PROCESSING, STORAGE, AND DISPOSAL OF LOW- AND INTERMEDIATE-LEVEL WASTE IN CANADA

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ABSTRACT

Canadian procedures and developments in the management of low- and intermediate-level waste are briefly discussed. Practical experience with solid and liquid volume reduction techniques, interim storage techniques, and centralized waste operations is reviewed. Permanent waste disposal developments in progress include waste processing methods, underground emplacement methods, and safety assessments. While the technology was developed for the Canadian situation, it can be applied either to LWR sites or to centralized waste operation sites in other countries.

BACKGROUND

Radioactive waste management began in Canada in February 1946, with the shallow burial at the Chalk River site of crated waste brought from off-site laboratories. Waste management has now grown to over 10,000 m^3 per year of a full spectrum of radioactive wastes from utilities, research and development activities, radioisotope producers and users, and the nuclear fuel industry. The largest waste management operations have been at the Chalk River Nuclear Laboratories (CRNL)[1,2] of Atomic Energy of Canada Limited (AECL) and the Bruce Nuclear Power Development (BNPD)[3] of Ontario Hydro (OH). Experience with low- and intermediate-level wastes (LILW) at these two establishments will be the main topic of this paper as representative of this type of activity in Canada. The Canadian Nuclear Fuel Waste Management Program (NFWMP)[4] is a major parallel effort for high-level wastes, but will not be discussed here.

At these two sites, waste management activities[5] include: development and implementation of waste source control, waste characterization, packaging and handling, processing, interim storage facilities and procedures, and strategies for final waste disposal. Development and application of safety assessment methods for each of these functions are also important, associated activities.

PHILOSOPHY OF WASTE MANAGEMENT

Initially, containment of the radionuclides, and thus public and environmental protection, were achieved by the hydrologic and geochemical nature of the site, coupled with access control and monitoring. Various in-ground, concrete structures were used with procedures to guarantee occupational safety in waste emplacement. This operational philosophy assumed a continuation of monitoring, maintenance, and land-use control, as long as the waste remained hazardous. Since some of the wastes would be hazardous beyond the design lifetime of the structures, eventual retrieval and transfer to other facilities might be required. Accordingly, Canadian waste management facilities and procedures[6] are licensed for optimum interim storage.

Although storage is providing safe management of LILW at an acceptable cost, the need for surveillance to be continued for perhaps hundreds of years imposes responsibilities and costs on future generations. With the objective of removing these future responsibilities, a development program[7] was begun ten years ago to establish the technology necessary for emplacement, achieving a permanent one-time disposal of LILW. The development and implementation of this technology will be described in a subsequent section of this paper.

GENERATING STATION WASTE MANAGEMENT

Ontario Hydro is a publicly-owned electric utility with 13,000 MWe of CANDU nuclear generating capacity in service or under construction. Low- and intermediate-level radioactive wastes arise from the operation of these plants.

The major part of reactor operating waste is housekeeping materials that are used in radioactive areas. Typical wastes include protective clothing, floor coverings used to control contamination, mop heads, filters, ion exchange resins, and miscellaneous maintenance hardware. The management of these wastes depends on the level of radioactivity. Most waste material is essentially non-radioactive and is shipped as low specific activity (LSA) in drums or 1 m^3 cubic containers. Type B overpacks are used for shipment of flasks containing the more active materials, such as cartridge filters and ion exchange resins.

