



DIVISION OF STATE FIRE MARSHAL

BUREAU OF UNDERGROUND STORAGE TANK REGULATIONS

FACT SHEET

www.com.state.oh.us

Bob Taft
Governor

Lt. Governor Jennette Bradley
Director

Robert Rielage
State Fire Marshal

Peter A. Chace
Bureau Chief

USING THE BIOSCREEN FATE & TRANSPORT MODEL for BUSTR CORRECTIVE ACTION SITES

Introduction

BIOSCREEN is a Microsoft® Excel based modeling program created by the US Environmental Protection Agency (USEPA), and based on Dominico fate and transport equations. BIOSCREEN predicts the amount of natural attenuation of dissolved hydrocarbons in confined or unconfined aquifers. The model is designed to predict only horizontal flow with a constant seepage velocity. This fact sheet outlines how to use the BIOSCREEN model for BUSTR corrective actions. You may find additional information concerning the BIOSCREEN model in the BIOSCREEN Users Manual (Newell, McLeod & Gonzales, 1996).

BIOSCREEN can be downloaded through the USEPA web site: www.epa.gov/ada/csmos/models.html, or by visiting the USEPA website (www.epa.gov) and running a search for "Kerr", then selecting the "Kerr Environmental Research Center Home Page". After reaching the homepage, click on "Software" and then "Download Ground-Water Software". The BIOSCREEN and other ground water models are available here for downloading. Download and review the BIOSCREEN instruction manual in addition to this fact sheet.

BUSTR Approach

BUSTR Tier 2 corrective actions described in Ohio Administrative Code 1301:7-9-13 allows for the use of fate and transport modeling to predict Chemical of Concern (COC) concentrations at an assumed Point of Exposure (POE). Ground water fate and transport modeling may be necessary in order to determine if future concentrations of COC's meet action levels or developed Site Specific Target Levels (SSTL's) at a POE. A Point of Demonstration (POD) located between the source area and POE is then used as a monitoring point to validate the model predictions. Currently, the only approved ground water fate and transport models for use at BUSTR sites are based on the Dominico analytical solute transport model.

BUSTR uses a two-phased approach to using the BIOSCREEN model. In the first phase (Tier 2 Evaluation), use BUSTR default values or site-specific data to predict chemical concentrations. Field data are then compared to the predicted values. If the field data exceed the predicted values, a Remedial Action Plan (RAP), Interim Response Action (IRA), or second phase of modeling may be conducted. In the second phase of modeling, you may calculate a site-specific biodegradation rate or calibrate the model to actual site data. The second phase of modeling must first be proposed and approved by BUSTR in a Tier 3 Evaluation proposal. **Do not adjust the BIOSCREEN model to fit the source (field) data curve in a Tier 2 Evaluation.**

More complex numerical models or analytical ground water fate and transport models may be used in a Tier 3 Site Evaluation with prior BUSTR approval. Demonstrate why alternate proposed models are appropriate for site conditions as part of your Tier 3 proposal.

Deleted:

Bureau of Underground Storage Tank Regulations

8895 East Main Street · PO Box 687 · Reynoldsburg · Ohio 43068-9009 · (614) 752-7938 7/28/09

Limitations: There are some limitations to the use of the BIOSCREEN model at BUSTR-regulated sites that include, but are not limited to, the following:

- BIOSCREEN may be used to model simple horizontal flow only (not vertical).
- Do not use BIOSCREEN with increasing or unstable chemical of concern concentrations.
- BIOSCREEN is not appropriate for areas with complicated hydrology; conditions where flow boundaries exist or near the influence of pumping wells (intermittent or constant).
- BIOSCREEN is not appropriate for conditions where ground water velocity changes significantly over the modeled area, ground water flow direction is not well defined, or in formations where diffusion is the prime mechanism of transport (heavy clays, slurry walls etc.).
- BIOSCREEN is not appropriate for modeling fractured formations.
- Do not use the Instantaneous Reaction portion of BIOSCREEN for evaluating BUSTR corrective action sites. For further discussion involving the Instantaneous Reaction section please see section 4 of this fact sheet.
- BIOSCREEN may be used to develop groundwater remediation SSTLs. Note that after groundwater contamination is remediated to desired concentrations, additional ground water sampling is required to supply new input values for the BIOSCREEN model.

