METHODOLOGY FOR INTEGRATED EVALUATION OF ALTERNATIVE SITING AND TREATMENT, STORAGE, AND DISPOSAL STRATEGIES FOR U.S. DEPARTMENT OF ENERGY WASTE MANAGEMENT

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ABSTRACT

A computational model named WASTE_MGMT has been developed by Argonne National Laboratory in support of the U.S. Department of Energy (DOE) Environmental Restoration and Waste Management (EM) Programmatic Environmental Impact Statement (PEIS) to assist in the analysis of alternative approaches to the management of existing and future radioactive wastes at DOE facilities. Input to the model includes waste inventory and characterization data at each DOE site; unit operations data for the facilities used for treatment, storage and disposal (TSD) of the wastes; and information about the alternative approaches for the TSD of the wastes and for the siting of such TSD facilities. The quantities calculated by the model include the air emissions of radionuclides and hazardous chemicals during operation of the TSD facilities, the quantities and characteristics of the wastes processed annually at these facilities, and the quantities and characteristics of the waste shipped among sites. These quantities are then used as input to calculate the cost and the environmental and socioeconomic impacts resulting from the TSD of the DOE wastes under various alternative management approaches considered in the EM PEIS.

INTRODUCTION

This paper describes the Argonne National Laboratory (ANL) WASTE_MGMT relational database management system that has been designed and implemented to provide an upper level assessment of alternative, integrated approaches to the management of existing and future wastes at U.S. Department of Energy (DOE) facilities. The system was initially designed to support analyses for the DOE Environmental Restoration and Waste Management (EM) Programmatic Environmental Impact Statement (PEIS); preliminary results for that application are also discussed.

The EM PEIS is being implemented to evaluate the strategies for alternative siting configurations for the treatment, storage, and disposal (TSD) of DOE wastes belonging to six general categories: high-level waste (HLW), low-level waste (LLW), transuranic waste (TRUW), low-level mixed waste (LLMW), chemical hazardous waste (HW), and greater-than-Class C (GTCC) LLW. The siting configurations considered generally fall under three classifications: decentralized, regionalized, and centralized. Under the decentralized alternative, the wastes are generally treated and stored at the sites where they are generated and disposed of at 13 sites throughout the country. Treatment and storage occur primarily at some regional and central locations under the regionalized and centralized alternatives, respectively. A no-action alternative (that includes only existing or approved waste management facilities) and, for most waste streams, a current program alternative (that would consist of the existing facilities plus those additional waste management facilities planned under the current DOE waste management program) are also considered.

Under each decentralized, regionalized, and centralized alternative, there may be several cases with different siting arrangements for each waste type. In addition, there may be more than one treatment option considered for each waste type. Consequently, the number of cases (i.e., site-technology combinations) to be analyzed for each waste type varies from a few to approximately 30.

The WASTE_MGMT model described in this paper was developed by ANL in response to the requirement of the EM PEIS to accurately and efficiently evaluate critical parameters associated with the complex array of waste inventories with multiple technology and siting options for TSD. An additional objective of the WASTE_MGMT model development was to provide the results of these parameter evaluations in a format that could be easily interpreted and transmitted for further use by ANL and other participants in the overall EM PEIS program in the evaluation of associated impacts. The uses of the WASTE_MGMT model results in the EM PEIS program are also briefly outlined in this paper.

METHODOLOGY

The WASTE_MGMT computational model is structured around three classes of data files that contain the input parameters used in the calculations. These input files as well as the output data that the model generates are described below. The model is implemented on an IBM-compatible personal computer using the MICROSOFT FOXPRO® relational database system. The execution times for a given case vary from a few minutes to a few hours on a computer with an INTEL 486 chip. The most time-consuming part of using the model is preparation of the input data files and printing of the output tables.

Input Files

The model needs three types of data files to analyze a case: a waste inventory and characterization file, a TSD module characterization file, and a case definition file.

Waste Inventory and Characterization: This file is specific to a waste type and is used to analyze all cases for that waste type. It contains the current inventory and future waste generation projections at each site. The waste is categorized according to treatability groups. For example, the treatability

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groups for LLW are 1) combustible, 2) noncombustible and noncompactible, 3) noncombustible and compactible, 4) surface-contaminated metal, 5) bulk-contaminated metal, 6) sludge/resin, 7) a general category containing all other solid LLW, 8) aqueous, 9) organic liquid, and 10) remote-handled. The inventory and generation rate are specified separately for each treatability group at each site. Also provided are the radiological profiles and/or chemical profiles of waste in each treatability group. The radiological profiles are given in terms of curie (Ci) concentrations of radionuclides, and chemical profiles are given as weight concentrations of hazardous chemicals.

