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J. G. Droppo
J. W. Buck

D. L. Strenge

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Pacific Northwest Laboratory
Richland, Washington 99352

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J. G. Droppo Jr.
D. L. Strenge
J. W. Buck

Pacific Northwest Laboratory
Box 999 K6-96
Richland, Washington 99352
(509) 376-7652

ABSTRACT

A risk computation model useful in environmental restoration activities was developed for the U.S. Department of Energy (DOE). This model, the Multimedia Environmental Pollutant Assessment System (MEPAS), can be used to evaluate effects of potential exposures over a broad range of regulatory issues including radioactive carcinogenic, nonradioactive carcinogenic, and noncarcinogenic effects.

MEPAS integrates risk computation components. Release, transport, dispersion, deposition, exposure, and uptake computations are linked in a single system for evaluation of air, surface water, ground water, and overland flow transport. MEPAS uses standard computation approaches. Whenever available and appropriate, U.S. Environmental Protection Agency guidance and models were used to facilitate compatibility and acceptance.

MEPAS is a computational tool that can be used at several phases of an environmental restoration effort. At a preliminary stage in problem characterization, potential problems can be prioritized. As more data become available, MEPAS can provide an estimate of baseline risks or evaluate environmental monitoring data. In the feasibility stage, MEPAS can compute risk from alternative remedies. However, MEPAS is not designed to replace a detailed risk assessment of the selected remedy. For major problems, it will be appropriate to use a more detailed risk computation tool for a detailed, site-specific evaluation of the selected remedy.

INTRODUCTION

Remedial action activities covered under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) include consideration of environmental and health risks. In the early stages of these efforts, a risk baseline must be defined. To select a remedial action, candidate remedies are compared in terms of their expected reduction of long-term risks, short-term occupational and public health risks, and potential risks if the remedy fails. Both current and possible future land uses are considered for the long-term risks.

Computation models play an important role in the risk assessment process. A baseline risk assessment, based on modeling impacts using preliminary site characterization data, can provide direction to environmental monitoring programs. Risk computation models provide a means of evaluating impacts of future land-use and remedy-failure scenarios. To fit a need for one type of risk computation model, the Multimedia Environmental Pollutant Assessment System (MEPAS) was developed for the U.S. Department of Energy (DOE). This paper describes the risk assessment process for environmental restoration and the role of MEPAS in that process.

As part of the environmental restoration activities at DOE sites, risk assessments must be conducted to determine potential environmental and human health impacts. This assessment of risk involves a number of concurrent efforts aimed at defining a level of risk for an activity.

A formal risk assessment refers to the process of defining risk levels associated with an activity. In addition to risk computations, a risk assessment can include site inspections; monitoring or measurement to better define release, transport, and exposure parameters; surveys to define usage rates and exposure pathways; and epidemiological studies. Risk computation may be viewed as an integration step in risk assessment, in which all of the information collected to date is combined to provide a quantitative estimate of risk.

The risks evaluated in a risk assessment for an environmental restoration activity can be logically divided into three groups: baseline, during remediation, and after remediation. The baseline and after-remediation impacts are evaluated as long-term chronic risks. The during-remediation impacts are evaluated as both long-term chronic and short-term acute risks.

The risks to the public are normally considered either as maximum individual or population risks. Depending on the model, the modeling assumptions, and the toxicity assumptions, the estimated risks will have varying degrees of conservatism.

RISK COMPUTATION MODELS

The MEPAS risk computation model is one of a wide range of models currently used to make risk-related decisions related to environmental restoration activities at sites contaminated with hazardous wastes. Figure 1 shows the relationships among different models relative to data requirements and uncertainty in estimated risk levels.

Screening Models

Screening models are used to determine whether a particular situation at a particular site should be considered as a potential problem. These models use general site information for input. Using either a value-based logic system or a very conservative physical model, a situation is defined as being either a possible problem or a nonproblem. The outputs from these models are normally inappropriate for relative ranking of problems.

The Hazard Ranking System (HRS) model as promulgated by the U.S. Environmental Protection Agency (EPA) is a screening model (1). An HRS score is computed for a site; if the score is above a defined value, the site is placed on the National Priority List (NPL). Consistent with this stage of problem characterization, EPA clearly states that the HRS score is not designed to rank the relative importance of problems.

Detailed Models

At the other extreme, detailed models are used to assess the levels of risk associated with relatively well-defined problems. Models for detailed analysis tend to focus on special sets of problems and special types of situations. The EPA provides separate models for different regulatory issues such as air emission evaluation, ground-water transport, nonradioactive exposure assessment, and radioactive exposure assessment. The U.S. Nuclear Regulatory Commission (NRC) provides a similar set of models for evaluating releases from commercial nuclear power plants. In addition, many of the major DOE facilities have site-specific models for assessing public exposures from radioactive material releases.

