Production and Accumulation of Low Level Radioactive Waste in Canada

Report to

Energy Mines and Resources, Atomic Energy Control Board, and Environment Canada

MacLaren Engineers

in association with

Senes Consultants Limited

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2.0 WASTE CHARACTERIZATION

2.1 General Description of Low Level Waste in Canada

Low level radioactive waste in Canada is traceable to four principal sources:

- Nuclear Fuel Cycle
- Atomic Energy of Canada Limited (AECL)
- Universities and Hospitals
- Industries

In addition to these sources, there are large quantities of contaminated soils which have resulted from waste management activities and remedial works.

This section presents an overall view of low level waste generated in Canada. The section following characterizes the waste generation in detail.

(i) Nuclear Fuel Cycle

The nuclear fuel cycle wastes are generated as by-products of mining and milling, uranium refining, fuel fabrication and nuclear power generation.

As discussed previously, mining and milling wastes are not included in the terms of reference in this study. Management of these types of wastes has been the subject of major research in the past few years and is currently being studied elsewhere.

- describe the regional distribution for each classification of waste across Canada
- recommend waste characterization criteria and guidelines for waste generators to enable them to classify their own future wastes.

assembling low level radioactive data from published sources (References 1-5). Draft tables were prepared on the basis of the published data as the first attempt at waste characterization and forecasting to the year 2000.

Radioactive waste generators were then contacted and sent draft tables to confirm their low level waste data and to supply additional data.

The data obtained from the various generators included:

- present annual waste volume
- present activities of significant radionuclides
- waste volume and radioactivity to present
- projections of waste volume and radioactivity to the year 2000.

Once the data were confirmed and further data sources exhausted, final characterization and forecasting was completed. The characterization tables were finalized and major comments on the waste data documented.

At this stage several methods for classification of the waste were developed. The main emphasis here was on the grouping of data to facilitate the development and analysis of the low level radioactive waste management concepts.

The characterized low level radioactive waste data were then classified and applied to:

- outline the current waste management practices for each classification

But does not include:

- mine or mill tailings
- irradiated fuel or high level waste.

Wastes such as ion exchange resins, filters and radioisotope production waste, often referred to as intermediate level waste, are also described in this study. These generally have higher specific activities than outlined above.

Low level waste can be large in volume with low specific activity (e.g. process residues) or small in volume with a higher specific activity (e.g. sealed sources). Low level waste contains radionuclides with half-lives from years (e.g. tritium) to several thousand years (e.g. radium).

1.2 Radioactive Waste Characterization and Classification

Radioactive waste characterization defines the properties of wastes (e.g. volume, activity). Waste classification groups wastes by common properties (e.g. specific activity, radionuclide half-life, radiological source).

The characterized waste data are used to forecast the production and accumulation of radioactive wastes. The waste classification data provide the basis for the definition of capacity and regional requirements for the development of low level radioactive waste management facilities.

1.3 Study Approach

Low level radioactive waste volumes and activities are currently recorded in various levels of accuracy and detail by the waste generators. The first stage of this study involved

1.0 INTRODUCTION

1.1 Definition of Low Level Wastes

"Radioactive Waste" can be defined as any waste material containing or contaminated with radionuclides in concentrations greater than that which would be considered by competent authorities as acceptable for uncontrolled use or release.

Radioactive wastes are of different physical and chemical forms and contain variable amounts of individual radionuclides with different half-lives and toxicities, as well as non-radioactive components with different properties.

Low level radioactive waste is most often defined by exclusion, i.e. all radioactive waste that is not irradiated fuel, high level waste or mine and mill tailings waste. The Nuclear Regulatory Commission in the United States discusses low level waste by excluding transuranic waste, irradiated nuclear fuel or by-product material as defined in the Atomic Energy Act (Reference 6).

Low level radioactive waste has not been quantitatively defined in Canada. The low level radioactive waste described in this study refers to material with:

- low specific activity (≤ 1 Ci/kg)
- limited concentrations of long-lived radionuclides (i.e. radionuclides with half-lives greater than 1000 years have specific activities $\leq 10^{-5}$ Ci/kg)

LIST OF TABLES AND FIGURES

The uranium refining wastes constitute the largest volume of low level waste presently being generated. These wastes consist primarily of residues (raffinate and ash) from the uranium trioxide (UO_3) and uranium hexafloride (UF_6) circuits and contaminated garbage produced in daily operations. The major radionuclide contaminants are uranium and radium in relatively low concentrations. All of the refinery wastes are generated by Eldorado Nuclear Limited, the only uranium refinery operating in Canada.

The fuel fabrication process (manufacturing of CANDU fuel bundles) generates a comparatively low volume of waste consisting of contaminated process garbage and a small volume of contaminated oil and pellet scrap. These wastes are contaminated with natural uranium.

Nuclear power generation wastes are generated in either reactor process stream purification systems or in maintenance operations. The purification systems generate waste ion-exchange resins and filters. The maintenance wastes consist of processible wastes which are suitable for incineration or compaction and non-processible wastes which are unsuitable for volume reduction. The maintenance wastes are contaminated mainly with short-lived radionuclides (^{60}Co, ^{137}Cs, ^{3}H). There are 13 power reactors presently generating wastes in Canada.

Additional sources of waste from the nuclear fuel cycle involve low level waste generated during decommissioning of nuclear facilities (reactors, refineries, etc.) and that generated during special remedial actions (e.g. retubing of a nuclear reactor). Several reactors (e.g. Gentilly I, NPD and

Douglas Point) may be decommissioned before the year 2000; however, as one of the favoured decommissioning strategies involves the sealing of the radioactive area for an extended period prior to dismantling, it is not clear that significant quantities of low level waste will arise from this source prior to the year 2000. In the case of retubing at Pickering, it is uncertain how much additional low level waste will be generated as a result of this activity. Because of the large uncertainties involved in the characteristics of the above wastes, they were not included in this study.

(ii) Atomic Energy of Canada Limited (AECL)

The AECL wastes are varied in nature and include radioisotope source material, lab garbage, animal and plant matter, old equipment, incineration ash, absorbed liquids, and ion exchange resins and filters. Both Chalk River Nuclear Laboratories (CRNL) and Whiteshell Nuclear Research Establishment (WNRE) carry out research in nuclear science and engineering. CRNL also receives wastes from segments of the nuclear fuel cycle, medical and research institutions and industries across Canada as well as contaminated soils. Commercial Products (CP) produces and distributes medical and industrial radioisotopes for use in all parts of Canada.

(iii) Universities and Hospitals

University and hospital wastes are generated in a number of institutions across Canada. Wastes include laboratory garbage, sealed sources, animal carcasses, accelerator wastes, radiopharmaceuticals and research reactor wastes. Most of this radioactivity is short-lived. The majority of these wastes are shipped to CRNL for disposal. Waste containing radionuclides with very short half lives are stored on-site to allow decay to de minimus levels of activity and are subsequently disposed of with non-radioactive wastes.

(iv) Industrial

The wastes in this class include those generated from industrial and research sources. These wastes are by-products of industrial processes, slags, sealed sources and contaminated garbage.

Wastes associated with non-radioactive industrial processes (e.g. slag from abrasives industry), but containing small amounts of natural radioactivity are normally classified as incidental wastes. These incidental wastes contain radioactivity but the radioactivity is not a significant feature of the material or process.

Only those incidental wastes of significant volume or radioactivity identified in Reference 4 have been included in this study. Other sources of these may also exist.

(v) Contaminated Soils

Large quantities of contaminated soils associated with the management of some low level waste (e.g. refinery residues) and remedial works (e.g. Port Hope, Bancroft, Scarborough) have accumulated over the years. These wastes are generally in the form of soil contaminated with small concentrations of Ra-226, natural uranium and, in some cases, arsenic. The major accumulations of contaminated soil are identified in this document. However, further sources not presently identified may have to be managed by the year 2000.

2.2 Waste Characterization

This section provides a comprehensive review of the nature of low level radioactive waste generated in Canada and as well provides a basis for subsequently grouping the wastes into various waste classifications with common characteristics described in Chapter 3.

The low level radioactive waste data are presented in Tables 2.1-2.8. Each table characterizes the wastes generated by a major generator or group of generators. The tables have the following headings:

Table 2.1 Nuclear Reactor Wastes
Table 2.2 Refinery Wastes
Table 2.3 Fuel Fabrication Wastes
Table 2.4 Atomic Energy of Canada Limited Wastes
Table 2.5 Universities and Hospital Wastes
Table 2.6 Incidental Wastes
Table 2.7 Industrial Wastes
Table 2.8 Contaminated Soil Wastes

Each table is subdivided into five columns as follows:

(i) Type of Waste and Location

- generator's name, waste type and/or location of waste.

(ii) Annual Rate of Waste Generation

- provides the present annual volume and total radioactivity generated. The radioactivity is given in activity (curies) for each major radionuclide generated, if available.

- a blank column indicates that no waste is presently generated.

(iii) Present Waste Accumulation

- provides the volume and present radioactivity (activity for each major radionuclide accumulated from first generation to the end of 1980, with radioactive decay taken into account).

- a blank column indicates that no waste has accumulated, usually indicating shipment off-site.

(iv) Projected Waste in Year 2000

- provides a predicted total of waste volume and radioactivity requiring waste management at the end of the century. These predictions are based on present data and any rate changes predicted by the waste generators. Radioactive decay is included in the calculation.

- a blank column indicates that no waste is accumulating, usually indicating shipment off-site.

(v) Comments

- provides miscellaneous comments on form of waste, how waste is presently managed, assumptions made with waste data, etc.

