Recent advances in the Army Risk Assessment Modeling System

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Abstract

The Army Risk Assessment Modeling System (ARAMS) was first released in June 2002. Since that time, there have been two additional releases that substantially advanced the state of ARAMS. The primary addition has been incorporation of the Terrestrial Wildlife Exposure Model (TWEM). TWEM computes receptor dose based upon ingestion of contaminated soil, sediment, water, and food. A life history database of species profiles and food preferences and a database of bioaccumulation factors are used to obtain food concentrations and ingested doses of compounds. Although TWEM is not spatially explicit, its strength is in these two databases, which will be continually updated. The Spatially Explicit Exposure Model (SEEM) has also been developed and is being added to ARAMS in 2004 to allow consideration of spatial aspects, such as home range, habitat quality, and areas of contamination. Similarly, a spatially explicit exposure model for fish, FISHRAND, has been developed and is being added to ARAMS in 2004. A new database of physicochemical properties and human toxicity values for military firing/training range compounds has been developed and added to the system. Seamless linkages have been developed for various Web-based databases, such as a terrestrial toxicity database. Additionally, a tool for developing conceptual site models has been added, as well as several new fate/transport models. This paper provides an overview of these and other recent advances in ARAMS as well as future additions to the system, which should be of interest to potential users for both military and non-military risk assessments involving baseline and future conditions.
Key words: human and ecological risk assessment, modeling, terrestrial wildlife exposure, ARAMS

1 Introduction

An overview of the initial version of ARAMS, along with an example application for human health risk assessment, can be found in the proceedings of the first conference on Brownfield Sites that met in Cadiz, Spain (Dortch and Gerald [1]). This paper provides an update of developments since 2002 as well as an example application for ecological risk assessment.

ARAMS is a computer-based, information delivery, modeling, and analysis system that integrates multimedia fate/transport, exposure, uptake, and effects of constituents, i.e., compounds of concern (COCs), including chemicals and radionuclides, to assess human and ecological health impacts and risks (http://www.wes.army.mil/el/arams/arams.html).

ARAMS uses an object-oriented, system framework to construct a computational conceptual site model composed of the environmental pathways and exposure routes linked to various models and databases for exposure and effects assessments. The system framework is based on the Framework for Risk Analysis in Multi-media Environmental Systems (FRAMES) (Whelan et al. [2]) developed by Battelle Memorial Institute, which operates the Pacific Northwest National Laboratory (PNNL) of the U.S. Department of Energy. FRAMES enables the user to specify, through objects, the pathways and risk scenarios and to choose which particular model or database to use for each object. Model, database, or other quantitative analysis modules can be added to FRAMES objects as long as the added modules consume and produce the type of information characteristic of the object.

The first version of ARAMS (version 1.0) was released in June 2002, and versions 1.1 and 1.2 were released in March 2003 and April 2004, respectively. Additional capabilities have been added to the system since the first release. Much of the development in the past two years was focused on adding components to allow ecological risk assessment. This paper provides an overview of new ARAMS' features and presents an example application for an ecological risk assessment.

2 Development description

The ARAMS main screen user interface has been improved and upgraded from Visual Basic (VB) to VB.NET. The VB.NET change was made to keep the system up to date with changes in the software industry and to provide more flexibility for using .NET web services.

Two primary improvements were made to the main screen user interface: (1) improved Help features, and (2) addition of a tool for developing a conceptual site model (CSM) during the planning phase of the risk assessment. The Help features now include sections on Getting Started with ARAMS/FRAMES, Main Screen user interface documentation, Project planning and CSM development, How to use FRAMES, Using FRAMES, Converting CSM to FRAMES components, Glossary, and About (ARAMS). The sections on Getting Started, CSM development, and Converting CSM to FRAMES components should prove very useful. For example, the Getting Started section now includes a list of all modules for all objects with a description of each including inputs and outputs. The FRAMES object classes and types are shown in Figure 1. When each object is selected in the help file, modules for the object are displayed with descriptions for each.

The CSM tool provides a means to help users plan their conceptual site model and to generate the CSM diagram as well as Table 1 for Risk Assessment Guidelines (RAGS) for Superfund, part D. The user can interactively construct a stem diagram (see Figure 2) for the CSM. Once the stem diagram has been developed, the user can automatically generate the CSM diagram (Figure 2) and RAGS-D Table 1. There is also a help file for guidance on how to develop a FRAMES CSM given a planning CSM diagram.

In addition to the FRAMES constituent database, there is now a DoD Range Database (Zakikhani et al. [3]) linked to the system. These databases are used for selecting chemical constituents of interest and their associated physical/chemical properties, environmental parameters, bio-transfer factors, and human toxicological reference values. The Range database is also available at the ARAMS Web site.

