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REMEDIAL ACTION ASSESSMENT SYSTEM (RAAS) - A COMPUTER-BASED METHODOLOGY FOR CONDUCTING FEASIBILITY STUDIES

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ABSTRACT

Because of the great complexity and number of potential waste sites facing the U.S. Department of Energy (DOE) for potential cleanup, the DOE is supporting the development of a computer-based methodology to streamline the remedial investigation/feasibility study process required for DOE operable units. DOE operable units are generally more complex in nature because of the existence of multiple waste sites within many of the operable units and the presence of mixed radioactive and hazardous chemical wastes. Consequently, Pacific Northwest Laboratory (PNL) is developing the Remedial Action Assessment System (RAAS), which is aimed at screening, linking, and evaluating established technology process options in support of conducting feasibility studies under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). It is also intended to do the same in support of corrective measures studies required by the Resource Conservation and Recovery Act (RCRA).

One of the greatest attributes of the RAAS project is that the computer interface with the user is being designed to be friendly, intuitive, and interactive. Consequently, the user interface employs menus, windows, help features, and graphical information while RAAS is in operation. During operation, each technology process option is represented by an "object" module. For example, the concentration of a contaminant exiting a treatment process, such as an incinerator, will be determined in the object module as a function of the input concentration, the residence time in the unit process, and the operating temperature. Object-oriented programming is then used to link these unit processes into remedial alternatives. (An example of a remedial alternative is vacuum extraction of volatiles from contaminated soil, followed by excavation, chemical fixation, and redisposal of the contaminated soil.) In this way, various object modules representing technology process options can communicate so that a linked set of compatible processes form an appropriate remedial alternative. Once the remedial alternatives are formed, they can be evaluated in terms of effectiveness, implementability, and cost. RAAS will access a user-selected risk assessment code to determine the reduction of risk after remedial action by each recommended alternative. The methodology will also help determine implementability of the remedial alternatives at the site and access cost estimating tools to provide estimates of capital, operating, and maintenance costs.

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This paper presents the characteristics of two RAAS prototypes currently being developed. These include the RAAS Technology Information System, which accesses information on technologies in a graphical and tabular manner, and the main RAAS methodology, which screens, links, and evaluates remedial technologies.

INTRODUCTION

The U.S. Department of Energy (DOE) is facing the major task of cleaning up hundreds of waste sites and completing remedial investigations and feasibility studies (RI/FSs) or facility investigations and corrective measures studies for each of these sites at its facilities across the nation. For example, DOE has 330 proposed operable units on the National Priorities List alone. The first 67 of these waste sites are tentatively scheduled for RI/FS completion in the 1992 to 1997 time frame with implementation of remediation technologies to commence subsequently (U.S. Department of Energy 1989 and U.S. Environmental Protection Agency 1989). The RI/FSs for the remaining 263 operable units will be done over the next 10 to 20 years. These waste sites can involve groundwater, deep and shallow soils with interstitial (pore) waters, surface waters, sediments, sludges, and buried wastes. The initial source of the contamination may have been ponds, drain fields, trenches, cribs, leaky tanks, or pipes. These fabricated structures are themselves part of the remediation puzzle at many sites.

DOE has established a program to expedite the cleanup process through the development of new technologies and integrated demonstrations of developed technologies. It is essential that these technologies be considered, along with established alternatives, for implementation during the RI/FS process. The intent of each RI/FS is to characterize the waste problems and environmental conditions at the operable unit(s), segment the waste remediation problems into manageable media-specific and contaminant-specific pieces, define the remediation objectives, and propose several general response actions to meet these objectives (U.S. Environmental Protection Agency 1988). This might involve various combinations of: a) no action; b) institutional controls; c) waste stabilization and containment; d) waste recovery and treatment; and e) in situ treatment. The RI/FS team must then identify and evaluate various combinations of technologies and associated processes that might be employed to meet the remediation objectives. Furthermore, it must provide defensible rationale why other combinations of technologies and processes are not as effective, implementable, cost competitive, or acceptable.

Although the steps in a feasibility study are relatively straightforward, there are many twists and turns along the way, especially considering the rigorous quality control that is demanded. A feasibility study analysis should be conducted in at least three different stages of the RI/FS process. First, the feasibility study should be conducted early in the site characterization process so that it can "drive" site remedial investigation activities. This could prevent the syndrome of overcharacterizing the site or repeating sampling and analysis activities at a later date. However, such an initial feasibility study analysis must be conducted with very limited site-specific information. This calls for the availability of a resident database of "engineering-judgement" values (with appropriate electronic tagging) to enable the user to forge ahead in an exploratory, screening mode. The feasibility study should be repeated later in the process to help drive the design of the treatability studies and the second phase of site characterization. Finally, the feasibility study should be again repeated at a later date to conduct the detailed evaluation of the remaining alternatives upon which cleanup can be negotiated with the regulator. To streamline this entire process and make it more defensible, Pacific Northwest Laboratory (PNL) is developing the Remediation Action Assessment System (RAAS). RAAS is a computer-based methodology that provides a discrete, useful product at each of these stages of the RI/FS process. Figure 1 shows graphically how RAAS contributes to the various stages of the RI/FS process.