The tables are described below, consecutively, each with a general description of the waste characteristics and a series of detailed comments which support the data in the tables.

1. Table 2.1 Nuclear Reactor Wastes

(i) Ontario Hydro

Ontario Hydro's low level radioactive waste can be divided into two waste streams: the waste generated during reactor maintenance and the waste resulting from on-line reactor purification systems.

The maintenance waste is large in volume and low in both total and specific activity. It consists mostly of nuclear station contaminated garbage and discarded equipment.

The purification system wastes are much lower in volume but orders of magnitude higher in specific activity. These wastes are mostly ion exchange resins and filters from reactor cooling and moderator heavy water purification systems.

Presently, all low level radioactive wastes are stored in engineered storage facilities (in-ground concrete trenches and tile holes and above ground vaults) at the Radioactive Waste Storage Site #2 at the Bruce Nuclear Power Development (BNPD). The BNPD Site #2 also contains a volume reduction

TABLE 2.1

NUCLEAR REACTOR (ONTARIO HYDRO)

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation			1980 Waste Accumulation			Projected Waste in Year 2000[1]			Comments
	Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	Volume (m^3)	Radioactivity[2] (Ci)	(Nuclide)	Volume (m^3)	Radioactivity[2] (Ci)	(Nuclide)	
1. Maintenance waste (miscellaneous garbage, ash, baled waste, compacted drums)										
(a) Bruce Nuclear Power Power Development (BNPD) Radioactive Waste Storage Site #2	1000	38	^{60}Co	6 500	150	^{60}Co	46 000	550	^{60}Co	- Half of initial tritium is assumed to escape during storage period - Waste presently stored in concrete trenches, by volume - 10% ash - 25% compacted - 65% non-processible
		13	^{137}Cs		74	^{137}Cs		460	^{137}Cs	
		3 000	^{3}H		7 500	^{3}H		50 000	^{3}H	
		74	($T_{1/2}$ <1y)							
(b) BNPD Site #1				900	<1	^{60}Co				
					<1	^{137}Cs				
					390	^{3}H				
2. Purification System Waste (ion exchange resin, filters)										
(a) BNPD Site #2	100	540	^{60}Co	500	1 800	^{60}Co	3 400	5 700	^{60}Co	- Half of initial tritium is assumed to escape during storage period
		450	^{137}Cs		2 300	^{137}Cs		12 000	^{137}Cs	
		2 000	^{3}H		4 500	^{3}H		18 000	^{3}H	
		10 000	^{14}C		55 000	^{14}C		340 000	^{14}C	
		810	($T_{1/2}$ <2y)							
(b) BNPD Site #1				70	100	^{60}Co				- Waste is presently stored in tile holes and in-station tanks
					250	^{137}Cs				
					400	^{3}H				
					7 000	^{14}C				

1. This projection includes any expected rate changes prior to 2000.

2. Decayed radioactivity.

TABLE 2.1 (Cont'd)

NUCLEAR REACTOR (HYDRO QUEBEC)

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	1980 Waste Accumulation Volume (m^3)	Radioactivity (Ci)	Nuclide)	Projected Waste in Year 2000 Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Comments
1. Maintenance Waste										
(a) Gentilly I	75	1 0.4	^{60}Co ^{137}Cs	540	5 2.6	^{60}Co ^{137}Cs	2 000	7 6	^{60}Co ^{137}Cs	- Processible maintenance waste is currently compacted at a ratio 3:1
(b) Gentilly II	120	2.6 0.9 600 5.7	^{60}Co ^{137}Cs ^{3}H ($T_{\frac{1}{2}}$ <1y)				1 900	27 13 3 500	^{60}Co ^{137}Cs ^{3}H	- Assumes Gentilly I produces waste at current rate to year 2000 - Half of initial tritium is assumed to escape during the storage period - Waste stored on-site
2. Purification System Waste										
(a) Gentilly I	7	38 32 700 57	^{60}Co ^{137}Cs ^{14}C ($T_{\frac{1}{2}}$ <2y)	60	170 210 4 900	^{60}Co ^{137}Cs ^{14}C	200	280 630 18 200	^{60}Co ^{137}Cs ^{14}C	
(b) Gentilly II	20	110 90 400 2 000 160	^{60}Co ^{137}Cs ^{3}H ^{14}C ($T_{\frac{1}{2}}$ <2y)				360	750 1 400 2 300 36 000	^{60}Co ^{137}Cs ^{3}H ^{14}C	

TABLE 2.1 (Cont'd)

NUCLEAR REACTOR (NEW BRUNSWICK ELECTRIC POWER COMMISSION)

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	1980 Waste Accumulation Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Projected Waste in Year 2000 Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Comments
1. Maintenance waste										
(a) Pt. Lepreau	75	2.6 0.9 600 5.7	^{60}Co ^{137}Cs ^{3}H ($T_{\frac{1}{2}}$ <1y)				1 425	27 13 3 500	^{60}Co ^{137}Cs ^{3}H	- Half of initial tritium is assumed to escape during the storage period - Waste stored on-site - Processible maintenance waste will be compacted at a ratio 4:1
2. Purification System Waste										
(a) Pt. Lepreau	20	110 90 400 2 000 160	^{60}Co ^{137}Cs ^{3}H ^{14}C ($T_{\frac{1}{2}}$ <2y)				360	750 1 400 2 300 36 000	^{60}Co ^{137}Cs ^{3}H ^{14}C	

facility with an incinerator and a baler. An above-ground warehouse type storage facility is presently under construction.

In addition, the following comments apply:

- All data were supplied by Ontario Hydro (References 8 and 9).
- The radioactivity of maintenance waste may be up to one-sixth of that indicated due to conservative measurement techniques.
- The BNPD Radioactive Storage Site #1 was completely filled in the mid 1970's.
- Waste accumulations in Site #2 represent the integrated production and decay of radioactivity over a period from 1973 to the end of 1980.
- Waste projections beyond 1981 are based on a constant annual rate of waste generation/unit power generation and on a projected total installed capacity reaching 12,000 MW in 2000.
- Initial tritium concentrations in maintenance wastes prior to volume reduction were assumed to be 2 Ci/m^3 (Reference 8).

(ii) Hydro Quebec

The waste generated in Hydro Quebec's nuclear reactors is similar in properties to Ontario Hydro's waste. It is stored in above-ground concrete trenches and filter storage structures in a radioactive waste management area on the Gentilly site.

In addition, the following comments apply:

- Gentilly I Nuclear Power Station waste volumes were based on Hydro Quebec data (Reference 10).

- Gentilly II Nuclear Power Station waste volumes were based on an Atomic Energy of Canada Ltd. report (Reference 11).

- No additional reactors are added in Quebec before the year 2000.

- The radioactivity characteristics were extrapolated from data based on Ontario Hydro waste.

(iii) New Brunswick Electric Power Commission

The waste generated at Pt. Lepreau Nuclear Power Station will be similar in properties to Ontario Hydro's waste. It will be stored in above-ground concrete structures in a waste management area on the Pt. Lepreau site when the reactor begins operations in 1982.

In addition, the following comments apply:

- Pt. Lepreau's waste data were based on an AECL report (Reference 11).

- The radioactivity characteristics were extrapolated from data on Ontario Hydro waste.

- It is assumed that no additional reactors are added before the year 2000.

2. <u>Table 2.2 Refinery Waste</u>

Eldorado Nuclear Limited (ENL) operates the only uranium refinery in Canada. Its wastes are primarily process residues, chemicals and contaminated garbage. The main volume of waste consists of residues which are relatively low in specific activity.

The refinery wastes are currently shipped to Port Granby Waste Management Area or are stored on-site in the Crane Storage Building.

The following comments apply to the tabulated data:

- Waste data were obtained from the Atomic Energy Control Board of Canada (Reference 4) and ENL (Reference 12).

- Waste has not been sent to the Welcome Waste Management Area since 1960.

- Large volumes of contaminated soil are associated with the Welcome and Port Granby Waste Management areas (listed in Table 8).

- The projected wastes to the year 2000 include the expansion of UF_6 production in Port Hope and a new UO_3 faci-

TABLE 2.2

REFINERY (ELDORADO NUCLEAR LIMITED)

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation: Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	1980 Waste Accumulation: Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Projected Waste in Year 2000: Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Comments
1. Welcome Waste Management Area										
(a) Process Residue				11 000	15 690 690 8	U-Nat ^{226}Ra ^{230}Th ^{232}Th	11 000	15 690 690 8	U-Nat ^{226}Ra ^{230}Th ^{232}Th	- Site use ceased 1960 - Other contaminants present in early residues - Contains approximately 1000 tonnes As
2. Port Granby Waste Management Area										
(a) Process Residue and Contaminated Materials				267 000	100 600 850 50	U-Nat ^{226}Ra ^{230}Th ^{232}Th	267 000	100 600 850 50	U-Nat ^{226}Ra ^{230}Th ^{232}Th	- High moisture content - Contains approximately 3400 tonnes As
(b) Incineration Ash	100		U-Nat				2 000		U-Nat	- Detailed composition unknown
(c) Contaminated Garbage (metals, wood, rubber, paper, etc.)	900		U-Nat				18 000		U-Nat	
(d) Calcium Fluoride	2 500		U-Nat				12 500		U-Nat	- Contains unneutralized KOH (~3%) - Starting mid 1980's CaF_2 may be recycled to steel mills
3. Crane Storage	1 000	43	U-Dep	450 3 500 2 100	19 10 6.5	U-Dep U-Nat ^{232}Th U-Nat ^{232}Th	10 000 3 500 2 100	400 10 6.5	U-Dep U-Nat ^{232}Th U-Nat ^{232}Th	- Limed raffinate - Flame reactor ash and misc solids, detailed composition unknown, but contains U-Nat and ^{232}Th

lity in Blind River and are based on the following additional assumptions:

- Raffinate will continue to be recycled to uranium mills
- Disposal of CaF_2 will be eliminated assuming that the recyling of this material to the steel companies is successful
- MgF_2 slag may be recycled depending on the international market for depleted uranium metal.
- The inventory of contaminated metal scrap will decrease as a result of current cleaning and recycling to alloy producers
- Ammonium nitrate will be disposed of as fertilizer or its production will be eliminated as a result of new processes
- Miscellaneous materials including incinerator ash will continue to require disposal
- Flame reactor ash will probably be reprocessed but will still provide some waste

\- The results of ENL recycling, minimizing or eliminating the generation of wastes in their refining and conversion operations will reduce the projected waste generation rates.

