A Forecasting Tool to Aid in the Management of Munitions Residue for Range Sustainment

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ABSTRACT

A forecasting tool is being developed to predict the fate and exposure concentrations of munitions residue to aid in managing ranges for sustainment. The tool is referred to as Assessment of Residue from Munitions On Ranges (ARMOR) and is being built from components that are available within the Adaptive Risk Assessment Modeling System (ARAMS™, Dortch, M. S., and Gerald, J.A., 2002) (http://el.erdc.usace.army.mil/arams/). ARMOR will estimate the amount of munitions residue mass deposited on ranges from high and low-order detonations as well as from sympathetic detonation of duds and determine the fate and transport of residue constituents through the environment (soil, surface water, and groundwater). This information can then be used to ascertain exposure concentrations and any potential threat to humans and the environment. ARMOR will provide range managers with the capability to determine when a problem is likely to occur and to adjust range usage to avoid compliance violations. An example application of the tool is presented where planned usage of the range is predicted to result in receiving water concentration of the explosive RDX that exceeds the public health advisory for RDX after 40 years. An alternative range usage scenario that does not exceed the advisory is also presented.

INTRODUCTION

The 1997 UXO Clearance Report to Congress estimated that millions of square meters throughout the United States, including 1,900 Formerly Used Defense Sites (FUDS) and 130 Base Realignment and Closure (BRAC) installations, potentially contain unexploded ordnance (UXO) and explosives contaminants. In addition, testing and training ranges which are essential to maintaining the readiness of the Armed Forces of the United States contain both UXO and munitions residues such as explosives. Recently, concerns have arisen over potential environmental contamination from residues of energetic materials at impact ranges. A key to sustaining training at firing ranges is the ability to predict future environmental impacts of range activities and adjust range use if necessary to avoid environmental compliance problems.

TOOL DESCRIPTION

ARMOR is being built using components of the ARAMS™ system. ARAMS can perform the same calculations, but ARMOR is being constructed with less features to reduce the learning and application time for users that may not be familiar with ARAMS. A new "Source" module was developed for ARAMS and ARMOR and is referred to as the Munitions Residue Characterization and Fate Model (MRCFM). The MRCFM contains a munitions residue loading component as well as residue fate in soil component. The loading component can estimate the mass loading onto the range over time based upon historical or planned munitions use. The fate in soil component of the MRCFM source module is based on the Multimedia Environmental Pollutant Assessment System (MEPAS) Computed Source Term Release Model (CSTRM) for soil (Streile et al., 1996). which uses the continuously stirred tank reactor approach (i.e. a single fully mixed or homogeneous soil compartment) to represent an impacted area. The CSTRM was modified to handle solid phase constituent mass in addition to aqueous phase, and a dissolution formulation by Lynch et al. (2003) was added to compute the mass flux of constituent from solid residue to aqueous phase constituent. The addition of a dissolution formulation option by Lever et al. (2005) is planned. Presently the tool handles only impact zones, but features have been built in to allow extension for firing points. The main input screen for the MRCFM user interface is shown in Figure 1.

Like ARAMS, ARMOR will use the Framework for Risk Analysis of Multimedia Environmental Systems (FRAMES) (http://mepas.pnl.gov/FRAMESV1/index.html) to provide an object-icon-based mechanism for linking disparate modules. ARMOR will have a user friendly interface to assist the user in selecting pre-defined and pre-populated templates that fit their site needs, thus reducing familiarization and set up time. Spatially distributed residue sources will be handled in two ways. One way involves the use of multiple instances of the MRCFM, such as one MRCFM module for each impact area as shown in Figure 2. The other way involves applying the results of the spatially distributed watershed model, GSSHA, that is being developed for range munitions residues. Mass transport flux from soil to other media, such as surface water and groundwater, as well as fate of constituents in the other media, can be modeled too so that concentrations can be predicted at points of interest.