Although each of these detailed assessment tools is appropriate for its intended application, extension beyond the intended application is often either difficult or even inappropriate. For example, a detailed exposure model developed for an arid site cannot be expected to be necessarily applicable to a non-arid site, and vice-versa.

Ranking Models

Between the screening and detailed models, ranking models (also referred to as prioritization models) are used to assess the relative importance of problems. Ranking and detailed models are mainly distinguished by the level of generality and the detail of required site-specific data. Often the same models can be applied for both ranking and detailed analysis.

A model for a ranking analysis must be able to handle the application-specific range of problems and situations. To be useful as a ranking model over a range of environmental restoration activities, a model must be able to consider a broad range of problems and potential impacts. The results are typically used to prioritize between problems or between competing aspects of a single problem. Reflecting data input and model limitations, results of these applications are used for relative comparisons over broad ranges of impacts.

The EPA provides a number of models that could be used in ranking applications. The EPA models range from screening guidance for preliminary conservative assessments to formal, documented computer models. The application guidance for these models is to use progressively more realistic assumptions and more detailed models to obtain better estimates of risk.

The subject model of this paper, MEPAS, was developed by DOE to estimate public health risks for ranking applications covering a broad range of regulatory issues (2). MEPAS was designed so that application was possible across a range of DOE sites at various stages of site characterization.

MULTIMEDIA ENVIRONMENTAL POLLUTANT ASSESSMENT SYSTEM (MEPAS)

MEPAS is a multimedia environmental assessment system that starts with contaminant releases and simulates the movement of contaminants though major transport pathways to human exposure routes. MEPAS provides estimates of human health impacts though air, water, and direct exposure routes. Model outputs include environmental concentrations, health impact parameters, and related parameters.

This section provides a brief description of the MEPAS methodology. More detailed descriptions of the MEPAS formulations are given by Droppo et al. (3) and Whelan et al. (4).

Approach

MEPAS is designed for ranking problems over a broad range of applications. Exposures and resultant health impacts are computed based on environmental concentrations at the receptor locations. The mathematical algorithms in MEPAS are based on standard approaches for modeling releases, transport and dispersion, and health impacts in atmospheric, ground water, surface water, and overland transport media. Inhalation, ingestion, direct contact, and direct exposure pathways are included in the health impact component. The interaction and coupling among the transport pathways and the exposure assessment component of MEPAS are illustrated in Figure 2.

To reduce the number of required inputs and standardize the values used for certain non-site-specific parameters, a MEPAS constituent database was developed (5). This MEPAS database contains toxicity data, transfer factors, chemical and physical constants, and other relevant constituent data. Toxicity data are based on EPA IRIS data whenever possible, with other references and estimation methods used only to supplement EPA data.

Human Health Impacts

The human health impacts are computed by MEPAS and expressed in terms of regulatory-based risk factors. MEPAS considers three types of constituent impacts: radioactive carcinogenic, chemical carcinogenic, and noncarcinogenic constituents.

The computation of risk factors uses regulatory levels based on protection of public health from harmful exposures to a constituent. Carcinogenic risk factors are based on increased cancer incidence. Noncarcinogenic risk factors are based on acceptable daily intakes for the chemicals of concern based on EPA guidance.

The risk factor for carcinogenic effects from radionuclides is calculated assuming low-level exposure over the lifetime of an individual. The risk factor is equal to the product of the computed individual lifetime dose and the health effects conversion factor.

Chemical carcinogenic risk factors are defined for ingestion and inhalation exposure routes that are estimated from cancer potency factors (primarily developed by the EPA). These cancer potency factors relate the daily intake per unit body mass averaged over an individual's lifetime to the risk of developing cancer.

For noncarcinogenic impacts, EPA (6) defines the chronic reference dose (RfD) as an estimate or reference dose "of an exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime." The MEPAS risk factors for noncarcinogenic impacts are the estimated dose divided by the RfD.

Although normally only one type of impact is associated with a given constituent, a constituent can actually have different types of impacts. For example, a few constituents are carcinogenic for one exposure route and noncarcinogenic for another exposure route. Constituents also may be of concern as a result of both their radioactive and their chemical properties.

Environmental Releases

Each of the four primary transport pathways considered by MEPAS (ground water, surface water, overland, and atmospheric) is associated with several environmental release types. Detailed information on these release types may be found in reference 7. For the ground water, surface water, and overland pathways, the possible release types are precipitation-driven release rate, known contaminant release rate, and known water concentration at the receptor. The atmospheric transport pathway in MEPAS has three major release types: 1) stack/vent releases, 2) suspension of contaminated soil, and 3) gaseous releases through volatilization.

