THE CHARACTERIZATION OF ONTARIO HYDRO'S SOLID RADIOACTIVE REACTOR WASTES

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INTRODUCTION

Currently, Ontario Hydro handles approximately 3,000 m^3 of low and intermediate level solid radioactive reactor wastes annually. Wastes are stored centrally at the Bruce Nuclear Power Development (BNPD) Radioactive Waste Operations Site.[1] This site has been in-service since 1974 and operational data such as the volume, and the radiation fields of stored nuclear station waste, have been routinely recorded. In addition, radionuclide analyses have been performed on several types of radioactive waste. This operational data is analysed and used to characterize the radioactive waste.

The operational data analysed in this paper were collected over the three-year period from 1976 to 1978, inclusive. Reactor wastes originated from Candu reactors at Douglas Point NGS and Pickering NGS-A, both mature stations, and Bruce NGS-A, a station in the commissioning phase during the above period of time.

The analysis presented in this paper represents the first step in the development of an automated waste data retrieval and analysis system for Ontario Hydro. Ready access and analysis of waste characterization data will facilitate planning for waste handling, processing, storage and disposal requirements for future nuclear stations and waste management facilities. An automated data retrieval and analysis system will also facilitate the assessment of the potential occupational and public impact of the waste management systems and provide records to meet regulatory requirements.

ORIGIN AND TYPES OF SOLID RADIOACTIVE REACTOR WASTE

Reactor waste may be divided into two major categories: waste originating from reactor maintenance operations and waste originating from in-line reactor fluid purification systems. The latter can be divided into two categories: those contacting fuel (primarily the reactor coolant system) and the remainder (primarily the moderator system).

Waste in the first category (Table I) consists of cleaning materials, protective clothing, contaminated metal parts and miscellaneous items. The waste is collected in plastic bags and generally has a low radiation field (less than 5 mR/h on contact). The radioactive contamination is heterogeneous and the average specific activity is low (less than 0.4 mCi/kg). The majority of this waste is presently processed either by compaction into 200 L drums or by incineration. The remainder is nonprocessible by virtue of its physical form or radiation level.

TABLE I

ONTARIO HYDRO'S SOLID RADIOACTIVE REACTOR WASTES

Origin of Waste	Type of Stored Waste	Storage Container
Nuclear Station Maintenance Operations	(a) Ash	2.5 m^3 rectangular container
	(b) Compacted Waste	200 L Drum
	(c) Nonprocessible Waste	Polyethylene bag 200 L Drum
Reactor Purification Systems	(d) Disposable Ion Exchange Columns	Pressure Vessel
	(e) Filter vessels and elements	Pressure Vessel, Drip can, plastic pipe
	(f) Bulk Ion Exchange Resin	3 m^3 cylindrical container

Waste from the reactor heavy water purification systems consists of disposable ion exchange (IX) columns, filter vessels and elements or IX resin slurried from permanent IX columns. This waste is generally handled in shielded containers since contact radiation fields are usually greater than 1 R/hr. The radioactive contamination is relatively homogeneous and the average specific activity is of the order of 20 mCi/kg or about two orders of magnitude greater than that of maintenance operations waste.

CHARACTERISTICS OF SOLID RADIOACTIVE REACTOR WASTES

Introduction

The reactor wastes described in this paper (Table I) are subdivided into six main types.

Wastes have been characterized according to their production rates, gamma radiation field distributions, and radionuclide compositions. The radiation fields measured on contact with the exterior of the containers were characterized using the methods described in Reference 2.

As a basis for comparison, three specific activity reference points are presented below; the scheduled quantity per kilogram, the transportation limit and a typical value for natural background radioactivity.

The scheduled quantity per kilogram, a regulatory limit set for radioactive material by the (Canadian) Atomic Energy Control Act (3), is a specific activity below which a license to possess the material is not required, although for solid reactor wastes, methods for removal of control must be approved by the Atomic Energy Control Board.

The transportation limit, 0.002 mCi/kg, is the specific activity below which material may be considered nonradioactive for transportation purposes as defined in the Canadian Transport Commission and US Department of Transport regulations.

A typical value for natural background radioactivity in soil of 0.0001 mCi/kg was derived by a review of existing literature on this subject.