- Measurements of ^{230}Th were scarce. Since most of the waste resulted from gravity concentrations of ore, the ^{230}Th content was assumed to equal that of ^{226}Ra. ^{230}Th is an important radionuclide since it is the parent of ^{226}Ra and has substantially higher inventories than ^{226}Ra (10-30 times as high) in yellowcake waste.

3. <u>Table 2.3 Fuel Fabrication Wastes</u>

There are three fuel fabricators presently manufacturing CANDU fuel bundles. The wastes generated are natural uranium contaminated process garbage, contaminated oil, wood, old equipment and pellet scrap. The waste is low in volume and activity. The pellet scrap is recycled and the remainder of the waste is currently shipped to CRNL for storage.

In addition, the following comments apply:

- The waste data are taken from the AECB report on low level radioactive waste in Canada (Reference 4) and discussion and correspondence with waste generators (References 13 and 23).

- Future waste generation data were derived from current waste generation rates by prorating on the basis of the projected (14 400 MW) and current (5200 MW) CANDU fuel requirements.

- Westinghouse Canada also stores 300 drums (45 gallon capacity) of contaminated soil on their property.

TABLE 2.3

FUEL FABRICATION

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation			1980 Waste Accumulation			Projected Waste in Year 2000			Comments
	Volume (m^3/y)	Radioactivity (Ci/y)	Radioactivity (Nuclide)	Volume (m^3)	Radioactivity (Ci)	Radioactivity (Nuclide)	Volume (m^3)	Radioactivity (Ci)	Radioactivity (Nuclide)	
1. Miscellaneous Low Level Wastes										
(a) Canadian General Electric (CGE)	266	1.3	U-Nat				12 000	46	U-Nat	- Waste is compacted and packaged - Waste shipped to and stored at CRNL
(b) Westinghouse Canada Ltd. (WCL)	180	1.9	U-Nat				6 500	69	U-Nat	- Non-metallic wastes could possibly be incinerated in the future
(c) Combustion Engineering	61	0.2	U-Nat				2 700	7	U-Nat	

4. Table 2.4 Atomic Energy of Canada Ltd. (AECL)

(i) Chalk River Nuclear Laboratories (CRNL)

Radioactive waste at CRNL originate both at CRNL and from various external sources. Shipments of waste to CRNL are made by the following generators:

- AECL Commercial Products
- Universities (Table 2.5)
- Industries (Table 2.7)
- Fuel Fabricators (Table 2.3)
- Reactor waste from the Nuclear Power Demonstration Plant, Rolphton operated by Ontario Hydro

The waste is varied in nature, as are the present storage methods. Low level waste from maintenance operations (miscellaneous garbage, etc.) has been stored in sand trenches in the past. This practice is being discontinued, as the Waste Treatment Centre will be coming into operation in 1982. The treated wastes in future will be in the form of bitumenized ash and baled waste.

Miscellaneous non-processible waste from the various external sources and that generated on-site are stored in concrete trenches. This waste varies widely in specific activity, radionuclide content and physical form. A limited amount of contaminated equipment (mainly from the NRX and NRU reactor vessels) is stored directly below ground.

Production of the radioisotope, ^{99}Mo, (which started in 1970) results in a relatively small volume of relatively high spe-

TABLE 2.4

ATOMIC ENERGY OF CANADA LTD.

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation			1980 Waste Accumulation			Projected Waste in Year 2000[1]			Comments
	Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	Volume (m^3)	Radioactivity[2] (Ci)	(Nuclide)	Volume (m^3)	Radioactivity[2] (Ci)	(Nuclide)	
1. Chalk River Nuclear Laboratories (CRNL):										
(a) Radioisotope Production (i) Tile Holes	50	3 700	^{90}Sr	190	23 000	^{90}Sr	280	77 000	^{90}Sr	- Annual volume and activity has been and will continue to increase at 10%/year - Annual volume reduced to 3 m^3/yr in 1986 following ^{235}U recovery - Wastes presently combined with cement - In 1986 wastes will be combined with glass
		3 100	^{137}Cs		20 000	^{137}Cs		63 000	^{137}Cs	
		0.24	^{99}Tc		2	^{99}Tc		7	^{99}Tc	
	0.0004		^{129}I		0.012	^{129}I		0.04	^{129}I	
	0.006		^{235}U		0.03	^{235}U		0.06	^{235}U	
	0.014		^{239}Pu		0.084	^{239}Pu		0.42	^{239}Pu	
		29 100	($T_{½}$<1y)							
(b) Miscellaneous Low Level Waste										
(i) Concrete Trenches (misc. waste from various industrial, university, hospital producers)	300	3 800	^{60}Co	12 000	41 000	^{60}Co	18 000	29 000	^{60}Co	- Assume annual rate constant to year 2000
		400	^{137}Cs		6 200	^{137}Cs		10 000	^{137}Cs	
		20	^{90}Sr		400	^{90}Sr		600	^{90}Sr	
		1	^{226}Ra		20	^{226}Ra		40	^{226}Ra	
		0.2	^{14}C		13	^{14}C		20	^{14}C	
		0.5	^{241}Am		9	^{241}Am		20	^{241}Am	
		180	^{152}Eu		2 200	^{152}Eu		3 000	^{152}Eu	
		300	^{147}Pm		1 200	^{147}Pm		1 200	^{147}Pm	
		0.3	$^{241}Am/Be$		6	$^{241}Am/Be$		10	$^{241}Am/Be$	
		0.6	^{85}Kr		7	^{85}Kr		10	^{85}Kr	
		0.01	^{204}Tl		0.05	^{204}Tl		0.05	^{204}Tl	
		90	^{3}H		1 100	^{3}H		1 400	^{3}H	
		9 100	($T_{½}$<2y)							

1. This projection includes any expected rate changes prior to 2000.

2. Decayed radioactivity.

TABLE 2.4 (Cont'd)

ATOMIC ENERGY OF CANADA LTD.

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	1980 Waste Accumulation Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Projected Waste in Year 2000 Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Comments
(ii) Sand Trenches (mics. garbage)				17 800	8 300 1.3 20 35	^{3}H ^{90}Sr ^{60}Co ^{137}Cs	17 800	3 000 1 2 21	^{3}H ^{90}Sr ^{60}Co ^{137}Cs	- Use of sand trenches discontinued
(iii) Ground Burial (Contaminated equipment)				200	Low Level	Misc. Nuclides	200	Low Level	Misc. Nuclides	- Ground burial discontinued
(c) Conditioned Wastes (Concrete trenches)										
(i) Bituminized Solids	40	65 2 43 98	^{60}Co ^{90}Sr ^{137}Cs ($T_{\frac{1}{2}}$ <2y)				720	448 29 634	^{60}Co ^{90}Sr ^{137}Cs	- Generation of conditioned waste to commence in 1982
(ii) Bituminized Ash	25	2 0.05 1 4	^{60}Co ^{90}Sr ^{137}Cs ($T_{\frac{1}{2}}$ <2y)				450	14 1 15	^{60}Co ^{90}Sr ^{137}Cs	
(iii) Baled Wastes	50	2 0.05 1 100 4	^{60}Cr ^{90}Sr ^{137}Cs ^{3}H ($T_{\frac{1}{2}}$ <2y)				900	14 1 15 560	^{60}Co ^{90}Sr ^{137}Cs ^{3}H	- Half of tritium is assumed to escape

TABLE 2.4 (Cont'd)

ATOMIC ENERGY OF CANADA LTD.

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation			1980 Waste Accumulation			Projected Waste in Year 2000			Comments
	Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Volume (m^3)	Radioactivity (Ci)	(Nuclide)	
2. Whiteshell Nuclear Research Establishment (WNRE)										
(a) Miscellaneous Low Level Wastes (Garbage, contaminated equipment, absorbed liquids)										
(i) In-ground Trenches	250	1.5 1.5	^{90}Sr, ^{137}Cs ($T_{\frac{1}{2}}$ <2y)	4 700	25	^{90}Sr, ^{137}Cs	7 000	200	^{90}Sr, ^{137}Cs	- Accumulations since 1965 - Use of inground storage ends 1984
(ii) In-ground Concrete bunkers	40	5 5	^{90}Sr, ^{137}Cs ($T_{\frac{1}{2}}$ <2y)	480	80	^{90}Sr, ^{137}Cs				- Above ground storage commences 1984
(iii) Compacted waste (above ground storage)	110	6.5 6.5	^{90}Sr, ^{137}C ($T_{\frac{1}{2}}$ <2y)							
(b) Purification System Waste										
(i) Concrete stand pipes (ion exchange resin, filters, waste from hot cell examinations)	8	75 75	^{90}Sr, ^{137}Cs ($T_{\frac{1}{2}}$ <2y)	170	570	^{90}Sr, ^{137}Cs	200	800	^{90}Sr, ^{137}Cs	- Ends in 1984 - Production after 1984 included in above ground storage

TABLE 2.4 (Cont'd)

ATOMIC ENERGY OF CANADA LTD.