Default Vs. Site-Specific: Use default soil parameter values provided in Table 1 of this Fact Sheet when using BIOSCREEN. Do not use the default soil parameter values from the BUSTR Technical Guidance Manual (July 2001) as they are intended for vadose zone soils. The default values in Table 1 are intended only for the BIOSCREEN model and may not be appropriate for other models. We recommend that you collect site specific soil and ground water data when using BIOSCREEN to determine clean-up goals for soil or ground water contamination, as using the BUSTR default values may predict overly conservative cleanup goals and result in escalated expenses of remediation.

All site-specific values used in this model must be from the aquifer matrix being modeled. Accurate values for the BIOSCREEN model inputs are required. Generating valid parameter values for modeling may require gathering data from the site in a manner not stated in Ohio Administrative Code or the BUSTR Technical Guidance Manual (such as fully penetrating wells and sampling of actual aquifer matrix).

Section 1: Hydrogeology

Seepage velocity (Vs): Seepage velocity is the actual interstitial groundwater velocity, equaling the Darcy velocity divided by effective porosity. Calculate seepage velocity by entering site specific or default values for hydraulic conductivity, hydraulic gradient and effective porosity.

Hydraulic conductivity (K): This is the horizontal hydraulic conductivity of the saturated zone. Slug tests or pump tests are conducted at the site to determine the site-specific hydraulic conductivity. Alternatively the default values listed in Table 1 of this Fact Sheet may be used. When slug tests or pump tests are performed to estimate horizontal hydraulic conductivity, we recommend performing at least three tests at different wells in the source area or near the plume's centerline. The highest hydraulic conductivity value must be used in the BIOSCREEN model. When using the default values listed in Table 1, use the value corresponding to the most permeable type of soil in the saturated zone, even if that type of soil is not the most predominant at the site. Also note the following:

- Pump tests must be performed if the contaminant plume is in a bedrock aquifer (slug test results cannot be used).
- Use at least one laboratory test (e.g., ASTM D-2487, ASTM C-136, ASTM D-422, etc.) of the most permeable portion of the saturated zone when determining the USCS Soil Classification type of the aquifer matrix.
- You may not use results from a vertical hydraulic conductivity test (ASTM D-5084) or the vertical hydraulic conductivity data presented in the BUSTR Technical Guidance Manual when using the BIOSCREEN model.

Hydraulic gradient (i): Hydraulic gradient is the slope of the potentiometric surface. Calculate the hydraulic gradient by constructing a potentiometric surface map using static water level data from ground water monitoring wells.

Deleted:

Bureau of Underground Storage Tank Regulations

8895 East Main Street · PO Box 687 · Reynoldsburg · Ohio 43068-9009 · (614) 752-7938, 7/28/09

Effective Porosity (n): This is a ratio of the interconnected voids to the bulk volume of the aquifer matrix. Site-specific values may be determined using EPA approved laboratory methods for Total Porosity (no adjustment is necessary to convert Total Porosity to Effective Porosity). Samples taken to obtain site-specific values must be taken from the aquifer matrix. You may alternatively use the default values listed in Table 1 of this fact sheet. You may not use the porosity values listed in the BUSTR Technical Guidance Manual or values obtained from unsaturated zone soil samples.

Section 2: Dispersion

Dispersivity Values (alpha x, alpha y, & alpha z): Dispersion is the process of mechanical mixing that occurs when contaminated ground water flows through a porous medium (soil) and mixes with the uncontaminated ground water. The three types of dispersion are longitudinal, transverse, and vertical. You must estimate the length of the contaminated plume (Lp), and enter that length directly onto the BIOSCREEN "input page". BIOSCREEN will then calculate the values for longitudinal, transverse, and vertical dispersivity.

Estimated Plume Length (Lp): The distance used for the plume length (Lp) is the down-gradient distance from the source area (i.e., area of highest concentration) to the point where the ground water concentration equals the BUSTR Action Level for the ground water ingestion pathway (ex: 0.005 mg/L for Benzene). Estimate Lp from field data and justify your result.

Section 3: Adsorption

Retardation Factor (R): The retardation factor is the ratio of the ground water seepage velocity to the rate that organic chemicals migrate in the ground water. Calculate the retardation factor by entering either site-specific data or BUSTR default values for Soil Bulk Density, Partition Coefficient and Fraction of Organic Carbon, listed in Tables 1 and 2. Use a retardation factor of 1 when modeling the transport of MTBE through an aquifer (as MTBE does not readily adhere to soil particles within the aquifer matrix). When modeling the transport of MTBE, the value of "1" should be directly entered into the input area for "Retardation Factor" (the values of "Soil Bulk Density", "Partition Coefficient" and "Fraction Organic Carbon" do not need to be entered).

