking agent to increase porosity and promote oxygen transport through pile

Other amendments may be added to provide optimal balance of carbon to nitrogen

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Amendment Spreadsheet

MIX #1									
Ingredient	Qty. (CY)	Qty. (lbs.)	% Carbon	% D.M.	Carbon (lbs.)	% Nitrogen	Nitrogen (lbs.)	C:N Ratio	Cost ($/Ton)
Straw	33	6,600	0.4240	0.88	2,462.59	0.0123	71.44	34.47	$65
Chicken Manure		0	0.1870	0.88	0.00	0.0558	0.00	3.35	$25
Alfalfa		0	0.3290	0.85	0.00	0.0314	0.00	10.48	$165
Cow Manure	12	17,100	0.3820	0.21	1,371.76	0.0257	92.29	14.86	$22
Vegetable Waste		0	0.4000	0.30	0.00	0.0140	0.00	28.57	$100
Saw Dust		0	0.6000	0.61	0.00	0.0008	0.00	750.00	$20
Wood Chips		0	0.6000	0.88	0.00	0.0008	0.00	750.00	$20
Soil	15	33,000							
Totals	60	56,700							
	Mix Density (lbs/CY) =		945		3,834.35		163.73	23.42	
	Mix Unit Cost ($/CY) =		$6.71						
MIX #2									
Ingredient	Qty. (CY)	Qty. (lbs.)	% Carbon	% D.M.	Carbon (lbs.)	% Nitrogen	Nitrogen (lbs.)	C:N Ratio	Cost ($/Ton)
Straw	43.25	8,650	0.4240	0.88	3,227.49	0.0123	93.63	34.47	$65
Chicken Manure	1.75	2,538	0.1870	0.88	417.57	0.0558	124.60	3.35	$25
Alfalfa		0	0.3290	0.85	0.00	0.0314	0.00	10.48	$165
Cow Manure		0	0.3820	0.21	0.00	0.0257	0.00	14.86	$22
Vegetable Waste		0	0.4000	0.30	0.00	0.0140	0.00	28.57	$100
Saw Dust		0	0.6000	0.61	0.00	0.0008	0.00	750.00	$20
Wood Chips		0	0.6000	0.88	0.00	0.0008	0.00	750.00	$20
Soil	15	33,000							
Totals	60	44,188							
	Mix Density (lbs/CY) =		736		3,645.06		218.23	16.70	
	Mix Unit Cost ($/CY) =		$5.21						

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What is Windrow Composting?

Compost mix (soil + amendments) formed into long piles called windrows (6' H x 14' W x 300' L)

Windrows mixed periodically by special equipment called a windrow turner

Turning windrows provides oxygen to compost pile to promote aerobic biodegradation

Water periodically added to windrow to maintain optimum moisture content

Windrow composting typically conducted inside a temporary, fabric-covered structure to prevent rainfall from saturating compost pile