The FRAMES Object Palette has been revised for improved understanding, where objects now appear under classes of objects as shown in Figure 1. For example, the Database Class contains all the database objects. Under the User Defined Class, there is a new User Defined Object which provides a single location for selecting and using all the various *known* modules for specifying known boundary conditions, such as known soil, air, water, and tissue concentrations.

An Overland Flow Object has been added to compute leaching and runoff from land surfaces. The Multimedia Environmental Pollutant Assessment System (MEPAS) Computed Source Term Release Model (CSTRM) (Streile et al. [4]) was modified to accept fluxes from other objects, thus functioning as a secondary source model. With this change, the MEPAS CSTRM Secondary Source Model could be added to the Overland Flow Object to provide estimates of constituent leaching and runoff from land surfaces. This feature is very useful when considering, for example, air deposition from an emission source to land surface and subsequent runoff from land surface into receiving waters.

Several Web-based databases have been linked to the system through database-client editors (DCE). There is now a Terrestrial Toxicity Database (TTD) (Wirtz and Fairbrother [5]) that contains ecological soil screening levels and ecological effects toxicity reference values for wildlife that can be used to screen soil concentrations and compute ecological hazard quotients (EHQ), respectively. There is also a bio-sediment accumulation factors (BSAF) database [6] that contains BSAF and percent lipid values for various aquatic organisms. BSAF is used to compute tissue residues (mg/kg) of constituents of concern in aquatic organisms. A DCE is under development for the Risk Analysis Information System (RAIS) [7]. The RAIS DCE will be used to retrieve constituent properties/environmental parameters/human toxicity values and ecological water and sediment screening values for use in the ARAMS system.

Figure 1: Object classes and types and associated icons

A DCE is being planned for the ECOTOX database [8], which will be used to retrieve bio-concentration factors (BCF). The great advantage of having live links to Web-based databases is that nothing has to be done to the ARAMS system to stay current as these databases are updated.

The biggest new asset of the current ARAMS release version (1.2) is the fielding of a terrestrial ecological risk assessment capability through the addition of the Terrestrial Wildlife Exposure Model (TWEM) (CH2M Hill [9] and Sample et al. [10]). TWEM takes soil, water, and sediment constituent concentrations and computes ingestion exposure dose for target terrestrial organisms, including reptiles and birds. Options are provided for estimating food constituent concentrations, including use of regressions and bioaccumulation factors (BAF) from a BAF database. There is also a life history

