CONCENTRATIONS AND BEHAVIOR OF ^{129}I, ^{99}Tc, AND ^{14}C IN LOW-LEVEL RADIOACTIVE WASTES FROM COMMERCIAL NUCLEAR POWER STATIONS

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ABSTRACT

Currently, radionuclide activity scaling factors are derived from radiochemistry measurements conducted on actual nuclear plant wastes. This method of deriving scaling factors has been shown to be vulnerable to problems with sampling representativeness, measurement variability, analytical detection limits, and an inability to account for changing plant conditions that shift scaling factors. This situation led to the development by the Electric Power Research Institute (EPRI) of RADSOURCE, a computer modeling technique that utilizes routinely analyzed reactor coolant isotopic data to produce a set of real-time scaling factors. In order to validate the RADSOURCE model, EPRI contracted with Battelle, Pacific Northwest Laboratories to construct a sampling devise to simulate a scaled-down version of a plant's purification demineralizer system, and then install, operate, collect, and analyze the mixed-bed resin samples. Rigorous radiochemical analytical techniques were used to measure ^{129}I, ^{99}Tc, ^{14}C, and other radionuclides used for developing activity scaling factors for the test resins. This paper discusses the results and conclusions drawn from the analyses of test resin samples collected for EPRI and for the Empire State Electric Energy Research Corporation (ESEERCO) in New York state. ESEERCO is conducting a separate research program with the sole intent of improving the accuracy of the ^{129}I and ^{99}Tc source term for radioactive waste generated by New York State's utilities. These data will be used to validate a separate modeling technique that determines the total ^{129}I and ^{99}Tc in the waste shipped to a low-level waste (LLW) disposal site on an annual basis.

INTRODUCTION

The purpose of this research program was to perform rigorous radioanalytical measurements to accurately determine the quantities of ^{129}I, ^{99}Tc, and ^{14}C collected on test resin columns designed to simulate purification demineralizers at nuclear power stations. These resins represent, by far, the major radwaste source for these isotopes. The results of this research will assist the utilities, state compacts, and regulatory agencies in assessing the accuracy of current and alternative methods for determination of ^{129}I, ^{99}Tc, and ^{14}C. Further, this study will provide insight into the removal efficiencies and performance of these radionuclides on ion exchange resins relative to the key isotopes used for scaling factors, e.g., ^{137}Cs and ^{60}Co. This behavior is particularly important in assessing the reliability of scaling factors used for inferring activity in waste packages. Additionally, this information is also critical for devising appropriate ways of sampling these resins to obtain representative samples that will give reliable scaling factors. For example, if the ^{129}I, ^{99}Tc, and ^{14}C do not load on ion exchange resins in the same manner as the gamma-emitters, then one could expect substantial separation of the isotopes from each other if complete mixing of the resins is not accomplished prior to grab sampling. The resulting grab samples would not give representative results for the scaling factors.

BACKGROUND INFORMATION

^{129}I and ^{99}Tc in Commercial Nuclear Power Station Radwaste

Currently, the estimates of ^{129}I and ^{99}Tc are judged to be overestimated by a significant factor. The over-estimates of ^{129}I and ^{99}Tc in LLW are caused by two factors: 1) the inadequate sensitivities of commercial laboratory methods to detect the very low concentrations of these nuclides in

waste streams, and 2) the non-homogeneity of the waste streams. As a result, most of the values reported in the industry data bases are either "less-than" values or values that are very close to the detection limit. Although the detection limits for these procedures are entirely adequate for determining the 10CFR61 waste classification of radwastes, they are most often not sensitive enough to quantitatively measure the actual concentrations of ^{129}I and ^{99}Tc present in the waste.

Because ^{129}I and ^{99}Tc are very difficult and expensive to measure, current practice in the nuclear power industry is to measure these radionuclides in a few samples of typical plant waste streams from each station on a periodic basis, and then develop activity scaling factors for ^{129}I and ^{99}Tc relative to the easily measured gamma emitters, ^{137}Cs and/or ^{60}Co. The plant-specific or generic scaling factors are then used to estimate the ^{129}I and ^{99}Tc concentrations in radwaste shipments prepared for disposal. However, for the reasons stated above, the $^{129}I/^{137}Cs$ scaling factors developed by the nuclear power industry and compiled by Best and Miller (1) and Cline, et al. (2) are conservatively high by several orders of magnitude.