Implementation

MEPAS is available as a stand-alone system on an IBM PC with a user-friendly shell, allowing problem definition, data entry, and model execution as described by Droppo and Hoopes (8). A hard disk is required for execution, and a math coprocessor is recommended. The MEPAS software requires about 2.5 mb of disk space; additional space is required for application data files. Input, references, and output are stored in computer files.

SELECTED MEPAS APPLICATIONS

MEPAS has been applied to evaluation and comparison of risks from both active and inactive operations. These studies range from a nationwide comparison of DOE problems (9) to single-site constituent rankings (10).

The DOE's Office of Environmental Audit used MEPAS to compute risks for environmental problems identified in DOE's Environmental Survey (2). A preliminary ranking was made of potential environmental problems at 16 DOE defense production facilities (9). Subsequently, problems were ranked at 35 DOE sites using risk-based parameters computed with MEPAS.

The DOE's Office of Environmental Restoration is developing a risk-based Priority System (PS) that provides information to optimize funding decisions. MEPAS is a tool that, depending on the level of data available, can be used for computing risks and risk reductions as input to future applications of the Priority System.

The Remedial Action Assessment System (RAAS), which is being developed by the DOE Office of Environmental Restoration, is a computer tool to help in the selection of a representative list of alternatives in the feasibility stage of EPA's guidance for remediation at CERCLA sites. RAAS will first screen possible technologies for to obtain a candidate list and then will provide attribute information on that list of candidates. The attributes will be based on a subset of EPA's ten attribute criteria (11). To help in this process, MEPAS will be provided as a tool for computing risk for alternative remedies.

SUMMARY AND STATUS

MEPAS is a computational tool that can be used in several phases of an environmental restoration effort. MEPAS can be used to compute potential risks at a preliminary stage in the problem characterization effort. As more data become available, MEPAS can be used to provide an estimate of baseline risk, or to evaluate environmental monitoring data. MEPAS can be used to compute risk from alternative remedies.

A baseline version of MEPAS is complete and available for applications. An extensive set of documentation is available which includes the formulations (3,4), guidance documents (7,12,13), a sensitivity study (14), and a validation report (15).

This version of MEPAS provides detailed intermediate files that list release rates, modeling assumptions, and computed concentrations in various environmental media. The risk output includes the population risk, maximum individual risk, time of arrival and peak exposure at a receptor, and how each exposure pathway contributes to the total risk.

Updates and additions are planned to make MEPAS more effective in environmental restoration applications. A module is being added to allow the determination of the range of risk uncertainty based on input uncertainty (14). Annual risk commitments for the first 100 years will be provided. Other modules for estimating occupational and acute exposures are also being formulated. Based on a suggestion by EPA, an ecological impact evaluation module is being implemented. Several planned updates to the environmental transport modules will increase the applicability of the code. The exposure computations are being updated to follow recent EPA guidance exactly.

ACKNOWLEDGMENTS

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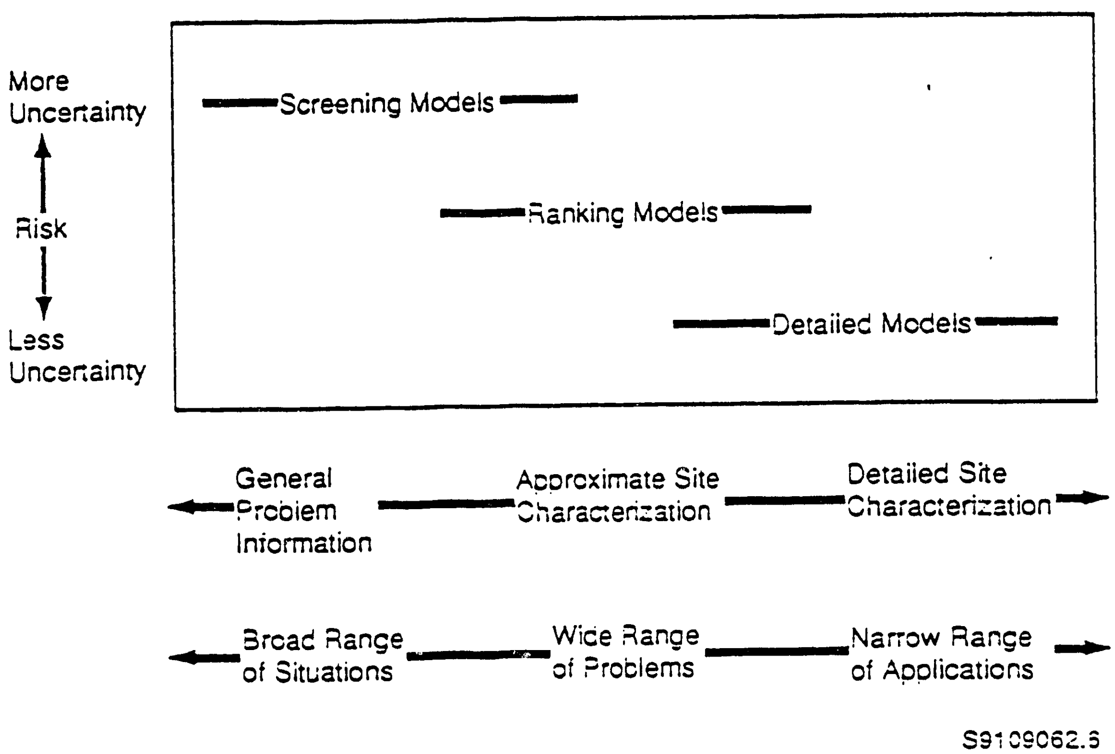