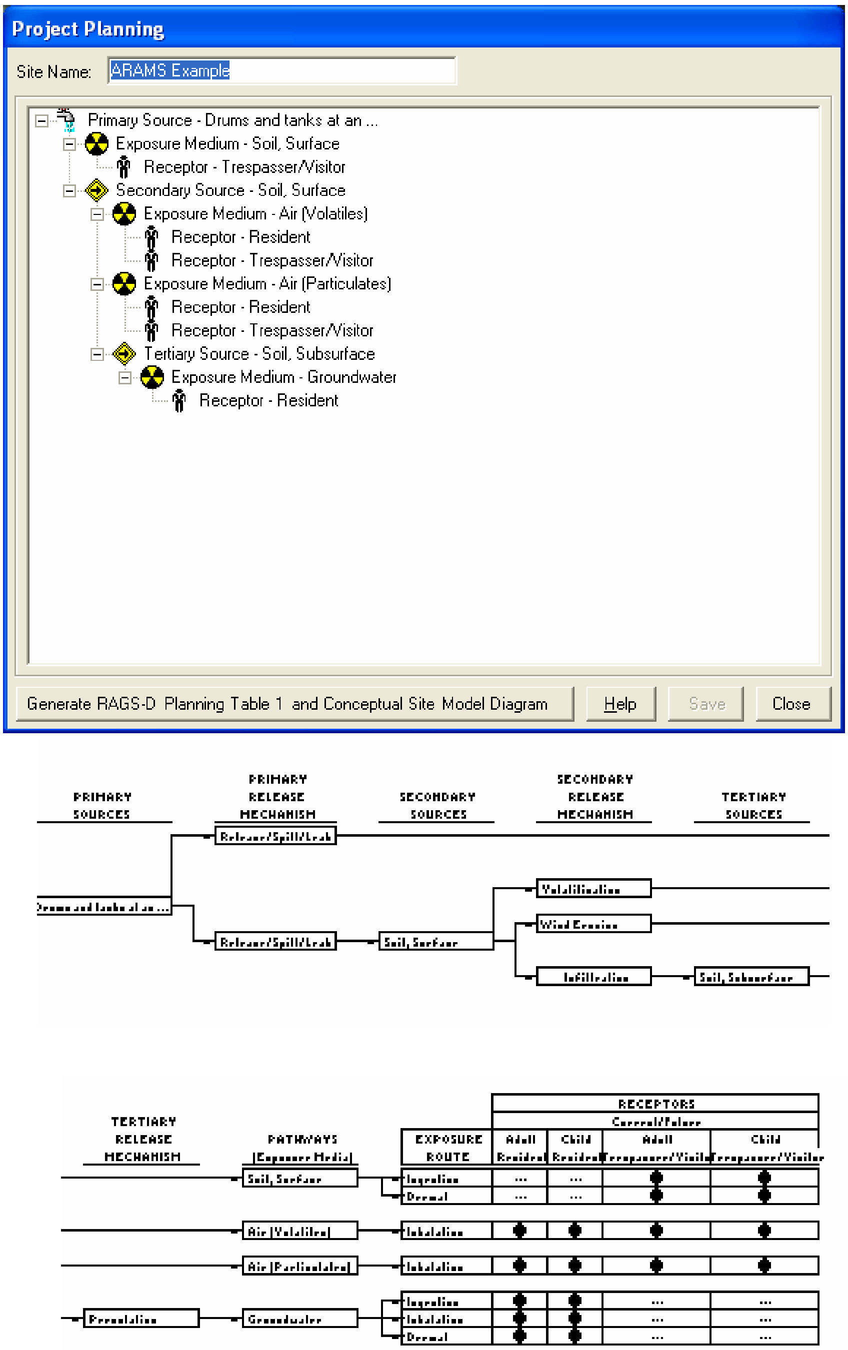

Figure 2: Example screens of tool to generate CSM and resulting CSM diagram

database for setting ingestion rates, home range, dietary items, and other factors considered in the model. Information passed to TWEM within FRAMES includes constituents of concern, target organisms, and media constituent concentrations (measured or computed by another model). Exposure doses (mg/kg/day) are output from TWEM and passed to the ecological effects object for calculating and displaying EHQ values. An example using TWEM is presented in the next section of this paper.

TWEM is not a spatially explicit model, i.e., the organism is assumed to be exposed to contaminated food/media based upon an area use factor (AUF), which is the ratio of site area to organism home range. If the home range is less than the site area, the AUF is set to 1.0. The computed dose is multiplied by the AUF to obtain the exposure dose. The Spatially Explicit Exposure Model (SEEM) (Menzie-Cura & Assoc. [11]) has been developed for more comprehensive analyses, where constituent concentrations and habitat type/quality can vary spatially. Multiple receptors can forage over the landscape within their home range but with preferences for habitat, thus allowing a varying dose that can be integrated over time to yield a more accurate representation of exposure dose and EHQ. The doses and EHQ values of the multiple receptors can be assessed to yield an effect on the population for the site. An aquatic spatially explicit model has been developed for fish, FISHRAND (Menzie-Cura & Assoc. [12]), which was based upon a model of PCBs for the Hudson River (TAMS [13]). SEEM and FISHRAND are being added to ARAMS during 2004.

3 Example application for terrestrial ecological assessment

The example illustrated here is hypothetical. Consider a 50 acres wetland contaminated with DDT in the sediment, water, and surrounding soil. A deciduous forest surrounds the wetland site. The ARAMS/FRAMES CSM is shown in Figure 3. The User Defined Object is used to specify known (or measured) soil, sediment, and water concentrations that feed into TWEM, which computes receptor doses. Output from TWEM feeds into the Eco Health Impacts Object, which uses the Wildlife assessment using TWEM Ecological Assessment Program (WEAP), to compute and display EHQ values. The databases required for this example include the Constituent database for selecting COCs and their properties, the Terrestrial Organism Selector (TOS) for selecting target organisms, and the TTD database for selecting TRVs.

Soil, sediment, and water concentrations of 10.0, 100.0, and 1.0 parts per million, respectively, were assumed. Multiple constituents can be addressed, but for simplicity in presenting this example, only one constituent (DDT) is considered. Two target receptor organisms are considered, Red Fox and Belted Kingfisher. The life history parameters for these receptors that were obtained from the TWEM life history database are shown in Table 1. The Tier 1 default home range was assumed, which is equal to the site area, thus, the AUF is 1.0. The diet and food concentrations for each receptor are shown in Table 2. The rule based option in TWEM for computing food concentrations was used, which uses in order of decreasing priority one of three methods: regression, BAF value,

