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IMPACTS-BRC: THE MICROCOMPUTER VERSION*

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IMPACTS-BRC: THE MICROCOMPUTER VERSION*

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ABSTRACT

The IMPACTS-BRC computer code was designed for use by the Nuclear Regulatory Commission and industry to evaluate petitions to classify specific waste streams as below regulatory concern (BRC). The code provides a capability for calculating radiation doses to a maximal individual, critical group, and the general population as a result of transportation, treatment, disposal, and post-disposal activities involving low level radioactive waste. Since IMPACTS-BRC is expected to be widely used, the code has been adapted for use on a microcomputer. The microcomputer version of the code provides several features that simplify its use and broaden its applicability. These features include (1) a menu-driven environment, (2) an input editor to simplify creation and editing of input files, (3) default input values and help screens to guide the user in analyzing a particular problem, (4) the ability to perform both parametric studies and Monte Carlo analysis to examine uncertainties, and (5) interactive graphics and statistics output. This paper describes the microcomputer version of IMPACTS-BRC and illustrates its use through an example application.

INTRODUCTION

Section 10 of the Low-Level Radioactive Waste Policy Amendments Act (LLRWPAA) of 1985 mandated that NRC establish policy and procedures for acting on petitions to classify very low-level radioactive waste streams as being below regulatory concern (BRC). In fulfillment of the LLRWPAA mandate, the NRC published in the Federal Register of August 29, 1986, a policy statement and staff implementation plan providing guidance for submittal of rulemaking petitions under 10 CFR 2.802. Included in the LLRWPAA policy statement was the requirement that the NRC use the IMPACTS-BRC computer code to evaluate petitions to exempt very low-level radioactive waste streams from NRC regulations. The NRC Commissioners are currently in the process of approving a broader NRC exemption policy that includes

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all commission regulated practices that involve minimal public health and safety impacts. Disposal of very low-level radioactive waste; the release for unrestricted public use of lands and structures with residual levels of radioactivity; the distribution, use and disposal of consumer products containing small amounts of radioactive material, and the recycle and reuse of residually contaminated materials and equipment are examples of classes of practices for which this policy may be applicable.

The Commissioners intend to establish an individual and collective dose limit as a floor below which further cost-risk reductions are not required in order to make a decision regarding the acceptability of a BRC exemption. The dose limits being discussed are 10 mrem/yr to an individual and 1000 person-mrem/yr to the surrounding population.

IMPACTS-BRC OVERVIEW

IMPACTS-BRC is a radiological assessment code that calculates annual radiological impacts to the maximal individual, critical groups, and the general population from transportation, treatment, disposal, and post-disposal activities involving very low-level radioactive waste (Oztunali and Roles, 1984). Impacts are calculated for multiple waste streams and pathways depending on the input data and the treatment and disposal options specified by the code user. Included within the disposal options is the ability to calculate impacts from sorting and/or recycling of metal containers and metal and glass materials.

Generic (default) environmental and population parameters are developed from typical data representing three geographical locations in the country. The sites include a humid site in a highly populated area (Northeast), a humid site in a moderately populated area (Southeast), and a semiarid site in a low populated area (Southwest). Facility design, operational, and personnel parameters are representative of data from typical treatment (incineration) and disposal (landfill) facilities. A small incinerator is considered for on-site incineration and a much larger municipal or hazardous waste (HW) incinerator is considered for off-site incineration. Since waste generation rates and disposal options differ for municipal solid waste and EPA defined hazardous waste, a distinction is made between disposal of radioactive waste in a municipal sanitary landfill and "mixed" waste in a hazardous waste landfill. The code distinguishes between two levels of operation for HW landfills. HW Type II landfills represent a higher level of performance and environmental characteristics based on experience and improved disposal technologies (lower groundwater impacts); HW Type I landfills represent average performance and environmental characteristics (higher groundwater impacts). Each scenario provides the user with the option of (1) incineration and disposal or (2)

disposal only (waste disposed in its generated form).

The five treatment and disposal options considered by the code are as follows:

1. On-site incineration and off-site disposal in a municipal landfill

2. Off-site municipal incineration and off-site disposal in a municipal landfill (includes sorting and recycle options for metal containers and metal and glass materials)

3. On-site incineration and off-site disposal in a hazardous waste (HW) Type II landfill (includes metal package recycle option)

4. Off-site HW incineration and off-site disposal in a HW Type I landfill (includes metal package recycle option)

5. Off-site HW incineration and off-site disposal in a HW Type II landfill (includes metal package recycle option)

The code calculates radiological impacts based on the waste treatment and disposal scenario and processing options as specified by the user. The selection of a particular scenario has significant influence on the calculated impacts, since there are a number of differences in the design, operation, and personnel requirements for the various treatment/disposal facilities.

