SELECTION AND EVALUATION OF POTENTIAL VERY LOW LEVEL WASTES (VLLW) FROM NUCLEAR POWER PLANTS

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ABSTRACT

The disposal of very low level radioactive waste (VLLW) generated at light water reactors presents a significant problem to the nuclear utility industry. The National Environmental Studies Project of the Atomic Industrial Forum has sponsored a study to develop and summarize information on VLLW to support de-regulation of streams that pose a negligible hazard. This paper presents preliminary results of this study, describes the methodology used in selecting candidate streams for detailed analysis, and estimates radiation doses from disposal of these wastes.

The study is divided into several sections which describe (1) the concept of regulatory cutoffs and its application to radioactive waste disposal, (2) the selection criteria for VLLW candidate streams, (3) the selection of candidate VLLW streams for study, (4) the potential disposal methods for VLLW, (5) limiting activities for various threshold dose levels, and (6) preliminary conclusions or recommendations available from the study. The results of the study described will be available as a technical document which can be used in support of a petition for exemption or rulemaking to NRC relating to a particular or generic waste stream.

INTRODUCTION

This report describes work undertaken for the National Environmental Studies Project (NESP) of the Atomic Industrial Forum (AIF). The work is currently in progress with the final report due to be published in about 2 months.

At the present time essentially all low level radioactive wastes from nuclear power plants may be disposed of only by transfer to a licensed disposal facility pursuant to the requirements of NRC Regulations 10 CFR Part 20 and 10 CFR Part 61. Even waste streams that actually contain only extremely small quantities of radioactive material of plant origin, or may contain such materials, are subject to these requirements. Such Very Low Level Wastes (VLLW) do not pose a significant risk to public health, and their treatment as Part 61 Low Level Wastes may impose disproportionate or unwarranted costs on the public.

In the past, and today under certain limited circumstances, NRC has permitted some Very Low Level Wastes to be disposed of by methods other than those specified in 10 CFR Part 61. It has been suggested that additional waste streams or types of wastes could be granted such exemptions, either generically or case-by-case, without compromising public safety, and with resulting substantial savings in financial and manpower resources and in scarce space at licensed radioactive waste burial facilities. NRC has expressed its willingness to consider petitions for rulemaking, and applications for exemption from current waste disposal requirements, on an individual waste stream, case-by-case basis.

The purpose of this study is to review the characteristics of low level waste streams generated in nuclear power facilities, determine which may be suitable for disposal by methods other than transfer to an NRC-licensed facility, and evaluate the benefits, risks, and costs of exempting such Very Low Level Wastes from the disposal requirements of NRC Regulations 10 CFR Part 61. This information would be appropriate for use in support of petitions for rulemaking or exemption requests.

The initial step in carrying out the project was to review the relevant literature to identify sources of information on waste characterization, disposal methods, waste handling operations, dose calculation methodology, handling and disposal cost estimates, and other useful data. Additional information was obtained from discussion with utility personnel responsible for radwaste management and contractors who compiled waste stream data bases. Much of the data were available in machine-readable form and were incorporated into the project data base for further analysis. Two major industry-wide data bases were identified: the NRC-SAI data and EPRI-Impell data. They were reviewed, and relevant data were incorporated into the project data base.

METHODOLOGY

Waste Stream Characterization and Selection

One of the most important parts of this study is the physical, chemical, and radiological characterization of the waste streams that are candidates for disposal by means other than those prescribed in 10 CFR Part 61. The approach used included five major steps: 1) a screening process, including definition of waste streams and information collection, review and evaluation, 2) characterization of the physical and chemical properties of each candidate waste stream, 3) characterization of the radiological properties of each candidate waste stream, 4) determination of expected volumes of each waste considered, and 5) preparation of the data bank and input for further analyses.

Qualitative selection criteria were developed to screen the available radwaste streams, as defined in the reviewed references. These criteria are listed as follows:

1. The quantity of waste produced by the system should be significant, when compared to the total waste generation of the plant.

2. The waste stream should be clearly definable and should be capable of separation from other waste streams.

3. The concentration and activity of the radionuclides should be low when compared to 10 CFR 61 Class A limits.

4. The physio-chemical characteristics of the waste should be compatible with wastes disposed of in conventional disposal facilities.

5. The treatment of candidate VLLW streams should not require major modifications to the facility to qualify as a VLLW.

6. Planned operational changes or plant modifications should not adversely affect the characteristics of the selected streams.

A number of waste streams were screened out for not meeting one or more of these criteria. These streams included the PWR primary cleanup filters, PWR and BWR primary cleanup resin, BWR condensate resin, BWR high purity waste filters, and BWR chemical waste filters. Each of these streams were determined to have radionuclide concentrations above 10 CFR 61 Class A limits.

Waste streams were reviewed to determine relative radionuclide concentrations. The primary source of this information was AIF/NESP-027, which quantifies radionuclide concentrations and compares them to the 10 CFR 61 limits. All waste streams which fell above the Class A limits were eliminated as candidates for this study, and those which fell within the Class A limits were ranked as a function of the percent of the limit. Table I presents this ranking, which is based on data presented in AIF/NESP-027. These waste streams are described in later sections. The ranking, and associated percent of the Class A limit, is not to be taken as an absolute comparison of these streams. It is, however, used to establish priorities for study under the current AIF/NESP project.

TABLE I

Candidate Waste Streams by Function of Class A Limit

Ranking	Waste Stream	% Class A Limit
1	BWR Trash	0.006%
2	PWR Trash	0.33%
3	PWR Steam Generator Blowdown Filter	0.5%
4	PWR Steam Generator Blowdown Resin	1.3%
5	PWR Condensate Resin	2.4%
6	PWR Dirty Waste Evaporator Bottoms	3.3%
7	BWR Low Purity Waste Resin	7.6%
8	BWR Low Purity Waste Filter	7.8%
9	PWR CVCS Evaporator Bottoms	21%
10	BWR High Purity Waste Resin	37%
11	BWR Chemical Waste Evaporator Bottom	53%
12	PWR Dirty Waste Filter	66%

Information was reviewed on the relative volume of candidate VLLW streams generated by the nuclear industry. The waste classification, and associated volume percentages (as a function of total waste generated by the nuclear industry) were compiled in NUREG-0782. This reference was used as the primary source of data, with supporting information provided by other reviewed references. Table II presents the ranking of waste streams by percent of total volume generated by the nuclear industry. The values are averages for the four regions described in NUREG-0782 and are used for comparison only.

TABLE II

Candidate Waste Streams by Percent of Generated Volume

Ranking	Ranking	% Total Volume* (approximate)
1	PWR Compactible Trash (P-COTRASH)	13%
2	BWR Compactible TRASH (B-COTRASH)	7%
3	BWR Concentrated Liquid (P-CONCLIQ)	7%
4	PWR Non-Compactible Trash (P-NCTRASH)	6%
5	BWR Filter Sludge (B-FSLUDGE)	5%
6	BWR Concentrated Liquid (B-CONCLIQ)	5%
7	BWR Non-Compactible Trash (B-NCTRASH)	3%
8	BWR Ion-Exchanger Resin (P-IXRESIN)	1%
9	PWR Ion-Exchanger Resin (B-IXRESIN)	1%
10	PWR Filter Cartridge (P-FCARTRG)	0.6%
11	PWR Filter Sludge (P-FSLUDGE)	0.2%

*for all wastes generated by the nuclear industry

A list of candidate VLLW streams was developed using the screening criteria and waste rankings described in the prior sections. This preliminary list, contained in Table III, uses the studies previously completed as a basis for initial ranking.

TABLE III

VLLW Stream Candidates

Ranking	Waste Stream
1	BWR Compactible Trash (B-COTRASH)
2	PWR Compactible Trash (P-COTRASH)
3	PWR Resins (P-IXRESIN) - Steam Generator Blowdown - Condensate
4	PWR Concentrated Liquid (P-CONCLIQ) - PWR Dirty Waste Evaporator Bottoms - PWR CVCS Evaporator Bottoms
5	PWR Filter Cartridge/Sludge (P-FCARTRG, P-FSLUDGE) - PWR Steam Geneerator Blowdown Filter
6	Contaminated Soil
7	Sandblasting Sand

Site Selection and Waste Stream Concentrations

For each candidate waste stream selected, available methods of disposal were investigated. The major methods considered were burial on the plant site, burial at a public landfill, burial at a hazardous waste disposal site, on-site incineration, incineration at a public or hazardous waste incinerator, and recycle. For each potential waste stream/disposal method combination selected, the parameters that characterize the disposal method and disposal site environment were determined, based on available data from the literature. Since this is a generic study, generalized but realistic site data were used. As part of this task, the input data on waste disposal methods was prepared, to be used in later analyses. The seven waste/disposal method combinations selected involved disposal by burial, either on site or at a sanitary landfill.

As part of the calculation of bounding activities, the inverse of the impact calculation was carried out. That is, for each isotope of interest, in the selected waste stream/disposal method combination, the maximum activity concentration and total annual activity that would result in a specified dose was determined. The results of these calculations were used to refine the selection of suitable waste streams and to indicate the monitoring and measurement capabilities necessary to assure that external dose levels and activity concentrations are acceptable for the disposal method application.

The inverse impact assessment computer program, INVERSE (formerly called INVIMPS), was used to calculate the activities for a unit threshold annual dose equivalent value (1mrem/year). This code, and its companion, IMPACTS, are described in the NRC report NUREG/CR-35855, and are now available to run on mini-computers and micro-computers.

In the INVERSE calculations, a generic sanitary landfill was chosen as the burial site for each of the seven waste streams. This sanitary landfill was chosen to be located in the Southeast region of the United States and approximately twenty miles from the generating site. A single vehicle for transportation of the VLLW was considered. Generic values for this sanitary landfill were then determined and summarized in Table IV. These predetermined generic values were later used to calculate the limiting concentrations for all operational activities (excluding incineration and sorting), ground water migration, and other scenarios such as radiological impacts to individuals residing onsite following facility closure. In addition, volumes, masses, and densities of the seven waste streams were determined and presented in Table V.

Using the sanitary landfill and waste stream values as input, the results of INVERSE computer program calculation listed limiting concentrations of 85 radionuclides for 15 different impact scenarios. Since only those radioactive wastes from the nuclear power fuel cycle were considered, all but 18 radionuclides were eliminated. Twelve of these 18 radionuclides are listed in 10 CFR Part 61 as candidate sources.

TABLE IV

Generic Sanitary Landfill Values

Disposal Site	South East, Rural
Disposal Type	Sanitary Landfill, Burial
Institutional Life	20 Years
Institutional Control	10 Years
City Annual Volume Disposal	2.94×10^4 m^3/yr

TABLE V

Volumes, Masses and Densities of the Seven Waste Streams

Waste Stream Name	Volume (m^3/yr)	Mass (MT/yr)	Density (MT/m^3)
Contaminated Soil	35	39.2	1.12
PWR Compacted Trash	375	300	0.78
PWR Filters	3	1.8	0.6
PWR Evaporator Bottoms	300	200	1.0
PWR Secondary Resins	36	32.4	0.9
BWR Compacted Trash	375	300	0.78
Sand Blasting Sand	311	504	1.62

Six additional radionuclides were also investigated, because they were also being analyzed and reported in NRC-SAI and EPRI-Impell reports.

From the preliminary results of the INVERSE computer calculation presented in Table VI, the following observations have been made.

1. The limiting scenario for a given radionuclide is the same for each waste stream.
2. The most frequent limiting scenario (50%) is leachate overflow (LA-OVF). In this scenario, disposal cell liners were assumed to be installed to prevent the migration of toxic materials out of the waste storage cells and into the aquifer beneath the disposal facility during the life span of the facility. (The same situation could arise from the disposal in highly or moderately impermeable soils which can be found frequently in the eastern U.S.).
3. The next important scenario (22%) is the transportation of high energy gamma emitting radionuclides (TR-MAX or transportation maximum). This scenario calculated the limiting concentrations that would result in a dose of 1 mrem/yr to the driver(s) of the transportation vehicle.
4. The intruder construction scenarios (INT-CO) and the intruder agriculture scenario (INT-AG) comprised the remainder of the limiting scenarios. In the intruder construction scenario, an individual or individuals inadvertently enter the disposal facility some time after the institutional controls have expired. This individual or individuals may excavate, install, and construct buildings which are later occupied. In the intruder agriculture scenarios, it is further assumed that those individuals, involved in the intruder construction scenario, consume food grown in soil contaminated by the decomposed waste excavated and distributed around the facility.

Calculation of Disposal Impacts

Calculations of the committed dose using the IMPACTS Computer Program will be performed for all seven waste streams and presented in the final NESP report. The first calculation has been made for PWR compacted trash and the results are presented in Table VII. The concentrations for this waste stream are given in Table VIII. These limiting concentrations were determined based on the concentrations from the INVERSE calculations presented in Table VI and the radionuclide fractional mixes presented in NUREG-0782. From Table VII, the following important observations are made:

1. The highest committed doses are found in the transportation scenario.
2. The next highest committed doses are found in the landfill operations scenario.

