U. S. Army Corps of Engineers Bioventing Subsurface Performance Checklist

Installation Name	______________________________
Site Name / I.D.	______________________________
Evaluation Team	______________________________
Site Visit Date	______________________________

This checklist is designed to facilitate the performance evaluation of a bioventing (BV) system for vadose zone soil remediation. It is divided into the following sections:

1) Evaluation team composition
2) Typical treatment objectives
3) References
4) Data collection requirements
5) Subsurface response evaluation
6) Adequacy of operations and maintenance
7) Typical performance problems
8) Alternatives for possible cost savings
9) Supplemental notes and data.

The checklist provides suggestions for information gathering, and space has been provided to record data and notes from the site visit. Supplementary notes, if required, should be numbered to correspond to the appropriate checklist sections.

1) Evaluation Team Composition

The following disciplines should be included in the evaluation team for the BV system:

- Geologist (site visit, subsurface performance evaluation)
- Process Engineer (site visit, above-ground equipment evaluation)
- Regulatory Specialist (regulatory requirements)
- Cost Engineer (cost of alternatives)

2) Typical Treatment Objectives

Verify that the treatment objectives established when the bioventing system was designed and installed are clear and still valid

Bioventing systems are typically used to stimulate aerobic biodegradation of organic contaminants in the vadose zone soils to achieve a specific contaminant concentration in the soil or to reduce the source of groundwater contamination. BV is more effective at degrading the volatile (and mobile) hydrocarbons than the heavier hydrocarbons. BV may not be able to meet a strict total hydrocarbons standard, especially for fuels heavier than gasoline. However, it may still be able to greatly reduce the risk due to direct exposure or risk resulting from groundwater contamination.

Note that the costs for operating a BV system are usually small, especially if air injection is used, thus the effort made to evaluate and monitor the system should be commensurate with the potential cost savings.

3) References

This checklist should be coordinated with the Vapor/Off-Gas Blower and Piping, Process Instrumentation and Control, Extraction and Monitoring Well, and Environmental Monitoring checklists. The following references may also be helpful:

EM 1110-1-4001 [1]: Soil Vapor Extraction and Bioventing
EPA 600/R-96/041: Diagnostic Evaluation of In-Situ SVE-Based System Performance
EPA 542/R-97/007: Analysis of Selected Enhancements for Soil Vapor Extraction
A324111 [2]: Principles and Practice of Bioventing – Volume I: Bioventing Principles
A324114 [2]: Principles and Practice of Bioventing – Volume II: Bioventing Design

4) Data Collection Requirements

The following information is needed to assess the performance of the bioventing system. Record the appropriate units with each value.

a) Describe the objectives for the BV system. If current objectives are poorly defined or not defined at all, describe what might be reasonable objectives given information from the owner and regulator. (e.g., fixed soil concentration of contaminants, negligible oxygen uptake rate as measured via respiration testing)

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b) What is the estimated future operation or remediation time? What is the basis for this estimate?

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c) Record the nameplate information from the blower, pumps, and other mechanical equipment for future reference.

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d) Sketch a process flow diagram (PFD), including valves and instrument locations, on the back of this sheet or on a separate sheet.

e) If modeling was performed, obtain a copy of the original BV modeling done as part of the system design. *(The design modeling may be useful in evaluating the operation of the system.)*

f) Is there a monitoring plan for collecting subsurface performance data? Is it being followed?

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4.1) Pressure/Vacuum Monitoring

a) Are the monitoring points distributed adequately across the site to determine three-dimensional pressure/ vacuum, oxygen distribution, and air flow paths? *(Monitoring points need not be placed throughout but should be placed in areas representative of the site geology, along the border of the area of concern, and midway between injection/extraction wells.)*

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b) Are measurements of water table fluctuations made to determine the possible effects on the BV system performance? Are measurements made with adequate frequency? Are barometric pressure readings recorded with the water table measurements and pressure / vacuum measurements?

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d) Have air permeability tests been conducted on the injection/extraction wells and air conductivities calculated for those locations?