Each scenario represents a complex series of release-transport-pathway combinations. The pathway dose conversion factor concept, developed in support of the 10 CFR 61 Environmental Impact Statement, is used to describe these various radionuclide release-transport-pathway combinations. The generalized approach to calculating potential radiological impacts to an individual from a given release scenario and a given BRC waste stream is as follows:

$$H = \sum_{i} \sum_{n} C_{in} \times I_{in} \times PDCF_n$$

where:

H = the dose rate (mrem/yr) to the individual.

C_{in} = the effective concentration (Ci/m^3) of radionuclide n in waste stream i.

I_{in} = a dimensionless interaction factor relating the conc. of radionuclide n in waste stream i to the conc. of the radionuclide at the biota access location (includes time delay, site design, waste form and package, and site selection factors)

$PDCF_n$ = the pathway dose conversion factor (mrem/yr per Ci/m^3) for radionuclide n.

The PDCFs are constructed assuming a combination of fundamental dose conversion factors (DCFs), human actions, and parameters typical of most environmental conditions. Seven PDCFs are defined in the code based on seven different

environmental pathways.

Equations used to calculate the PDCFs adopt the following generic form:

$$PDCF_{irs} = \sum_{p=1}^{N} C_{ips} F_{ips} DCF_{irp}$$

where:

$PDCF_{irps}$ = the pathway dose conversion factor (50-year dose commitment in mrem/yr) specific to nuclide (i), organ (r), pathway (p), and scenario (s);

N = the total number of pathways in the scenario;

C_{ips} = the concentration (Ci/m^3) of nuclide (i) in the medium of pathway (p) via scenario (s);

F_{ips} = the pathway usage factor of nuclide (i) of pathway (p) via scenario (s) which is considered in the calculation of the accumulated radiation dose to man, and;

DCF_{irp} = the fundamental dose conversion factor, a value specific to a given nuclide (i), pathway (p), and organ (r) which is used to calculate radiation dose commitments.

Five sets of fundamental dose conversion factors (DCFs) are used to represent different exposure pathways. These include two internal DCFs (50-year committed inhalation and ingestion) and three sets of DCFs for direct radiation exposure applications. The last three DCFs depend upon the particular biota access location considered, and include factors for volume contamination of soil (mrem/yr per pCi/m^3), surface contamination of soil or other materials (mrem/yr per pCi/m^2), and air immersion (mrem/yr per pCi/m^3). The values of these fundamental DCFs are a function of the radionuclide of concern, the solubility class, and the organ receiving the dose.

The fundamental DCFs, PDCFs and impact calculations are given in terms of eight body organs (lung, stomach wall, lower large intestine wall, kidneys, liver, red marrow, bone surface, and thyroid) plus the "committed effective dose equivalent." The calculation of the committed effective dose equivalent is based on ICRP 26 and 30 methodology.

CODE MODIFICATIONS

Typically, radionuclide concentrations or radiation levels from the material to be released from regulatory control are the actual measurements that can be made, and doses are then estimated by exposure pathway analysis using assumptions related to the ways in which people might become exposed. These assumptions usually incorporate sufficient conservatism in modeling to account for uncertainties so that the actual dose would be expected to be lower than the calculated dose. However, as dose limits have decreased, there is a greater chance that conservative parameters will erroneously predict values that infringe upon or exceed regulatory limits. IMPACTS-BRC has been modified to

allow the user to replace default parameters with more realistic values that are bounded with uncertainty limits. The modified software (named IMPACTS-PC) provides all the capabilities of IMPACTS-BRC while also allowing the user to perform uncertainty and sensitivity analyses. Major features of IMPACTS-PC are described below.

IMPACTS-PC is no longer a single computer code but is instead a suite of four computer codes. The structure of the software package is shown in Figure 1.

