SEGREGATION OF LOW-LEVEL DRY ACTIVE WASTE

Lester Kornblith, Jr.
National Nuclear Corporation
Potomac, Maryland 20854

Michael D. Naughton
Electric Power Research Institute
Palo Alto, California 94303

Luther Welsh
National Nuclear Corporation
Mountain View, California 94043

ABSTRACT

A program has been carried out to characterize the Dry Active Waste (DAW) stream from a typical PWR power plant in order to determine the usefulness of large-volume DAW monitors for segregating such waste in order to dispose of it in appropriate facilities.

A waste monitor using plastic scintillation counters was used for measuring the waste. The monitor had a volume of about 300 liters and an overall efficiency of about 12% for a typical fission product mixture. It provides automatic compensation for background radioactivity and can measure a bag of waste in less than a minute, including background measurements.

Six hundred consecutively generated bags of DAW were measured. These had a total activity of about one millicurie and an average specific activity of about 540 nanocuries per kilogram. About half of the bags contained less than 1000 nanocuries and had specific activities of less than 100 nanocuries per kilogram.

Based on simplified preliminary calculations, it appears that an evaluation of the risks of disposal of bags such as these in a landfill other than a low-level waste disposal facility could be carried out that would demonstrate that such disposal of half or more of these bags would not result in any substantial hazard, either short or long term.

INTRODUCTION

This paper presents the major findings of an Electric Power Research Institute (EPRI) study RP1557-9.[1] The study was directed at evaluating Dry Active Waste (DAW) monitoring techniques for effective segregation of uncontaminated wastes or wastes that are only slightly contaminated. Four objectives were defined for the project:

1. To characterize the distribution of the measured activity (nCi/kg) in DAW from an operating commercial nuclear plant;
2. To establish the reliability of large-volume monitoring, compared to hand methods;
3. To demonstrate calibration techniques for large-volume DAW monitors; and
4. To quantify the effectiveness of segregation procedures to reduce the volume of DAW at an operating nuclear power plant.

The first objective has been achieved as it relates to a particular plant during normal power operation. The reliability of large-volume monitoring has been established, although it is not yet possible to devise a suitable index for comparing its reliability to that of hand methods. A calibration technique has been developed and demonstrated. The final objective has been achieved to the extent that all of the necessary data are in hand to quantify the effectiveness of segregation procedures at this plant, once an appropriate set of segregation criteria has been selected. A set of criteria must be developed as a separate project, based on calculated health effects and legal requirements. To become of practical value, such a set of criteria would have to be acceptable to and accepted by the Nuclear Regulatory Commission and, in some cases, appropriate State or local authorities. Given such criteria and the data developed in this project, the effects of segregation can easily be quantified.

The instrument used for large-volume monitoring was the WCM-10 Waste Curie Monitor manufactured by National Nuclear Corporation. It was set up in the Auxiliary Building of the Sequoyah Nuclear Plant of the Tennessee Valley Authority. A group of bags of contaminated Dry Active Waste collected during April and the first half of May, 1983 constituted the sample tested.

Each bag was measured with a hand-held detector in accordance with the normal procedure and then measured in the WCM-10. Most bags were then opened on a frisking table and the contents hand-frisked. If individual items having high activity were identified, these were removed and the bags remeasured. This was effective in only a few cases, because of the relatively uniform contamination of the material in most bags. The results from the six hundred sample bags were analyzed in three sequential groups of 200 bags each to give a measure of consistency. A record was kept of which bags went into each of about a dozen "test drums" and the total measured activity put into each drum compared to the estimated activity measured in the manner normally used to obtain shipping information for shipment to the waste disposal site.

The remaining sections of the paper will discuss the background of the project, the equipment used, the calibration method developed, the data collected, and the conclusions reached.

BACKGROUND

Disposal of low-level radioactive waste is becoming increasingly burdensome to nuclear power plant operators. The number of active burial sites has been reduced to two and the operation of new sites is still fairly far in the future. Both shipping and disposal costs are increasing at an unprecedented rate. These impacts have been compounded by additional restrictions on shipping and disposal, both by the States and the NRC, as well as by the disposal site operators. These factors all impose additional costs and workloads on the power plant operators.

In addition to the burdens identified above, it has long been recognized that the space available at disposal sites is limited and should be used for material requiring application of the conditions currently imposed on disposal of radioactive waste and not for disposal of material that could safely be disposed of more simply. The NRC reinforced this point in October, 1981, in its policy statement on low-level waste volume reduction.

The DAW stream in a nuclear power plant contains a large volume of low level waste. The majority of this material is of extremely low level, but it frequently is mixed with some material of somewhat greater activity. Some plants attempt to provide a system for the separate collection of noncontaminated material from controlled areas, but this has seldom been very successful and the material usually ends up commingled with the contaminated material. In addition, where the segregation has been carried out, there is often reluctance, for public relations reasons, to release the material locally. Even if this is not a problem, licensees properly will not release the material without a check to assure that it is in fact uncontaminated. Because of the increasingly sensitive measuring equipment becoming available, this, in turn, leads into questions regarding the level at which one considers material to be non-contaminated and how that level is to be measured.