Soil Bulk Density (rho): This value is the bulk density (in kg/L) of soil within the aquifer matrix and may be different from bulk densities obtained from above the saturated zone. Obtain soil bulk density from geo-technical analysis of soil within the aquifer matrix or by using the BUSTR default value (Table 1) based on the most permeable soil type encountered within the saturated zone. If a site-specific value is used in the model, use samples from the aquifer matrix in the assumed migration pathway.

Partition Coefficient (Koc): This value indicates a contaminant's affinity for the organic carbon fraction of soil within the aquifer matrix. It is a chemical-specific value and must be changed for each chemical of concern. Use Table 2 or the BUSTR Technical Guidance Manual, Appendix F, page F-5 (Soil-Water Partition Coefficient).

Fraction Organic Carbon (Foc): This value is the fraction of the aquifer soil matrix that is composed of natural organic carbon in uncontaminated areas. This value is obtained through laboratory analysis of soil from within the aquifer matrix or by using the BUSTR default value of 0.001 (ASTM 1995). The BUSTR default values listed in the Technical Guidance Manual are for vadose zone soils and may not be used in the BIOSCREEN model. BUSTR recommends the Walkley-Black method to determine the fraction of organic carbon because most soils in the aquifer matrix contain less than one-percent organic carbon. **If a percent of organic matter is obtained through laboratory analysis (such as ASTM-D2974), you must multiply percent organic matter by a conversion factor of 0.58 to give a percent of organic carbon.**

Deleted:

Section 4: Biodegradation

1st Order Decay Coefficient & Solute Half-Life (lambda & t-half): BIOSCREEN allows the user to run the model using three different decay types, as follows:

- transport with no decay
- transport with first-order biodegradation
- transport with “instantaneous” biodegradation reactions

During the Tier 2 Evaluation, run the model using both the “no decay” assumption, and an estimate of either a first-order biodegradation decay coefficient (lambda) or a dissolved plume solute half-life ($t_{1/2}$). You must use BUSTR default values for the decay coefficient or the solute half-life in Tier 2. These default values are found in Table 2 of this fact sheet, and in Appendix F of the BUSTR Technical Guidance Manual (use the most conservative TGM value). You must use the “transport with no decay” model when evaluating the transport of MTBE.

You may develop a site-specific half-life or decay rate in a Tier 3 Evaluation and utilize the “transport with first order biodegradation decay” model. Develop site-specific values for first order decay coefficients through statistical analysis (such as a regression analysis) or by calibrating the BIOSCREEN model to actual site data. Requirements for a Tier 3 Evaluation are found in Ohio Administrative Code 1301:7-9-13(O).

Instantaneous Reaction Model: BUSTR does not allow the use of the BIOSCREEN model to evaluate contaminant migration based on the “Instantaneous Reaction Model” assumptions. This is due to the difficulty of collecting accurate measurements and because the concentrations of electron acceptors used in the model do not account for the biodegradable, non-BTEX, organic compounds.

Section 5: General

Modeled Area Length: The distance from the source area to the point of exposure (POE). You may be required to evaluate the BIOSCREEN model using different Modeled Area Length input values.

Modeled Area Width: This value is entered directly and must equal or exceed the width of the contaminant plume.

Simulation time: If the Soluble Mass parameter of the BIOSCREEN model is entered as “infinite”, increase the simulation time until the contaminant concentration at the point of exposure reaches steady state conditions. If the Soluble Mass parameter is entered as a finite value, adjust the simulation time so that the chemical of concern concentration at the Point of Exposure is equal to its maximum value.

Section 6: Source Area

Source Thickness in Saturated Zone: This value is the depth of contamination in the saturated zone within the source area. Use either site-specific data or the BUSTR default value of 10 feet. Site-specific data is gathered by obtaining samples from wells within the source area that are screened at different depths (nested wells or other approved technologies) or by determining the amount of water table fluctuation (i.e., the smear zone). For most petroleum release sites, a value of 10 feet is sufficient. If more dense chemicals (such as chlorinated compounds) are present at the site then the 10 feet thickness may not be appropriate and site-specific data must be used.