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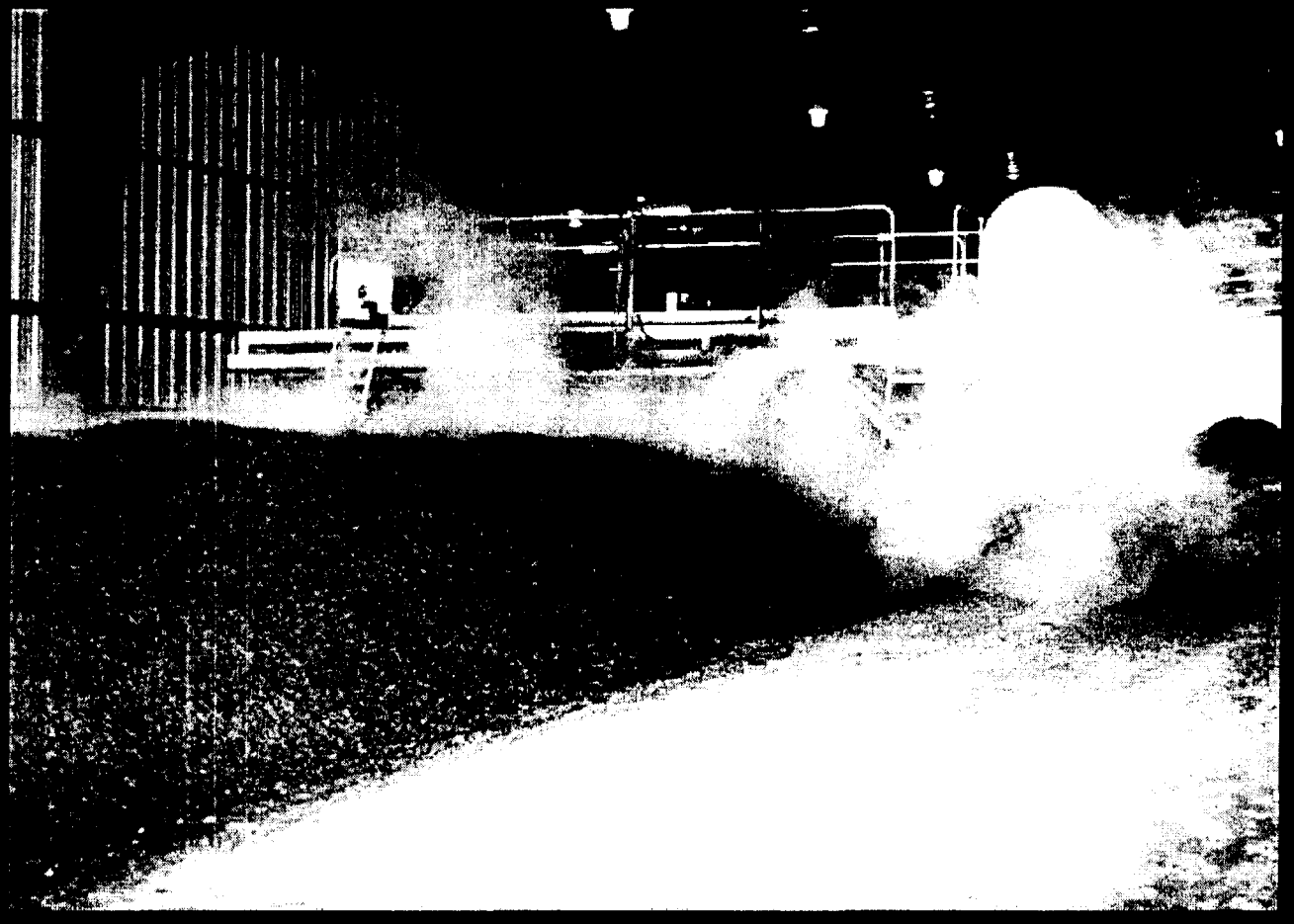
Windrow Turner