In view of the above considerations, in early 1982 National Nuclear Corporation (NNC) proposed to the Electric Power Research Institute (EPRI) a program to test its Waste Curie Monitor, Model WCM-10, in a realistic plant environment to achieve the objectives defined in the Introduction. It was NNC's belief that the proposed study, together with a subsequent safety analysis based on the data obtained, could be used to prepare a license amendment request to the NRC to justify disposal of a large fraction of this relatively innocuous waste stream either in a utility-owned land-fill within the site boundary or in a local public land-fill.

In June, 1982, EPRI contracted with NNC to carry out the program. The Tennessee Valley Authority (TVA) was contacted by NNC and agreed to support the program by providing the use of TVA facilities and the manpower necessary to carry out the on-site activities. The work was originally planned for the Browns Ferry site, but operational considerations later required a move to Sequoyah. Various plant contingencies delayed the start of full scale operations until the beginning of April, although calibration work was performed in the meanwhile. During a six week period ending May 13, 1983, 600 bags of waste were generated and measured.

EQUIPMENT DESCRIPTION

The monitor used for measuring the radioactive material content of the bags is the National Nuclear Corporation Model WCM-10 Waste Curie Monitor. This is a large-volume high-sensitivity monitor with a counting volume measuring about 24" wide by 27" high by 29" deep. It uses six 25" by 19" by 1-1/2" plastic scintillators (including one in the door) as detectors. The detectors and counting volume are surrounded by a 1-1/2" lead shield to reduce background. The scintillations are detected by photomultipiers, amplified, and counted. The number of counts accumulated during the counting interval (normally 10 seconds with an option of 100 seconds) is divided by the setting of a calibration control and each count out of the driver gives a single count on the digital read-out. Proper selection of the calibration control setting makes the digital read-out direct reading in nanocuries. An alarm is provided that can be set at any desired nanocurie level to light a red or green signal at the end of each measurement, providing guidance to unskilled operators.

A background count is taken before each sample count is made. The circuitry automatically subtracts this count from the subsequent sample count. The difference, which appears on the digital read-out, represents the true radioactivity of the sample with continuous updating of a changing background. This method of operation permits use of the monitor in areas having background radiation levels typical of those to be found where DAW measurements are likely to take place. Care must be taken, however, to avoid making measurements when high-activity material (e.g., drums containing curie quantities of waste) are being moved in the immediate vicinity of the monitor. The background level will, however, affect the sensitivity and accuracy of the monitor.

The monitor is quite sensitive and has an overall efficiency of about 12% for a typical fission product mixture. It is not, however, very energy dependent and cannot be used for isotopic discrimination.

CALIBRATION

The first topic we consider as part of the calibration procedure is the measurement of the radiation background and analysis of its impact. Following that we will discuss the preparation and measurement of calibration samples, and, finally, the selection of an appropriate calibration setting for the monitor.

Background Measurements

As mentioned above, background measurements are made before each sample measurement. Two aspects of the background are of interest. First is the amount of background and its effect on accuracy and sensitivity, and the second is changes between the times of the background and sample measurements.

The amount of background radiation penetrating the shielding and striking the detectors basically determines the minimum amount of activity that can be measured. A measurement sequence consists of first measuring the background by going through a counting cycle with the monitor empty and then putting in the sample and measuring sample-plus-background counts. The background number is then subtracted from the sample-plus-background. The uncertainty in this can be shown to be proportional to the square root of the sample counts plus twice the background counts. The proportionality factor turns out to be one over the square root of the calibration factor (the calibration factor is the number of counts detected in ten seconds for a source of one nanocurie or, for single gamma disintegrations, 370 times the efficiency).

Several series of measurements, totalling a few thousand seconds, were carried out over two or three days. These showed that the levels in the location selected for the monitor were the *equivalent of about* 100-120 nanocuries. From this we can calculate that the uncertainty is about two nanocuries if we are measuring a very small sample, about 3% of the measured value for a sample of 100 or so nanocuries, one-half percent for a one microcurie sample and less for larger samples.

The other factor of interest in background measurement is temporal changes. The first of the background measurement series used 100-second counts and was spread over several hours. The uncertainty calculated from these measurements was about 2-1/2 nano-

curies, whereas the uncertainty calculated on a statistical basis was about 1/2 nanocurie. This indicates that over this period of time there were background changes equivalent to several nanocuries. Since it was apparent by that time that 10-second counts would be used for the final measurements, the remaining background series were run with that interval. Analyses of these measurements showed that during time periods of the order of five minutes there were no discernible changes in background, except when identifiable activities, such as the movement of nearby waste drums, were taking place. On this basis, it was concluded that the monitor's background compensation capability was acceptable and that the measurement accuracy, as it relates to statistical and background effects, was 4 nanocuries for small samples, about 5 nanocuries for a one microcuries sample and increased as the square root of the sample size for larger samples.

Calibration Sample Preparation

In order to obtain accurate measurements, the WCM-10 should be calibrated with samples having isotopic distributions similar to the material to be measured after calibration. Although the instrument is not very energy-dependent, there is a slight dependence because at very low energies (e.g., under 100 kev) gamma rays are attenuated by the 1/16th-inch stainless steel liner and at relatively high energies fewer of the gammas lose their energy in the plastic detectors. Since most of the isotopes of interest have gammas between about 0.2 and 1.5 mev, these variations are not very significant. More important is the fact that some isotopes have two gammas per disintegration. The only one of these of interest is Cobalt-60, but this is a very important isotope as far as the makeup of DAW is concerned.

At Sequoyah it was known from previous experience that the isotopic distribution of the DAW stream (and most of the other contamination in the plant) is very similar to that of the water entering the clean-up system. This is basically reactor primary system water that has decayed a few weeks. This was selected as a suitable source of materials for preparing samples.

The first samples measured were one-liter samples prepared by using full strength or diluted water taken from the clean-up system before the demineralizers. Isotopic distributions and specific activities were measured in the laboratory. The samples were then measured in the WCM-10 and new calibration control settings calculated. Some samples taken after demineralization were also measured. Although the isotopic distributions were somewhat different from the before-demineralizer samples, as would be expected, the calculated calibration factors were essentially the same. This would be expected since the change in the abundance of Cobalt-60 relatively small. The absolute value of the calibration factor, however, was significantly lower than expected. Since it was known from the laboratory analysis that the samples contained significant amounts of Xenon-133 (a very low energy gamma emitter), it was concluded that, although neither the WCM-10 or the laboratory detector saw much of it (because of self-absorption in the sample), the algorithm used in the laboratory for abundance calculations made a correction for this, whereas the WCM-10 did not. Subsequent samples were more thoroughly deaerated to eliminate part of this problem, but it was also decided that a measuring geometry with less self-absorption should be used.

It was decided that the most desirable configuration for the calibration sample would be a bag of rags, geometrically similar to the bags of trash, with the liquid sample dispersed in the rags. A new set of samples was prepared in this way. Before preparing the bags, however, an 800-ml sample was measured in a Marinelli beaker, both in the laboratory and in the WCM-10. As expected, the calibration factor calculated from the Marinelli beaker measurements was higher than that calculated from the 1-liter bottle measurements and the factor calculated from the measurements of the dispersed samples was higher yet. The final number determined to be the "best value" for the calibration control setting was 66. Since the sample contained about 34% Cobalt-60, the efficiency calculated from this measurement was 13%, not inconsistent with previous estimates.

The five samples finally used contained from 14 to 1100 nanocuries.

Calibration Setting Selection

The "best value" of the calibration setting, as noted above, was found to be 66. In the interest of conservatism, it was decided to increase the sensitivity (decrease the calibration setting) to make allowance for two factors - geometric changes and changes in isotopic composition.

When making up the first dispersed sample, the liquid was inadvertantly concentrated in one part of the rag bundle, with the result that the monitor reading was affected by whether that section of the bag was adjacent to the wall of the monitor or not. The opportunity was taken to make a series of measurements to determine how large an effect to anticipate as a result of assymetries in the samples. Based on these measurements, it was decided to make about a 10% allowance for geometric effects.

The most significant effect of changes in isotopic composition on calibration comes from the varying number of gammas per disintegration resulting from varying fractions of Cobalt-60. As mentioned earlier, the measured amount of Cobalt-60 was about 34% of the total activity. This results in an average of about 1.34 gammas per disintegration. If this abundance should drop to 20%, the number of gammas would drop about 10% to 1.20. Even if there were no Cobalt-60 at all, a most unlikely occurrence, the drop in number of gammas would only be 25%. Since this is the non-conservative direction, it was decided to make an additional allowance for this effect that would fully take care of a drop to 20% Cobalt-60, which is about all that could be expected, and provide a reasonable margin for worse situations. With respect to increases in Cobalt-60 fraction, these would cause the results to err in the conservative direction. Actually, the effect of Cobalt-60 on the calibration is somewhat less than calculated here, because the detector is slightly less sensitive to Cobalt-60 gammas than to the lower energy gammas that predominate the other common isotopes.

As a consequence of these considerations and the desire to provide some margin for statistical effects, it was decided to apply an additional 10% sensitivity increase. The final calibration setting selected was 54.

This sort of application of conservatism factors does not lend itself to a simple expression of probable error. We concluded, however, that the measured value was unlikely to be low by more than 3 nanocuries, even for samples of low radioactivity, and unlikely to be high by more than 20%. If the "best value" setting had been used, all of the activity data discussed below would be reduced by 22%.

DATA AND ANALYSIS

Data were collected on 600 consecutive bags of DAW. The data taken on each included bag number, maximum external dose rate, WCM-10 reading, and weight. If the dose rate was low enough (less than 2 mrem/hr), the bag was opened on the frisking table and a general description of the contents recorded. If the contents were such that it seemed likely that much of the radioactivity was concentrated on a few items, these were removed and the bag remeasured. This was only done on a few bags, as in most cases the contamination was widely distributed or the contents were wet.

The data were handled in three batches of 200 bags each. The specific activity of each bag (in nCi/kg) was calculated and lists were prepared ranking the bags by both total and specific activity. The two lists for the first batch are shown in Tables I and II. The data on each bag includes a figure (in the column headed "Fraction Below") showing the fraction of the activity in the batch that is contained in the bags lower on the list. For example, the bag ranked 117th in total activity contained 485 nanocuries and the 83 bags having less activity contained, in total, only 1.23% if the activity in the batch. This allows us to select any cut-off point and readily determine the fraction of the bags and the total activity falling below that cut-off.

The first batch, for which data are shown, contained about 20% more activity than the average for all of the batches, but was otherwise typical. It had a measured content of 0.990 millicuries and weighed 1442.6 kilograms. The average specific activity was 687 nCi/kg. For the 600 bags, the total activity was 2.35 millicuries, the weight was 4366 kilograms and the average concentration was 538 nCi/kg.

Depending on the method of analysis selected, either total or specific activity may be the parameter of interest in calculating radiation exposure. In the first category, for example, one might select 100, 1000, and 5000 nanocuries as cut-off points. Table I shows that the first would include 39 (19-1/2%) of the bags in the first batch, the second would include 106 bags, and the 5000 nCi cut-off would include 147, or almost 3/4 of the bags. The concentration, or specific activity, data can be handled in the same way. One can also calculate the number meeting a combined set of criteria, such as 1000 nanocuries of total activity and 200 nCi/kg. This, for the first batch, would include 103 bags. There are seven more that meet the specific activity criterion only and three that meet the total activity criterion only.

Figure 1 shows the percentage of the bags having less than a given total activity per bag and the percentage having less than a given specific activity. Figure 2 shows the fraction of the total activity as a function of the number of bags with the bags ranked by total content. This curve is close to logarithmic. Both figures include the data for all 600 bags.

There is no way to make a simple graphic presentation of the relationship between dose rate measurements and radioactivity content. It is obvious, of course, that there is a general correlation between the two, but there are many exceptions. This is illustrated, for example, by looking in Table I at the 22 bags measuring over 20 microcuries. Dose rates range from less that 0.5 to 40 mrem/hr. The sequence and values of the numbers are almost entirely unrelated. With respect to the dose rates for the low activity bags, the readings are pretty much a function of the background at the moment and of the care taken by the technician. Unfortunately it was impossible to have a single technician assigned to this program continuously. Many readings, particularly in the first batch, were simply recorded as "less than" some amount rather than as a specific reading. Close consideration of these data make clear that at the low levels we are concerned with, dose rates cannot be used as a criterion for determining a disposal mode.

CORRELATION OF WCM-10 AND SHIPPING MEASUREMENTS

An attempt was made to correlate the measurements made in this program with the normal shipping measurements. One hundred and thirty-five of the bags were packed into 13 identified drums. From 6 to 18 bags went into each. The total activity in these drums was then determined by the method normally used at Sequoyah in preparing shipping information.

This method consists of making dose rate measurements with a hand-held instrument at a distance of three feet from the hottest point on the drum surface. This value (in mrem/hr) is then multiplied by an empirical constant (which varies with drum weight) to give the radioactivity content in millicuries.

The data produced for shipment yielded results several orders of magnitude higher than the numbers obtained by adding the measured values of the individual bags. For example, one drum, by WCM-10 measurements contained 10.6 microcuries, but by the shipping papers contained 2.0 millicuries. Inquiry showed that the empirical constant for this drum weight (less than 250 pounds) was 20 and the dose rate recorded was "less than 0.1 mrem/hr", presumably the bottom of the scale on the instrument used. The number 0.1 was then used in the calculation with the result noted. The formulae used for heavier drums have larger constants, with the amusing result that a 501 pound drum of clean sand, measured with an instrument that could measure down to natural background levels, would be shipped as containing over 4 millicuries. If measured with the instrument actually used, it would be shipped as containing 30 millicuries!

The equations used at Sequoyah are very conservative. This probably is appropriate for the purpose for which it was intended, but makes them useless for confirming the measurements made in this program.

CONCLUSIONS

The data show that for the conditions existing at Sequoyah during the measurements, most bags of waste had very low levels of radioactivity. Ten percent of them contained about 60% of the total activity and the top 30% contained 90% of the total. Forty percent of the bags contained negligible amounts, totalling about 1% of the entire activity.

The distributions found, however, could not have been found by dose rate measurements with a hand-held instrument. A monitor measuring total activity with a good geometrical efficiency was necessary.

Calibration techniques were demonstrated that show good agreement with laboratory measurements of samples.

If an acceptable set of disposal criteria are developed, a method is at hand for applying the criteria to the DAW stream from a plant. The activity distribution developed for the Sequoyah plant, which clearly shows that a substantial fraction of the DAW is only slightly contaminated, takes on added importance when considered with the fact that DAW comprises approximately 50 % of nuclear plant wastes. [2] The annual disposal cost of DAW is in the range of $500,000 per

Bag No.	nCi	nCi/kg	Dose Rate	Fract. Below	Rank
124	28215	2713	5.	0.9715	1
30	27283	5931	4.	.9439	2
131	26157	1557	5.	.9175	3
77	25674	1712	5.	.8916	4
121	25175	3497	15.	.8662	5
193	25152	1996	1.5	.8408	6
134	25068	5014	3.	.8155	7
43	25000	2500	G 10.	.7902	8
159	24993	10414	30.	.7650	9
191	24957	5199	40.	.7398	10
139	24887	2963	5.	.7146	11
132	24884	3770	6.	.6895	12
11	24700	5370	1.5	.6646	13
149	24547	6460	2.5	.6398	14
92	24347	2029	10.	.6152	15
9	24329	3201	10.	.5906	16
12	24234	4660	6.	.5662	17
100	23594	2107	6.	.5424	18
176	23125	3854	2.	.5190	19
97	23070	2563	4.	.4957	20
35	21406	3453	L 0.5	.4741	21
194	20145	1865	1.	.4538	22
118	19400	898	L 1.	.4342	23
146	18433	2711	1.5	.4156	24
85	15747	1486	L 1.	.3997	25
6	14563	2511	1.5	.3850	26
135	14430	2886	L 2.	.3704	27
54	12565	1848	L.0.5	.3577	28
180	12532	2848	1.	.3450	29
14	11908	2481	L 0.5	.3330	30
82	11639	2645	3.	.3213	31
169	11257	612	L 1.	.3099	32
91	11243	3123	G 2.	.2985	33
86	11019	1837	G 2.	.2874	34
102	10489	1345	L 1.	.2768	35
171	10154	861	L 0.5	.2666	36
163	9809	1168	1.	.2567	37
48	9070	872	L 0.5	.2475	38
64	8653	848	L 1.	.2388	39
160	8551	1474	1.5	.2301	40
122	8434	1833	5.	.2216	41
153	7478	623	L 0.5	.2141	42
120	7374	376	L 0.5	.2066	43
142	7092	844	L 0.5	.1995	44
184	7027	799	L 0.5	.1924	45
173	6727	782	L 1.	.1856	46
197	6310	830	0.5	.1792	47
179	6074	1519	2.	.1731	48
41	5937	1562	L 0.5	.1671	49
154	5617	1755	3.	.1614	50
182	5244	1639	L 1.	.1561	51
83	5201	482	L 1.	.1509	52
24	5127	712	L 0.3	.1457	53
49	4979	1245	L 0.5	.1407	54
59	4961	1240	0.7	.1357	55
178	4929	1027	L 1.	.1307	56
200	4797	343	L 0.5	.1258	57
192	4586	695	L 0.5	.1212	58
136	4441	516	L 1.	.1167	59
15	4402	667	L 0.3	.1123	60
119	4204	1168	L 1.	.1080	61
3	3999	238	L 0.5	.1040	62
96	3816	830	L 1.	.1001	63
175	3789	202	L 1.	.0963	64
31	3501	625	L 0.2	.0928	65
141	3300	471	L 0.5	.0894	66
117	3291	185	L 0.5	.0861	67
65	3171	529	L 0.5	.0829	68
103	3158	232	L 0.5	.0797	69
10	3151	426	L 0.5	.0766	70
195	3078	405	L 0.5	.0734	71
113	3012	519	L 0.5	.0704	72
123	2719	324	L 1.	.0677	73
187	2601	245	L 0.5	.0650	74
66	2359	288	L 1.	.0626	75
147	2237	1243	L 1.	.0604	76
190	2234	135	L 0.5	.0581	77
155	2185	910	L 0.5	.0559	78
58	2152	399	L 0.5	.0538	79
61	2062	322	L 0.5	.0517	80
157	2022	109	L 1.	.0496	81
189	1968	205	L 0.5	.0476	82
115	1957	376	L 0.5	.0457	83
95	1924	310	L 0.5	.0437	84
94	1918	1199	L 0.5	.0418	85
133	1811	412	L 1.	.0400	86
181	1702	140	L 0.5	.0382	87
114	1627	209	L 1.	.0366	88
69	1612	322	L 0.5	.0350	89
18	1500	192	0.1	.0335	90
125	1400	111	L 0.5	.0320	91
185	1321	315	L 0.4	.0307	92
143	1262	574	L 0.5	.0294	93
34	1222	145	L 0.5	.0282	94
199	992	90	L 0.5	.0272	95
8	937	247	L 0.5	.0263	96
57	935	213	L 0.5	.0253	97
13	864	139	L 0.5	.0244	98
90	839	113	L 1.	.0236	99
105	827	153	L 0.5	.0228	100
36	787	151	L 0.5	.0220	101
156	753	86	L 1.	.0212	102
196	709	91	L 0.5	.0205	103
23	690	133	0.2	.0198	104
130	681	117	L 0.5	.0191	105
22	666	111	L 0.3	.0184	106
186	650	191	0.1	.0176	107
140	614	81	L 1.	.0172	108
55	596	75	L 0.5	.0166	109
101	571	77	L 0.5	.0160	110
20	569	135	0.1	.0154	111
78	551	39	L 0.5	.0148	112
128	528	189	L 0.5	.0143	113
28	526	138	L 0.2	.0138	114
168	525	219	L 0.5	.0132	115
99	493	67	L 0.5	.0128	116
52	485	66	L 0.5	.0123	117
198	481	71	L 0.5	.0118	118
21	463	83	0.2	.0113	119
174	453	189	L 1.	.0109	120
165	446	72	L 0.5	.0104	121
161	445	32	L 0.5	.0100	122
17	440	54	0.1	.0095	123
60	415	56	L 0.5	.0091	124
110	356	71	L 1.	.0087	125
104	334	31	L 0.5	.0084	126
40	313	71	L 0.5	.0081	127
111	287	103	L 0.5	.0078	128
164	279	23	L 0.5	.0075	129
107	256	61	L 1.	.0072	130
32	253	84	L 0.5	.0070	131
137	248	59	L 0.5	.0067	132
170	239	33	L 0.5	.0065	133
75	235	13	L 1.	.0063	134
63	234	73	L 0.5	.0060	135
26	230	88	0.1	.0058	136
79	226	13	L 1.	.0056	137
87	224	70	L 0.5	.0053	138
51	222	31	L 0.5	.0051	139
166	216	90	L 0.5	.0049	140
29	211	39	L 0.2	.0047	141
138	198	76	L 1.	.0045	142
70	193	32	L 0.5	.0043	143
71	193	37	L 0.5	.0041	144
172	189	10	L 0.5	.0039	145
44	184	38	L 0.5	.0037	146
46	178	11	L 0.5	.0035	147
162	176	42	L 0.5	.0034	148
7	173	46	L 0.5	.0032	149
42	169	34	L 0.5	.0030	150
106	158	18	L 0.5	.0029	151
80	156	34	L 0.5	.0027	152
116	152	19	L 0.5	.0025	153
73	149	47	L 1.	.0024	154
68	144	65	L 0.5	.0022	155
112	135	96	L 0.5	.0021	156
56	133	44	L 0.5	.0020	157
84	124	6	L 0.5	.0019	158
53	123	32	L 0.5	.0017	159
150	112	17	L 0.5	.0016	160
108	103	52	L 0.5	.0015	161
39	100	31	L 0.5	.0014	162
167	98	16	L 1.	.0013	163
177	96	28	L 0.5	.0012	164
16	87	31	L 0.2	.0011	165
145	86	5	L 0.5	.0010	166
25	78	5	L 0.2	.0010	167
50	76	29	L 0.5	.0009	168
129	73	9	L 0.5	.0008	169
67	72	33	L 0.5	.0007	170
151	72	12	L 1.	.0007	171
72	71	22	L 0.5	.0006	172
81	71	10	L 0.5	.0005	173
126	68	6	L 0.1	.0005	174
1	57	7	L 0.1	.0004	175
144	46	9	L 0.5	.0003	176
47	44	8	L 0.5	.0003	177
158	44	14	L 1.	.0003	178
188	39	10	L 0.5	.0002	179
183	30	7	L 0.5	.0002	180
74	29	3	L 1.	.0002	181
33	26	22	L 0.5	.0001	182
62	26	3	L 0.5	.0001	183
152	20	6	L 0.5	.0001	184
76	18	4	L 1.	.0001	185
98	17	11	L 0.5	.0001	186
5	16	9	L 0.5	.0000	187
38	15	4	L 0.5	.0000	188
148	14	3	L 0.5	.0000	189
89	11	2	L 0.5	.0000	190
4	10	1	L 0.5	.0000	191
45	10	2	L 0.5	.0000	192
2	6	1	L 0.5	.0000	193
109	6	2	L 0.5	.0000	194
19	3	1	0.1	.0000	195
27	2	0	L 0.2	.0000	196
37	2	0	L 0.5	.0000	197
88	2	1	L 1.	.0000	198
93	2	0	L 1.	.0000	199
127	2	0	L 0.5	.0000	200