Place Figure 1 here.

CHARACTERISTICS OF THE REMEDIAL ACTION ASSESSMENT SYSTEM

In terms of directly supporting the technology development program being conducted by DOE, RAAS 1) provides a vehicle for collecting and sharing detailed information on technologies and regulations, 2) helps implement newly developed technologies as they emerge from demonstration, testing, and evaluation, 3) compares newly developed technologies with more established alternatives, and 4) can be used to support the selection and evaluation process for integrated demonstrations of existing and newly developed technologies.

In terms of supporting the RI/FS process, RAAS is being designed to be a complementary member of an RI/FS team. As such, it provides 1) a comprehensive information source and broad-based expert advisor to the team; 2) a vehicle for documenting (archiving) the computer's and the RI/FS team's assumptions, data selections, and decisions; 3) a mechanism for identifying site and technology data collection requirements early in the RI/FS process; 4) a mechanism for recommending treatability study procedures; 5) a "cut-and-paste" tool for dumping text-type technology descriptions and tables of technologies that were excluded from further consideration and the rationale for their exclusion; and 6) a vehicle for capturing an RI/FS team's experiences and transmitting this information to other teams across DOE.

RAAS must also permit sensitivity (i.e., what if) studies and thus prompt an RI/FS team to consider innovative and potentially less costly solutions. Those experienced in RI/FS studies tell us that human experts often subliminally select technology combinations that they know the most about and with which they have grown comfortable. Since the overall costs of the DOE environmental restoration problem may be in the range of many tens of billions of dollars, prompting users to consider innovative, less costly technologies may ultimately prove to be one of RAAS's greatest contributions. RAAS is also expected to save millions of dollars by reducing the time and effort required to do (and redo) RI/FSs. RAAS could minimize challenges to the results of many feasibility studies by having the computer explore a much broader array of potential alternatives and document why these alternatives were or were not selected.

RAAS TECHNOLOGY INFORMATION SYSTEM

The RAAS Technology Information System provides the user a graphical display of the technologies that are being included in the main RAAS methodology. It is a stand-alone, computer-based system that identifies and sorts remedial technology information. To date, 88 technologies have been identified for inclusion in the RAAS Technology Information System. These are listed in Table 1. Depending on the technology, various process options of each technology are described within the technology description. For example, the rotary kiln, controlled air, and fluidized bed incinerators are described as process options within the incineration technology entry. The information developed for each of these technologies includes:

- a graphical depiction or flow diagram of the process
- a brief narrative description of the process (one to three pages)
- engineering parameters such as power and space requirements
- applicability information as the technology relates to contaminant and media type (e.g., soil, groundwater, sludge)
- regulatory constraints such as compliance with air, water, and solid waste discharge regulations
- limiting technical constraints such as pH or particulate loading limits on feed materials to a unit process
- a graphics screen that accesses information on technologies that are generally combined with the specific technology of interest (pretreatment processes or processes for treatment of residual waste streams)
- a list of sites where the technology has been considered or implemented in the past
- a list of key technical references.

Table I. Technologies Included in the RAAS Technology Information System

Information on each of these categories is accessed through the active screen shown in Figure 2. The cursor is simply clicked on the block of information desired for a particular technology that the user wants to access.

Place Figure 2 here.

The technology information has been derived primarily from existing databases (attained via subcontract with private industry), technology reports, and past feasibility studies. The contents of new technology databases are evaluated as they emerge and, to the extent practicable, technology information is adapted for the RAAS Technology Information System.

Development of the user-friendly personal computer program for accessing the technology information was conducted in parallel with the development of the technology information. The computer system selected was the MacIntosh IIc® series personal computer with 5 megabytes of memory and equipped with a 256 color monitor. The program uses Supercard® as its platform software for the user interface and ORACLE® for the database in which the technology information is stored and sorted. The user interface relies on a mouse with pull-down menus to eliminate the necessity of keyboard entries. The demonstration model has been shown to numerous potential user groups with great acceptance of the tool. The first operational version, after incorporation of comments from field testing, is expected to be completed in September, 1991.