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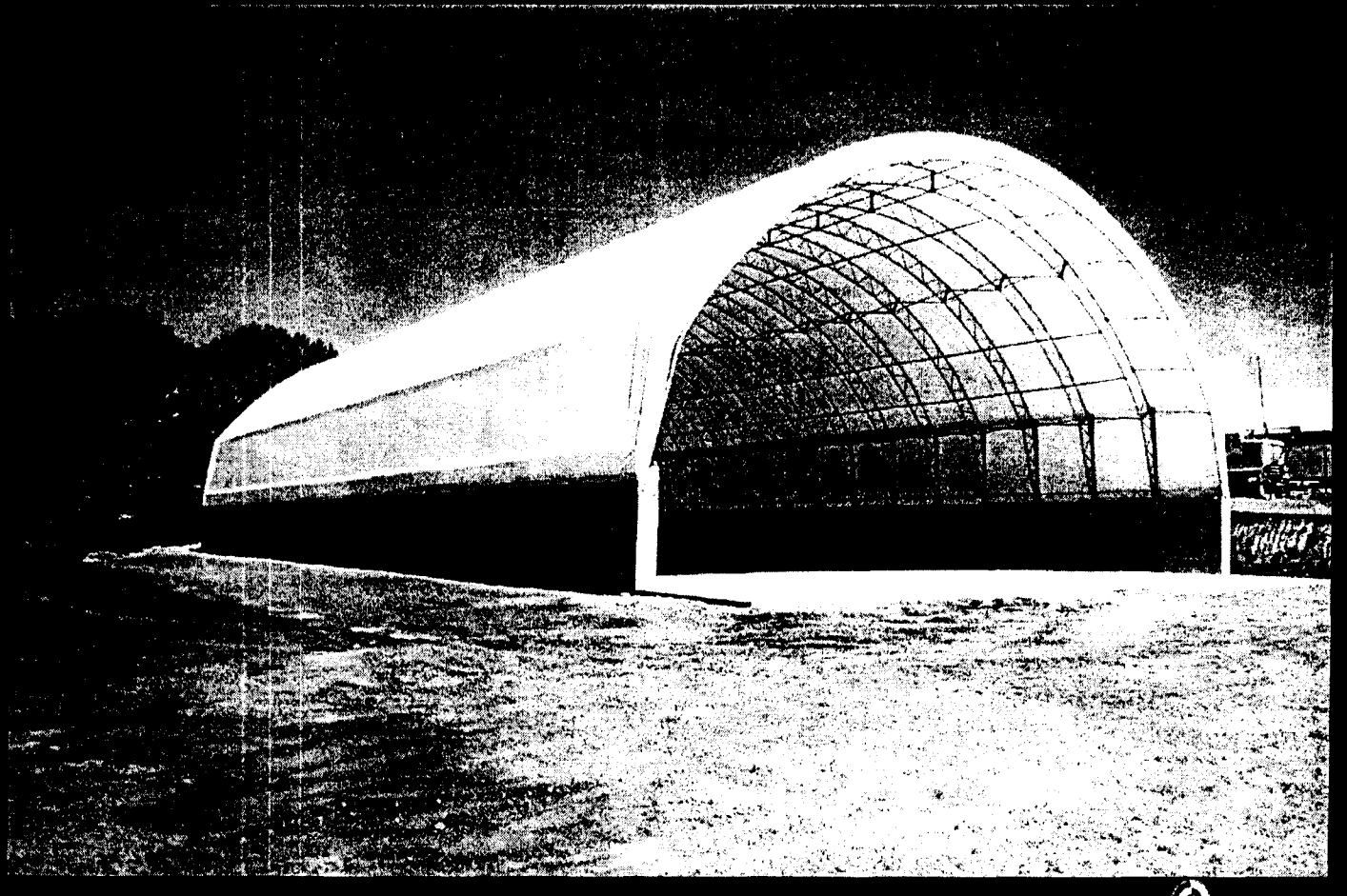
Temporary Structure



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How Windrow Composting Degrades TNT

TNT degrades through a combined anaerobic/aerobic process

Anaerobic biodegradation occurs in the absence of oxygen

Aerobic biodegradation occurs in the presence of oxygen

Anaerobic biodegradation promotes reduction of nitro groups on the TNT molecule

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How Windrow Composting Degrades TNT *(continued)*

Aerobic biodegradation promotes the humification of the reduced TNT metabolites

Compost pile in aerobic stage after windrow is turned.

As oxygen in pile is utilized, pile turns anaerobic until turned again

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Critical Processing Characteristics in Windrow Composting

- Porosity
- Free air space
- Moisture content
- Particle size
- Temperature
- Carbon to nitrogen ratio
- pH

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Successful Remediation Using Windrow Composting

Umatilla Depot - Hermiston, Oregon

Naval Surface Warfare Center - Crane, Indiana

Joliet Army Ammunition Plant - Elwood, Illinois

U.S. Naval Submarine Base - Bangor, Washington

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Primary Factors Affecting Cost of Windrow Composting

Treatment building size controls volume of soil that can be treated at one time (batch size), and therefore, time required to complete remediation

Optimum remediation cost is a trade-off between major fixed and variable costs

Major fixed costs include temporary treatment building and contact water management system