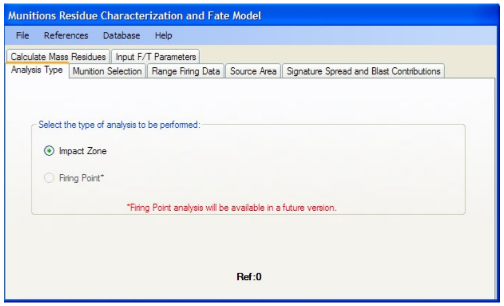

Figure 1. The MRCFM user-interface

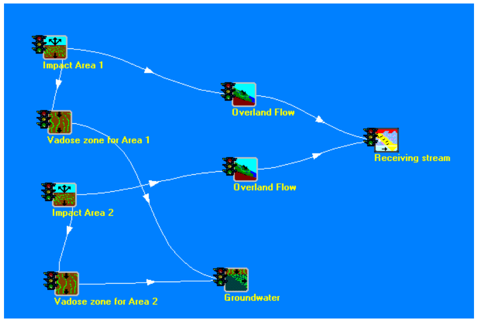

Figure 2. Use of MRCFM for two impact areas with multi-media transport/fate

VALIDATION

The fate and transport components of this tool for soil, vadose zone, and groundwater were applied to Demolition Area 2 of Massachusetts Military Reservation (MMR) by Dortch, Fant, and Gerald (2007). The residue mass loading rate was not known, but it was estimated. Model results compared favorably to measured soil and groundwater concentrations (Figures 3 and 4) that were obtained approximately 20 to 25 years after the site was used. It was encouraging that the model could forecast reasonably accurate information over a relatively long time period between residue release and groundwater contamination. This study indicated a need for better information for estimating dissolution rate for various types of explosives compounds (e.g., C4) and degradation rates of explosives in groundwater.

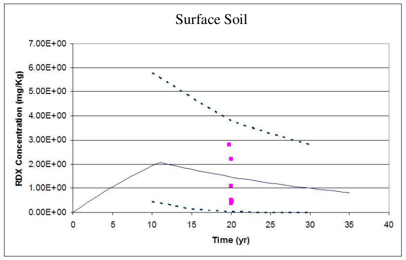

Figure 3. Measured (symbols), computed baseline (solid line), and computed upper and lower 95 % confidence interval (dashed lines) of soil RDX concentrations versus time at Demo Area 2

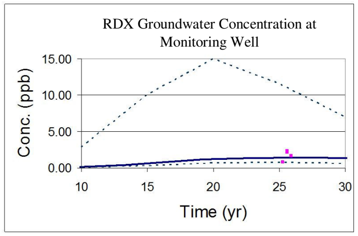

Figure 4. Measured (symbols), computed baseline (solid line), and computed upper and lower 95 % confidence interval (dashed lines) of groundwater RDX concentrations versus time at Demo Area 2

EXAMPLE APPLICATION

This application demonstrates how the tools can be used to aid range management to avoid future compliance problems. The MRCFM model was applied with a receiving stream (surface water) model for a hypothetical firing range of 500 m x 500 m to determine if and when stream concentrations of RDX would exceed the protective public advisory criteria of 2 parts per billion (ppb). Munitions used on the hypothetical range included 3,000 rounds per year each of 81 mm mortar and 155 mm howitzer with an assumed low order rate and yield of 2 % per year and 25 %, respectively, used for 50 years. Only overland runoff to a relatively small receiving stream was considered in this example. The stream was located 3 km down gradient of the range. Runoff from the vegetated site was characteristic of a moderately wet climate with about 25 inches of annual rainfall. The receiving stream had an annual average flow of 0.5 m^3/sec. The computed stream concentration versus time forecasted for this range usage scenario is plotted in Figure 5. These results indicate that the public health advisory of 2 ppb could be exceeded after about 40 years of range use.

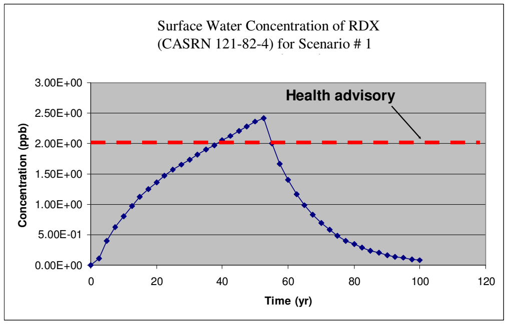

Figure 5. Computed receiving stream concentration of RDX versus time

At this point the range manager may want to consider alternative scenarios for range use that may avoid this situation to ensure range sustainment. Assuming the same number of rounds per year of firing, the manager might consider alternating the use of this firing range with an alternate range on 10 year cycles, i.e., use for 10 years and leave idle for 10 years. The results of this scenario indicate that this type of use could avoid the problem as shown in Figure 6.

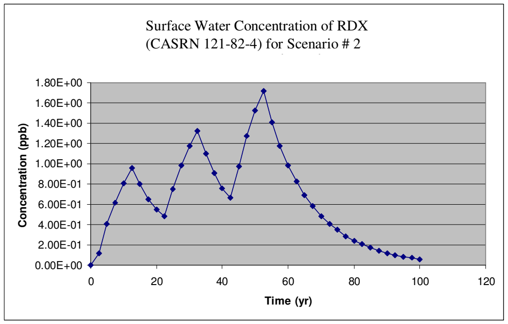

Figure 6. Computed receiving stream concentration of RDX versus time for alternative use scenario

SUMMARY

A tool has been developed for forecasting the fate of munitions residue on ranges and receiving surface water and groundwater. The tool will be released in a user friendly application called ARMOR. ARMOR will allow range managers to forecast if and when their ranges could encounter compliance problems associated with exceeding advisory concentrations of munitions constituents in soil, surface water, and groundwater. ARMOR can then be used to evaluate various range use management strategies to avoid problems, thus, sustaining the ranges for future use.

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