(L = Less than, G = Greater than)

TABLE I

First 200 Bags, Ranked by Total Radioactivity

Bag No.	nCi	nCi/kg	Dose Rate	Fract. Below	Rank
159	24993	10414	30.	0.9747	1
149	24547	6460	2.5	.9499	2
30	27283	5931	4.	.9224	3
11	24700	5370	1.5	.8974	4
191	24957	5199	40.	.8722	5
134	25068	5014	3.	.8469	6
12	24234	4660	6	.8225	7
176	23125	3854	2.	.7991	8
132	24884	3770	6.	.7740	9
121	25175	3497	15.	.7486	10
35	21406	3453	L 0.5	.7270	11
9	24329	3201	10.	.7024	12
91	11243	3123	G 2.	.6910	13
139	24887	2963	5.	.6659	14
135	14430	2886	L 2.	.6513	15
180	12532	2848	1.	.6387	16
124	28215	2713	5.	.6102	17
146	18433	2711	1.5	.5916	18
82	11639	2645	3.	.5798	19
97	23070	2563	4.	.5565	20
6	14563	2511	1.5	.5418	21
43	25000	2500	G 10.	.5166	22
14	11908	2481	L 0.5	.5046	23
100	23594	2107	6.	.4807	24
92	24347	2029	10.	.4562	25
193	25152	1996	1.5	.4308	26
194	20145	1865	1.	.4104	27
54	12565	1848	L 0.5	.3977	28
86	11019	1837	G 2.	.3866	29
122	8434	1833	5.	.3781	30
154	5617	1755	3.	.3724	31
77	25674	1712	5.	.3465	32
182	5244	1639	L 1.	.3412	33
41	5937	1562	L 0.5	.3352	34
131	26157	1557	5.	.3088	35
179	6074	1519	2.	.3027	36
85	15747	1486	L 1.	.2868	37
160	8551	1474	1.5	.2781	38
102	10489	1345	L 1.	.2675	39
49	4979	1245	L 0.5	.2625	40
147	2237	1243	L 1.	.2603	41
59	4961	1240	0.7	.2552	42
94	1918	1199	L 0.5	.2533	43
163	9809	1168	1.	.2434	44
119	4204	1168	L 1.	.2392	45
178	4929	1027	L 1.	.2342	46
155	2185	910	L 0.5	.2320	47
118	19400	898	L 1.	.2124	48
48	9070	872	L 0.5	.2032	49
171	10154	861	L 0.5	.1930	50
64	8653	848	L 1.	.1842	51
142	8092	844	L 0.5	.1771	52
197	6310	830	0.5	.1707	53
96	3816	830	L 1.	.1669	54
184	7027	799	L 0.5	.1598	55
173	6727	782	L 1.	.1530	56
24	5127	712	L 0.3	.1478	57
192	4586	695	L 0.5	.1432	58
15	4402	667	L 0.3	.1387	59
31	3501	625	L 0.2	.1352	60
153	7478	623	L 0.5	.1276	61
169	11257	612	L 1.	.1163	62
143	1262	574	L 0.5	.1150	63
65	3171	529	L 0.5	.1118	64
113	3012	519	L 0.5	.1087	65
136	4441	516	L 1.	.1043	66
83	5201	482	L 1.	.0990	67
141	3300	471	L 0.5	.0957	68
10	3151	426	L 0.5	.0925	69
133	1811	412	L 1.	.0907	70
195	3078	405	L 0.5	.0876	71
58	2152	399	L 0.5	.0854	72
120	7374	376	L 0.5	.0779	73
115	1957	376	L 0.5	.0760	74
200	4797	343	L 0.5	.0711	75
123	2719	324	L 1.	.0684	76
69	1612	322	L 0.5	.0668	77
61	2062	322	L 0.5	.0647	78
185	1321	315	L 0.4	.0633	79
95	1924	310	L 0.5	.0614	80
66	2359	288	L 1.	.0590	81
8	937	247	L 0.5	.0581	82
187	2601	245	L 0.5	.0554	83
3	3999	238	L 0.5	.0514	84
103	3158	232	L 0.5	.0482	85
168	525	219	L 0.5	.0477	86
57	935	213	L 0.5	.0467	87
114	1627	209	L 1.	.0451	88
189	1968	205	L 0.5	.0431	89
175	3789	202	L 1.	.0393	90
18	1500	192	0.1	.0378	91
186	650	191	0.1	.0371	92
174	453	189	L 1.	.0367	93
128	528	189	L 0.5	.0361	94
117	3291	185	L 0.5	.0328	95
105	827	153	L 0.5	.0320	96
36	787	151	L 0.5	.0312	97
34	1222	145	L 0.5	.0299	98
181	1702	140	L 0.5	.0282	99
13	864	139	L 0.5	.0273	100
28	526	138	L 0.2	.0268	101
190	2234	135	L 0.5	.0246	102
20	569	135	0.1	.0240	103
23	690	133	0.2	.0233	104
130	681	117	L 0.5	.0226	105
90	839	113	L 1.	.0218	106
125	1400	111	L 0.5	.0203	107
22	666	111	L 0.3	.0197	108
157	2022	109	L 1.	.0176	109
111	287	103	L 0.5	.0173	110
112	135	96	L 0.5	.0172	111
196	709	91	L 0.5	.0165	112
199	992	90	L 0.5	.0155	113
166	216	90	L 0.5	.0153	114
26	230	88	0.1	.0150	115
156	753	86	L 1.	.0143	116
32	253	84	L 0.5	.0140	117
21	463	83	0.2	.0135	118
140	614	81	L 1.	.0129	119
101	571	77	L 0.5	.0124	120
138	198	76	L 1.	.0122	121
55	596	75	L 0.5	.0115	122
63	234	73	L 0.5	.0113	123
165	446	72	L 0.5	.0109	124
198	481	71	L 0.5	.0104	125
110	356	71	L 1.	.0100	126
40	313	71	L 0.5	.0097	127
87	224	70	L 0.5	.0095	128
99	493	67	L 0.5	.0090	129
52	485	66	L 0.5	.0085	130
68	144	65	L 0.5	.0083	131
107	256	61	L 1.	.0081	132
137	248	59	L 0.5	.0078	133
60	415	56	L 0.5	.0074	134
17	440	54	0.1	.0070	135
108	103	52	L 0.5	.0069	136
73	149	47	L 1.	.0067	137
7	173	46	L 0.5	.0065	138
56	133	44	L 0.5	.0064	139
162	176	42	L 0.5	.0062	140
78	551	39	L 0.5	.0057	141
29	211	39	L 0.2	.0055	142
44	184	38	L 0.5	.0053	143
71	193	37	L 0.5	.0051	144
80	156	34	L 0.5	.0049	145
42	169	34	L 0.5	.0048	146
170	239	33	L 0.5	.0045	147
67	72	33	L 0.5	.0044	148
161	445	32	L 0.5	.0040	149
70	193	32	L 0.5	.0038	150
53	123	32	L 0.5	.0037	151
104	334	31	L 0.5	.0033	152
51	222	31	L 0.5	.0031	153
39	100	31	L 0.5	.0030	154
16	87	31	L 0.2	.0029	155
50	76	29	L 0.5	.0028	156
177	96	28	L 0.5	.0027	157
164	279	23	L 0.5	.0025	158
72	71	22	L 0.5	.0024	159
33	26	22	L 0.5	.0024	160
116	152	19	L 0.5	.0022	161
106	158	18	L 0.5	.0021	162
150	112	17	L 0.5	.0019	163
167	98	16	L 1.	.0016	164
158	44	14	L 1.	.0016	165
79	226	13	L 1.	.0016	166
75	235	13	L 1.	.0013	167
151	72	12	L 1.	.0013	168
98	17	11	L 0.5	.0012	169
46	178	11	L 0.5	.0011	170
188	39	10	L 0.5	.0010	171
172	189	10	L 0.5	.0008	172
81	71	10	L 0.5	.0008	173
144	46	9	L 0.5	.0007	174
129	73	9	L 0.5	.0006	175
47	44	8	L 0.5	.0006	176
183	30	7	L 0.5	.0006	177
1	57	7	L 0.1	.0005	178
152	20	6	L 0.5	.0005	179
126	68	6	L 0.1	.0004	180
84	124	6	L 0.5	.0003	181
145	86	5	L 0.5	.0002	182
25	78	5	L 0.2	.0001	183
76	18	4	L 1.	.0001	184
38	15	4	L 0.5	.0001	185
148	14	3	L 0.5	.0001	186
74	29	3	L 1.	.0000	187
62	26	3	L 0.5	.0000	188
109	6	2	L 0.5	.0000	189
89	11	2	L 0.5	.0000	190
45	10	2	L 0.5	.0000	191
5	16	2	L 0.5	.0000	192
88	2	1	L 1.	.0000	193
19	3	1	0.1	.0000	194
4	10	1	L 0.5	.0000	195
2	6	1	L 0.5	.0000	196
127	2	0	L 0.5	.0000	197
93	2	0	L 1.	.0000	198
37	2	0	L 0.5	.0000	199
27	2	0	L 0.2	.0000	200