Discussion of Analytical Results

The rate of production and specific activity of reactor waste are influenced by the operating conditions at the nuclear stations. Fuel failures result in an increase in the production rate and specific activity of spent reactor coolant ion exchange resins. The production rate of spent moderator IX resin, used primarily to remove reactivity control chemicals from the moderator systems, increases during periods of frequent shutdowns and deratings. Maintenance operations waste is produced at a fairly constant rate with increases of varying degrees during major shutdowns involving work in contaminated areas.

Maintenance Operations Waste

Maintenance operations waste, accounting for 94% of the total volume of reactor waste, was found to have a specific activity less than 0.4 mCi/kg and represent about 6% of the total radioactivity of the reactor waste (Table II). Typical contact radiation fields were found to be of the order of 10 mR/h, and more than 99% of this waste, had contact radiation fields of less than 1R/h. A typical radiation field distribution, that for nonprocessible waste is shown in Fig. 1. This was best represented by a log extreme value distribution, the median of which occurred at 20 mR/hr. Radiation field distributions from ash containers and compacted waste were also log normal in character with medians occurring at 9.5 mR/hr and 9.0 mR/hr respectively. Normal handling procedures are suitable for this type of waste, and radiation dose expenditures by personnel are generally low. Shielding requirements of the waste storage structures are also minimal.

The log normal distribution of the specific activity of ash samples exhibited a median value of 0.04 mCi/kg. The typical gamma-emitting radionuclide composition of maintenance operations waste can be represented by that found for ash (Table III). After five years of decay it is dominated by ^{60}Co and ^{137}Cs.

Except for ash, all stored reactor wastes contain tritium. Based on tritium emissions from the radioactive incinerator, the specific activity of tritium on incinerable wastes has been calculated to be 20 mCi/kg. The specific activity of tritium in other wastes is estimated to be less than this level.

TABLE II

SPECIFIC ACTIVITIES AND RELATIVE QUANTITIES OF REACTOR WASTE

Type of Radioactive Waste		Radioactivity of Waste				Percentage of Total Annual Volume	
		Specific Activity (mCi/kg)		Average Annual Activity (Ci)	Percentage of Total Activity	Before Processing	After Processing
		Median	Average				
Incinerable	Maintenance Operations Waste	–	<0.01	1	0.1	53	
Ash	Maintenance Operations Waste	0.036	0.041	1	0.1		8
Compactible	Maintenance Operations Waste	–	0.1	20	1	28	
Compacted	Maintenance Operations Waste	0.04	0.1	20	1		21
Nonprocessible	Maintenance Operations Waste	0.1[a]	0.34	140	5	15	57
Disposable Ion Exchange Columns	Purification System Waste	23	34	700	23	1	4
Filters	Purification System Waste	11	26	470	16	1	2
Bulk Ion Exchange Resin	Purification System Waste	12	12	1 620	55	2	8

[a] Nonprocessible waste with no measureable radiation field (80% of total) is excluded from distribution

