

# THE AFCEE PERFORMANCE MONITORING TECHNOLOGY MATRIX

**Farrukh Ahmad**

Groundwater Services, Inc.  
2211 Norfolk, Suite 1000, Houston, Texas 77098-4044  
Phone: (713) 522-6300, Email: fahmad@gsi-net.com

Coauthors:

Charles J. Newell, Groundwater Services, Inc.  
James R. Gonzalez, Air Force Center for Environmental Excellence – ERS

## **Background**

In 1999 (AFCEE A, 1999) it was projected that the Department of Defense (DoD) will spend over one billion dollars in the current decade on the operation, maintenance, and monitoring (OM&M) of environmental remediation systems. Concern over this high cost for OM&M has led to the introduction of AFCEE's Remedial Process Optimization (RPO) program, which aims to evaluate and improve site remediation processes so that maximum risk reduction can be achieved for each dollar spent. Phase II of the RPO process is designed to incorporate existing regulatory requirements such as 5-year Record of Decision (ROD) reviews under CERCLA, RCRA permit reapplications, and "Operating Properly and Successfully (OPS)" remediation system demonstrations at BRAC sites scheduled for property transfer to private parties. One of the key elements of the Phase II RPO is the evaluation of the effectiveness of an existing remedial system in relation to the established site-specific cleanup goals. Both the establishment of cleanup goals as part of individual remediation system's data quality objectives (DQOs), and the evaluation of individual remediation system performance necessitate an understanding of the minimum monitoring requirements for that particular remediation technology.

## **Discussion**

Monitoring a remediation system to evaluate its performance requires not only measurements of target contaminant concentration in the affected media over time and space, but also requires monitoring of various operational (e.g., process flowrates) and indicator parameters (e.g., pH, redox potential, electron acceptor concentrations) to support a reasonable closure of the contaminant's mass balance and to ensure that the applied technology is behaving as anticipated. Process performance indicator parameters are specific to the type of target contaminant(s), the type of remediation technology (e.g., biological versus non-biological), and the nature of the contaminated media (e.g., solid versus aqueous). Currently, there is no single product that concisely defines the parameters requiring monitoring for a given remediation technology and the frequency of such monitoring. Existing information tools either offer detailed descriptions of various technologies or provide detailed information into various field sampling and analytical methods, completely overlooking the technology performance evaluation perspective.

The AFCEE Performance Monitoring Technology (PMT) Matrix is a simple information tool that provides planning-level information on minimum performance monitoring requirements for remediation technologies listed in the AFCEE Technology Matrix (Table 1(a) and (b)), which is also known as the Federal Remediation Technologies Roundtable (FRTR) Matrix. The AFCEE PMT Matrix bridges the gap between existing information tools on technology descriptions (e.g., AFCEE/FRTR Matrix) and tools on field sample collection and laboratory sample analysis methods (e.g. the FRTR Field Sampling & Analysis Matrix and the USEPA Field Analytical Technologies Encyclopedia) by focusing on the identification of monitoring information required to evaluate remediation technology performance. In addition, the PMT Matrix provides technology-specific information on the frequency of monitoring and/or the technology phase requiring monitoring (e.g. startup). The PMT also offers limited recommendations on analytical methods. The AFCEE PMT Matrix was developed in two forms: a quick-reference poster with tabulated information on each technology (Figure 1), and a more detailed HTML web-based version with monitoring profile files for each remedial technology listed within the AFCEE/FRTR Matrix. Each detailed remediation technology profile file provides a brief technology description, the types of contaminants it has been successfully used to treat, its indicators or measures of performance, their suggested monitoring frequency, recommended analytical methods for evaluating these indicators, and a table summarizing key performance evaluation information.

## References

Air Force Center for Environmental Excellence (AFCEE) A, *Remediation Process Optimization Handbook*, Draft Final, December 1999.

AFCEE B, *Air Force Remedial Process Optimization Field Procedures and Quality Assurance Handbook*, Version 2.0, December 1999.

AFCEE C, *Environmental Analytical Protocols: A Program Manager's Survival Guide*, Version 1.1, August 1997.

Federal Remediation Technologies Roundtable (FRTR) Matrix, [www.frtr.gov](http://www.frtr.gov).

FRTR, *Field Sampling and Analysis Technologies Matrix*, Version 1.0, [www.frtr.gov/site](http://www.frtr.gov/site).

United States Environmental Protection Agency (USEPA), *Field Analytical Technologies Encyclopedia*, [fate.clu-in.org](http://fate.clu-in.org).

Figure 1. Summary Poster for the AFCEE Performance Monitoring Technologies Matrix.