Source Zones (width and concentration): Use the highest concentrations of chemicals of concern and their associated zone widths from the center of the immediate source area or adjacent source zone. These concentrations and their associated distances represent concentrations perpendicular to the centerline of the plume and ground water flow. All five of the source zones do not have to be entered. For the purposes of applying BIOSCREEN to a BUSTR site, enter a minimum of two source zone area widths with their respective COC concentrations. This may require the installation of additional data points perpendicular to the plume centerline for input into BIOSCREEN. Additional

Deleted:

information concerning the insertion of source zone concentrations is available in the BIOSCREEN User's Manual (Newell, McLeod and Gonzales, 1996).

Source Half-Life: Assume the source half-life and soluble mass are infinite unless a specific mass of contaminant is known at the site. If a known amount of soluble mass is inserted into the BIOSCREEN model, you must justify the value based upon known data concerning the amount of the specific release or well defined COC concentrations in all media of the source area. For most BUSTR sites the infinite source half-life and soluble mass assumption is appropriate.

Section 7: Field Data for Comparison

Enter the values of "Concentration" and "Distance from Source" using site-specific data to give data points for comparison to the model predicted values. Obtain these values from wells within the source area and from wells located near the centerline of the plume. The concentrations entered must be for one sampling event time interval and from sampling points that show stable to decreasing chemical of concern concentrations over time. **Increasing or unstable chemical of concern concentrations are indications that the BIOSCREEN model is not appropriate for the site. Do not adjust the actual BIOSCREEN model to fit the source (field) data curve in a Tier 2 Evaluation.** Due to highly fluctuating contaminant concentrations at petroleum release sites from sampling event to sampling event, the source data curve must be provided to show that the model predicted values are conservative when compared to actual site data. Calibration of the BIOSCREEN model to actual site data is allowed in a Tier 3 Evaluation.

Section 8: Choose Type of Output to See

Use the Centerline option. Choose the "Run Centerline" option, the "Calculate Animation" button is then used to give a step-by-step picture of the plume migration with respect to time. This option is used to show that the plume has reached its steady state condition. The "Run Array" option can also pictorially demonstrate the plume migration.

Model Validation

Monitoring of actual contaminant concentrations at the site is required to validate the predictions made by the BIOSCREEN model. The sampling point used to validate the model is defined as the Point of Demonstration (POD). The point of demonstration must be located on the contaminant plume centerline (line connecting the source area with the Point of Exposure (POE)). The model must also predict a concentration of the chemical of concern at the POD (if the model predicts a value of zero, that point may not be used for the POD). The POD must also show some actual concentration of the contaminant (not a non-detect value) to verify the evaluation point is in the contaminant migration pathway. The POD is then monitored to evaluate the model predictions. In some cases it may be necessary to install more than one POD. The time required for monitoring depends on the time that the model predicts the specified chemical concentration. If BIOSCREEN predicts that it takes a certain number of years for contamination to move from the source area to the POD, the POD must be monitored for that number of years to validate the model assumptions. For example, if the BIOSCREEN model predicts a concentration of 20 parts per-billion benzene at the POD in two years, the POD must be monitored for two years. If the concentration of benzene at the POD exceeds the predicted value of 20 parts per-billion within those two years, the model predictions are not valid.

Ohio Administrative Code 1301:7-9-13(R)(1)(c) states that a minimum of four quarters of monitoring be completed, unless the owner/operator can demonstrate that a shorter time is appropriate. BUSTR may approve bi-annual or annual monitoring may be substituted for quarterly monitoring if the required monitoring period is significantly greater than one year. If bi-annual or annual monitoring is approved, you must take samples at approximately the same time each year to account for fluctuations within the aquifer. All validation monitoring plans must be pre-approved by BUSTR.

Deleted:

Bureau of Underground Storage Tank Regulations

8895 East Main Street · PO Box 687 · Reynoldsburg · Ohio 43068-9009 · (614) 752-7938, 7/28/09

In certain cases, you may use historical data to validate the BIOSCREEN model predictions. For example, if five years of groundwater monitoring has already been performed at the appropriate source, POD, and POE locations, then you may be able to use this data to validate the BIOSCREEN predictions. To do this, the initial sampling events are used to predict concentrations in subsequent years. BUSTR will consider the use of historical data to validate modeling on a case-by-case basis.