Major variable costs include equipment rental and operating labor

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Advantages/Disadvantages of Using Windrow Composting

Advantages

- Satisfies CERCLA statutory preference for treatment via biodegradation and humification
- Treated compost may be returned to site as a soil amendment

Disadvantages

- Composting will not treat inorganic contaminants at site such as lead
- High fixed costs make composting cost-effective for larger volumes of contaminated soil
- Treated compost is not suitable as structural backfill

Potential Opportunities of Cost Savings

USACE-Huntington is preparing to implement windrow composting for a site at WVOW

Treatment building purchased for WVOW may be disassembled for reconstruction at PBOW, lowering fixed costs for PBOW remediation projects

Other equipment purchased for WVOW might also be used at PBOW

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Background Groundwater Study

Former Plum Brook Ordnance Works, Sandusky, Ohio

PBOW Project Status/Review Meeting
NASA Plum Brook Station
September 11, 2002

PBOW Background Groundwater Study

- Background distributions were characterized for 23 TAL metals, 17 PAHs, and BTEX in groundwater
- Background data set was developed for comparison to site data
- Data set includes 21 samples from 5 monitoring wells screened in bedrock
- 1 to 6 samples collected from each well

PBOW Background Groundwater Study

Characterization of Background Distributions:

- Statistical methodology based on EPA guidance
- Handling of nondetects
- Distributional assumptions
- Handling of outliers
- Calculation of summary statistics

PBOW Background Groundwater Study

EPA Guidance:

- *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance* (EPA/530/SW-89/026, February 1989)
- *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance* (EPA/530/R-93/003, July 1992)
- *Statistical Methods for Evaluating the Attainment of Cleanup Standards, Volume 3, Reference-Based Standards for Soils and Solid Media* (EPA/230/R-94/004, June 1994)
- *Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites* (EPA/540/S-96/500, December 1995)
- *The Lognormal Distribution in Environmental Applications* (EPA/600/R-97/006, December 1997)

PBOW Background Groundwater Study

Handling of Nondetects:

- Nondetects were replaced with ½ the reporting limit

PBOW Background Groundwater Study

Checking Distributional Assumptions:

- Data were tested for a lognormal distribution first, because trace element data generally follow this type of model (EPA, 1992)
- If lognormality could not be demonstrated, then normality testing was performed
- If neither a normal nor a lognormal distribution could be demonstrated, then the distribution was characterized as nonparametric
- Analytes with greater than 15 percent nondetects were automatically treated as nonparametric (EPA, 1989)

PBOW Background Groundwater Study

Handling of Outliers:

- Sample locations were selected to avoid potentially contaminated areas, and the analytical results were validated and found to be free of errors; under these conditions, there was no justification to remove any statistical outliers - However MW 20 is candidate [illegible]
- However, nondetect results for Nov. '97, May '98, and Jan. '02 samples from well PB-BED-MW20 were characterized by unusually high reporting limits (e.g., cadmium RL of 100 ug/L for the May '98 sample vs. 5 ug/L for the remaining samples); these results were removed from the background data set

PBOW Background Groundwater Study

Calculation of Summary Statistics:

- Summary statistics tables provide a a complete description of each background distribution
  - Number of valid samples (*n*)
  - Percent nondetects
  - Distribution type
  - Minimum
  - Maximum
  - Arithmetic mean
  - Median
  - Standard deviation
  - 95th upper tolerance limit

PBOW Background Groundwater Study

95th UTL:

- A measure of the upper bound of the background distribution
- Based on the 95th upper confidence limit of the 95th percentile, which is designed to have a 95% probability of being greater than the true 95th percentile of the population, and can be thought of as a nonparametric 95th UTL
- Chebychev method was used to calculate the 95th UTLs

PBOW Background Groundwater Study

95th UTL:

- The calculated 95th UTLs are in some cases larger than the maximum detected concentration in the background data set; this is expected, because there is a low probability of 21 samples adequately sampling the upper range of a distribution, especially if the distribution has a broad range (which is the case for the major elements at PBOW)
- If all of the results for a given analyte are nondetect, then the 95th UTL is expressed as less than the maximum detection limit