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	1980 Waste Accumulation Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Projected Waste in Year 2000 Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Comments
(ii) Above ground storage (solidified waste from Active Liquid Waste Treatment Center, non-processible and compacted waste from hot cell examinations)	27	125 125	^{90}Sr, ^{137}Cs ($T_{\frac{1}{2}}$ <2y)				460	1 900	^{90}Sr, ^{137}C	- Use starts in 1984
(c) Alpha contaminated waste (hot cells, etc)										
(i) In-ground concrete bunkers	6		U,Th,Pu isotopes	40		U,Th,Pu isotopes	80		U,Th,Pu isotopes	- Low concentrations of alpha emitters - In-ground storage ends 1984
(ii) Above-ground storage	6		U,Th,Pu isotopes				100		U,Th,Pu isotopes	- Above-ground storage starts 1984
3. AECL-Commercial Products (CP)										
(a) Internal Production	10	200 80 3 3 3 3 3 3 3	^{14}C ^{60}Co ^{127}Cs ^{226}Ra ^{63}Ni ^{90}Sr ^{36}Cl ^{241}Am ^{3}H							- Sent to CRNL
(b) External Industries	55	6 4	^{14}C ^{60}Co							

cific activity waste. This is immobilized in Portland cement and stored in tile holes. Also stored in tile holes are small volumes of irradiated fuel (outside the scope of this study) and purification system waste (fission and corrosion products).

Low specific activity liquids have been discharged directly into the ground in a liquid waste management area. This practice, started in 1953, has resulted in a large area of contaminated soil. The volume of soil contaminated and the degree of contamination are difficult to estimate and are presently under investigation by CRNL. This contaminated soil will not be considered in this study.

The direct discharging of liquids into the ground will be discontinued when the Waste Treatment Facility comes into operation in 1982. Most of the radioactivity will be removed from the liquids by ultra-filtration, reverse osmosis and evaporation and the resulting radioactive solids will be combined with bitumen and stored.

Other low specific activity liquid wastes presently stored in in-ground tanks will be similarly treated. Liquid wastes from early reprocessing experiments (high level waste) will be treated and immobilized in glass.

In addition, the following comments apply to the data in Table 2.4:

- The waste volumes and characteristics are based on communications with CRNL personnel (References 14 and 15).

- CRNL is currently reviewing all of its waste characteristics.

- Waste characteristics represent averages of data for the period 1965 to 1978 inclusive.

- The annual waste generation rate for concrete trenches prior to 1965 was assumed to be half the present rate (Reference 14).

- The present rate of waste generation was assumed to remain constant to the year 2000 (Reference 14).

- The following assumptions were made in determining the radioactivity of the various nuclides in the concrete trenches (References 14 and 15):

    - Fission and activation product radioactivities of the concrete trench wastes were added and the radionuclide composition for bitumenized ash was assumed.

    - Waste contaminated with ^{60}Co radioactivity was stored in both tile holes and concrete trenches according to the magnitude of the annual radioactivity.

- Waste in sand trenches was assumed to have a similar radionuclide composition to bitumenized ash although the average specific activity is much lower; an initial tritium concentration of 0.3 Ci/m^3 was assumed.

(ii) Whiteshell Nuclear Research Establishment (WNRE)

Low level radioactive wastes at WNRE are presently stored in in-ground soil trenches, concrete bunkers and concrete standpipes. Generally, the wastes in the in-ground trenches and concrete bunkers are miscellaneous low specific activity waste which comprise about 95% of the total waste volume, whereas that in the concrete standpipes is purification system waste of much higher specific activity and only 3% of the volume. About 2% of the waste volume is alpha contaminated waste and is stored in the in-ground concrete bunkers. By 1985, the use of in-ground structures will have ceased and above-ground storage will be used. In addition, the suitable low specific activity waste will be compacted.

The data presented were based on a personal communication (Reference 16).

(iii) AECL Commercial Products (CP)

The AECL CP lab generates its own waste resulting from its radioisotope production and, in addition, acts as a depot for some waste en route to CRNL from industries and universities. All waste from CP is sent packaged to CRNL. The total annual volume of waste handled is very small.

The data presented is based on a personal communication (Reference 17).

5. <u>Table 2.5 Universities and Hospital Wastes</u>

Almost all university and hospital wastes are sent to CRNL for storage. Most of the wastes consist of sealed sources, lab garbage, animal and plant matter, and radiopharmaceuticals. Some large universities (e.g. University of Toronto, University of Alberta) act as depots for radioactive waste from hospitals and small local industries prior to shipment to CRNL. University and hospital wastes are low in volume with relatively high specific activities.

In addition, the following comments apply:

- The data are from References 4, 18-22.

- The present annual rates of generation are assumed to remain constant to the end of the century; however, the rate of generation at many of the facilities fluctuates greatly from year to year.

- Many of the wastes generated in universities and hospitals have half-lives less than one year and are not considered here. These wastes are stored on-site to allow decay to de minimus levels of activity and are disposed of by conventional methods.

- Some universities generate uranium milling waste which is outside the scope of this study.

TABLE 2.5

UNIVERSITIES AND HOSPITALS

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation			1980 Waste Accumulation			Projected Waste in Year 2000			Comments
	Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Volume (m^3)	Radioactivity (Ci)	(Nuclide)	
Low Level Waste (lab garbage, immobilized liquids, animal carcasses, sealed sources)										- University waste generally sent to CRNL
1. U of Calgary & Alberta	10	0.032 1042 0.0009 3.2 0.005 2	^{14}C ^{3}H ^{226}Ra ^{137}Cs ^{99}Sr $^{241}Am/Be$							- U of A has storage facilities on site for waste with half-life less than 18 months - Non-university waste (e.g. hospitals) also handled
2. U of Guelph	0.002	0.0001	^{14}C	0.009	0.003	^{14}C	0.009	0.003	^{14}C	- Buried directly into ground, now sent to CRNL - Contains ^{3}H
3. McGill	45	0.240 0.480 0.0001 0.06	^{3}H ^{125}I ^{14}C $(T_{1/2} < 2y)$							
4. McMaster										
(a) Spent IX resin	1.2	0.25	^{110}Ag, ^{124}Sb							
(b) Lab Waste	10	5 0.01 0.5 0.1	^{3}H ^{14}C ^{51}Cr ^{35}S							
5. U of Montreal	10	19 0.013 0.0003	^{3}H ^{14}C ^{226}Ra							- Rate of generation increasing annually by small amounts
6. U of Ottawa	15	0.1 0.1	^{14}C ^{3}H							- Some temporarily stored at University

TABLE 2.5 (Cont'd)

UNIVERSITIES AND HOSPITALS

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	1980 Waste Accumulation Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Projected Waste in Year 2000 Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Comments
7. U of Toronto	250	1 1 1	^3H ^{14}C ($T_{\frac{1}{2}}$ <2y)							- Previously stored on site
8. TRIUMF	15	20 700	^{60}Co ($T_{\frac{1}{2}}$ <2y)							- Lab garabge, ion exchange resin - Activity unknown
9 U of Waterloo	4.5		^{14}C ^3H							
10. U of Laval	5.0	3.5	^{14}C							- Contains ^3H
11. U of British Columbia	1.5		^{14}C							- Activity unknown
12. Simon Fraser	1.0	0.001	^{241}Am							- Contains ^{60}Co, ^{14}C
13. Carleton	0.5		^{14}C ^3H							- Activity unknown

6. Table 2.6 Incidental Wastes

Incidental wastes are generated as by-products of non-radioactive processes. They are large in volume and low in specific activity. They are usually in slag form and stored loosely on-site. The practice of storing such waste directly on soil may result in the contamination of the soil. The extent of this contamination is difficult to estimate at present; therefore, the contaminated soil associated with this waste type is not included.

In addition, the following comments apply:

- The data are from Reference 4.
- Chromasco, Deloro and Fundy no longer produce radioactive waste.
- Several other industries in Canada generate very small quantities of low level radioactive waste and were not included in the table.
- Other generators, e.g. fertilizer manufacturers, etc. have also not been included in the table.
- A density of 3.0 g/cm^3 has been assumed for slag waste.

7. Table 2.7 Industrial Wastes

The industrial low level radioactive wastes are generated through the use or production of radioactive materials. The

TABLE 2.6

INCIDENTAL

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation			1980 Waste Accumulation			Projected Waste in Year 2000			Comments
	Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Volume (m^3)	Radioactivity (Ci)	(Nuclide)	
1. Chromasco Ltd.				60	0.35	^{232}Th	60	0.35	^{232}Th	- Stored in drums on-site
2. Deloro Mining and Smelting				100 000	23	U-Nat	100 000	23	U-Nat	- Slag dumped on property
					30	^{226}Ra		30	^{226}Ra	- Contains 27 tonnes As
					30	^{230}Th		30	^{230}Th	
3. Exolon Co. of Canada Ltd./Norton Research Corp.	1 000	0.35	U-Nat	20 000	7	U-Nat	40 000	16	U-Nat	- Dumped in Walker Brothers quarry, Thorold, Ontario
		1.2	^{232}Th		3.5	^{232}Th		28	^{232}Th	
		0.05	^{226}Ra		1.8	^{226}Ra		3.5	^{226}Ra	
		0.05	^{230}Th		1.8	^{230}Th		3.5	^{230}Th	
4. Fundy Chemical Company				500	1.8	^{232}Th	500	1.8	^{232}Th	- Slag stored on site in transportation container
					0.35	U-Nat		0.35	U-Nat	
					0.35	^{226}Ra		0.35	^{226}Ra	
					0.35	^{230}Th		0.35	^{230}Th	
5. Masterloy Prod. Ltd.	80	1.0	U-Nat	6 000	7.6	U-Nat	7 600	99	U-Nat	- Slag pile on property
		0.18	^{232}Th		10.6	^{232}Th		14	^{232}Th	- Waste now drummed
		0.02	^{226}Ra		0.7	^{226}Ra		1	^{226}Ra	- Contains 1 tonne As
		0.02	^{230}Th		0.7	^{230}Th		1	^{230}Th	

TABLE 2.7

INDUSTRIAL

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation: Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	1980 Waste Accumulation: Volume (m^3)	Radioactivity[1] (Ci)	(Nuclide)	Projected Waste in Year 2000: Volume (m^3)	Radioactivity[1] (Ci)	(Nuclide)	Comments
1. Hawker Siddeley	2.5	0.9	^{232}Th	45	0.5	^{232}Th	95	18	^{232}Th	- Industrial Waste generally sent to CRNL - Drummed and stored in a pit
2. Saskatchewan Research Inst. and Industries							150	11	U-Nat	- Amok Ltd. Cluff Lake Waste Management Facility will commence operations late 1980's
3. Agriculture Canada Research Station				15	0.001 0.043	^{14}C ^{133}Ba	15	0.001	^{14}C	- Plant and soil extracts buried in ground
4. Defence Research Estab. Suffield										
(a) Ground burial (misc. low level waste)				200		^{226}Ra ^{14}C ^{60}Co ^{137}Cs	200		^{226}Ra ^{14}C ^{60}Co ^{137}Cs	- Activities unknown
(b) Concrete Vaults (sealed sources)				75		^{60}Co ^{137}Cs	75		^{60}Co ^{137}Cs	
5. Health Protection Branch	8.5	1.5 < 1 < 1 < 1 < 1	^{14}C ^{3}H ^{226}Ra ^{137}Cs ^{60}Co							- Absorbed liquids, animal carcasses
6. National Research Council (NRC)	5		^{60}Co ^{3}H ^{14}C							- Sealed sources, absorbed liquids, animal carcasses - Activities unknown

1. Decayed radioactivity.

TABLE 2.7 (Cont'd)

INDUSTRIAL

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation			1980 Waste Accumulation			Projected Waste in Year 2000			Comments
	Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	Volume (m^3)	Radioactivity[1] (Ci)	(Nuclide)	Volume (m^3)	Radioactivity[1] (Ci)	(Nuclide)	
7. Agriculture Research Branch	4.5		^{3}H ^{14}C							- Contamin. plants & Soils - Activities unknown
8. Agriculture Canada Animal Research Centre	2.5	0.040								- Animal carcasses, contaminants unknown
9. Ontario Cancer Found. Ottawa Civic Hops.	<1	0.180	^{226}Ra							- Ra needles & tubes
10. Ayerst Laboratories	10		^{14}C ^{3}H							- Absorbed liquids, glass - Activities unknown
11. Biotronik Life Systems	<1	210	^{147}Pm							- Sealed sources
12. N.E.N. Canada	<1	<0.5 <0.5 <0.5	^{14}C ^{204}Tl ^{3}H							- Absorbed liquids
13. Sentrol Systems Ltd.	<1	4.1 0.06 0.70 0.010	^{85}Kr ^{90}Sr ^{137}Cs ^{204}Tl							- Sealed sources
14. Consolidated Bathurst	<1	0.035	^{85}Kr							- Sealed sources
15. La Compagnie Price Ltée	<1	0.275	^{85}Kr ^{90}Sr ^{204}Tl							- Sealed sources - Activities of ^{90}Sr, ^{204}Tl unknown

1. Decayed radioactivity

TABLE 2.7 (Cont'd)

INDUSTRIAL

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation			1980 Waste Accumulation			Projected Waste in Year 2000			Comments
	Volume (m^3/y)	Radioactivity (Ci/y)	(Nuclide)	Volume (m^3)	Radioactivity[1] (Ci)	(Nuclide)	Volume (m^3)	Radioactivity[1] (Ci)	(Nuclide)	
16. Sherritt Gordon Mines					^{232}Th					– Waste dumped on property – Waste production unknown
17. Other Industrial & Research Waste	5	720 15 4 3 <1 <1	^{60}Co ^{137}Cs ^{85}Kr ^{3}H ^{226}Ra ^{241}Am							– Wastes in form of sealed sources, contaminated equip. & various sorts of gauges

1. Decayed radioactivity

volume of waste generated and the total activities of the radionuclides are low. The data in this table is based on Reference 4.

In addition, the following comments apply:

- There also exist numerous smaller generators of low level waste which have been included in summary form in the tables. Most of these wastes are sealed sources.

- Most industrial wastes are sent to CRNL. Some wastes are stored on-site in containers or directly in the soil.

- A specific gravity of 1.7 g/cm^3 has been assumed for soil waste.

8. Table 2.8 Contaminated Soil Wastes

There are four sources of contaminated soil wastes considered in this study - Port Hope, Scarborough, Chalk River Nuclear Laboratory and Eldorado Nuclear Limited.

The contaminated soils are very large in volume and low in specific activity. The contaminated soils all contain long lived radionuclides such as uranium, radium or thorium and, in some instances, contain arsenic.

In addition, the following comments apply:

- The Port Hope data were based on Reference 1.

TABLE 2.8

CONTAMINATED SOIL

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation			1980 Waste Accumulation			Projected Waste in Year 2000			Comments
	Volume (m^3/y)	Radioactivity (Ci/y)	Radioactivity (Nuclide)	Volume (m^3)	Radioactivity (Ci)	Radioactivity (Nuclide)	Volume (m^3)	Radioactivity (Ci)	Radioactivity (Nuclide)	
1. Port Hope										
(a) Rollins Ravine				52 000	8 11 8	^{226}Ra U-Nat ^{230}Th	52 000	8 11 8	^{226}Ra U-Nat ^{230}Th	- Contaminated soil, ash pottery - Some waste mixed in municipal garbage - Some As present
(b) Alexander Ravine				6 300	0.53 0.2 0.53	^{226}Ra U-Nat ^{230}Th	6 300	0.53 0.2 0.53	^{226}Ra U-Nat ^{230}Th	- Contaminated equipment, ash, soil, misc. refuse
(c) CN/CP Viaducts				2 200	0.11 0.003 0.11	^{226}Ra U-Nat ^{230}Th	2 200	0.11 0.003 0.11	^{226}Ra U-Nat ^{230}Th	- Contaminated soil
(d) Port Hope Waterworks				1 500	0.07 0.002 0.07	^{226}Ra U-Nat ^{230}Th	1 500	0.07 0.002 0.07	^{226}Ra U-Nat ^{230}Th	- Contaminated soil
(e) Sewage Treatment Plant Storage Area				1 100	0.06 0.001 0.06	^{226}Ra U-Nat ^{230}Th	1 900	0.10 0.003 0.10	^{226}Ra U-Nat ^{230}Th	- Contaminated soil - 800 m^3 projected to year 2000
(f) Strachan Street Ravine				8 400	0.70 0.3 0.70	^{226}Ra U-Nat ^{230}Th	8 400	0.70 0.3 0.70	^{226}Ra U-Nat ^{230}Th	- Process solids, ash
2. Scarborough				3 200	0.13	^{226}Ra	3 200	0.13	^{226}Ra	- Contaminated soil
3. CRNL										
(a) Port Hope				50 900	3 3	^{226}Ra ^{230}Th	50 900	3 3	^{226}Ra ^{230}Th	- Contaminated soil from Port Hope sent to CRNL - Contains 2.1 tonnes As
(b) Ottawa Site #1				20 500	7 7	^{226}Ra ^{230}Th	20 500	7 7	^{226}Ra ^{230}Th	- Contaminated soil from Ottawa sent to CRNL with less than 1 kg As total
(c) Ottawa Site #2				2 800	3 3	^{226}Ra ^{230}Th	2 800	3 3	^{226}Ra ^{230}Th	

TABLE 2.8 (Cont'd)

CONTAMINATED SOIL

LOW LEVEL RADIOACTIVE WASTE CHARACTERISTICS

Type of Waste and Location	1980 Rate of Waste Generation			1980 Waste Accumulation			Projected Waste in Year 2000			Comments
	Volume (m^3/y)	Radioactivity (Ci/y)	Radioactivity (Nuclide)	Volume (m^3)	Radioactivity (Ci)	Radioactivity (Nuclide)	Volume (m^3)	Radioactivity (Ci)	Radioactivity (Nuclide)	
4. ENL										
(a) Welcome				440 000	100 53 53	U-Nat ^{226}Ra ^{230}Th	440 000	100 53 53	U-Nat ^{226}Ra ^{230}Th	- Contaminated soil - Contains 45 tonnes As
(b) Port Granby				123 000	60 30 30	U-Nat ^{226}Ra ^{230}Th	123 000	60 30 30	U-Nat ^{226}Ra ^{230}Th	- Contains 27 tonnes As

- The projected waste in the year 2000 in the Sewage Treatment Plant Storage Area was based on planned future building and excavation in Port Hope.