Aside from providing an early, usable product, the RAAS Technology Information System will be linked with the main RAAS methodology as a user help feature. The curious user of RAAS can access explanations of technologies or specific information that was used to formulate object modules of technologies considered by the main RAAS methodology. This feature is critical in gaining acceptance of the RAAS methodology by the user community.

MAIN RAAS METHODOLOGY

Another key accomplishment for the RAAS project has been the completion of the demonstration prototype of the main RAAS methodology. This part of the RAAS project is developing the product that selects, screens, links, and evaluates remedial alternatives in support of the feasibility studies required for every DOE operable unit. Some of the methodology's features include

- screening and linking of technology unit processes into remedial alternatives
- comparative evaluation of technologies and remedial alternatives in terms of established EPA criteria
- documentation of assumptions and decisions made by the user, crucial in defending the recommended alternative for each waste site
- recommendations for treatability tests and site characterization requirements for streamlining the remedial investigation portion of the RI/FS process
- upgrade mechanisms for keeping technology information current
- internal consistency checks to ensure data inputs by the user are consistent with previous data entries and results
- an internal risk assessment model for back calculating cleanup objectives from health-based risk criteria and a data gate for accessing user-selected technology risk assessment models.

The main RAAS methodology is based on object-oriented programming. For each technology unit process, an "object" module is developed for RAAS to describe the controlling characteristics, including the inputs, outputs, and the processing rules and constraints. For example, final concentrations of a contaminant exiting an ion exchange treatment process might be related to the input concentration specified by a pretreatment air-stripping process through direct communication among technology objects. Similarly, the application of in situ vitrification might be constrained by the percentage of organic litter in the soil as specified by internal rules in its object module. Each object-oriented module will have its input and output specifications and its own set of internal operating or process rules and local data. Let us illustrate further.

Numerous ways exist in which various unit processes could be combined into waste containment and/or treatment trains. Therefore, methodology is required to sort these potential combinations and suggest viable alternatives for further considerations. The purpose of this effort is to develop a linking scheme that will allow the RAAS user to identify the "most likely" trains of the particular site problem.

It is impractical to "hard-code" this complex problem. Therefore, a method must be employed that allows the computer program to interact with itself in a free-flowing manner and to interact with the RAAS user and a variety of external databases during operation. Object-oriented computer programming accomplishes this function. In this object-oriented approach, a unit process or technology is represented by an object, and the objects can send messages and ask questions of each other or request more information (Thomas 1989). For example, a certain treatment object may "know" that it is good at handling nonvolatile organics as long as the waste stream it receives does not also contain certain quantities of heavy metals and radionuclides. If such waste constituents are present, the object may send out a request message to all other waste separation and/or treatment objects asking if any of them can deal with the heavy metals and/or organics prior to the waste stream being delivered to the organic treatment process. This concept is illustrated in Figure 3. Since all other unit processes (objects) presumably contain local information and rules about what they can and cannot do, return messages will only be received from viable candidate processes or possibly more information will be requested of the original sender.

Place Figure 3 here.

It is important to understand that the human user can and should interact frequently with this process by sending his or her own messages and asking questions of the system. Inversely, the computer program must be able to solicit additional or clarifying information from the user and expect the user to make certain decisions along the way. RAAS is <u>not</u> a black box that the user just turns on and waits for the final answer. The user is an integral, interactive part of the computer methodology. This object-oriented computational approach facilitates this function and minimizes the number of hardwired (hard-coded) connections that are built into the computer model. Although object-oriented programming is very intuitive, powerful, and flexible, it has only recently been made available due to the much greater computing capacity (size, speed) of mini- and micro-computers and commercial software shells now on the market.

CONCLUSIONS

Development of the RAAS Technology Information System and the prototype of the main RAAS methodology has been successful in accomplishing three goals during the project's first year of development. These accomplishments have:

- provided a tool for users to comment on the functionalities and user interface features for development of the first operable versions of RAAS due in late 1991.

- provided a vehicle for gaining acceptance of the RAAS methodology from the regulatory and technical community.

- demonstrated to the development team that object-oriented programming can be used to determine whether technologies are applicable for specific waste site conditions and to effectively construct remediation trains.