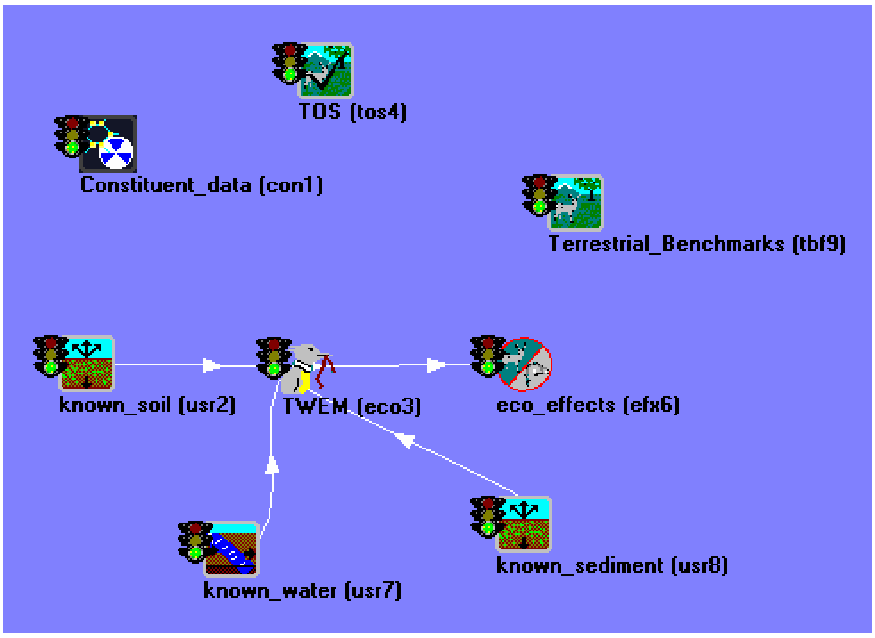

Figure 3: ARAMS/FRAMES CSM for ecological assessment using TWEM

or a log K_{ow} relationship (K_{ow} is octonol to water partition coefficient). If the BAF database does not provide parameters for any of the three methods, then the Tier 1 default of BAF=1.0 is used. As can be noted in Table 2, a BAF of 1.0 was used for most food items due to sparseness of data in the BAF database. Work is continuing during 2004 to add more values to the BAF and life history databases.

Receptor doses computed by TWEM are shown in Table 3. Doses are obtained by multiplying media concentrations by ingestion rates. Food concentrations are weighted with proportion of diet and summed to get total food dose. EHQ values computed by WEAP are shown in Table 4. EHQ is the ratio of does to TRV. The TTD DCE was used to select TRVs by jurisdiction. The Oak Ridge National Lab was selected for this example, which gave very conservative values for lowest observable adverse effects level (LOAEL) for reproduction of 0.0028 mg/kg/day for birds (based on a Brown Pelican) and no observable adverse effects level (NOAEL) for reproduction of 0.8 mg/kg/day for mammals (based on rats). For this example, the contamination in the wetland sediment and water pose a very high risk for the Belted Kingfisher, thus, indicating a need to further consider remediation of the wetland sediments.

Table 1: Life history parameters for target organisms

Target organism	Food ingestion rate (mg/kg/day)	Water ingestion rate (mg/kg/day)	Soil or sediment proportion of diet (fraction)	Body weight (kg)	Home range (acres)
Red Fox	0.16	0.086	0.028	3.94	50
Belted Kingfisher	0.11	0.11	0.010	0.125	50

Table 2: Diet and food concentrations for target organisms

Target organism/diet	Food proportion of diet (fraction)	Food estimation method	Pathway	Food concentration (mg/kg)
Red Fox				
Plants	0.311	BAF=0.079	Soil	0.79
Small mammals	0.617	BAF=1	Soil	10.0
Birds	0.002	BAF=1	Soil	10.0
Terr. invert.	0.042	BAF=1	Soil	10.0
Soil	0.028	NA	Soil	10.0
Belted Kingfisher				
Fish	0.46	Log K_{ow}=6.53	Water	6.53
Small mammals	0.01	BAF=1	Soil	10.0
Reptiles	0.27	BAF=1	Soil	10.0
Benthic invert.	0.24	BAF=1	Sediment	100.0
Sediment	0.01	NA	Sediment	100.0

Table 3: Computed doses (mg/kg/day) from TWEM

Receptor	Soil	Sediment	Water	Food	Total
Red Fox	0.04	0.0	0.09	1.10	1.23
Belted Kingfisher	0.0	0.11	0.11	3.28	3.50

Table 4: Computed EHQ values from WEAP

Receptor	Soil	Sediment	Water	Food	Total
Red Fox	0.05	0.0	0.11	1.37	1.53
Belted Kingfisher	0.0	39.3	39.3	1,171	1,249

4 Summary

ARAMS version 1.2 now has features for addressing terrestrial ecological risk assessment through the use of TWEM for computing wildlife exposure doses from water, soil, sediment, and food pathways. The Terrestrial Toxicity Database can be used to gather TRVs and eco soil screening levels for comparison to exposure doses and soil concentrations, respectively, within WEAP. Later versions of ARAMS will allow for spatially explicit ecological analyses using SEEM and FISHRAND.

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