# The Air Force Center for Environmental Excellence

## Performance Monitoring Technology Matrix

### Solid Media (Soil, Sediment, and Sludge)

	Visual Inspection	Vapor or Air Release	Appearance / Odor	Air Temperature	Infiltration Monitoring (if Saturated)	Moisture / Freezing/Thawing	Temperature	Moisture Content	Soil pH	Hydrocarbons (C, N, P)	Metal Toxicants	Bioassays	Concentration	Supernatant Levels	Microbiologic Treatability Test	Respiratory Gas (O & CO <sub>2</sub> )	Respiration Test	Trace Monitoring	CO <sub>2</sub> (gas)	CO <sub>2</sub> (aq)	CO <sub>2</sub> (aq)	CO <sub>2</sub> (aq)	CO <sub>2</sub> (aq)	
<b>In Situ Biological Treatment</b>																								
Bioventing	N		S			N	N	N							R	SA	SA	R						
Enhanced Bioremediation	N	R <sup>1</sup>	R <sup>1</sup>	N											N	S	N	N	R					
Natural Attenuation (Soils)																								
Phytoremediation (Phytoextraction)	W <sup>2</sup>					N	N	N	N	N													SA	M <sup>3</sup>
<b>In Situ Physical / Chemical Treatment</b>																								
Soil Fracturing	B,C	B,C	N																					
Soil Flushing	N		P,R		P										N			N					P,Q	
Soil Vapor Extraction (SVE)	N	N	S														GA	SA	M				B,C	
Solidification/Stabilization	N <sup>4</sup>				P																			BA
<b>In Situ Thermal Treatment</b>																								
Thermally Enhanced SVE	N	N	S			N																		B,C
<b>Ex Situ Biological Treatment</b>																								
Biopiles	N	S,M			M	B,M	B,M	B,M							N <sup>4</sup>	S,M	S,M							B,R
Composting	N				S,M	B,M	B,M	B,M									S,M							H,M
Landfarming	N					B,R	B,M	B,R	B,R								S,M							R
Slurry-Phase Biological Treatment			N <sup>4</sup>		P,S	M		M	B,M	N	M	M			N <sup>4</sup>	M								M
<b>Ex Situ Physical / Chemical Treatment</b>																								
Chemical Extraction	N <sup>4</sup>				P										N									B,R
Chemical Reduction/Oxidation	N <sup>4</sup>		N <sup>4</sup>																	W <sup>5</sup>	W <sup>5</sup>			
Mechanical Separation	N <sup>4</sup>																							R
Soil Washing	N <sup>4</sup>		R <sup>2</sup>																					R <sup>2</sup> , R <sup>2</sup> , S
Soil Vapor Extraction	N	N																						M, B,C
Solidification/Stabilization	N <sup>4</sup>				S																			B,C
<b>Ex Situ Thermal Treatment</b>																								
Hot Gas Decontamination	N					N																		B,C
Incineration	N <sup>4</sup>																			W <sup>5</sup>				D,W <sup>5</sup>
Open Burn / Open Detonation	C																							B,C
Thermal Desorption	N																							B,R
<b>Containment</b>																								
Standard RCRA Landfill Cap	N			S	S																			B,R
Evapotranspiration Cap	N			S	S																			B,R
<b>Other</b>																								
Excavation, Retrieval, and Disposal	N																							R, R, B,C

### Aqueous Media (Groundwater, Surface Water, and Leachate)

	Visual Inspection	Vapor Release & Precipitation	Appearance / Odor	Temperature	Conductance	pH / Alkalinity	Electron Acceptors / Donors (O <sub>2</sub> , NO <sub>3</sub> , Fe <sup>2+</sup> )	Hydrocarbons (C, N, P)	Trace Monitoring	CO <sub>2</sub> (gas)	CO <sub>2</sub> (aq)	CO <sub>2</sub> (aq)	CO <sub>2</sub> (aq)	CO <sub>2</sub> (aq)
<b>In Situ Biological Treatment</b>														
Enhanced Aerobic Biodegradation	R <sup>2</sup>	R <sup>2</sup>												
Enhanced Anaerobic Biodegradation		R												
Natural Attenuation														
Phytoremediation (Phytostabilization)	W													
<b>In Situ Physical / Chemical Treatment</b>														
Air Sparging		R			R	D,R	D,R							B,R
Biostirring	N				R	B,R	D,R							B,R
Directional Wells					R	R								B,R
Dual Phase Extraction	N	R	R		B,R	B,R	R							B,R
Hot Water / Steam Stripping					N		N							B,R
Hydrofracturing	R <sup>2</sup>	R <sup>2</sup>			B,C									B,C
In-Well Air Stripping / Recirculation					R									S, B,R
Passive / Reactive Treatment Walls					D	R	R							B,R
<b>Ex Situ Biological Treatment</b>														
Bioreactors	N		R		N	M	N	M	M	M	M	M	N <sup>4</sup>	B,M
Constructed Wetlands	R		R											B,R
<b>Ex Situ Physical / Chemical Treatment</b>														
UV Oxidation	N		R											B,R
Air Stripping	N	W	R											B,R
Liquid Phase Carbon Adsorption			R											R
Ion Exchange			R											R
Precipitation/Coagulation/Flocc.			R				R							R, R
Separation	N		R				R							R
Spray Irrigation	N													N, N, M <sup>3</sup>
<b>Containment</b>														
Slurry Walls														2/Y
Containment Pumping														Q
Deep Well Injection	N	R					R							S, R
<b>Air Emissions / Off-Gas Treatment</b>														
Biofiltration	N	R	R											R
Thermal Oxidation	N	R	R											R
Catalytic Oxidation	N	R	R											R
Vapor Phase Carbon Adsorption	N	R	R											R