Figure 1. Screening, Ranking, and Detailed Risk Models

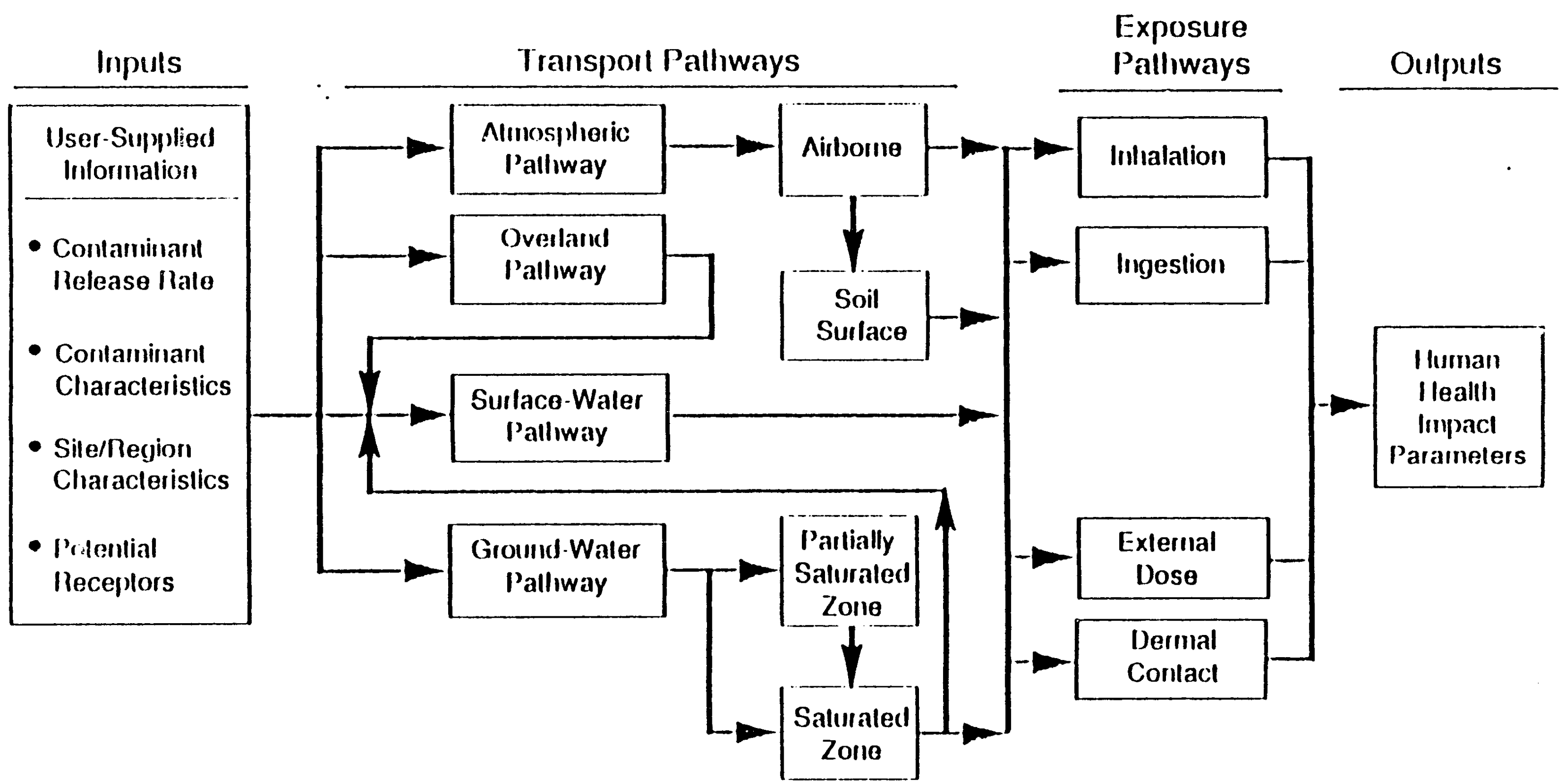

Figure 2. MEPAS Transport and Exposure Pathways

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