Data Presentation & Information Submitted to BUSTR

Summarize your BIOSCREEN modeling work in a report with the following information:

- Selection and justification of input values in table format (default, literature, site-specific – see Table 3).
- Discussion of final model outputs.
- Determination of the time (years) to reach “steady state”.
- Sources of error and uncertainty.
- Summary of findings, conclusions, and recommendations.
- Printouts of the BIOSCREEN input screen showing all of the values used to run the model. Do this for each chemical of concern evaluated.
- Printouts of the BIOSCREEN output centerline screen at “steady state” for each chemical of concern evaluated. Include both the “no degradation” and the “first-order decay” concentrations and curves.
- Site map showing the source area, plume length, plume width, ground water flow direction, monitoring well locations, BIOSCREEN centerline from the source area to point of demonstration (POD) and point of exposure (POE), and other pertinent features.
- Tables of all data used in verifying the model including any calculations, laboratory results, etc.
- Printouts of the BIOSCREEN centerline output screen predicting a concentration of the chemical of concern at the POD.

Table 1: BUSTR Saturated Zone Soil Type Default Values

| Saturated Zone Soil Type | Soil Classification Symbol | Horizontal Hydraulic Conductivity (cm/sec) | Porosity | Bulk Density (kg/L) | Fraction of Organic Carbon in Saturated Zone |
|--------------------------|----------------------------|--|----------|---------------------|--|
| Clay | MH, CH, OH | 1 x 10e-5 | 0.20 | 1.8 | 0.001 |
| Silt | ML, CL, OL | 1 x 10e-3 | 0.30 | 1.7 | 0.001 |
| Silty Sand | SM, SC | 1 x 10e-1 | 0.30 | 1.6 | 0.001 |
| Clean Sand | SW, SP | 1 | 0.30 | 1.5 | 0.001 |
| Gravel | GW, GP, GM, GC | 10 | 0.35 | 1.4 | 0.001 |

*BUSTR default values shall be used when site-specific data is unknown

Table 2: BUSTR Chemical Specific Default Values

| Chemical of concern | Partition Coefficient (L/kg) | Solute Half-Life (years) |
|-----------------------------|----------------------------------|----------------------------------|
| Benzene | 58.9 | 1.97 |
| Toluene | 182 | 0.08 |
| Ethyl benzene | 363 | 0.62 |
| Xylene | 240 | 1.00 |
| Methyl-tertiary Butyl Ether | See Section 3 of this Fact Sheet | See Section 4 of this Fact Sheet |

* For chemicals-of-concern not listed in the above table please reference the BUSTR Technical Guidance Manual, Appendix F, page 7.

Deleted:

Bureau of Underground Storage Tank Regulations

8895 East Main Street · PO Box 687 · Reynoldsburg · Ohio 43068-9009 · (614) 752-7938 7/28/09

Table 3: Example Input Table

| INPUT/ PARAMETER | INPUT | UNIT | REFERENCE * |
|---|-------|----------------------------------|-------------|
| SEEPAGE VELOCITY | | ft/yr | |
| HYDRAULIC CONDUCTIVITY | | cm/sec | |
| HYDRAULIC GRADIENT | | ft/ft | |
| POROSITY | | cm ³ /cm ³ | |
| ESTIMATED PLUME LENGTH | | ft | |
| RETARDATION FACTOR | | | |
| SOIL BULK DENSITY | | kg/L | |
| PARTITION COEFFICIENT | | L/kg | |
| FRACTION ORGANIC CARBON | | | |
| 1 ST ORDER DECAY COEFFICIENT | | per year | |
| SOLUTE HALF LIFE | | years | |
| MODELED LENGTH | | ft | |
| MODELED AREA WIDTH | | ft | |
| SIMULATION TIME | | years | |
| SOURCE THICKNESS IN SATURATED ZONE | | ft | |
| SOURCE HALF-LIFE | | years | |
| SOLUBLE MASS | | kg | |

Formatted
Formatted
Formatted

*When referencing field data, refer to the appropriate report where this information was previously presented to BUSTR.

Formatted

References

1. American Society for Testing and Materials (ASTM), 1995, "Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites", ASTM E-1739-95, Philadelphia, PA.
2. Dominico, P.A. 1987. An Analytical Model for Multidimensional Transport of a Decaying Contaminant Species. Journal of Hydrology, 91 (1987) 49-58.
3. Newell, C.J., McLeod R.K. and J.R. Gonzales, 1996. "Bioscreen Natural Attenuation Decision Support System", Users Manual Version 1.3, National Risk Management Research Laboratory, Office of Research and Development, USEPA, Cincinnati, OH.
4. Bureau of Underground Storage Tank Regulations (BUSTR), 2001, "Technical Guidance Manual for 1999 Closure and Corrective Action Rules". Ohio Department of Commerce, Division of State Fire Marshal. Columbus, OH.

Deleted: