# ESTIMATING WASTE DISPOSAL QUANTITIES FROM RAW WASTE SAMPLES

C.A. Negin
C.S. Urland
Grove Engineering, Inc.
Washington Grove, MD 20880

C.G. Hitz
GPU Nuclear Corporation
Middletown, PA 17017

ABSTRACT

Estimating the disposal quantity of waste resulting from stabilization of radioactive sludge is complex because of the many factors relating to sample analysis results, radioactive decay, allowable disposal concentrations, and options for disposal containers. To facilitate this estimation, a microcomputer spread sheet template was created. The spread sheet has saved considerable engineering hours.

## INTRODUCTION

A significant challenge at Three Mile Island Unit 2 (TMI-2) is planning for the disposal of radioactive materials normally not encountered at power plants. The unusual nature of the materials includes their physical form (for example, sludges, silt, cork, metal component with thermally embedded contaminants, resin beds with fuel fines), the type of contamination (predominantly Cs-137, Sr-90), and the potential for transuranic (TRU) isotopes.

Some of these wastes are potentially "abnormal" (i.e., not suitable for commercial shallow land disposal) primarily because the concentration of transuranics in TMI-2 wastes is greater than at other plants. There is a need to identify wastes as potentially abnormal as soon as sample results are available to determine if special disposal action is required. Since there is an agreement for the U.S. Department of Energy (DOE) to dispose of abnormal waste, on a cost reimbursable basis, it is important to know which material is candidate for such disposal. For those wastes that are commercially disposable, it is important to provide early estimates of the total quantity and number of shipments considering packaging form and size, and waste loading per package.

Planning for the disposal of these materials requires radioisotopic characterization of samples or direct spectrographic analysis. From this information, the quantities of waste that will result are estimated. Estimating disposal quantities is complex because one must simultaneously consider 1) a variety of regulated waste disposal limits for several nuclides, 2) volumes and densities of the final waste form, and 3) inference of the amounts of difficult-to measure nuclides. Decisions on how to package wastes involve a variety of container sizes and whether to use solidification or high-integrity containers to achieve waste stability requirements.

Performing such estimates with a calculator or slide rule will require about a day per sample or group of samples, will be subject to tedium error, and, in order to evaluate options, will have to be conducted several times. Because of the complexity, a microcomputer spread sheet was developed to implement a method for estimating waste disposal quantities from raw waste sample results. ("Raw" refers to wastes before processing and packaging for disposal.)

The application is ideally suited for computerized spread sheet because:

- o A spread sheet is easy to program and modify
- o A spread sheet can be modified "on the fly" during an evaluation, for example, adding an isotope not previously reported in sample analysis results
- o Options can be readily evaluated by executing several cases
- o Sensitivities can be readily evaluated by varying input or built-in values
- o A template can be established and replicated for each case or set of cases

This was done on an Apple LISA desktop computer. The formulas can be entered in any of several other spread sheets such as Lotus, Multiplan, Visicalc, etc.

We emphasize that this is a planning tool. Shipping and disposal certifications are based on individual package analysis at the time of packaging. Certification at GPU Nuclear uses mainframe computer codes specifically designed for 10CFR compliance and approved by the NRC.

## TECHNICAL APPROACH

The overall technical approach is to compare the concentrations of important radionuclides in a sample to the allowable burial concentrations, considering:

- o Burial concentration limits, by group and by category
- o Scaling factors that are used to infer quantities of radionuclides which cannot be easily measured

- Radioactive decay of the scaling nuclides between the date of scaling factor determination and the date of sample analysis
- Density of the solids in the sludge sample
- Density of the final waste form, solidified or dewatered
- The sum-of-the-fractions method for determining proximity to the limits

The desired results for estimated quantities are the minimum final solidified product volume per unit weight, or volume, of the solids in the sample (i.e., "raw" waste) and the quantity of raw waste per disposal package. Four ratios of interest are:

- Volume of shipped product per unit volume of raw waste
- Volume of shipped product per unit weight of raw waste
- Volume of raw waste per disposal package
- Weight of raw waste per disposal package

## IMPLEMENTATION: SPREAD SHEET INPUT

The features of the spread sheet are diagrammed in Fig. 1. User inputs include:

1) sample identification,

2) the analysis date for decay correction of scaling factors (Scaling factors are based on either previous samples or ORIGEN computer runs which reference the core fission product and transuranic inventory on the day of the accident.),

3) assumptions for raw waste density, processed waste density, and packaged volumes, and

4) the results of the waste sample radioisotopic analysis.

An example of spread sheet input is shown in Fig. 2.