A detailed analysis will be given in the final report along with a complete summary of all the results from the IMPACTS calculations.

TABLE VI

Limiting Concentrations for the INVERSE Calculations

Waste Stream Scenario Concentration (μCi/ml) Radionuclide	Soil	PWR Compacted Trash	PWR Filters	PWR Evaporator Bottoms	PWR Resins	BWR Compacted Trash	Sand Blasting Sand
H-3	INT-AG* 3.94E-02	INT-AG 3.59E-03	INT-AG 4.6E-01	INT-AG 4.6E-04	INT-AG 3.84E-03	INT-AG 3.59E-03	INT-AG 4.44E-03
C-14	LA-OVF 3.21E-02	LA-OVF 2.92E-03	LA-OVF 3.75E-01	LA-OVF 3.75E-04	LA-OVF 3.12E-03	LA-OVF 2.92E-03	LA-OVF 3.61E-03
Fe-55	LA-OVF 4.28E+01	LA-OVF 4.39E+00	LA-OVF 5.63E-01	LA-OVF 5.63E-04	LA-OVF 4.69E-02	LA-OVF 4.39E+00	LA-OVF 5.43E+00
Co-60	TR-MAX 8.17E-05	TR-MAX 7.43E-06	TR-MAX 9.53E-04	TR-MAX 9.53E-07	TR-MAX 7.94E-05	TR-MAX 7.43E-06	TR-MAX 9.19E-06
Ni-59	LA-OVF 1.62E+00	LA-OVF 1.48E-01	LA-OVF 1.9E+01	LA-OVF 1.9E-02	LA-OVF 1.58E-00	LA-OVF 1.48E-01	LA-OVF 1.83E-01
Ni-63	LA-OVF 5.53E-01	LA-OVF 5.04E-02	LA-OVF 6.46E-00	LA-OVF 6.46E-03	LA-OVF 5.38E-01	LA-OVF 5.04E-02	LA-OVF 6.23E-02
Sr-90	LA-OVF 4.37E-02	LA-OVF 3.98E-03	LA-OVF 5.10E-01	LA-OVF 5.10E-04	LA-OVF 4.25E-02	LA-OVF 3.98E-03	LA-OVF 4.92E-03
Nb-94	TR-MAX 1.33E-04	TR-MAX 1.21E-05	TR-MAX 1.55E-03	TR-MAX 1.55E-06	TR-MAX 1.3E-04	TR-MAX 1.21E-05	TR-MAX 1.5E-05
Tc-99	LA-OVF 6.24E-03	LA-OVF 5.67E-04	LA-OVF 7.27E-02	LA-OVF 7.27E-05	LA-OVF 6.06E-03	LA-OVF 5.67E-04	LA-OVF 7.02E-04
I-129	LA-OVF 2.35E-05	LA-OVF 2.14E-06	LA-OVF 2.75E-04	LA-OVF 2.75E-07	LA-OVF 2.29E-08	LA-OVF 2.14E-03	LA-OVF 2.65E-06
Cs-137	TR-MAX 3.73E-04	TR-MAX 3.4E-05	TR-MAX 4.36E-03	TR-MAX 4.36E-06	TR-MAX 3.63E-07	TR-MAX 3.4E-02	TR-MAX 4.2E-05
Ce-144	TR-MAX 4.69E-03	TR-MAX 4.27E-04	TR-MAX 5.47E-02	TR-MAX 5.47E-05	TR-MAX 4.56E-06	TR-MAX 4.27E-01	TR-MAX 5.28E-04
Pu-238	INT-CO 2.18E-03	INT-CO 1.98E-04	INT-CO 2.54E-02	INT-CO 2.54E-05	INT-CO 2.12E-06	INT-CO 1.98E-01	INT-CO 2.45E-04
Pu-239	INT-CO 1.58E-03	INT-CO 1.44E-04	INT-CO 1.84E-02	INT-CO 1.84E-05	INT-CO 1.54E-06	INT-CO 1.44E-01	INT-CO 1.78E-04
Pu-241	INT-CO 6.34E-02	INT-CO 5.77E-03	INT-CO 7.39E-01	INT-CO 7.39E-04	INT-CO 6.16E-05	INT-CO 5.77E-00	INT-CO 7.13E-03
Am-241	LA-OVF 5.48E-05	LA-OVF 4.99E-06	LA-OVF 6.4E-04	LA-OVF 6.4E-07	LA-OVF 5.33E-08	LA-OVF 4.99E-03	LA-OVF 6.17E-06
Cm-242	INT-AG 4.22E-01	INT-CO 3.84E-02	INT-CO 4.92E-00	INT-CO 4.92E-03	INT-CO 4.1E-04	INT-CO 3.84E+01	INT-CO 4.74E-02
Cm-244	LA-OVF 2.84E-03	LA-OVF 2.58E-04	LA-OVF 3.31E-02	LA-OVF 3.31E-05	LA-OVF 2.76E-06	LA-OVF 2.58E-01	LA-OVF 3.19E-04