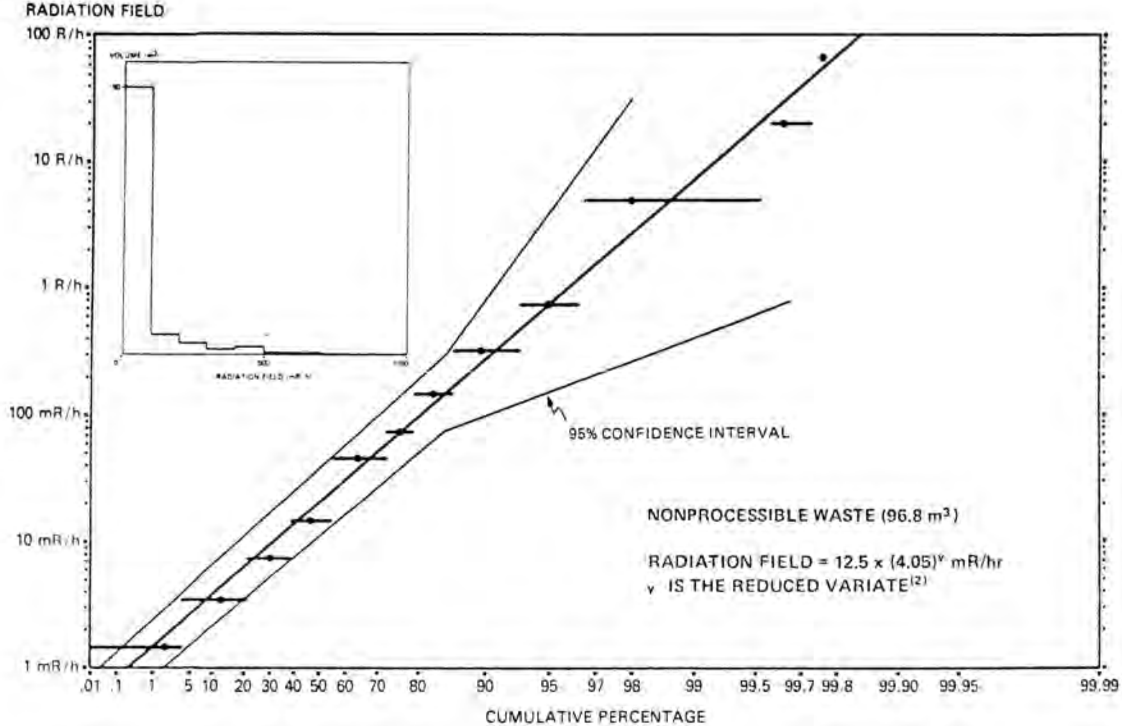

Fig. 1. LOG EXTREME VALUE DISTRIBUTION OF THE CONTACT RADIATION FIELDS FROM NONPROCESSIBLE WASTE

Carbon-14 is produced mainly by the neutron activation of oxygen-17 in the moderator and reactor coolant heavy water and is removed to a large extent by ion exchange. No measurements have been made of concentrations of ^{14}C in maintenance operations waste.

The ratio of the specific activity of ^{90}Sr to that of ^{137}Cs was measured to be 1:100 in reactor coolant water and the water from the active liquid waste dispersal tanks. This corresponds to a specific activity for ^{90}Sr of between 0.02 and 0.3 μCi/kg in maintenance operations waste. This is of the order of natural background radioactivity.

Purification System Waste

Purification system waste accounts for 4% of the total annual volume of reactor waste and has specific activities ranging from 6 to 37 mCi/kg. About 94% of the total radioactivity of reactor waste is contained in the purification system waste (Table II). Typical contact radiation fields from containers of this waste are about 10 R/h and more than 99% of the waste has contact radiation fields greater than 1 R/h. The radiation field distributions all exhibited a log normal behaviour with median contact radiation fields of 10.5 R/hr and 14.5 R/hr for filters and IX columns, respectively. The distribution for filters is shown in Fig. 2. Handling is usually performed in shielded flasks and transportation and storage requirements are considerably more stringent than those for maintenance operations waste.

Unlike maintenance operations waste, the radionuclide compositions of the various types of purification system waste are diverse (Table III). Ion exchange resin from the reactor coolant system is dominated by cesium radioisotopes. The specific activity of ^{14}C on reactor coolant ion exchange resin has been determined to be approximately 3 mCi/kg.

Reactor coolant system filters, as would be expected, contain a relatively small amount of ^{137}Cs and the radioactivity is dominated by short-lived radioisotopes (Table III). Thus, within five years, the radioactivity on the filters decays to about one tenth of its initial value. No measurements have been made of the ^{90}Sr or ^{14}C content of filters, but as these radioisotopes are anticipated to be mainly in solution, the contribution to the total radioactivity is expected to be small.

TABLE III

RADIONUCLIDE COMPOSITION OF ONTARIO HYDRO REACTOR WASTES

Isotope[a]	Half-life (days)	Percentage of Total Radioactivity					
		Incinerator Ash		Particulates in Reactor Coolant System		Ion Exchange Resin (no decay)	
		No Decay	Five Years Decay	No Decay	Five Years Decay	Reactor Coolant Resin	Moderator Resin
^{60}Co	1 920	28	62	15	76	1	61
$^{95}Zr/Nb$	66	19	–	49	–	–	–
^{137}Cs	10 950	9	34	2	19	65	–
^{134}Cs	730	2	2	–	–	25	–
^{144}Ce	284	11	–	17	2	–	–
^{106}Ru	368	10	1	10	3	–	–
^{65}Zn	245	6	–	2	–	–	–
^{51}Cr	28	4	–	–	–	–	33
^{58}Co	72	–	–	5	–	–	–