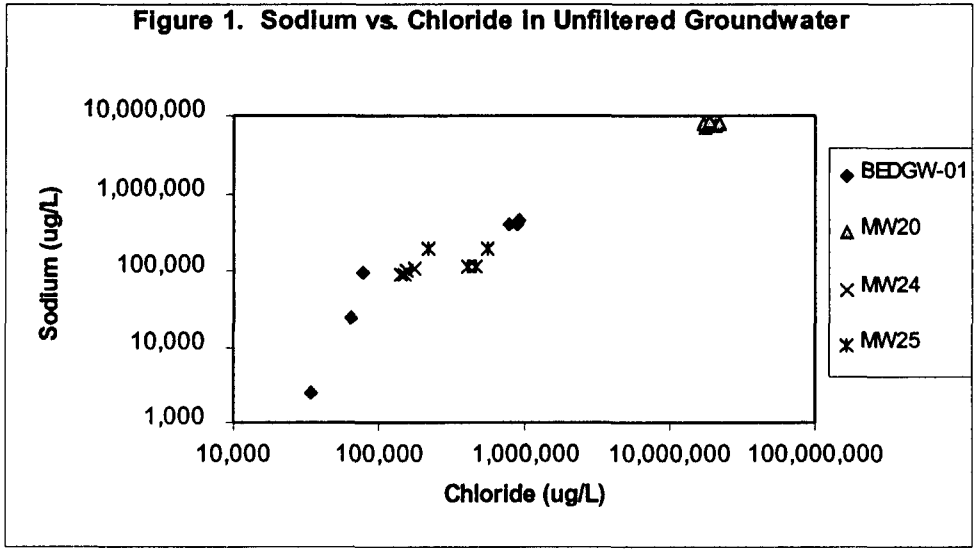
PBOW Background Groundwater Study

Strong compositional gradients in PBOW groundwater (redox, salinity):

- Violate the assumptions required for valid statistical background characterizations and site-to-background comparisons
- Preclude ~~trend~~ Subsurface analysis
- Geochemical behavior of elements should be considered when evaluating site data

PBOW Background Groundwater Study

Strong compositional gradients



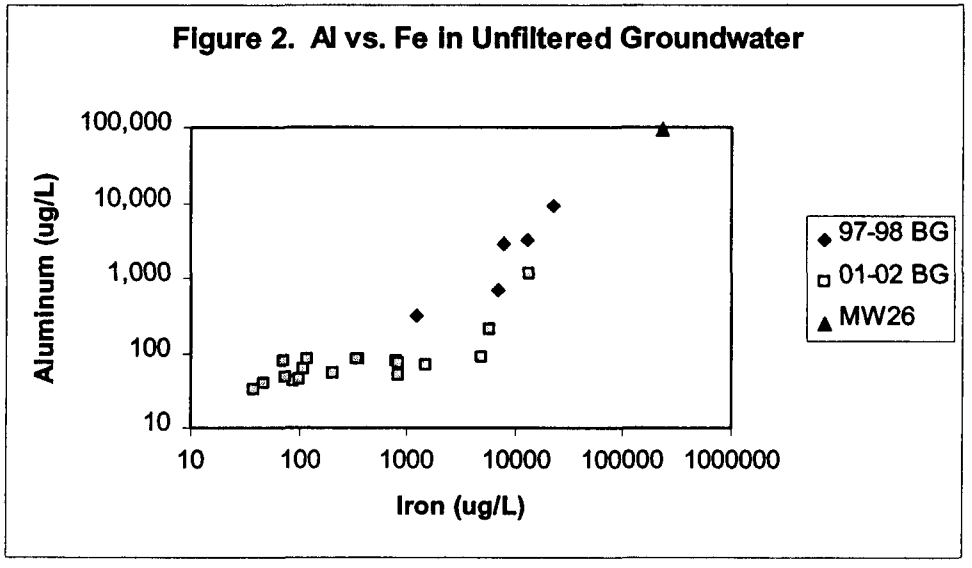
PBOW Background Groundwater Study

1997/98 Data (collected with bailers)