- The Scarborough data were based on a remedial report (Reference 3) for these soils.

- The contaminated soil has an assumed density of 1700 kg/m^3.

- The CRNL soil originated at Port Hope and Ottawa.

2.3 Present Waste Management Practices and Treatment Technologies

Low level radioactive waste is treated and stored using many different techniques by the various waste generators. The current waste management practices are summarized in Figure 2-1 for each waste generator. Figure 2-1 illustrates the flow of low level radioactive waste from the origin of generation to the current storage destination. The data used in the flow diagrams are based on the waste charaterization data.

The flow diagrams detail the following information:

- Current annual rate of waste generation for each waste generator (in m^3/y).

- Form of the waste generated (e.g. miscellaneous garbage, soil).

- Storage destination of the waste (e.g. AECL, on-site).

- Waste treatment currently used (e.g. compaction, incineration).

- Facility used for waste storage (e.g. slag piles, trenches).

- Form of the waste stored (e.g. loose material, containers).

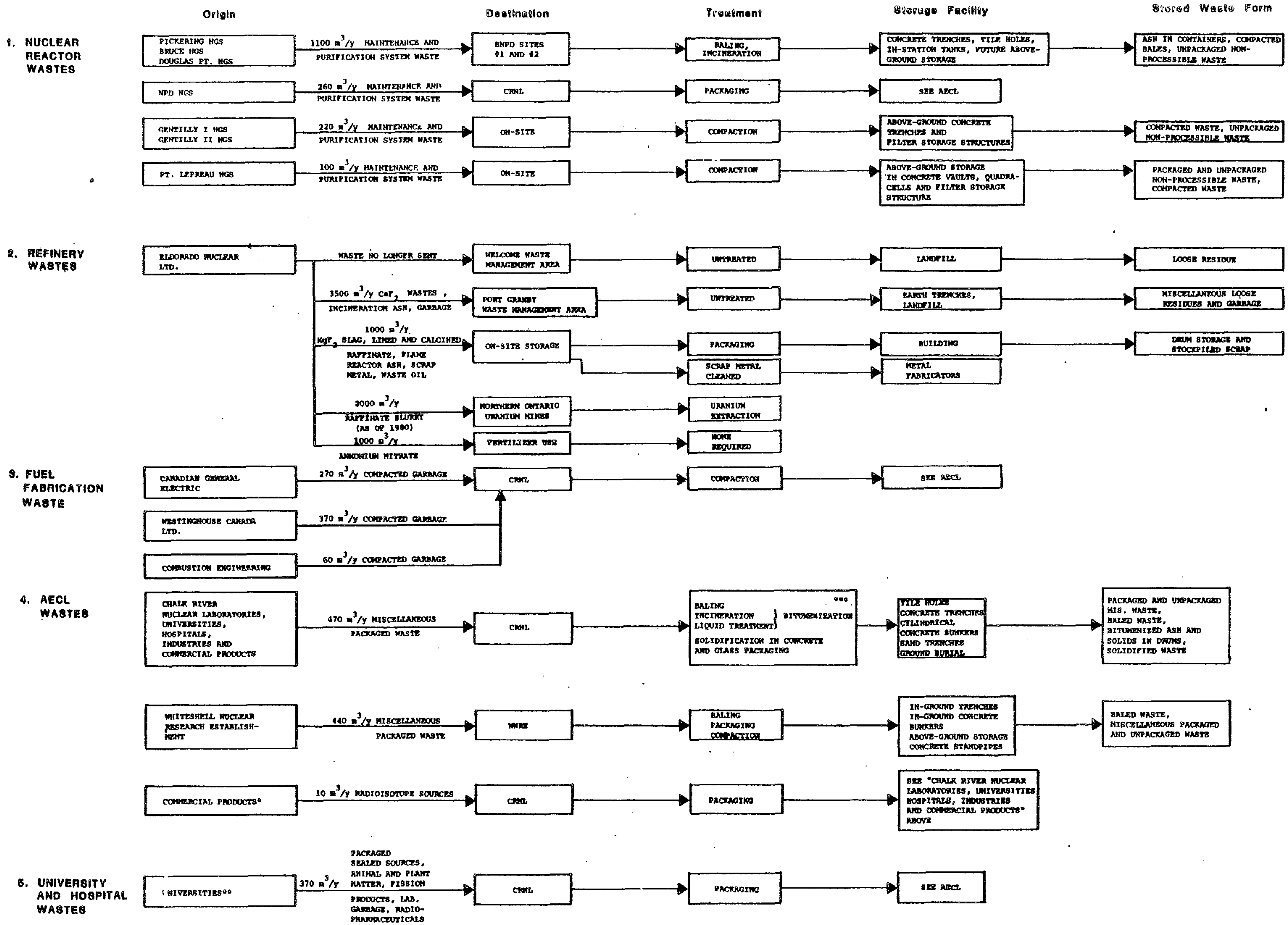
Upon the inspection of the flow sheets (Figure 2-1), the following points are noteworthy:

i) The Nuclear Reactor Wastes are volume reduced, wherever possible, and stored in engineered waste facilities (e.g. tile holes, concrete trenches). The storage facilities are in most instances, owned and operated by the utilities. Volume reduction of wastes is by incineration and compaction (or baling). There is no further treatment of volume reduced waste.

ii) The Refinery Wastes are either packaged (e.g. drummed) or stored loosely in licensed landfill waste management areas local to the refinery. The storage facilities are owned and operated by the refinery. Some waste is recycled for recovery of reusable material.

iii) The Fuel Fabrication Wastes are compacted and sent to Chalk River Nuclear Laboratory.

iv) At present, the bulk of AECL solid wastes are stored untreated in both landfill and engineered concrete facilities located at Chalk River and Whiteshell. Volume reduction methods, under development and planned



*COMMERCIAL PRODUCTS ALSO ACTS AS A TRANSFER DEPOT FOR 55 m^3/y INDUSTRIAL AND UNIVERSITY WASTE EN ROUTE TO CRNL

**UNIVERSITIES INDICATED IN TABLE 2.5. MAJOR UNIVERSITIES ALSO HANDLE HOSPITAL WASTE

***TREATMENT FACILITIES UNDER CONSTRUCTION PRACTICES TO BE IMPLEMENTED IN THE NEAR FUTURE

CURRENT WASTE MANAGEMENT SYSTEM FLOW

Figure 2.1a

Category	Origin	Flow	Destination	Treatment	Storage Facility	Stored Waste Form
6. INCIDENTAL WASTES	CHROMASCO LTD.	DISCONTINUED	ON-SITE	PACKAGING	GROUND BURIAL	DRUMS
	DELORO MINING AND SMELTING	DISCONTINUED	ON-SITE	UNTREATED	SLAG PILE, LANDFILL	LOOSE MATERIAL
	EXOLON CO. OF CANADA LTD./NORTON RESEARCH CORP.	1000 m^3/y SLAG	WALKER BROTHERS QUARRY, THOROLD, ONT.	UNTREATED	QUARRY	LOOSE MATERIAL
	FUNDY CHEMICAL CO.	DISCONTINUED	ON-SITE	PACKAGING	FIELD STORAGE	TRANSPORTATION CONTAINERS
	HASTERLOY PROD. LTD.	80 m^3/y SLAG	ON-SITE	PACKAGING	SLAG PILE	LOOSE MATERIAL, DRUMS
7. INDUSTRIAL WASTES	HAWKER SIDDELEY	3 m^3/y	ON-SITE	PACKAGING	PIT	DRUMS
	SASKATCHEWAN RESEARCH INSTITUTIONS & INDUSTRIES	BEGINNING LATE 1980'S	CLUFF LAKE WASTE MANAGEMENT FACILITY			
	AGRICULTURE CANADA RESEARCH STATION	DISCONTINUED	ON-SITE	UNTREATED	GROUND BURIAL	SOIL AND PLANT MATTER
	DEFENCE RESEARCH ESTAB. SUFFIELD	DISCONTINUED	ON-SITE	UNTREATED	GROUND BURIAL CONCRETE TRENCHES	MISC. WASTES, SEALED SOURCES
	OTHER INDUSTRIES (LISTED IN TABLE 2.7)	40 m^3/y PLANT AND ANIMAL MATTER, SEALED SOURCES, ABSORBED LIQUIDS, MISC. WASTE	CRNL	PACKAGING	SEE AECL	
8. CONTAMINATED SOIL WASTES	PORT HOPE WASTES: ROLLINS RAVINE, ALEXANDER RAVINE, STRACHAN ST. RAVINE CN/CP VIADUCTS, PORT HOPE WATERWORKS, SEWAGE TREATMENT PLANT STORAGE AREA	CONTAMINATED SOIL	REMAINS IN-SITU 72000 m^3	UNTREATED	NONE*	SILTY CLAY, ASH, REFUSE
	SCARBOROUGH	CONTAMINATED SOIL	REMAINS IN-SITU 3200 m^3	UNTREATED	NONE	SILTY CLAY
	PORT HOPE REMEDIAL SITES OTTAWA SITE #1 AND #2	74200 m^3 CONTAMINATED SOIL REMOVED 1976-80	CRNL	UNTREATED	LANDFILL	SILTY CLAY
	ELDORADO NUCLEAR LTD: WELCOME AND PORT GRANBY WASTE MANAGEMENT AREAS	CONTAMINATED SOIL	REMAINS IN-SITU 560000 m^3	UNTREATED	LANDFILL	SILTY CLAY

*SOME WASTE STORED IN SANITARY LANDFILL -2500 TONS IN TEMPORARY STORAGE COMPOUND

CURRENT WASTE MANAGEMENT SYSTEM FLOW

Figure 2.1b

for implementation in the near future, include baling and incineration of solids, and ultra-filtration, reverse osmosis and evaporation of radioactive liquids. Further treatment will consist of bituminization of ash and evaporator residues. Waste from the ^{99}Mo production is presently combined with Portland cement and will be immobilized in glass in the future.

v) The University Wastes are packaged and sent to CRNL for storage. These wastes are not treated further.

vi) The Incidental Wastes are stored on-site in slag piles, landfill or quarries. The waste is stored untreated as loose material or packaged. There is no further treatment.

vii) The Industrial Wastes are usually packaged and stored on-site or at CRNL. The storage techniques include ground burial and containment in concrete trenches. There is no further treatment.

viii) The majority of Contaminated Soil Wastes remain on-site. Some soil has been transported to CRNL for landfill storage as part of remedial cleanup operations undertaken by the Federal Provincial Task Force (Reference 1).