## IMPLEMENTATION: SPREAD SHEET CALCULATIONS

### Scaling of Nuclides

The concentrations of difficult to measure radionuclides are calculated with the use of scaling factors. For example, Ni-63 is inferred (i.e., scaled) from measured concentration of Co-60, which is routinely reported in sample results. The scaling factor is based on previous analyses where the Ni-63 was measured. Because Ni-63 decays very slowly relative to Co-60, the scaling factor for Ni-63 will increase as Co-60 decays. The justification for scaling nickel from cobalt has been established by the Electric Power Research Institute (EPRI) as well as others.

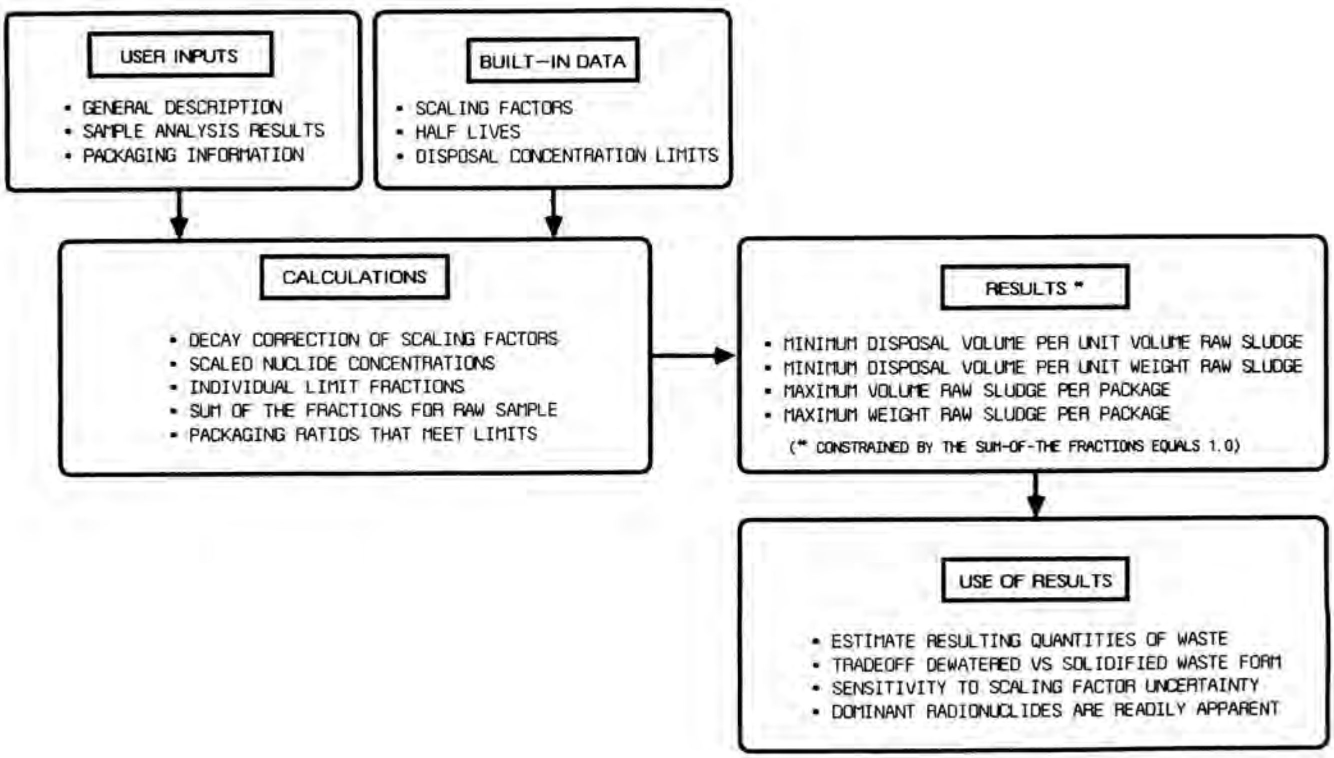


Fig. 1. Spread sheet features and use.

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SPREAD SHEET TO CALCULATE WASTE DISPOSAL VOLUME
 AND PACKAGING EFFICIENCY FROM SAMPLE ANALYSIS
        (C.A. Negin, C.S Urland...11/84)

              <<< INPUTS >>>
     ** SAMPLE GENERAL INFORMATION **
   Sample location ---------------------------->   OPEN
         "         ----------------------------> STAIRWELL
   Sample taken date-------------------------->  6/23/82
   Sample analysis date for decay correction-->  8/30/82
   Sample analysis laboratory----------------->  WHEDL
        ** WEIGHT AND VOLUME INPUT **
Enter solids density (g/cc for solids) ----------->  1.2
Enter solidified waste specific gravity --------->  1.6
Enter minimum binder/waste volume ratio --------->  .50
Enter usable cubic feet per disposal package ---->   40