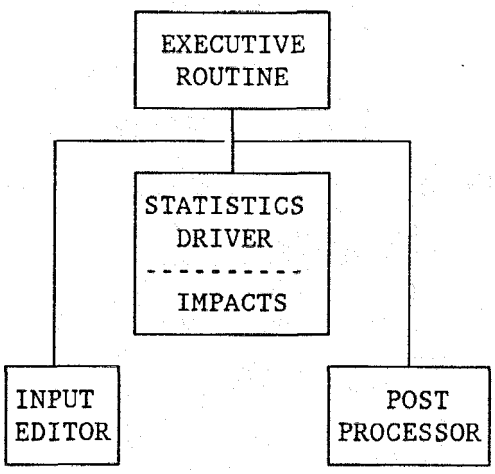

Figure 1. Structure of IMPACTS-PC Software

The primary function of the EXECUTIVE ROUTINE is to direct program execution to the appropriate module based upon the current status of input and output files and menu options selected by the user. The EXECUTIVE ROUTINE also performs the major file management functions and provides other utilities such as allowing the user to print the input file or modify screen colors.

The INPUT EDITOR provides a menu-driven facility for creating and editing IMPACTS input files. The input prompts and help screens substantially reduce the need for user reference to an input manual. Figure 2 shows an example input screen. This screen allows the user to specify variable distributions for certain waste management facility properties. The user can also specify variable distributions for regional properties (e.g., infiltration rates and groundwater travel times) as well as waste stream properties including radionuclide concentrations. The types of available distributions are shown on the bottom left of the screen. Input distributions can be sampled using either Monte Carlo or the efficient Latin Hypercube Sampling technique (Iman and Conover, 1980). If desired, the user can specify correlations among input variables. In this case IMPACTS-PC uses a technique developed by Iman and Conover, (1989) to induce the requested correlations in the sampled values.

The STATISTICS DRIVER performs the statistical sampling and serves as a driver for the IMPACTS code. The normal (deterministic) IMPACTS results are directed by the STATISTICS DRIVER to an ASCII disk file that can be viewed or printed at the user's convenience. Other output (statistical results and time-dependent groundwater impacts) are written to a binary disk file for use by the POST PROCESSOR.

EDIT VARIABLE GROUP --FACILITY INFORMATION

VARIABLE	MINIMUM	BEST EST.	MAXIMUM	DISTRIB.
Atms. Disp. Fact.-Elev.(u/m^3)		1.600E-13		Fixed
Exp. Duration Fact.-Inc.		.333		Fixed
Atms Disp Fact/G Level (u/m^3)		9.100E-11		Fixed
Exp. Duration Fact.-Ops.		.333		Fixed
Waste-Air Transfer Fact.-Inc/L	3.700E-12		3.700E-10	LogNormal
Waste-Air Transfer Fact.-Inc/M	7.410E-12		7.410E-10	LogNormal
Waste-Air Transfer Fact.-Inc/H	1.480E-11		1.480E-09	LogNormal
Waste-Air Transfer Fact.-Ops/L		1.700E-11		Fixed
Waste-Air Transfer Fact.-Ops/M		3.390E-11		Fixed
Waste-Air Transfer Fact.-Ops/H		6.700E-11		Fixed
Exp. Area-Off Site Rel.(m^2/d)		86		Fixed
Exp. Area-Eq Ops/Unpkg (m^2/d)		71		Fixed
Exp. Area-Others (m^2/d)		15		Fixed
Cover Mixing Efficiency		.59		Fixed
Waste Emplacement Efficiency		.8		Fixed

Fixed Triangular Edit distribution parameters for variable data.
Normal Uniform Hit Esc to continue.
LogNormal LogUniform

Figure 2. Example Input Screen

The POST PROCESSOR provides statistical results including minimum, maximum, mean and standard deviation values. Also available are simple and partial correlations between input and output values. Correlations between input and output values help identify those input variables that have the greatest influence on output uncertainties. Available graphical results include cumulative and complementary cumulative distribution functions, histograms, scatter plots and x-y plots. The user can also examine the numerical values of the various outputs on the screen. The available output options are illustrated in the example problem below.

EXAMPLE PROBLEM

The example problem assumes waste to be treated and disposed in a municipal incinerator and sanitary landfill facility located in the Southeast region of the country. The example problem uses the default environmental and facility parameters as in the original code. Two waste streams are considered. Waste stream 1 consists primarily of gamma emitters to affect the transportation impacts; waste stream 2 consists of mainly alpha emitters to affect incineration impacts. While the regional and

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facility properties are realistic to conservative, the radionuclide concentrations of the waste streams are purely fictional and are used for illustration only. Thus, this example problem serves primarily to illustrate the outputs available from IMPACTS-PC. Each run of IMPACTS-PC produces the same deterministic results as the original code using best-estimate input values provided by the user. In addition, if requested by the user, IMPACTS-PC produces statistical results by performing repeated trials using input variable distributions provided by the user. Both types of results were produced for the example problem. In all instances where input quantities were assigned a variable distribution for statistical calculations, the assigned range of values encompassed the best-estimate value used in the deterministic calculations. The remaining discussion will focus on two specific impacts: dose to the maximally exposed individual mainly from transportation of waste stream 1 (TR-MAX) and dose to the maximally exposed worker mainly from incineration of waste stream 2 (IN-MWR).