(L = Less than, G = Greater than)

TABLE II

First 200 Bags, Ranked by Specific Radioactivity

year per unit. Utilities could effect a substantial cost reduction in this area through segregation of waste materials. EPRI intends to support the reexamination of disposal of DAW to determine if all of the present practices are necessary to protect public health and safety.

1. NATIONAL NUCLEAR CORPORATION, "Segregation of Uncontaminated Dry Active Waste," EPRI NP3299, Electric Power Research Institute (1983).

2. GILBERT ASSOCIATES, INC., "Identification of Radwaste Sources and Reduction Techniques. Volume 1: Implementation Handbook" EPRI NP3370, Electric Power Research Institute (1984).

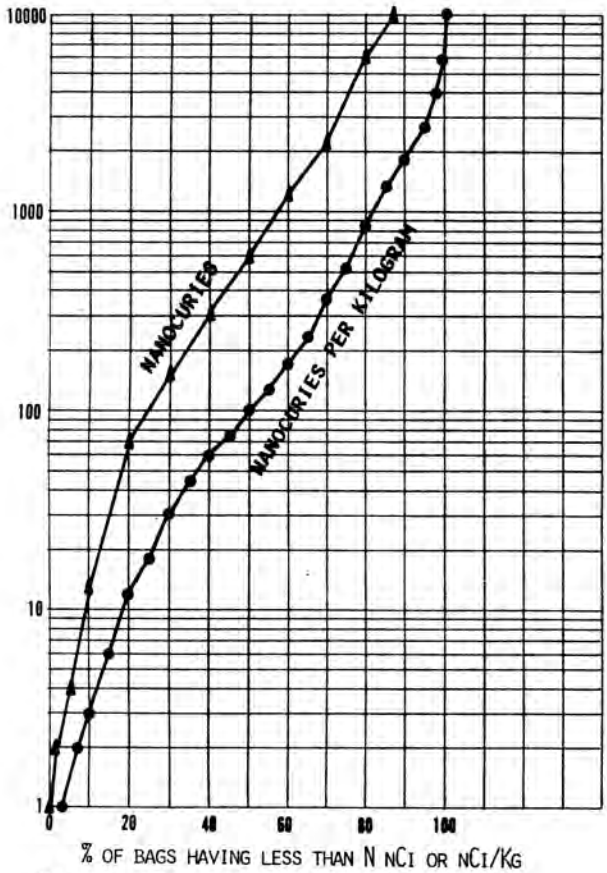

FIG. 1. TOTAL OR SPECIFIC ACTIVITY VS. PERCENTAGE OF BAGS.

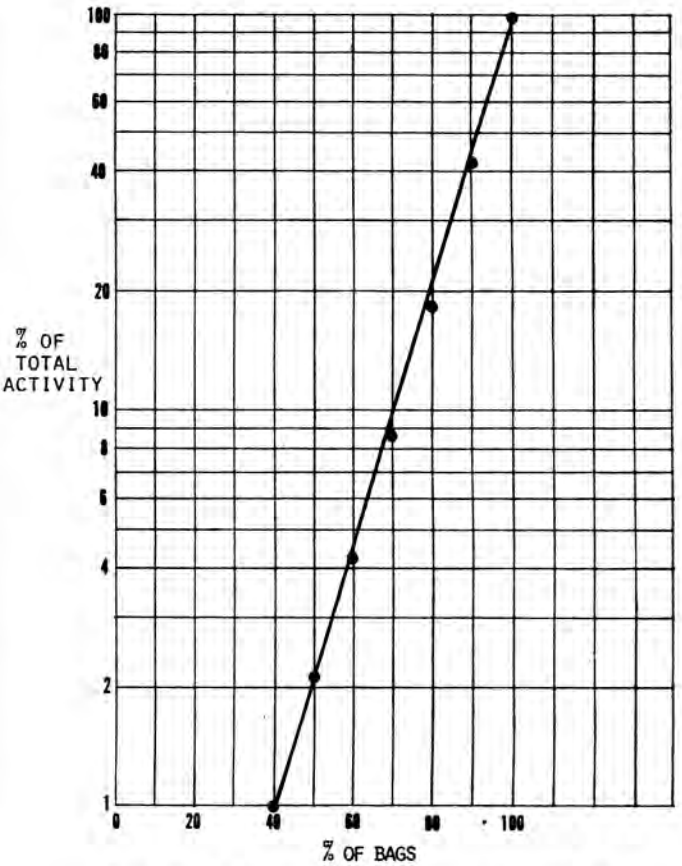

FIG. 2. PERCENTAGE OF TOTAL ACTIVITY VS. PERCENTAGE OF BAGS.