*See NUREG/CR-3585 for Description of Scenario.

TABLE VII

Impacts for PWR Compacted Trash

Scenario	Total Body Dose
Transportation	
Maximum Driver	4.97 E-01 mrem/yr
Total Occupational	9.97 E-01 person-mrem/yr
Population	1.30 E+00 person-mrem/yr
Intruder Impacts	
Construction	1.43 E-02 mrem/yr
Agriculture	4.85 E-02 mrem/yr
Exposed Waste Impacts	
Intruder Air	2.67 E-04 person-mrem/yr
Intruder Water	2.17 E-05 mrem/yr
Erosion Air	1.04 E-04 person-mrem/yr
Erosion Water	9.95 E-05 mrem/yr
Operational Impacts	
Population	3.25 E-04 person-mrem/yr
Individual	5.62 E-05 mrem/yr
All Workers	7.05 E-02 person-mrem/yr
Maximum Worker	7.05 E-02 mrem/yr
Leachate Accumulation	
Operational	3.46 E-03 mrem/yr
Overflow	6.34 E-02 mrem/yr
Airborne	7.79 E-02 person-mrem/yr
Ground Water Impacts	
Intruder Well	
40 yr	7.77 E-06 mrem/yr
200 yr	7.84 E-09 mrem/yr
2,000 yr	2.99 E-06 mrem/yr
Population Well	
40 yr	0.00 E+00 person-mrem/yr
200 yr	0.00 E+00 person-mrem/yr
2,000 yr	7.03 E-10 person-mrem/yr
Population Surface Water	
40 yr	0.00 E+00 person-mrem/yr
200 yr	0.00 E+00 person-mrem/yr
2,000 yr	2.49 E-11 person mrem/yr

TABLE VIII

Data Used for PWR Compacted Trash Impacts Calculation

Radio-nuclide	Inverse Concentration (μCi/ml)	NUREG-0782 Fraction	Limiting Waste Stream Concentration (μCi/ml)
H-3	3.59 E-03	1.75 E-02	6.28 E-05
C-14	2.92 E-03	9.31 E-04	2.71 E-06
Fe-55	4.39 E+00	1.56 E-01	6.79 E-01
Co-60	7.43 E-06	4.59 E-01	3.41 E-06
Ni-59	1.48 E-01	5.91 E-04	8.74 E-05
Ni-63	5.04 E-02	1.72 E-01	8.66 E-03
Sr-90	3.98 E-03	1.55 E-03	6.17 E-06
Mb-94	1.21 E-05	1.87 E-05	2.26 E-10
Tc-99	5.67 E-04	7.83 E-06	4.44 E-09
I-129	2.14 E-06	2.31 E-05	4.94 E-11
Cs-137	3.40 E-05	1.77 E-01	6.02 E-06
Pu-238	1.98 E-04	4.68 E-04	9.26 E-08
Pu-239	1.44 E-04	4.59 E-04	6.61 E-08
Pu-241	5.77 E-03	1.42 E-02	8.19 E-05
Am-241	4.99 E-06	3.26 E-04	1.63 E-09
Cm-244	2.58 E-04	1.66 E-04	4.28 E-08

Cost-Benefit Analysis

The incremental risks costs, and benefits of disposal of the VLLW streams by these alternate means, compared to Part 61 methods, will be presented in the final report. The risks are expressed in terms of individual and collective doses to workers and to members of the public, calculated with the code IMPACTS. The impacts of disposal of the wastes at a licensed burial facility, needed for comparison purposes, are based on published information. The economic, regulatory, and other costs and benefits involved are being evaluated. The risk/cost/benefit analysis methodology, data, and results will be presented in the final report. Also included in that report will be a discussion of the ALARA implications of the de-regulation of Very Low Level Waste streams.

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