Table 1 compares results of the deterministic (best-estimate) calculations with results from the statistical calculations.

If these results were part of a BRC petition, the deterministic results might lead one to conclude that TR-MAX from waste stream 1 is acceptably below the regulatory limit of 10 mrem/yr, whereas IN-MWR from waste stream 2 appears to exceed the limit slightly. However, the results of the statistical calculations indicate that TR-MAX has a mean value of 6.76 and a maximum value of 37.9 mrem/yr, whereas IN-MWR has a mean of 1.54 and a maximum value of 11.7 mrem/yr. Clearly these two impacts bear further investigation.

Table 1

Comparison Between Best Estimate and Statistical Results

	Best Est.	Min.	Max.	Mean	Std. Dev.
TR-MAX	1.18	0.77	37.9	6.76	5.47
IN-MAX	10.7	0.07	11.7	1.54	1.73

Figures 3 and 4 show complementary cumulative distribution functions (ccdf's) for TR-MAX and IN-MWR. A ccdf shows the probability of the plotted variable exceeding the value along the horizontal axis. Thus, it appears that TR-MAX exceeded 10 mrem/yr in about 20% of the trials, whereas only 1 trial out of 200 exceeded 10 mrem/yr for IN-MWR.

Simple and partial correlation coefficients help identify those input variables that have the strongest influence on output uncertainties (Iman, et. al., 1985). The simple correlation coefficient measures the strength of a linear relationship between a dependent (output) variable and a given independent (input) variable. The simple correlation does not account for the fact that several other input variables are varying simultaneously. The

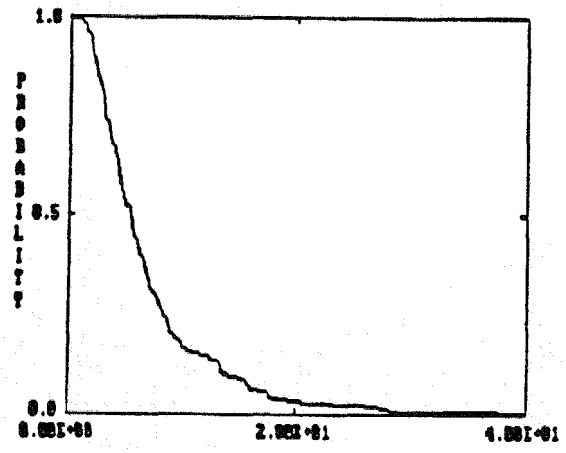

Figure 3. Transportation Impacts
Maximum Individual (mrem/yr)

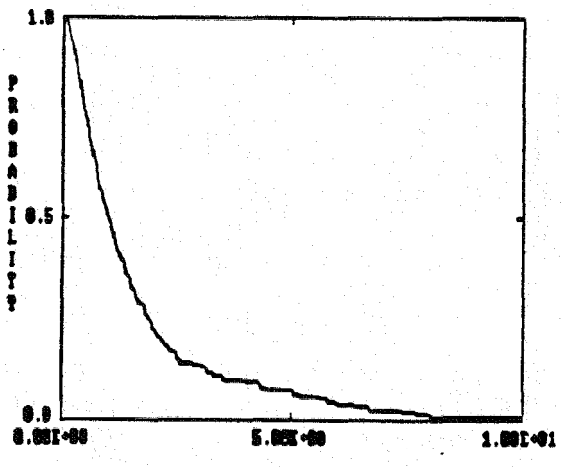

Figure 4 Incineration Impacts
Maximum Worker (mrem/yr)

partial correlation, on the other hand, attempts to subtract out the effects of other input variables to indicate the strength of a linear relationship between an output variable and a specific input variable. Simple and partial correlation on ranks are presented in Tables 2 and 3 for TR-MAX and IN-MWR. The rank transformation is applied before correlations are calculated because this transformation linearizes any monotonic relationship between independent and dependent variables. For a detailed discussion on the rank transformation see Conover and Iman (1981). The results presented in Table 2 indicate that the isotopic concentration of Co-60 is the most important imput variable for TR-MAX followed by the concentrations of Cs-137 and Co-58. To further illustrate the relationship between the concentration of Co-60 and TR-MAX, Figure 5 presents a scatter plot between these two quantities. The strong influence of the concentration of Co-60 on TR-MAX is apparent in this figure.