[a] major radioisotopes only

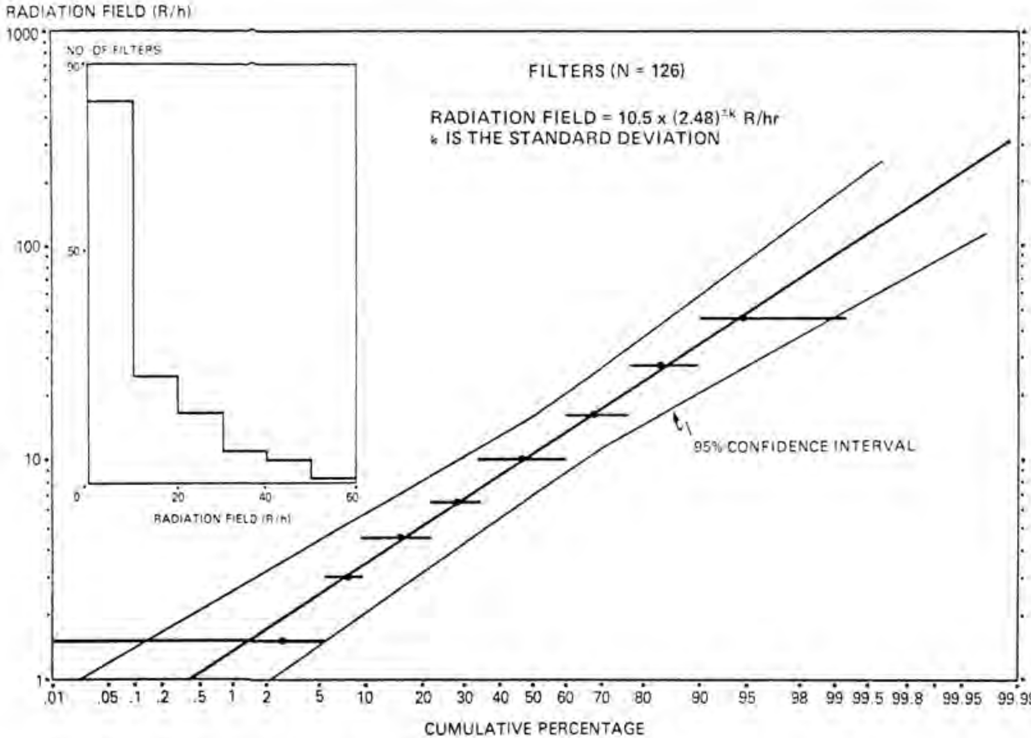

Fig. 2. LOG NORMAL DISTRIBUTION OF THE CONTACT RADIATION FIELDS FROM FILTERS

The major radioisotope on ion exchange resin from the moderator system is ^{60}Co. No fission products are normally present in the moderator system. The specific activity of ^{14}C was measured to be between 47 mCi/kg and 210 mCi/kg.

IMPLICATIONS ON ONTARIO HYDRO WASTE MANAGEMENT PRACTICES

At present the storage of maintenance operations waste, of low average specific activity (<0.4 mCi/kg) and low contact radiation fields (approximately 10 mR/h), uses in-ground concrete vaults. A thick walled reinforced concrete warehouse-type structure is being acquired for the future storage of this type of waste. This type of structure is less costly, utilizes land more effectively, and can be built in a shorter time period. Since 86%, by volume, of reactor waste results from maintenance operations, the use of this structure is expected to significantly reduce waste management costs.

In Fig. 3 it is seen than gamma-emitting radioactivity in maintenance operations waste generally decays to low specific activities within a short period of time. In fact, 65% of the total volume of reactor waste prior to processing has an average specific activity below the scheduled quantity per kilogram for ^{137}Cs and ^{60}Co. This is an important consideration in planning waste classification schemes for waste disposal.

With regard to purification system waste, the large differences between the radionuclide compositions and specific activities of filters, reactor coolant resin and moderator resin emphasize the need to segregate these types of waste, both at source and during storage. If the retrieval of filters is convenient, then it may be economic to transfer them to less expensive storage structures after a few years when their radioactivity has decayed to a small fraction of their initial value.