3.0 WASTE CLASSIFICATION

3.1 Introduction

The low level radioactive waste characterized for each waste generator in Chapter 2 can be grouped into various classes depending on sets of common characteristics. An overriding prerequisite for a successful waste classification system is that the waste be physically separable into the defined classes. This is largely dependant on the waste management practices of the waste generator. Current waste management practices are varied and unless some standardized requirements are defined, an optimum waste classification system, suitable for various disposal methods or facilities, cannot be developed.

In this study, a coarse classification system was developed in an attempt to systematically group Canada's low level wastes according to characteristics which may help to define requirements of treatment and/or disposal method. Since this classification system is crude, a more detailed classification system should be developed to provide direction for future waste management practices (especially disposal) of the various generators of low level radioactive waste.

3.2 Development of General Waste Classes

General waste classes were developed for low level radioactive waste sharing common characteristics in the following areas:

- Volume
- Specific/Total Activity
- Waste Form (from generator, prior to disposal)
- Half-life of Major Radionuclides
- Chemical Properties
- Ability to Dilute Waste
- Other Radiological Concerns.

The waste from the major generators could then be grouped into five general classes with properties shown on Table 3.1.

It should be noted that reactor purification and ^{99}Mo production wastes are not considered in this study because of their high specific activity and uncertainty in future treatment methods and since these wastes should be managed in the same manner as high level wastes. This class of wastes accounts for an accumulated volume of 5300 m^3 and a total radioactivity of 600,000 Ci, mainly ^{14}C.

It can be seen from Table 3.1 that classes 3-5 could potentially be subdivided further. Of these, only the reactor maintenance waste in class 4 can be sub-divided at present on the basis of existing data and waste management practices.

Thus, for the purposes of this study, no attempt will be made to develop a more detailed classification system than that

TABLE 3-1

WASTE CLASS DESCRIPTION

Class Number	Waste Source	Waste Characteristics Table Number	Accumulated Volume in Year 2000 (m^3)	Relative Specific Activity (Ci/kg)	Waste Form (Source)	Waste Form (Disposal)	Half-Life (y)	Chemical Concerns	Dilutability	Comments
1.	a) Contaminated Soil	2.8	~10^6	10^{-6} - 10^{-5}	Bulk, Loose	Bulk, Loose	>100	As	Yes	Slight radon emissions
	b) Incidental Waste	2.6	10^5 - 10^6	10^{-6} - 10^{-5}	Bulk, Loose	Bulk, Loose	>100	Varied	Yes	Slight radon emissions
2.	Refinery Residue	2.2	10^5 - 10^6	10^{-5} - 10^{-4}	Bulk, Loose	Bulk, Loose	>100	As	Yes	Radon emissions
3.	a) Refinery garbage	2.2	10^4 - 10^5	10^{-5} - 10^{-4}	Bulk, Loose	Bulk, Loose	>100	Varied	Yes	Part of waste may be treated
	b) Fuel Fabricators	2.3	10^4 - 10^5	10^{-5} - 10^{-4}	Packaged	Packaged	>100	Inert	Yes	
4.	a) Reactor Maintenance	2.1	10^4 - 10^5	<10^{-2}	Packaged, Loose	Packaged, Loose	<100	Inert	Yes	
	b) AECL	2.4	10^4 - 10^5	<10^{-2}	Packaged, Loose	Packaged, Loose	<100	Inert	Yes	
5.	a) University	2.5	10^3 - 10^4	Mixed	Packaged	Packaged	Mixed	Varied	No*	* For most of waste
	b) Industrial	2.7	<10^3	Mixed	Packaged	Packaged	Mixed	Varied	No*	

TABLE 3.2

TABULATION OF ACCUMULATED WASTE BY WASTE CLASS

Waste Class No.	Waste Description	Waste Accumulated in year 2000: Volume (m^3)	Radioactivity (Ci)	(Nuclide)	Comments
1.	Contaminated Soil and Incidental Waste (bulk, loose waste)	860 000	140	^{226}Ra	Contains 100 tonnes As
			45	^{232}Th	
			300	U-Nat	
			140	^{230}Th	
2.	Refinery Residue (bulk, loose waste)	280 000	1 300	^{226}Ra	Contains approximately 4 400 tonnes As
			60	^{232}Th	
			120	U-Nat	
			1 540	^{230}Th	
3.	Refinery and Fuel Fabricator Garbage (packaged)	35 000	130	U-Nat	
			400	U-Dep	
			6.5	^{232}Th	
4.	Reactor and AECL Maintenance Waste (packaged, loose)	86 000	1 100	^{60}Co	
			1 400	^{137}Cs	
			50	^{90}Sr	
			61 000	^{3}H	
5.	University, Hospital, Industrial Waste (packaged)	18 000	29 000	^{60}Co	- Waste in CRNL concrete trenches - Possibility of segret-acting out some high specific activity portion of this waste exists
			10 000	^{137}Cs	
			600	^{90}Sr	
			40	^{226}Ra	
			20	^{14}C	
			20	^{241}Am	
			3 000	^{152}Eu	
			1 200	^{147}Pm	
			10	$^{241}Am/Be$	
			10	^{85}Kr	
			0.05	^{204}Tl	
			1 400	^{3}H	

discussed above. However, guidelines for the development of detailed sub-classes will be given in Chapter 4. It is important that optimum waste management practices be instituted by the waste generator as soon as feasible in preparation for a safe and efficient disposal system.

3.3 Projected Waste Volumes by Classification

Using the general waste classes given in Section 3.2, the projected wastes (volumes and radioactivities) that will be accumulated for disposal in the year 2000 can be tabulated. Only those wastes that have been adequately characterized in Chapter 2 are included in this tabulation. Table 3.2 presents the waste accumulations in the year 2000 of the five waste classes. The reactor purification and ^{99}Mo production waste has not been included.

Waste in Classes 1 and 2 have similar properties in that they constitute large volumes of loose bulk, low specific activity waste containing ^{226}Ra, ^{232}Th, and U-Nat (natural uranium). The specific activity of the waste in Class 2 is higher than that of Class 1, however, the potential for dilution of this waste by uncontaminated soil or municipal refuse exists.

Waste in Class 3 has similar characteristics (loose bulk, low specific activity) to waste in Classes 1 and 2. However, its volume is relatively smaller.

Waste in Class 4 is different than wastes in the previous three classes in that its specific activity is higher and it is composed of relatively shortlived radionuclides. However, if Class 4 waste is further segregated according to waste characteristics, some of this waste could be considered for disposal in the same facility as Classes 1 to 3 wastes.

Class 5 contains only those wastes which are present in the concrete trenches at CRNL. The major portion of the radioactivity in this waste is contained in a small percentage of the total volume, however, it is not possible to separate this numerically for this study. Efforts to physically separate out this portion will be made by CRNL at the time when retrieval becomes necessary.

3.4 Geographic Distribution of the Wastes

Low level radioactive waste is produced from coast to coast across Canada. Figure 3-1 indicates the location of waste generation areas across Canada according to the classes of wastes discussed previously. Reactor purification and radioisotype production wastes are included for comparison purposes.

In Figure 3-1, bar graphs are used to illustrate the total volume and activity of low level radioactive wastes expected to be generated in each province to the end of the century. Above the bar graphs are "pie" diagrams which illustrate the breakdown, by waste class, of the total volumes and activities.

The bar graphs are plotted on a logarithmic scale in order to cover the range of volumes and activities (i.e. 1-1 000 000 m^3 and 1-1 000 000 Ci) for each province.

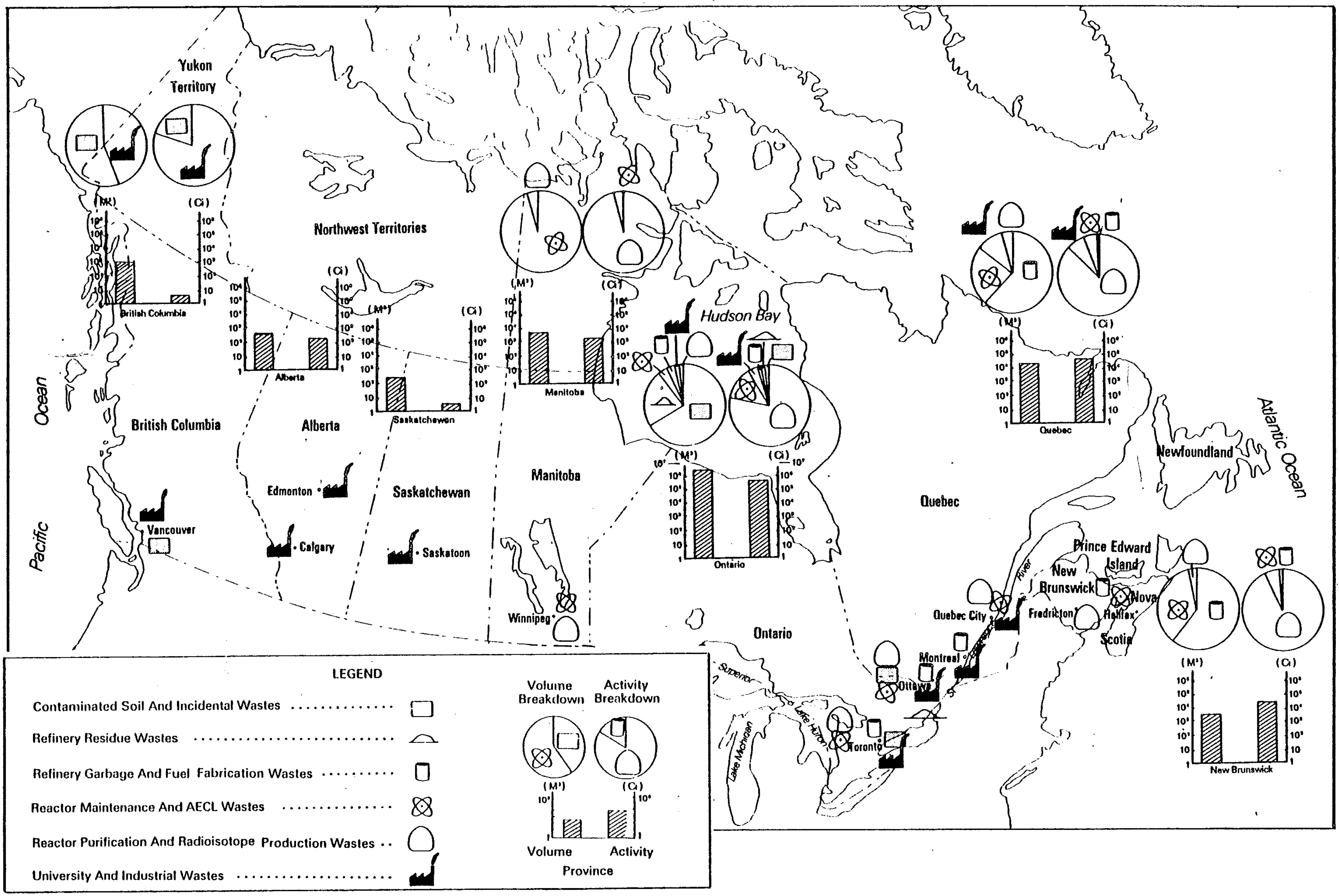


FIGURE 3.1 PROJECTED LOW LEVEL RADIOACTIVE WASTE ACCUMULATION TO THE YEAR 2000 BY PROVINCE

On analysis of the distribution of waste across Canada, it can be seen that the majority of low level radioactive waste, both in terms of volume and activity, is generated in southern Ontario and Quebec.

British Columbia, Alberta and Saskatchewan have significantly smaller waste generation as do the Atlantic provinces. The two exceptions are New Brunswick and Manitoba which generate substantial quantities and activities of wastes.

British Columbia (B.C.), Alberta and Saskatchewan generate primarily university and industrial wastes. B.C. also generates a significant volume of incidental wastes.

Manitoba generates primarily reactor maintenance and reactor purification wastes at Whiteshell Nuclear Research Establishment.

New Brunswick generates mainly reactor maintenance and reactor purificication wastes and a significant volume of fuel fabrication wastes.

Ontario generates the largest volume and activity of wastes of all categories with contaminated soil and refinery residues comprising the largest volume and reactor purification and radioisotope production wastes comprising the highest activities.

Quebec generates the second highest volume and activity of wastes with fuel fabrication and reactor maintenance waste omprising the largest volume and reactor purification waste comprising the highest activity.

4.0 SUMMARY AND RECOMMENDATIONS

The present low level waste management practices in Canada are varied, ranging from storage of packaged radioactive materials in engineered structures to storage of loose contaminated soil and refinery residues on the surface of the ground. In total, over 1.3 million cubic metres of low level radioactive wastes have been identified. These contain different radionuclides varying from activation products from nuclear power reactors to the long-lived naturally occurring radionuclides such as ^{238}U and ^{226}Ra. The wastes have been grouped into five general classes according to their common characteristics.

The practices of packaging and treating of these wastes prior to storage vary widely from generator to generator. The most common volume reduction techniques currently employed are incineration and compaction (or baling). However, very few waste generators employ these techniques and only a small percentage of the waste is treated. Only CRNL plans, in the near future, to immobilize its ash in bitumen. Some refinery wastes and radioisotope production wastes undergo treatment to recover reusable portions of the waste.

A further breakdown according to treatment of several of the five general waste classes is possible. This will be discussed below.

From a consideration of the regional distribution of the low level radioactive wastes, it is obvious that by far the largest quantity of waste is located and being produced annually in Ontario. Thus, Ontario should be considered as the prime location for a low level radioactive waste disposal facility. The western provinces (B.C., Alberta, Saskatchewan) generate such small quantities of radioactive materials that a separate disposal facility would not be justified. At present, radioactive wastes from these provinces (with the exception of the incidental waste in B.C.) is shipped to CRNL.

A significant quantity of radioactive waste is generated in Manitoba by WNRE. The quantities are sufficient to warrant disposal in a small disposal facility located in Manitoba. Such a facility could also service the western provinces. Alternatively, all of the western provinces including Manitoba could ship their waste to a central facility located in Ontario.

An eastern regional facility serving Quebec and the Maritimes can be considered. However, wastes from both the western and eastern regions of Canada are of sufficiently small volume to make transportation to a facility located in Ontario a reasonable alternative.

It is apparent from this review of the low level radioactive waste management system presently existing in Canada that this system is far from optimum and several steps should be taken to improve waste management practices prior to the construction of an operating disposal facility. The following recommendations address the steps that should be considered by the various waste generators.

Recommendation #1 - Waste Characterization:

Waste generators should ensure that all stored radioactive waste and, in future, all waste sent to a disposal facility is well characterized. The waste characteristics should include the following information:

- type or class (see Recommendation #2)
- physical description and properties (e.g. density)
- chemical properties (if possible)
- volume
- specific activity
- radionuclide composition (i.e. percentage of specific activity for each major radionuclide)
- treatment received or further treatment possible
- special comments pertinent to wastes.

Techniques should be developed to accurately obtain each of the above characteristics and these should be reviewed periodically. Deficiencies or errors resulting from the use of these techniques should be clearly documented. Records of waste characteristics should be properly maintained and periodic summaries of these characteristics should be compiled by the generators. Existing waste data should be reviewed and summarized according to the above.

A consolidated waste characterization program should provide waste generators with a basis for analysing their current waste management program and facilitate future safe disposal of these wastes.

Recommendation #2 - Waste Classification:

A waste classification system primarily directed towards disposal should be developed. Each waste generator should review their existing low level radioactive wastes and develop classes of waste with common characteristics.

Several waste generators (e.g. nuclear reactors, AECL) have a wide variety of waste with widely differing characteristics. A system of segregating these wastes into classes prior to disposal would greatly facilitate their safe disposal.

The following are additional considerations that may be incorporated into a classification system:

- Classes could be based on existing and potential treatment methods (as in classes 3 and 4). For example, incinerable waste, compactible waste and waste that cannot be volume reduced could be treated as separate classes (a classification presently used by some waste generators). Some potential treatment methods such as the stripping of ^{14}C from resins in the reactor moderator purification system can change the resulting waste from a long-lived hazard (half-life of ^{14}C is 5730 yrs) to a short-lived hazard (major radionuclide would be ^{60}Co, half-life 5 yrs).

- A further subdivision according to specific activity and radionuclide content would be especially beneficial in the case of class 5. Short and long-lived isotopes could be grouped based on specific activities. In fact, waste in this class could probably be included in the other four classifications if it is segregated at source.

Recommendation #3 - Standardization of Waste Management Practices:

Once common waste characterization and classification systems are established for the low level radioactive waste generators, a basis for the optimization of their waste management practices should exist. Using this common basis, an effort should be made to standardize these waste management practices.

This could be implemented by the following steps:

- development of guidelines for waste generators for characterizing their wastes as in recommendation #1

- development of guidelines for the establishment of a common waste classification system as in recommendation #2

- incorporation of the above guidelines by waste generators into their waste management practices

- review how waste management practices of waste generators conform to waste characterization and classification guidelines

- recommendations of an optimum standardized waste management system for each waste generator

- the type of disposal used should be compatible with the characteristics of the waste class.

- to ensure that wastes are appropriately characterized and classified at source, a screening mechanism should exist at the disposal facility as a check for compliance.

APPENDIX A

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APPENDIX B

GLOSSARY

Disposal:	Operations designed to isolate waste from people and the environment, with no expectation of retrival after emplacement.
Specific Activity:	Total radioactivity for a given radionuclide per unit mass of waste.
Storage:	Retention of waste in a manner that provides for surveillance, human control and subsequent retrieval.
Volume Reduction:	Various methods of waste treatment, such as compaction of solids, aimed at reducing the volume of waste.
Waste Characterization:	Describing the various properties of wastes both quantitatively and qualitatively.
Waste Classification:	Grouping of wastes into classes with similar characteristics.
Waste Package:	The waste form and any container and other engineered barriers (e.g. absorber materials), as prepared for handling, transport, storage and/or disposal.