**Key**

A = Annual  
 C = Confirmation / Post-Completion  
 N = As Needed  
 Q = Quarterly  
 S = Before or During Startup  
 2/Y = Semi-Annually

B = Baseline  
 M = Monthly  
 P = Pilot Test or Treatability Stage  
 R = Regularly  
 W = Weekly  
 3/Y = 3 Times per Year

**Notes (Superscripts)**

1. Either air or water injection rate applies.
2. During growing season.
3. During emplacement/injection or active treatment.
4. For non-POL contaminants only.
5. Whenever changed.
6. During H<sub>2</sub>O<sub>2</sub> addition; threshold toxicity = 100 - 200 ppm.

**Recommended Common Analytical Methods**

- COC (aqueous or solid): VOCs by SW-846 8240 or 8260; SVOCs by SW-846 8270; Pesticides by SW-846 8081; Explosives by SW-846 8330; and, metals by SW-846 Series 6000 and 7000 methods.
- COCs (gas): EPA TO-3 (BTEX/MTBE/TPH), TO-14 (Non-polar VOCs), and TO-15 (Polar/Non-polar VOCs).
- Common Anions: SW-846 9036.
- Physical/Chemical Properties: pH by EPA 9040; Conductance by EPA 9050A; TOC by EPA 9060; Alkalinity by EPA 310.1; DO by EPA 360.1; and, Redox (ORP) by D1498.

**Table 1. Performance Monitoring Technology Profiles for Contaminated Media**

**(a) Solid Phase**

In Situ Biological Treatment	Bioventing Enhanced Bioremediation Natural Attenuation in Soils Enhanced Anaerobic Bioremediation Phytoextraction Phytostabilization
In Situ Physical/Chemical Treatment	Soil Fracturing Soil Flushing Soil Vapor Extraction Thermally Enhanced Soil Vapor Extraction Solidification/Stabilization
In Situ Thermal Treatment	Hot Water Injection/Steam Stripping
Ex Situ Biological Treatment	Biopiles Composting Landfarming Slurry Phase Biological Treatment
Ex Situ Physical/Chemical Treatment	Chemical Reduction/Oxidation Chemical Extraction Mechanical Separation Soil Washing Soil Vapor Extraction Solidification/Stabilization
Ex Situ Thermal Treatment	Hot Gas Decontamination Incineration Open Burn/Open Detonation Thermal Desorption
Containment	Standard RCRA Caps Evapotranspiration Caps
Other	Excavation, Retrieval, and Disposal

**(b) Aqueous Phase**

In Situ Biological Treatment	Natural Attenuation in Groundwater Enhanced Aerobic/Anaerobic Biodegradation Phytoremediation-Phytoextraction
In Situ Physical/Chemical Treatment	Air Sparging Bioslurping Directional Wells Dual Phase Extraction Thermal Oxidation Hydrofracturing In-Well Air Stripping/Recirculation Passive/Reactive Treatment Walls
Ex Situ Biological Treatment	Bioreactors Constructed Wetlands
Ex Situ Physical/Chemical Treatment	Adsorption/Absorption Ultraviolet Oxidation Air Stripping Liquid Phase Carbon Adsorption Containment Pumping Ion Exchange Precipitation/Coagulation/Flocculation Gravity Separation Spray Irrigation Soil Vapor Extraction
Containment	Slurry Walls, Deep Well Injection
Air Emissions/Off-Gas Treatment	Catalytic Oxidation Vapor Biofiltration, Vapor Phase Carbon Adsorption