     ** RADIONUCLIDES IN SAMPLE (uCi/gm) **
       Enter concentration of Mn-54t ----------->       .53
||||||||||||||||||    "     Co-58t ----------->
|                |    "     Co-60t ----------->    114.20
| t indicates    |    "     Sr-90  ----------->   4900.00
| nuclides with  |    "     Ru-106t ---------->     35.90
| half lives     |    "     Ag-110t ---------->       .80
| less than 5 yrs|    "     Sb-125t ---------->    136.00
|                |    "     Cs-134t ---------->    173.00
||||||||||||||||||    "     Cs-137 ----------->   2032.00
                      "     Ce-144 ----------->     44.00
Enter all other nuclides with half life < 5 yrs-->
Enter assumed or measured C-14 ------------------>     0.0
Enter assumed or measured H-3 ------------------->     0.0

            **TRANSURANICS**
Enter EITHER nCi of Pu-239 & 240/gm of sample --->
                 OR nCi of U-238/gm of sample---->   1.2523
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Fig. 2. Spread sheet input.

For samples in which a direct measure is reported for a nuclide that normally would be scaled, the measured value can be entered directly in the spread sheet cell that has the scaling formula for that nuclide.

Transuranic concentrations are scaled in three ways to allow comparison of results. Scaling is based on measurements of U-238 or Pu-239 plus Pu-240 or Ce-144. This redundancy is needed for two reasons. First, sample analysis results from different laboratories may report uranium or plutonium or both. Second, scaling from Ce-144 cannot always be trusted. (For example, experience at TMI-1 is that cerium can be indicated where there are essentially no transuranics or much less than scaling would project.) This is especially the case for trace quantities of transuranics.

By comparing results of transuranic scaling from two different radionuclides at the planning stage, one can gain insights regarding the validity of the information. Because the categorization of waste is very sensitive to small quantities of transuranics, understanding the uncertainties is important.

Individual Fractions

Ratios of individual nuclide concentrations to their disposal limit concentrations are calculated. This provides terms for the later sum-of-the-fractions. Displaying these individual fractions allows observation of which nuclide is controlling. That is, the higher individual fractions are more important. It can also provide insights as to the validity of the sample analysis relative to other analyses of the same material. An example of the spread sheet display is shown in Fig. 3.

Sum-of-the-fractions

Individual fractions are then summed, by group and category, to obtain a "sum-of-the-fractions" for the raw waste sample. This is an intermediate result, as solidification and/or packaging will usually reduce the nuclide concentrations for disposal qualification.

When the sum-of-the-fractions is greater than 1.0 for all groups and categories, it will be necessary to assess credit for the weight and volume of the as-packaged form. The four ratios shown in Fig. 1 as Results are then calculated using the input densities and package volumes. Only the worst-case results are displayed (that is, the most limiting nuclide group and the highest concentrations).

IMPLEMENTATION: APPLICATION EXAMPLES

Three examples of the use of this tool are:

Auxiliary Building Sump Sludge

The auxiliary building sump at TMI-2 received a wide variety of inflows (e.g., from floor drains and overflowing tanks) during the accident and subsequent decontamination of the building. Two samples of the sump were analyzed for cesium, strontium, and plutonium.

The spread sheet results indicated that: 1) the raw sample concentrations are Category C; 2) the Group 1 short-lived nuclides are controlling; and 3) in both cases, Cs-137 is dominant. The variations between the two samples do not change the conclusions. A summary of the results is shown in Table I. The concentration

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              <<< DISPOSAL CALCULATIONS >>>              OPEN
                                                      STAIRWELL
        ** INDIVIDUAL FRACTIONS FOR RAW SAMPLE **
Category A       <5yrs & Co-60                              .86
Category A       H-3                                        0.0
Category A       Ni-63                                    27.66
Category A       Sr-90                                147000.00
Category A       Cs-137                                 2438.40
Category A/B     C-14                                       0.0
Category A/B     Tc-99                                     1.23
Category A/B     I-129                                      .11
Category A/B     Pu-238 & 239 & 240                       57.25
Category A/B     Pu-241                                  223.78
Category A/B/C   Am-241                                    4.76
Category A/B/C   Cm-242                                     .03
Category B       Ni-63                                     1.38
Category B       Sr-90                                    39.20
Category B       Cs-137                                   55.42
Category C       Ni-63                                      .14
Category C       Sr-90                                      .84
Category C       Cs-137                                     .53
Category C       C-14                                      0.0
Category C       Tc-99                                      .12
Category C       I-129                                      .01
Category C       Pu-238 & 239 & 240                        5.73
Category C       Pu-241                                    2.24

        ** SUM OF THE FRACTIONS FOR RAW SAMPLE **
                           Group 1: Category A   149466.92
                                    Category B       96.00
                                    Category C        1.51

                           Group 2: Category A      287.16
                                    Category B      287.16
                                    Category C       12.89
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Fig. 3. Spread sheet sum-of-the-fractions.

in the waste will be controlled by the cement-to-waste ratio, and for the assumed value of 50% cement, about 1300 pounds of waste can be solidified in a 40 cubic-foot container.