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CAPTIONS

Figure 1. RAAS Contributions to the Remedial Investigation/Feasibility Study Process

Figure 2. Screen for Accessing Technology Information in the RAAS Technology Information System

Figure 3. Object-Oriented Programming Allows Technology Objects to Communicate with Each Other to Form Remedial Alternatives (treatment trains)

Table 1. Technologies Included in the RAAS Technology Information System

INSTITUTIONAL ACTIONS

access controls
alternative water supply
groundwater use restrictions
land use restrictions
monitoring

CONTAINMENT

capping
constructed barriers
dust and vapor supression
erosion control
extraction/injection wells
liners
subsurface drainage
surface water control

RECOVERY OR REMOVAL

bulk material storage
dredging
drum and debris removal
excavation
extraction wells
pipelines
surface water control
transportation
underground storage tank removal

VOLUME REDUCTION

air stripping
bioaccumulation
coagulation/flocculation
crystallization
dewatering
distillation
electrokinetic separation
evaporation (forced)
open air evaporation

VOLUME REDUCTION (cont)

freeze crystallization
gas absorption and adsorption
gas particulate removal
gravity separation
ion exchange
liquid adsorption
liquid-liquid extraction
media filtration
membrane separation
oil/water separation
soil vapor extraction
soil flushing
in situ soil heating
soil washing
solids classification
solvent extraction
thermal desorption

TOXICITY REDUCTION

aerobic biological treatment
anaerobic biological treatment
calcining
catalytic destruction
catalytic oxidation
chlorinolysis
dehalogenation
hydrolysis
in situ biodegradation
in situ vitrification
in situ chemical treatment
incineration
molten solids processing
neutralization
oxidation

TOXICITY REDUCTION (cont)

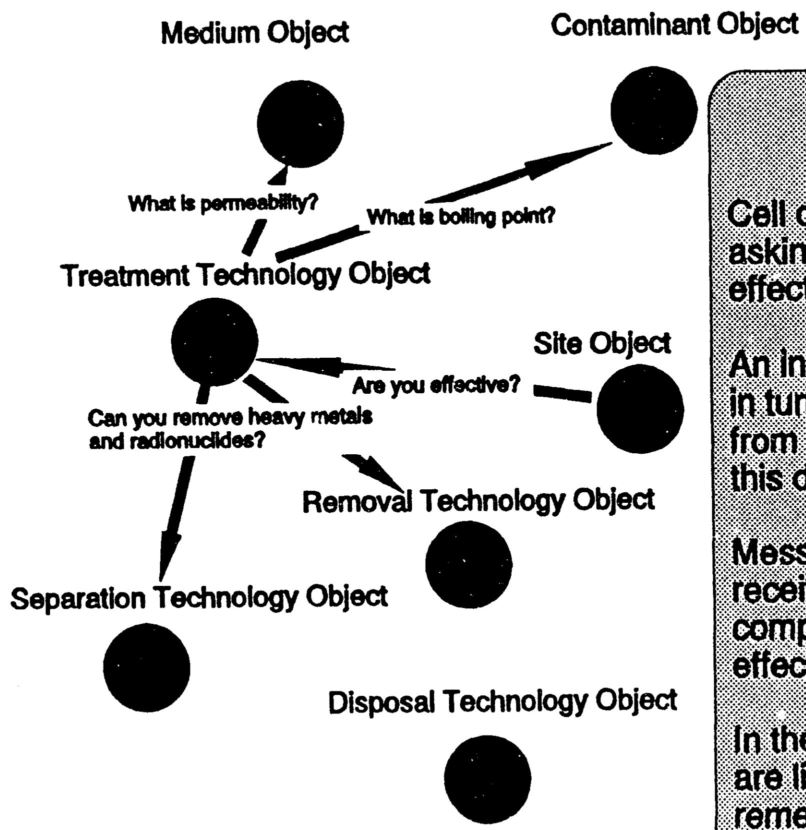
photolysis
precipitation
pyrolysis
reduction
roasting
wet air oxidation

MOBILITY REDUCTION

bioaccumulation
encapsulation
in situ solidification
in situ sorption
in situ vitrification
molten solids processing
solidification and stabilization

DISPOSAL

deep well injection
discharge to POTW
discharge to surface water
gaseous discharge to atmosphere
geologic repository
in situ water disposal
in situ soil disposal
injection wells
land application
landfill
low level waste burial
materials reuse
mixed waste landfill
off-site disposal
open air evaporation
TRU disposal
waste to energy



DEVELOPING ALTERNATIVES

Cell object initiates process by asking each technology if it is effective.