TSD Module Characterization: This file contains the unit operations parameters for the modules used to treat, store, and dispose of the waste described in the waste inventory and characterization file. The parameters currently included in the file are output quantities from a module (treated product, liquid and solid residuals, and air emissions) per unit waste fed into the module, volume concentration factor for the treated product, and the required resources (e.g., fuel and water) per unit waste fed into the module. The same file is used to analyze all cases for a particular waste type.

Case Definition: This file specifies, for wastes belonging to each treatability class at each site, the process trains for TSD and source-destination transportation links. The model allows for pretreatment of waste at place of origin, shipment to another site for treatment, and shipment of treatment residues to another site for disposal. The treatment and disposal of the waste may take place at the same site, which may also be the same site at which the waste was generated. The secondary waste streams generated during treatment of primary wastes are accounted for. Table I provides an example of a case definition file used for LLW. The table shows only a part of the actual file used in the analyses. Each case to be analyzed has a separate case definition file.

Description of Output Variables

The ANL WASTE_MGMT model combines the waste inventory and characterization information, TSD module characterization information, and the case definition to calculate the following:

- Annual quantities and characteristics of the wastes shipped among sites,
- Annual quantities and characteristics of the wastes processed by each TSD module,
- Annual air emissions of radionuclides and hazardous chemicals resulting from the operation of the TSD modules, and
- Annual generation rates and characteristics of secondary waste streams or discharges resulting from the operation of the TSD modules.

Tables II and III provide examples of output files generated for a LLW case. Table II shows part of a waste transportation data file that includes for each source-destination site pair the total quantity of waste shipped in a year (both volume and mass) as well as the total curies of radionuclides in the waste being shipped. Table III is part of another output file that lists the throughput (quantity of waste fed into a TSD module in a year) and annual quantities of radionuclides emitted to the atmosphere during normal operations. The air releases are provided for each treatment and storage module at each site. The sum of the releases from all the modules at a site is also listed. The throughput quantities can also be provided by waste treatability category.

APPLICATION OF METHODOLOGY

The ANL WASTE_MGMT model is being used in the development of the EM PEIS. Currently, the model is being exercised to evaluate the management options for LLW and LLMW inventories at approximately 50 sites and TRUW inventories at approximately 15 sites.

For LLW, the waste inventory and characterization file and the TSD module characterization file have been prepared by ANL. The approximately 30 cases were defined by META/Berger in consultation with DOE, ANL, and other EM PEIS participants. These cases have been entered into appropriate case definition files, and the model has been exercised by ANL. The results from the model are being utilized in the overall EM PEIS program as follows:

- The air emissions and surface water effluents during normal operations and the throughput values are being used to calculate radiological doses and health effects to workers and the general public (Oak Ridge National Laboratory is the lead).
- The throughput quantities are being used to calculate TSD module costs, worker populations, and the resource requirements for the construction of new modules and for the operation of all modules (EG&G, Idaho, is the lead).
- The quantities and characteristics of the waste shipped among sites are being provided to the transportation risk assessment group at ANL for the calculation of radiological doses and health effects to transportation workers and the general public along the transportation routes. Impacts from both the incident-free transport and those resulting from probable transportation accidents are calculated.
- The throughput quantities and characteristics are being provided to the facility accident analysis group at ANL for the estimation of air emissions of radionuclides during postulated TSD facility accidents.
- The cost, worker population, other facility resource requirements, and transportation requirements are being used to estimate the socioeconomic impacts and cumulative impact assessments (META/Berger is the lead).

For LLMW to be consistent with the site treatment plans being prepared by the sites as mandated by the Federal Facility Compliance Act (FFCA) of 1992, the waste inventories and generation rates and the treatment process flow charts developed by the DOE Mixed Waste Treatment Project (MWTP) have been used. Approximate methods have been developed by ANL for characterizing the radiological and chemical profiles of the wastes. These methods, though approximate, are deemed satisfactory for use in a PEIS. The unit operations parameters for characterization of the TSD modules have been developed by ANL in consultation with the MWTP staff. The MWTP staff also calculated the throughput quantities in terms of the total volume of waste handled at each of the TSD modules. Argonne added the radiological and chemical characterization information to the waste inventories and throughput values provided by the MWTP and used the WASTE_MGMT model to generate the air and water emissions, throughput characterization, and waste shipment data for approximately 30 cases.