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e) Have tracer tests been conducted to verify air flow paths and adequate travel times/velocities? *(Refer to EPA 600/R-96/041, Diagnostic Evaluation of In-Situ SVE-Based System Performance, Chapter 2. Note that for BV systems, the soil gas oxygen content is a good of an indicator of air flow.)*

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f) Is there a modeling report available for any airflow modeling done as part of the design or operation of the system? *(The modeling may be useful in evaluating deviations in actual operation from what was anticipated in design.)*

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4.2) Chemical Monitoring

a) Does monitoring include periodic sampling of oxygen, carbon dioxide, and hydrocarbon vapors at the monitoring points?

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b) Are periodic respiration tests performed according to standard protocols? Is the frequency of respiration testing adequate? *(Respiration tests are typically done every 3-6 months for the first year, and annually thereafter. Data from respiration tests can be used as one indicator of whether it is necessary to continue BV operations.)*

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c) Are samples taken to determine indoor air quality in nearby buildings or vapor concentrations in underground structures? *(This is a concern only where structures exist near a BV system that is using air injection.)*

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4.3) Well Performance

a) Are air flows and pressure/vacuum levels measured in each injection/extraction well? Are these measurements made with the same frequency as the monitoring point measurements?

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5) Subsurface Response Evaluation

Every BV system is different and the evaluation of the performance data must be made with the specific objectives and system configuration in mind. The following are general considerations that are common to most soil vapor extraction systems.

5.1) Pressure/Vacuum Distribution

a) Construct pressure/vacuum isopleth maps of the site. Are the pressure/vacuum distribution consistent with design predictions? Does the pressure/vacuum distribution (in three dimensions) indicate good oxygen delivery and prevention of migration to potential receptors?

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b) Estimate travel times or velocities for air through the target zone. Do the travel times/velocities indicate adequate throughput in the entire target zone? *(Consider the three-dimensional flow, particularly at open or leaky sites. Refer to EM 1110-1-4001, Chapter 5.)*

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c) Are the well depths and screened intervals adequate to optimally direct air through the target zone? Consider that injected/extracted air may be travelling through uncontaminated rather than contaminated soil horizons. (*Prepare hydrogeologic cross sections using available well boring logs, including the injection/extraction wells, if cross sections of the area of concern are not available.)*

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d) Is the air injection or extraction properly distributed among the wells to optimally treat the target zone effectively? *(It may be appropriate to recommend an optimization study if there is some indication that the system is pumping more air than necessary to achieve goals).*

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e) Prepare time versus flow graphs for each injection/extraction well to determine if there were significant changes in flow rates over time.

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f) Is there evidence that water table fluctuations have limited the system's ability to remediate parts of the target zone?

5.2 Chemical Concentrations

a) Construct soil gas concentration isopleth maps of the site. Are the soil gas oxygen data indicative of good air distribution? *(This is an important indicator of successful treatment although good oxygen distribution does not mean that the system is running optimally. Flow rates could be higher than needed.)*

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b) Does respiration test data indicate that organic contaminants are still being biodegraded?

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c) Construct soil gas concentration versus time graphs for the contaminants of concern at each monitoring point. Have individual monitoring points reached a consistent asymptote on the concentration versus time graph without significant rebound? *("Significant rebound" might be defined as an increase of 25-50% above the asymptote concentration value at the time of shutdown of the BV system.)*

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6) Adequacy of Operations and Maintenance

a) Has the entire system been operating with enough consistency to achieve its objective in a reasonable time? *(A good operational target should be 90% uptime or better.)*

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b) Are the monitoring points constructed to yield reliable results (short screens, checked for plugging/response)?

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c) Have contaminant concentrations been declining in most of the target zone?

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d) Would a surface cover direct air more effectively through the target zone? *(A cover would have to be more cost-effective than additional wells and air flow rates)*

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e) Have soil samples been taken to confirm cleanup and compared to standards? Have these samples been taken at proper locations, e.g., near stagnation zones and midway between injection / extraction wells? *(Because the cost of soil boring sampling and analysis is typically high, relative to the cost of BV operation, soil boring sampling should not be performed until there is strong evidence indicating that cleanup goals have been reached.)*____

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f) Verify that the ancillary equipment are maintained per manufacturers recommendations.

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g) Verify that instruments, controls, and alarms are working. Are there provisions to notify an operator of malfunctions when the unit is unattended?

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h) Verify that the concentrations are sampled and analyzed in accordance with the sampling and analysis plan designed to assess the system performance. Determine if any additional monitoring is needed to evaluate the operating conditions.