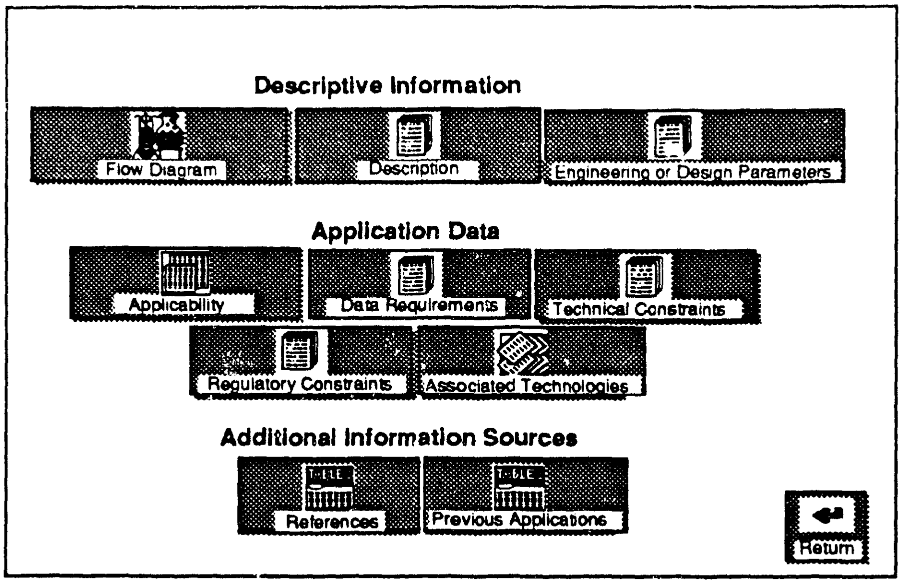
An individual technology must in turn ask for information from other objects to make this determination.

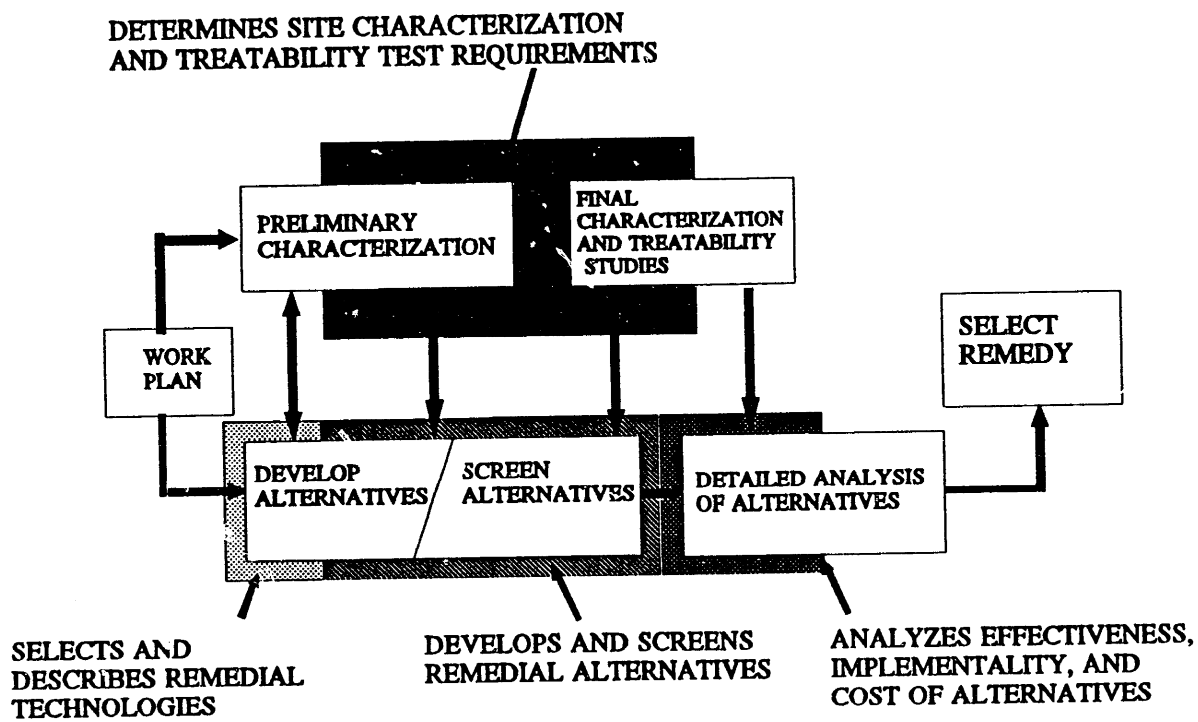
Messages are sent and received as each technology computes its own effectiveness.

In the process, technologies are linked together to form a remediation alternative

RAAS TECHNOLOGY INFORMATION SYSTEM

INFORMATION ACCESS SCREEN

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FINAL CHARACTERIZATION AND TREATABILITY STUDIES
WORK PLAN
SELECT REMEDY
DEVELOP ALTERNATIVES
SCREEN ALTERNATIVES
DETAILED ANALYSIS OF ALTERNATIVES
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