Moderator resin is not normally contaminated by fission products. The major gamma-emitting radioisotope, ^{60}Co, decays to the typical background radioactivity levels in roughly eighty years. The major radioisotope in the reactor coolant system resin is ^{137}Cs, and thus the radioactivity of this resin decays at a much slower rate.

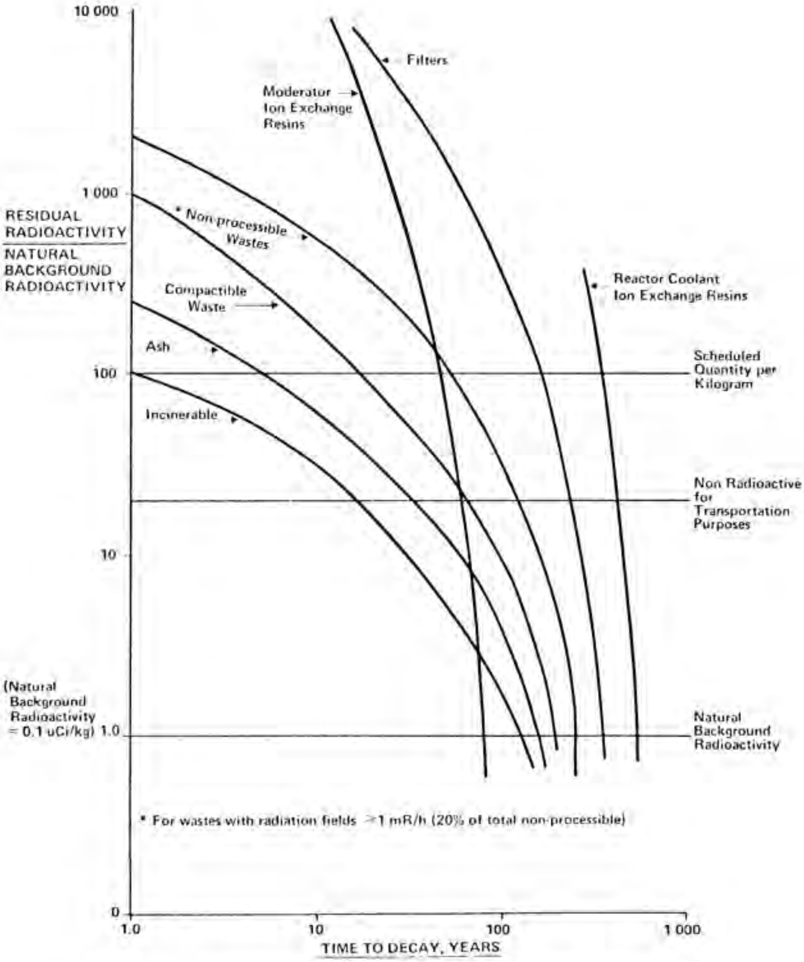

Fig. 3. Standardized Radioactivity Decay Curves for Reactor Wastes.

It is apparent from the data presented that there is a significant difference between the characteristics of maintenance operations waste and purification system waste and that differences in waste management strategy are appropriate.

This characterization of Ontario Hydro's reactor wastes is limited by the accuracy of the measurements available, and by the lack of data to characterize certain properties of waste. This paper contains an analysis of radioactive reactor wastes arising over a three-year operating period. Since manual analysis techniques were employed, it was necessary to limit the period over which waste generation was considered, and the complexity of analysis techniques. Presently, solid radioactive reactor waste data is being input into a computerized data base. This will allow much greater flexibility in the choice of analysis techniques. It will be possible in the characterization of waste to include incoming data on a routine basis with a minimum of effort. Correlation of reactor waste characteristics with station operating conditions and other factors will also be facilitated. Automated storage, retrieval and analysis of reactor waste data is an important development for waste characterization in the future.

REFERENCES

(1) Ontario Hydro Waste Storage Concepts and Facilities, T.J. Carter, G.A. Mentes, presented at the Waste Management 1976 Conference, Tucson, Arizona, October 1976.

(2) Probability Charts for Decision Making, J.R. King, 1971, Industrial Press Incorporated, New York, New York.

(3) Atomic Energy Control Act, Atomic Energy Control Regulations, SOR/74-334, June 4, 1974, Schedule 1.