- These data should be excluded if contamination were suspected, but evaluation of these results indicates otherwise
- Inorganics concentrations are higher in these samples, but they are proportionally higher (as seen in correlation plots of trace and major elements)

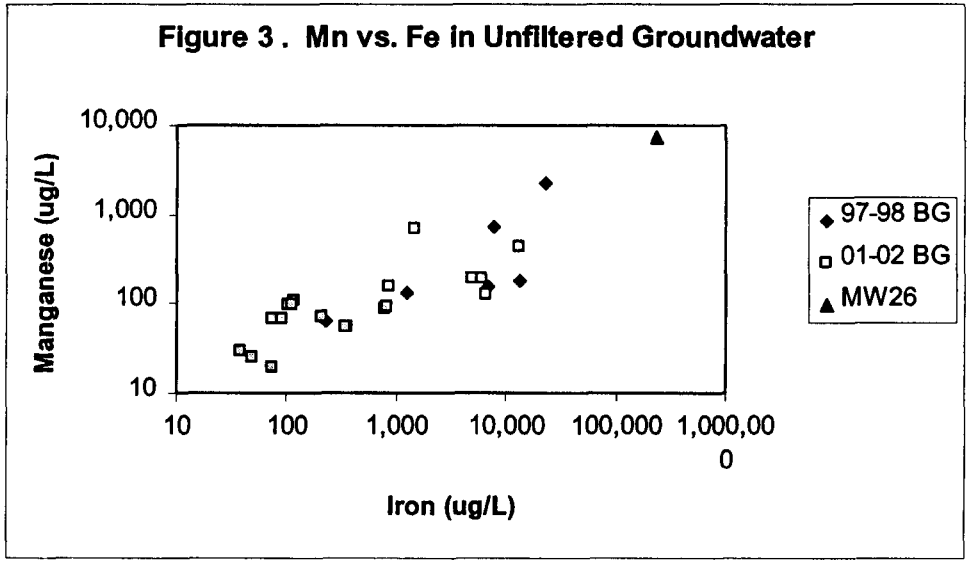
PBOW Background Groundwater Study

Background Data (unfiltered)



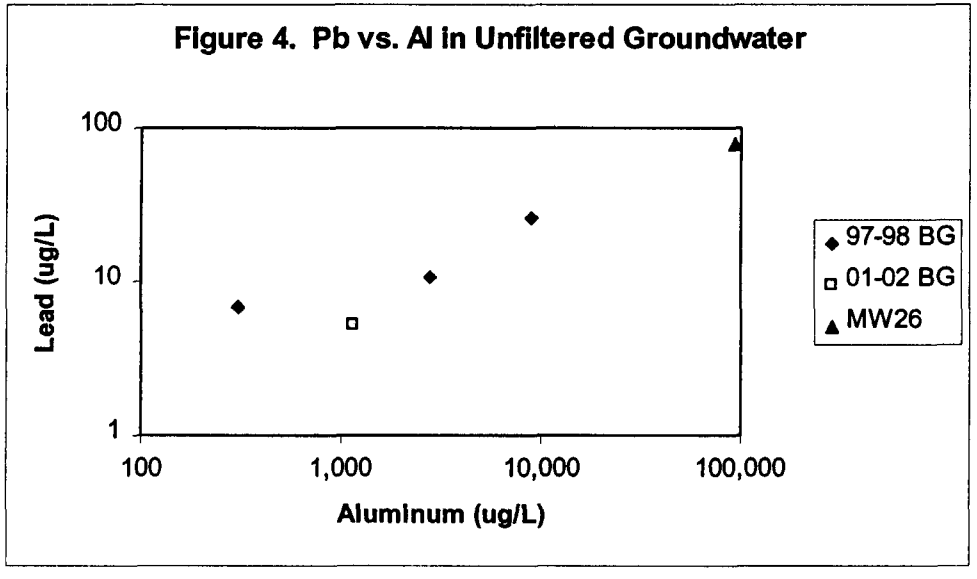
PBOW Background Groundwater Study

Background Data (unfiltered)