TABLE I

Partial ANL WASTE_MGMT Computational Model Case Definition File for LLW[a]

Origin Site	Treat-ability Group	Pretreatment at Origin Site				Treatment Site	Treatment Train at Treatment Site						Disposal Site	Disposal Option
		1[b]	Output	2[b]	Output		1[b]	Output	2[b]	Output	3[b]	Output		
AMES	01	PACKAGING	PROD	-	-	FEMP	INCINERATION	PROD	SOLIDIFI	PROD	-	-	ORNL	TUMULUS
AMES	01	PACKAGING	PROD	-	-	FEMP	INCINERATION	LRES	SOLIDIFI	PROD	-	-	ORNL	TUMULUS
AMES	02	PACKAGING	PROD	-	-	-	-	-	-	-	-	-	ORNL	TUMULUS
ANL-E	02	PACKAGING	PROD	-	-	-	-	-	-	-	-	-	ORNL	TUMULUS
ANL-W	01	PACKAGING	PROD	-	-	INEL	INCINERATION	PROD	SOLIDIFI	PROD	-	-	INEL	SHALLOW LAND
ANL-W	01	PACKAGING	PROD	-	-	INEL	INCINERATION	LRES	SOLIDIFI	PROD	-	-	INEL	SHALLOW LAND
ANL-W	02	PACKAGING	PROD	-	-	-	-	-	-	-	-	-	INEL	SHALLOW LAND
ANL-W	03	PACKAGING	PROD	-	-	INEL	SUPERCOMPACT	PROD	-	-	-	-	INEL	SHALLOW LAND
ANL-W	03	PACKAGING	PROD	-	-	INEL	SUPERCOMPACT	LRES	SOLIDIFI	PROD	-	-	INEL	SHALLOW LAND
ANL-W	05	-	-	-	-	INEL	SIZE	PROD	-	-	-	-	INEL	SHALLOW LAND
ANL-W	08	AQUEOUS	PROD	-	-	-	-	-	-	-	-	-	ANL-W	DISCHARGE
ANL-W	08	AQUEOUS	SRES	SOLIDIFI	PROD	-	-	-	-	-	-	-	INEL	SHALLOW LAND
HANF	01	PACKAGING	PROD	-	-	HANF	INCINERATION	PROD	SOLIDIFI	PROD	-	-	HANF	SHALLOW LAND
HANF	01	PACKAGING	PROD	-	-	HANF	INCINERATION	LRES	SOLIDIFI	PROD	-	-	HANF	SHALLOW LAND
HANF	02	PACKAGING	PROD	-	-	-	-	-	-	-	-	-	HANF	SHALLOW LAND
HANF	03	PACKAGING	PROD	-	-	HANF	SUPERCOMPACT	PROD	-	-	-	-	HANF	SHALLOW LAND
HANF	03	PACKAGING	PROD	-	-	HANF	SUPERCOMPACT	LRES	SOLIDIFI	PROD	-	-	HANF	SHALLOW LAND
HANF	04	-	-	-	-	HANF	SIZE	PROD	-	-	-	-	HANF	SHALLOW LAND
HANF	05	-	-	-	-	HANF	SIZE	PROD	-	-	-	-	HANF	SHALLOW LAND
HANF	06	SOLIDIFI	PROD	-	-	-	-	-	-	-	-	-	HANF	SHALLOW LAND
HANF	07	-	-	-	-	-	-	-	-	-	-	-	HANF	BELOW GROUND
HANF	09	PACKAGING	PROD	-	-	HANF	INCINERATION	PROD	SOLIDIFI	PROD	-	-	HANF	SHALLOW LAND
HANF	09	PACKAGING	PROD	-	-	HANF	INCINERATION	LRES	SOLIDIFI	PROD	-	-	HANF	SHALLOW LAND

[a] Abbreviations: AMES = Ames Laboratory, ANL-E = Argonne National Laboratory-East, ANL-W = Argonne National Laboratory-West, AQUEOUS = general aqueous treatment, DISCHARGE = treated water discharge, FEMP = Fernald Environmental Management Project, HANF = Hanford, INEL = Idaho National Engineering Laboratory, LRES = liquid residual, PROD = product, SIZE = size reduction, SOLIDIFI = solidification, SRES = solid residual, and SUPERCOMPACT = super compaction.