Previous measurements conducted at Battelle on a limited number of low-level waste samples from several PWR and BWR stations by extremely sensitive and accurate mass spectrometry or neutron activation analysis have shown that the true concentrations of ^{129}I are two to four orders of magnitude lower than values reported in the industry data bases.(3)

^{14}C in Commercial Nuclear Power Station Radwastes

Similar problems to that of ^{129}I may also affect the ^{14}C values for the industry data base. Some of the problems related to the industry data base for ^{14}C have been summarized by Vance et al.(4) As shown in Table I, there are discrepancies in the existing industry data bases for the $^{14}C/^{60}Co$ scaling factors. The $^{14}C/^{60}Co$ scaling factors reported by Cline et al. (2) for the BWR and PWR full data bases are 47 and 5.4 times higher, respectively, than the scaling factors reported by Best and Miller.(1)

Also, the scaling factors reported by Best and Miller (1) systematically decrease by two orders of magnitude with increasing sample activity. This is probably a reflection of reporting lower-limit-of-detection (LLD) values or values very near the detection limit for ^{14}C in the low and medium activity samples that are one to two orders of magnitude higher than the actual ^{14}C concentrations in the samples.

TABLE I

$^{14}C/^{60}Co$ Radwaste Scaling Factors (from Vance, 1988)

Reference	Sample Type	$^{14}C/^{60}Co$ Scaling Factor BWR	PWR
NUREG/CR-4101 (2)	Full Data Base	3.5E-2	6.5E-2
NP-5077 (1)	Full Data Base	7.4E-4	1.2E-2
	Low Activity	3.8E-3	5.4E-2
	Medium Activity	7.6E-4	3.6E-3
	High Activity	3.1E-5	9.9E-4

EXPERIMENTAL

Sampling

The concentrations and distributions of ^{129}I, ^{99}Tc, and ^{14}C are being determined on mixed-bed ion exchange resin used at PWR stations and on powdered mixed-bed resin used at BWR stations. These radionuclides are being determined relative to the gamma-emitting radionuclides used for developing scaling factors, e.g., ^{60}Co, ^{137}Cs, and possibly others. In this manner, the tracking behavior of these isotopes from their source-term (the primary coolant) to the main waste streams (primary and liquid radwaste cleanup resins) can be determined.

For PWR stations, a scaled-down version of a plant's primary purification demineralizers is being placed in-line in the primary coolant sampling line, and primary coolant is being passed through the resin column for several days to as long as 6 weeks to simulate the cleanup operations and resin loading at a commercial nuclear power station. The test column consists of a 40-cm-long by 2.5-cm i.d. plexiglass tube with stainless steel screens placed on each end to contain the resin. The column is filled with 30 cm of the standard mixed-bed ion exchange resin routinely used at each station for cleanup of the primary coolant. The primary coolant flow rate through the column is scaled-down proportionally to the size of the column and typically is about 80 ml/min. Columns are being installed at a number of stations to obtain an adequate data base for determining the concentrations and distributions of the isotopes on the resins and for computing reliable scaling factors and testing of ion exchange models. After exposure of the column to the primary coolant, the column is disconnected and carefully packaged for shipping to BNW for radionuclide analyses.

For BWR stations, the typical powdered resin used for primary coolant cleanup is utilized in a scaled-down, in-line filter assembly to simulate the cleanup process used at BWR stations. A Millipore stainless steel in-line filter holder

(2-cm diameter) is loaded with 1.2 g of powdered resin to form a 0.6-cm-thick bed, and reactor coolant is pumped through the resin bed at 42 ml/min for 48 hours. The resin is then shipped to Battelle for radionuclide analyses.

The reactor coolant sampling periods for the test resin columns at the PWR stations are relatively short compared to the normal operational processing times for full-scale purification demineralizers at PWR stations (up to one year). Also, the length of the test resin columns (30 cm) are relatively short compared to the 90-120 cm deep purification demineralizer beds used at PWR stations. However, because of the high distribution coefficients for I^- and Tc (VII), which reflect a very strong affinity for anion exchange resin, it is anticipated that the differences in operating times and resin column lengths did not seriously effect the distribution of these radionuclides on the resin columns. The simulated BWR powdered test resins were also operated for a much shorter time than the actual demineralizers at the stations, but again, the high distribution coefficients for I^- and Tc (VII) for these resins should capture most of these radionuclides.

At Battelle, four of the PWR resin columns were carefully sectioned into twelve 2.5-cm-long segments for determining the vertical distribution of the radionuclides on the columns. The resin segments were analyzed for ^{129}I and ^{99}Tc by highly sensitive mass spectrometry to give accurate and reliable distributions of these isotopes on the resin column. For the three most radioactive resin columns, the ^{129}I activities were high enough to measure by radiochemical separations and photon counting on a beryllium window intrinsic germanium spectrometer. The ^{14}C on each segment was analyzed for total carbon species by a combustion technique followed by purification and liquid scintillation counting. The gamma-emitting radionuclides were determined by high-resolution gamma-ray spectrometry utilizing intrinsic germanium detectors. In addition, ^{90}Sr and Pu were measured in several of the test columns.

The BWR powdered resin samples were analyzed for ^{129}I, ^{99}Tc, ^{14}C, and the gamma emitters using the same measurement techniques.

The analytical uncertainties in the radiochemical analyses and gamma spectrometry were generally better than ±10%. The errors associated with the sampling and aliquoting were likewise estimated at about ±10%. Thus, the total propagated procedural error in the measurements was on the order of approximately ±14%.

Radiochemical Procedure Development

The ^{129}I and ^{99}Tc are being measured by two mass spectrometric techniques. Thermal emission mass spectrometry (TEMS) is the more sensitive method for ^{129}I (see Table II), but the purification chemistry is time-consuming and the sample throughput is quite slow. The second technique is inductively coupled plasma mass spectrometry (ICPMS). This method is less sensitive than TEMS, but is more rapid and convenient. Furthermore, the sensitivity of ICPMS, particularly when coupled to an electrothermal vaporization (ETV) graphite furnace or an ultrasonic nebulizer, is sufficiently great to allow measurements of ^{129}I and ^{99}Tc in most of the mixed bed resin and powdered resin samples obtained in this study.

TABLE II

Comparison Of ^{129}I and ^{99}TC Measurement Methods

Method	Detection Limit (microcuries)	
	129I	^{99}Tc
Counting	5E-7	5E-7
ICPMS	1E-8	1E-8
ICPMS/ETV	1E-11	8E-10
NAA	4E-13	---
TEMS	4E-13	
AMS	8E-14	

ICPMS - inductively coupled plasma mass spectrometry
ICPMS/ETV - inductively coupled plasma mass spectrometry/electrothermal vaporization
NAA - neutron activation analysis
TEMS - thermal emission mass spectrometry
AMS - accelerator mass spectrometry

It was necessary to develop new radiochemical purification procedures to separate the ^{129}I and ^{99}Tc from the resin and reactor coolant samples for final analyses by ICPMS/ETV. This analytical method does not require that the final separated sample be absolutely radiochemically pure, since the measurement is made by mass spectrometry rather than beta or photon counting. However, it is essential that the final 1 ml of purified 1N HNO_3 solution be free of alkali metal ions, since they interfere with the ICPMS measurement. It is also essential that the ^{129}I be in the iodate form to provide maximum instrument response during the volatilization portion of the ICPMS/ETV measurement. The analytical flow schemes for the ^{129}I and ^{99}Tc measurements of mixed bed ion exchange resin have been described elsewhere.(5,6)

RESULTS

To date, the PWR mixed-bed ion exchange resin columns from PWR Stations A through F, plus the BWR powdered resin beds from BWR Stations 1 through 4 have been analyzed for gamma emitters ($^{134,137}Cs$, ^{60}Co, etc.), and the non-gamma emitters ^{129}I, ^{99}Tc, and ^{14}C.

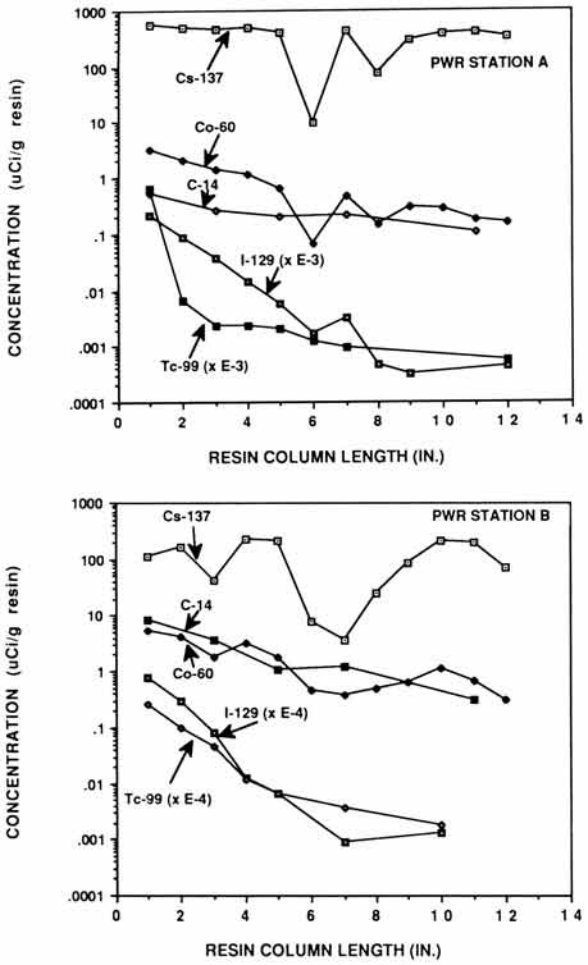

Fig. 1. Radionuclide distributions on PWR stations A and B test resin columns.

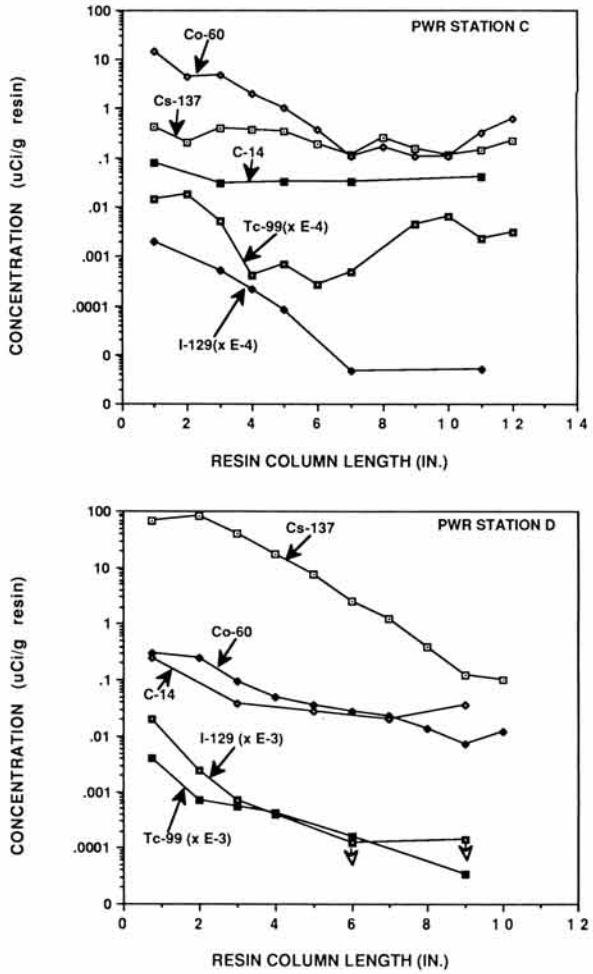

Fig. 2. Radionuclide distributions on PWR stations C and D test resin columns.

Radionuclide Distributions on PWR Mixed Bed Resin Columns

The distributions of ^{14}C, ^{60}Co, ^{99}Tc, ^{129}I, and ^{137}Cs on the test resin columns from PWR Stations A and B are shown in Fig. 1. The distributions of all radionuclides except ^{137}Cs showed a rather systematic decrease in concentration with depth of the resin bed. The ^{137}Cs, which is used for scaling to ^{129}I and ^{99}Tc, exhibited an erratic distribution on the resin and generally decreased little from the top to the bottom of the resin. Because of the relatively long sampling duration for these columns, the ^{137}Cs became essentially saturated on the resin, and analyses of the inlet reactor coolant concentrations during the test indicated that only about 19% and 39% of the ^{137}Cs at PWR Station A and PWR Station B, respectively, was retained on the test resin column. However, the ^{129}I and ^{99}Tc decreased by approximately three orders of magnitude over the first 8 to 10 in. (20.3 to 25.4 cm) of the resin column, and it appears that the resin captured essentially all of the ^{129}I and ^{99}Tc rather efficiently. The ^{60}Co decreased about 20- to 30-fold over the lengths of the resin columns. The ^{14}C distribution on the PWR Station B resin column closely tracked with the ^{60}Co, but on the PWR Station A column the ^{14}C concentration decreased somewhat slower than that observed for ^{60}Co. This similar tracking behavior was somewhat surprising in view of the very different production modes and chemistries of these two isotopes, but provides encouragement that ^{14}C may be scaled to ^{60}Co for PWR deep bed resins better than might have been expected.

The radionuclide concentrations on the PWR Station C and PWR Station D test resin columns are shown in Fig. 2. The ^{137}Cs distribution on the PWR Station C resin column decreased only slightly over the length of the column, indicating saturation of the ^{137}Cs had occurred as also observed in the PWR Station A and B test resin columns. The ^{129}I concentrations on the PWR Station C resin decreased nearly three orders of magnitude over the length of the column; the ^{99}Tc initially decreased about two orders of magnitude over the first 4 to 5 in. (10.2 to 12.7 cm) of the resin and then increased over the bottom 6 in. (15.2 cm) of the resin column. The ^{60}Co concentrations decreased about two orders of magnitude, but the ^{14}C concentrations de-

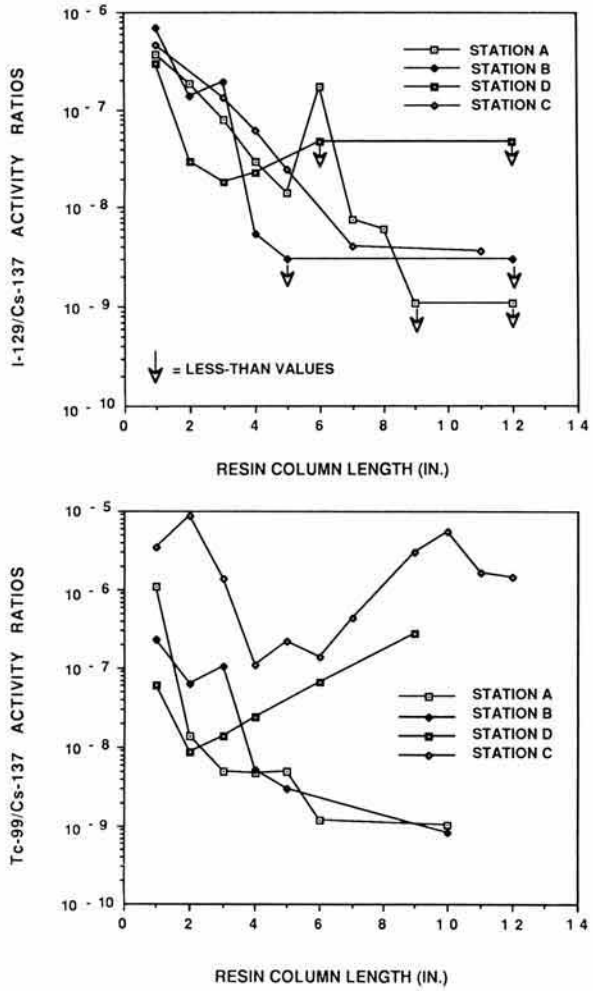

Fig. 3. Variability of $^{129}I/^{137}Cs$ and $^{99}Tc/^{137}Cs$ activity ratios on test resin columns from PWR stations.

creased only about a factor of two over the top 3 in. (7.6 cm) of the column and then remained steady over the remaining length of the column. This column displayed the poorest tracking behavior for ^{14}C and ^{60}Co.

The PWR Station D test resin column operated about half as long as the other columns due to technical difficulties, but the radionuclide distributions on the test resin were similar to those observed for the other stations except for ^{137}Cs. The ^{137}Cs did not appear to saturate the PWR Station D resin column and the ^{137}Cs decreased rather uniformly by about three orders of magnitude over the length of the column. The ^{129}I and ^{99}Tc concentrations likewise decreased two to three orders of magnitude over the length of the column. The ^{14}C and ^{60}Co tracked quite closely over the length of the column similar to that observed for the PWR Station B test resin column, and both decreased by over an order of magnitude.

Variability of Activity Scaling Factors on Resin Columns

It is of major importance to determine the tracking behavior of ^{129}I, ^{99}Tc, and ^{14}C on ion exchange resin used for primary coolant cleanup relative to the gamma-emitting nuclides used for developing scaling factors, i.e., ^{137}Cs and ^{60}Co. The distribution of these radionuclides on mixed-bed resin columns gives an indication of the variability that can be expected in scaling factors for primary cleanup resins, which represent by far the most important low-level radwaste source of these nuclides. This information is critical for developing sampling strategies for primary cleanup resin to ensure representative sample collection for 10CFR61 radionuclide assays for determining waste classification. Fig. 3 illustrates the variability of the $^{129}I/^{137}Cs$ and $^{99}Tc/^{137}Cs$ activity scaling factors observed for the four PWR mixed-bed resin columns that were sectioned for analyses. The $^{129}I/^{137}Cs$ scaling factors generally decreased by about two orders of magnitude over the top 5 to 6 in. (12.7 to 15.2 cm) of the resin column, and probably decreased another order of magnitude over the remaining lower half of the columns if the ^{129}I was detectable in the lower half of all columns. This extreme variability over a resin column length of only 12 in. (30.5 cm) points out the critical need for thoroughly homogenizing spent primary cleanup resins particularly at PWR stations before collecting grab samples for radionuclide analyses.

The variability of the $^{99}Tc/^{137}Cs$ activity scaling factors with resin column depth was more erratic than that observed for the $^{129}I/^{137}Cs$. The PWR Stations A and B showed a rather systematic three orders of magnitude decrease in the $^{99}Tc/^{137}Cs$ ratio over the lengths of the resin columns. The PWR Station D and PWR Station C columns had $^{99}Tc/^{137}Cs$ ratios which varied as much as two orders of magnitude over the lengths of the resin columns, but in a non-uniform manner. However, the conclusions are the same as those stated for the $^{129}I/^{137}Cs$ ratios, e.g. primary

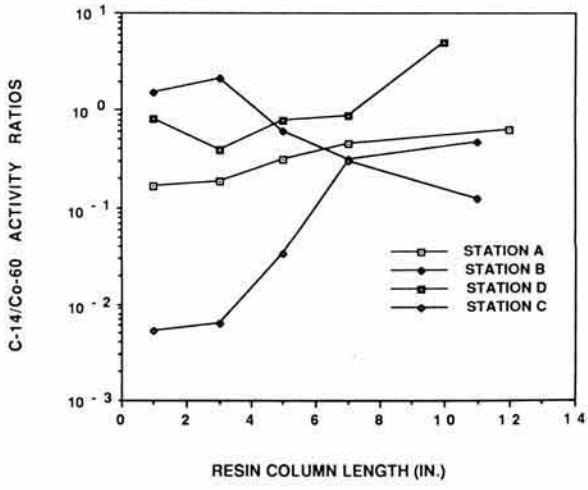

Fig. 4. Variability of $^{14}C/^{60}Co$ activity ratios on test resin columns from PWR stations.

cleanup resins become extremely layered with respect to the scaling factor distributions and very thorough mixing of the resins prior to grab sampling is critical for obtaining representative samples for radiochemical analyses.

Figure 4 shows the variability in the $^{14}C/^{60}Co$ activity ratios as a function of resin depth. This ratio generally varied less than a factor of ten over the lengths of the resin column, except for the PWR Station C column which had ratios varying by two orders of magnitude. The PWR Station C column was unique in that much lower ^{14}C concentrations were measured in this resin column relative to the other plants. Although the variability of the $^{14}C/^{60}Co$ ratios was not as extensive as those observed for the $^{129}I/^{137}Cs$ and $^{99}Tc/^{137}Cs$, it was still sufficiently large to require thorough mixing of primary cleanup resins prior to grab sampling.

Because of the extreme variability in the ^{129}I and ^{99}Tc activity scaling factors over very small depths of the simulated mixed bed primary cleanup resins, it is obvious that the potential for sampling errors could be very large for such

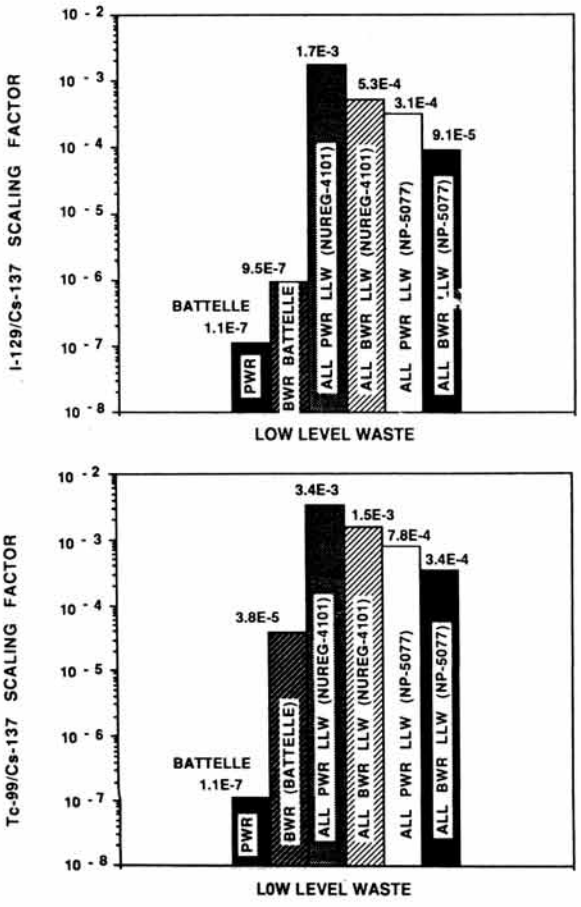

Fig. 5. Comparison of industry and Battelle $^{129}I/^{137}Cs$ and $^{99}Tc/^{137}Cs$ scaling factors.

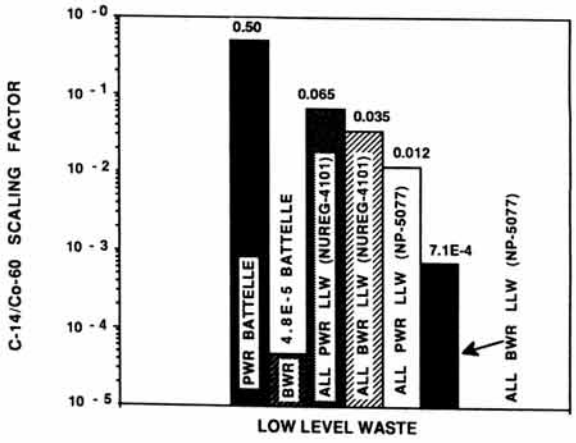

Fig. 6.Comparison of industry and Battelle $^{14}C/^{60}Co$ scaling factors.

non-homogeneous types of waste streams. Thus, it may be desirable to develop alternate methods for determining the inventories of these radionuclides in nuclear plants.

Radionuclide Inventories on Resins and Generic Activity Ratios

Table III gives the total radionuclide inventories for the entire PWR resin columns and the BWR powdered resin beds. For the sectioned PWR resin columns, the total radionuclide inventories were determined by summing the quantities contained in each segment of resin. These inventories were used for calculating the plant-specific and generic activity ratios for primary cleanup test resins for PWRs and BWRs given in Table IV. As shown in Table IV, the geometric mean of the $^{129}I/^{137}Cs$ ratios for the PWR stations was 9-fold lower than for the BWR stations, and the $^{99}Tc/^{137}Cs$ geometric mean for PWR stations was 313 times lower for the BWR stations. The $^{14}C/^{60}Co$ ratios were the opposite, with the PWR plants higher by at least four orders of magnitude compared to the BWR stations.

Comparison of Battelle and Industry Scaling Factors

Figure 5 and Fig. 6 graphically show a comparison of the $^{129}I/^{137}Cs$, $^{99}Tc/^{137}Cs$, and $^{14}C/^{60}Co$ activity scaling factors for the primary cleanup test resins measured at Battelle with industry scaling factors for all types of PWR and BWR waste (generic scaling factors) given by Cline, et al. (2), Best and Miller (1), and Vance.(4) Table V lists the ratio of industry/Battelle scaling factors for these radionuclides.

TABLE III

Summary of Long-lived Radionuclide Concentrations For Primary Cleanup Resins From PWR and BWR Stations

PWR Stations	Total gm resin	Primary Coolant Volume Sampled (liters)	Radionuclide Inventory on Total Resin (μCi) ^{14}C	^{60}Co	^{99}Tc	^{129}I	^{137}Cs
PWR Station A	52.33	2430	11.9	43.5	2.13E-3	1.45E-3	19410
PWR Station B	52.71	1884	98.5	78.4	1.39E-4	3.50E-4	6080
PWR Station C	41.87	4608	1.61	76.5	1.75E-5	1.03E-6	9.79
PWR Station E	42.50	227	1.07	0.799	7.34E-6	1.25E-5	295
PWR Station D	36.00	234	2.46	3.14	2.72E-5	1.07E-4	806
PWR Station F	39.37	222	1.76	0.816	1.72E-5	1.95E-5	35.5
BWR Stations							
BWR Station 1	1.478	121	4.7E-4	8.84	7.91E-5	5.17E-7	2.63
BWR Station 2	1.189	119	< 1.1E-3	46.6	4.79E-5	1.17E-6	5.61
BWR Station 3	1.258	121	< 5.3E-3	10.3	7.4E-5	4.1E-6	0.0612
BWR Station 4	1.173	118	< 9.5E-4	10.8	3.53E-6	2.3E-7	< 0.05

TABLE IV

Summary of Long-lived Radionuclide Scaling Factors for Primary Cleanup Test Resins From PWR and BWR Stations

PWR Stations	Activity Ratios (scaling factors) $^{129}I/^{137}Cs$	$^{99}Tc/^{137}Cs$	$^{14}C/^{60}Co$
PWR Station A	7.47E-8	1.10E-7	0.274
PWR Station B	5.76E-8	2.29E-8	1.26
PWR Station C	1.05E-7	1.79E-6	0.0210
PWR Station E	4.24E-8	2.49E-8	1.34
PWR Station D	1.33E-7	3.37E-8	0.783
PWR Station F	5.49E-7	4.85E-7	2.16
geometric mean:	1.06E-7	1.11E-7	0.504
BWR Stations			
BWR Station 1	1.97E-7	3.01E-5	5.3E-5
BWR Station 2	2.09E-7	8.54E-6	< 2.4E-5
BWR Station 3	4.1E-6	7.4E-5	< 4.9E-5
BWR Station 4	> 4.9E-6	> 7.7E-5	< 8.8E-5
geometric mean:	9.54E-7	3.48E-5	< 4.8E-5

TABLE V

Ratios of Industry Scaling Factors For All Types of Low-Level Waste With Battelle Scaling Factors For Primary Cleanup Test Resins

	Ratio of Industry/Battelle Scaling Factors		
	$^{129}I/^{137}Cs$	$^{99}Tc/^{137}Cs$	$^{14}C/^{60}Co$
All PWR LLW (NUREG-4101)	15,000	31,000	0.13
All PWR LLW (NP-5077)	2,800	7,100	0.024
All BWR LLW (NUREG-4101)	560	39	730
All BWR LLW (NP-5077)	96	8.9	15

As shown in the figures and summarized in Table V, the ^{129}I/137Cs ratios measured at Battelle by highly sensitive mass spectrometric and photon counting techniques gave scaling factors that were two to four orders of magnitude lower than the industry data bases. The largest differences were for the PWR stations where the industry scaling factors were 15,000 and 2,800 times higher than the Battelle values. The differences were not as great for the BWR stations, with the $^{129}I/^{137}Cs$ ratios for the industry data bases being 560 and 96 times higher than the Battelle ratios. Similar results were observed for the $^{99}Tc/^{137}Cs$ ratios. The $^{99}Tc/^{137}Cs$ ratios for the industry data bases were 31,000 and 7,100 times higher than the Battelle values for PWR stations and 9 to 39 times higher for the BWR stations. The $^{14}C/^{60}Co$ industry scaling factors were about 8 to 42 times lower than Battelle values for the PWR stations, and 15 to 730 times higher for the BWR stations.

SUMMARY

The highly sensitive measurements of ^{129}I, ^{99}Tc, and ^{14}C conducted at Battelle provide accurate assessments of the concentrations and distributions of these radionuclides on simulated purification demineralizer test resins from PWR and BWR stations relative to gamma emitting radionuclides used for developing scaling factors.

Because of the magnitude of the variability observed for the ^{129}I and ^{99}Tc activity scaling factors in the test resin columns, it is critical that important waste streams such as purification demineralizer resins and liquid radwaste cleanup resins be adequately homogenized prior to grab sampling for 10CFR61 radionuclide analyses.

An alternative solution, developed at EPRI is the RADSOURCE computer code. RADSOURCE analyzes reactor coolant gamma isotopic data to predict waste stream-specific 10CFR61 nuclide scaling factors for the time period represented by the gamma isotopic data. RADSOURCE calculates a set of scaling factors for user-specified waste types for the following fuel-source 10CFR61 nuclides: ^{90}Sr, ^{99}Tc, ^{129}I, ^{241}Pu, ^{242}Cm, and TRU radionuclides.

RADSOURCE provides for the derivation of scaling factors for non-fuel source 10CFR61 nuclides, ^{14}C and ^{63}Ni, from radiochemistry data using a linear regression technique.

It is expected that, with the validation of the isotopic modeling contained in the program, using these Battelle data, RADSOURCE will be used as an analytical tool to supplement and eventually replace the sampling method of deriving scaling factors. Scaling factors will be produced for nuclides such as ^{129}I where there have been no measurements and improved plant specific scaling factors will be produced for other nuclides.

Finally, as discussed earlier, ESEERCO is employing an alternative model, which also uses reactor coolant measurements, to verify the annual quantities of ^{129}I and ^{99}Tc disposed of at a LLW facility from each of its nuclear power plants.

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