PBOW Background Groundwater Study

Background Data (unfiltered)



PBOW Background Groundwater Study

Background Data (unfiltered)

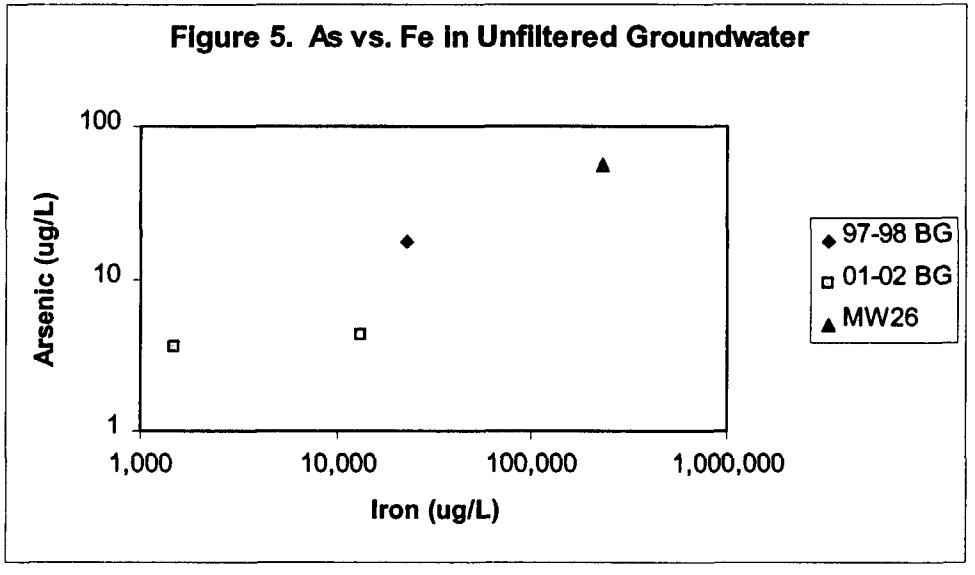


Table O-3

Summary Background Statistics for PAHs in Groundwater (ug/L)
Former Plum Brook Ordnance Works, Sandusky, Ohio

Analyte	n	Percent Nondetect	Distribution Type	Minimum	Maximum	Mean	Median	Standard Deviation	95th UTL
Acenaphthene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Acenaphthylene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Anthracene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Benzo(a)anthracene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Benzo(a)pyrene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Benzo(b)fluoranthene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Benzo(ghi)perylene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Benzo(k)fluoranthene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Chrysene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Dibenz(a,h)anthracene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Fluoranthene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Fluorene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Indeno(1,2,3-cd)pyrene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
2-Methylnaphthalene	20	75	Nonparametric	1.1	10	4.63	<10	1.74	12
Naphthalene	20	80	Nonparametric	2.9	<10	4.77	<10	1.44	11
Phenanthrene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10
Pyrene	20	100	Nonparametric	<5.0	<10	4.51	<10	NA	<10

n - Sample size.
NA - Not applicable.
ug/L - Microgram(s) per liter.
UTL - Upper tolerance limit.

Table O-4

Summary Background Statistics for BTEX in Groundwater (ug/L)
Former Plum Brook Ordnance Works, Sandusky, Ohio

Analyte	n	Percent Nondetect	Distribution Type	Minimum	Maximum	Mean	Median	Standard Deviation	95th UTL
Benzene	20	55	Nonparametric	0.25	110	14.34	<1.0	32.5	160
Ethylbenzene	20	70	Nonparametric	0.15	38	5.22	<1.0	11.13	55
Toluene	20	50	Nonparametric	0.26	100	13.8	<1.0	30.74	151
Xylenes (total)	20	50	Nonparametric	0.44	210	28.36	<1.0	63.06	310

n - Sample size.
NA - Not applicable.
ug/L - Microgram(s) per liter.
UTL - Upper tolerance limit.