[b] Number refers to the sequence of treatment modules in the treatment train.

TABLE II
Partial ANL WASTE_MGMT Computational Model Output File of LLW Transported Among Sites for a Given Alternative Case

Waste Stream LLW Origin Site AMES Destination Site ORNL	Volume m^3/year 1.09E+01	Mass kg/year 2.98E+04
	Radionuclide	Activity Ci/yr
	Tl-208	4.22E-07
	Pb-212	1.11E-06
	Bi-212	1.11E-06
	Po-212	7.20E-07
	Po-216	1.11E-06
	Ra-224	1.11E-06
	Ra-228	6.68E-06
	Ac-228	6.68E-06
	Th-228	1.11E-06
	Th-231	6.43E-06
	Th-232	6.77E-05
	Th-234	8.24E-03
	Pa-234	8.44E-07
	Pa-234m	8.24E-03
	U-235	6.40E-06
	U-238	8.24E-03
	Pu-238	6.50E-04
	Pu-239	4.96E-05
	Pu-240	1.73E-04
	Pu-241	2.39E-02
	Am-241	9.93E-07
	Cm-242	1.39E-05
	Cm-244	4.96E-06

For TRUW, some of the cases being analyzed for the EM PEIS require treatment according to Land Disposal Restrictions, which are similar to the restrictions imposed on LLMW. For these cases, an approach similar to that used for the LLMW cases is being used to evaluate the TRUW cases. Other TRUW cases require either no or minimal treatment to satisfy the Waste Isolation Pilot Plant (WIPP) waste acceptance criteria or an intermediate level of treatment to limit the generation of gas following emplacement in the WIPP. The same approach is being used to evaluate these cases as outlined for LLW.

Because the number of sites involved and the number of cases that need to be analyzed for HLW, HW, and GTCC wastes are relatively few compared to the other three waste types, the WASTE_MGMT model has not been used to evaluate the alternatives for these waste types. Plans exist to incorporate the data for these waste types into the format required by the WASTE_MGMT computational model and to use the model in any future analyses.

Plans also exist to automate the linkages from the WASTE_MGMT computational model to the transportation risk assessment and facility accident analysis models developed at ANL. The WASTE_MGMT model has been designed to accommodate other facility- or site-specific unit operations factors, such as resource requirements (resource required per unit of waste processed), unit cost factors (cost per unit of waste processed), and unit-risk factors (risk per unit of contaminant released). Most of these factors are either already available or will be available when the Draft EM PEIS is completed. Use of these factors, in conjunction with the ANL WASTE_MGMT computational model, could provide DOE decision makers with a valuable strategic planning tool.

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TABLE III
Partial ANL WASTE_MGMT Computational Model Output File for a Given Alternative Case

Waste Stream LLW Site AMES		
PACKAGING	Thoughput Volume m^3/year 1.06E + 01	Throughput Mass kg/year 2.99E + 04
Radionuclide	Throughput Activity Ci/yr	Air Release Ci/yr
Tl-208	4.50E-07	1.93E-14
Pb-212	1.19E-06	5.12E-14
Bi-212	1.19E-06	5.12E-14
Po-212	7.68E-07	3.30E-14
Po-216	1.19E-06	5.12E-14
Ra-224	1.19E-06	5.12E-14
Ra-228	7.12E-06	3.06E-13
Ac-228	7.12E-06	3.06E-13
Th-228	1.19E-06	5.12E-14
Th-231	6.86E-06	2.95E-13
Th-232	7.23E-05	3.11E-12
Th-234	8.79E-03	3.78E-10
Pa-234	9.01E-07	3.87E-14
Pa-234m	8.79E-03	3.78E-10
U-235	6.83E-06	2.93E-13
U-238	8.79E-03	3.78E-10
Pu-238	6.94E-04	2.98E-11
Pu-239	5.30E-05	2.27E-12
Pu-240	1.85E-04	7.97E-12
Pu-241	2.55E-02	1.09E-09
Am-241	1.06E-06	4.55E-14
Cm-242	1.48E-05	6.38E-13
Cm-244	5.30E-06	2.27E-13