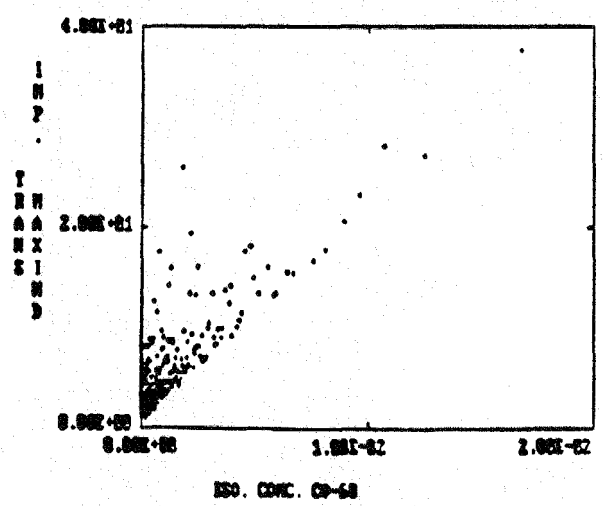

Figure 5 Scatter Plot
Concentration Vs Dose

If such results were presented as part of an actual BRC petition, a

Table 2. Correlation Coefficients
Transportation Impacts MAX. IND.

CORRELATION COEFFICIENTS

RANK	NAME	PARTIAL	SIMPLE
1	ISO. CONC. CO-60	0.86	0.74
2	ISO. CONC. CS-137	0.63	0.35
3	ISO. CONC. CO-58	0.62	0.36
4	ISO. CONC. CO-57	0.12	0.06
5	Site Fact.- Water/Ers (u/m^3)	0.11	0.02
6	Pop Fact.- Air/Ers (per-u/m^3)	0.11	0.05
7	Avg. Wind Vel. @ Fac. (m/s)	-0.08	-0.05
8	Pop Fact.- Air/Ops (per-u/m^3)	-0.07	-0.03
9	Dust Mob. Rate-Ers (g/m^2/s)	-0.05	-0.00
10	Waste-Air Transfer Fact.-Inc/L	0.04	0.04

TOP 10 COEFFICIENTS FOR THE SELECTED VARIABLES

Table 3. Correlation Coefficients
Incineration Impacts MAX. WKR.

CORRELATION COEFFICIENTS

RANK	NAME	PARTIAL	SIMPLE
1	Waste-Air Transfer Fact.-Inc/H	0.75	0.50
2	ISO. CONC. PU-242	0.74	0.48
3	ISO. CONC. PU-239	0.74	0.49
4	ISO. CONC. PU-236	0.42	0.23
5	Waste-Air Transfer Fact.-Inc/M	0.35	0.17
6	GW Travel Time-Intr. Well (y)	-0.19	-0.06
7	Pop Fact.- Air/Ops (per-u/m^3)	-0.16	-0.05
8	Waste-Air Transfer Fact.-Inc/L	0.12	0.05
9	ISO. CONC. PU-241	0.11	0.06
10	ISO. CONC. CM-242	-0.09	-0.03

TOP 10 COEFFICIENTS FOR THE SELECTED VARIABLES

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clear need would be indicated for better information on the concentrations of Co-60, Cs-137, and Co-58.

Table 3 shows correlations calculated for IN-MWR. In this case, the most important input variable is the waste-to-air transfer factor for incineration followed by the concentrations of Pu-242 and Pu-239.

SUMMARY

The IMPACTS-BRC computer code was designed for use by the Nuclear Regulatory Commission and industry to evaluate petitions to classify specific waste streams as below regulatory concern (BRC). Default environmental and facility parameters provided with the code are quite conservative to ensure that actual doses from treatment and disposal of the wastes would likely be below calculated dose levels. However, as dose limits have decreased, there is an increasing possibility that conservative input parameters will erroneously predict doses that could exceed regulatory limits.

A microcomputer version of the code (IMPACTS-PC) has been developed to address this concern. IMPACTS-PC provides the same deterministic outputs as IMPACTS-BRC. In addition, IMPACTS-PC uses Monte Carlo techniques to quantify uncertainties in predicted doses and to identify those input parameters that make the greatest contributions to these uncertainties. IMPACTS-PC provides a menu-driven user environment, input help screens, and interactive statistics and graphics output.

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