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7) Typical Performance Problems

a) Is there evidence that some parts of the target zone are not receiving adequate oxygen? This may be due to inadequate air injection/extraction rates, wells too far apart, improper well screen depths, surface irrigation, or short circuiting of air. Consider increasing air extraction/injection rates, terminating irrigation, or adding wells in non-responsive areas.

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b) Is there evidence of short-circuiting along the well casing, through nearby utility corridors, or through soil fractures or other subsurface features?

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c) Have the injection/extraction rates failed to reach the rate projected during design or those needed for efficient treatment? This may be due to poor well installation, unexpected stratigraphy, improper operation/balancing of well system, ground water upwelling, or improper blower sizing. Consider well replacement, additional wells, re-balancing the system, ground water control, resizing the blower.

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d) Is there evidence that the oxygen concentrations are high but the oxygen uptake rates are low (relative to the mass of contaminant in the soil)? This may indicate that some contamination is isolated from the monitored air paths, nutrients or moisture are limiting, the soil is too cold for efficient biodegradation, the more readily degraded hydrocarbons have been consumed, the monitoring points are short-circuiting to the surface, or the site contamination has been degraded. If justified by costs, consider adding moisture or nutrients, adding new monitoring points, providing subsurface heating, or adding additional wells. Also consider shutting wells down.

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e) Is there evidence that water table fluctuations have isolated contaminants from or introduced additional contaminants into the BV treatment zone. Consider biosparging or limited pumping to control water table fluctuations.

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f) Has there been unexpected contamination found outside the target zone or any indication of an unknown source? *(An investigation into another source may be warranted.)*

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8) Alternatives for Possible Cost Savings

The contaminant compounds remaining in the vadose soils and/or their concentrations may have changed sufficiently that other alternatives are more cost effective. Consider the following:

a) Has the system reached its cleanup objectives? Determine if the BV operation is still necessary or have the concentrations decreased so that the operation can be terminated?

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b) Have the oxygen uptake rates approached an asymptotic value? Consider whether redistributing flows, system pulsing, or soil vapor extraction might remove additional contaminant mass.

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c) Can additional wells be placed in the area of concern, or the injection/extraction rates from existing wells be redistributed in a way that would economically speed remediation? *(It may be possible to install additional wells and achieve objectives at a lower total flow rate. However installing new wells may be difficult to justify, given the relatively low cost of operating BV systems. If it is discovered that air is not reaching certain areas, then installation of additional wells may be necessary. Also it may be possible to increase the radius of influence of some wells by alternating the airflow between wells within one part of the site and wells with a different part of the site.)*

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d) Can individual wells be removed from the system? Can the above-ground system operate efficiently at a reduced flow rate? Evaluate the cost savings by reducing the number of wells. *(In some cases, the capacity gained by removing non-productive wells may allow higher airflow rates through the more contaminated parts of the site. However blowers may need to be adjusted or changed to different sized units to accommodate changes in airflow / pressure requirements.)*

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e) If the cleanup objectives have not yet been met, can the system be turned off and natural attenuation be allowed to achieve the cleanup objective while remaining protective of human health and the environment? *(If the oxygen content of soil gas stays above 5% following cessation of BV, rates of biodegradation will probably not be increased by BV and natural attenuation may well be the most appropriate remedy to address remaining hydrocarbons. Refer to Air Force protocols for evaluating natural attenuation)*

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f) In some cases, other technologies may be able to accomplish the same objectives or speed clean up. The application of these alternative technologies should be economically justified based on present worth analysis compared to the cost of the current system.

- Thermal enhancement to bioventing (usually not cost effective, but may be appropriate in rare circumstances)
- Passive bioventing (i.e., atmospheric pressure changes deliver air into the subsurface)
- Gaseous nutrient or moisture addition
- Biosparging (delivers oxygen while sparging contaminants from the ground water)
- Multiphase extraction, or bioslurping
- Soil excavation for source removal or ex-situ treatment

9) Supplemental Notes and Data

There are _______ pages of supplemental notes and data attached to this checklist.

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[1] EM: USACE Engineering Manual, available at www.usace.army.mil/inet/usace-docs/

2 Air Force Center for Environmental Excellence (AFCEE) Protocol, available at www.afcee.brooks.af.mil/ER/toolbox.htm