TABLE I

Auxiliary Building Sump Sludge

| Sample # | Raw Waste Sum-of-the-fractions | | Maximum Pounds Raw Waste per Container | |
|---|---|---|---|---|
| | Category B | Category C | Category B | Category C |
| 1 | 15.3 | .23 | 173 | 1323 |
| 2 | 7.2 | .09 | 357 | 1323 |

Reactor Building Basement Sediment

Six analyses of the TMI-2 reactor building basement sediment were obtained between June 1982 and December 1983. The sources of the sediment were silt from the introduction of river water (as a result of containment air cooler relief valve operation), particles of fuel in the reactor coolant delivered to the basement (as a result of the rupture disk operation on a drain tank that receives the pressurizer relief valve discharge), and pre-accident cement dust and floor dirt.

The results of the analyses vary considerably with respect to nuclide content. The variation is undoubtedly real, as these are very small samples taken over a very large area. The spread sheet results shown in Table II indicate that a range of between 300 and 1500 pounds of sediment can be packaged in a 40 cubic-foot liner and the package will remain within disposal limits. It is judged that of the order of 1000 pounds of sediment is in the basement. This translates into two or three packages if all the material is first collected and homogenized before solidification.

TABLE II

Reactor Building Basement Sediment

| Sample Location | Category C Raw Waste Sum-of-the-fractions | Maximum Lbs. Raw Waste per Container |
|---|---|---|
| Open Stairwell #1 | 12.9 | 308 |
| Open Stairwell #2 | 9.9 | 404 |
| Covered Hatch | 0.2 | 1498 |
| N.E. Quadrant | 0.05 | 1498 |
| S.W. Quadrant | 3.8 | 1053 |
| Sump Pump | 9.1 | 440 |

Control Rod Drive Leadscrews

The control rod drive leadscrews are 12-foot long threaded rods that connect the control rod drive motors to the absorber section of the control rods. Three control rod drive leadscrews were removed from the TMI-2 reactor vessel head to allow access for video inspection of the damaged core in advance of head removal. Most of the removed leadscrews were shipped off site for analysis.

One segment of leadscrew retained at TMI-2 has a 30 R/hr contact radiation level. This leadscrew section presents a unique disposal problem: high transuranic contamination is fixed to the surface as a result of high temperature exposure to the degraded core materials during the accident.

Although it is not sludge, nevertheless, this leadscrew section is amenable to analysis using the spread sheet. The input was determined by assuming the measured activity on the surface was distributed throughout the volume.

Two methods of packaging were evaluated: 1) cement encapsulation in a 55-gallon drum, and 2) cement encapsulation in a 40-cubic-foot container. For each package, the transuranic concentration was determined via direct measurement of Pu-239 and Pu-240, and comparison of these results to scaling from Ce-144.

The results are shown in Table III and are expressed as pounds of leadscrew per package. Since the section of leadscrew weighs about 7 pounds, cement encapsulation in a 55-gallon drum was recommended as the preferred disposal method. Although it is observed that the cerium scaled results are a factor of three different from the plutonium scaled results, the recommendation does not change.

TABLE III

Control Rod Drive Leadscrew Section

| | Leadscrew Sum-of-the-fractions | | Maximum Pounds Leadscrew per Container | |
|---|---|---|---|---|
| Case | Cat. B | Cat. C | Cat. B | Cat. C |
| **55-gallon Drum** | | | | |
| Ce-144 Scaling | 398.6 | 21.2 | 1.8 | 34.5 |
| Pu Scaling | 160.2 | 8.6 | 4.6 | 85.3 |
| **40 $ft^3$ Liner** | | | | |
| Ce-144 Scaling | 398.6 | 21.2 | 10.0 | 187.8 |
| Pu Scaling | 160.2 | 8.6 | 24.8 | 464.1 |

## WRAP UP

The time invested to develop the spread sheet was regained with the first two applications. It has been, and will continue to be used extensively to evaluate whether waste is "abnormal" and to estimate the resulting quantities of commercially disposable waste. These results are used with other spread sheets for cost estimation, which then supports packaging decisions and budget allocation for waste disposal.

The uses discussed here are TMI-2 specific, however, the method can be readily adapted for other specific applications. It is intended that this spread sheet, along with a more generic version which will calculate the sum-of-the-fractions for any waste, will be published by EPRI in the near future. In the meantime, anyone who wishes to have a copy of the formulas for either of these two spread sheets may obtain them by calling the authors' office (301)258-2727.