CENTRALIZED WASTE FACILITIES

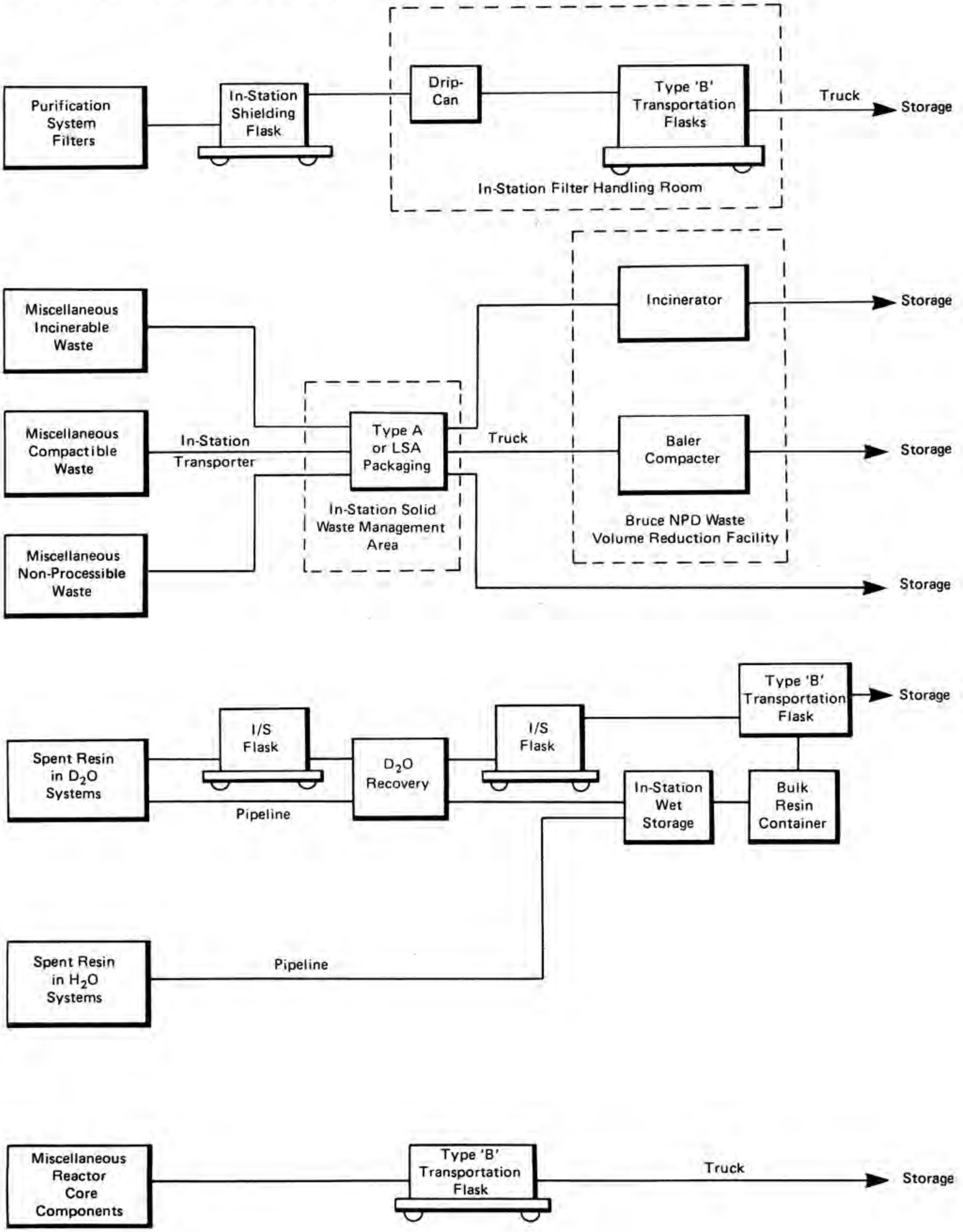
For the past 20 years, OH has operated a centralized waste management facility at the BNPD site, receiving waste from the nuclear stations for processing and storage. Figure 1 illustrates the radioactive waste handling procedure used.

An incinerator and compactor are used to reduce the volume of processible wastes and to increase storage efficiency. Combustible wastes up to 0.2 mSv/h (20 mR/h) are processed in a batch-loaded (2,000 kilograms), pyrolysis-type incinerator, and achieve an average volume reduction of about 40:1.

A mechanical compactor and baler are used to reduce the bulk of compactible waste. Drums are used as the container for the compaction process, and bagged waste is alternately added and compressed until the drums are filled. The volume reduction achieved is about 4.5:1.

Balers are also used to reduce bulk waste. A rectangular cardboard form (0.4 m^3) is used as the container.

FIGURE 1. RADIOACTIVE SOLID WASTE MANAGEMENT FLOWSHEET



After compaction, the package is tied with steel straps and double wrapped in plastic for storage. The method produces a more efficient storage package, with a volume reduction of 7.5 to 9.0:1.

STORAGE FACILITIES

Ontario Hydro has adopted a conservative approach in the management of nuclear waste. At the present time, materials are placed in a retrievable manner in engineered structures, with multiple barriers between the waste material and the environment. The confinement controls are shown on Figure 2. The encompassing grey till provides a natural barrier with low permeability and good retardation characteristics. The concrete container and granular-filled interspace are provided with drainage collection and sampling holes. Surface drainage collection systems and monitoring wells, placed at various levels and distances from the facility, provide additional control. No credit is taken for the carbon steel containers and polyethylene bags that are used to package the waste materials.

The waste storage facilities are designed such that the dose rate at 1 meter from a fully loaded and sealed facility is less than 25 μSv/h (2.5 mR/h). The design and operating emissions target for the waste site is 1 percent of the regulation limits for all types of emissions. The storage structures are regarded as interim storage facilities, and have a design lifetime of 50 to 100 years. Only solid wastes are placed in storage; liquids are processed and immobilized. Where radioactive life exceeds the lifetime of the storage structures, waste materials will be retrieved and restored or sent to a disposal facility.

Ontario Hydro currently uses four basic methods for storage, depending on the type of waste.

(a) Shallow, in-ground, reinforced concrete trenches (Figure 2) are used to store the low-level processed and non-processible wastes. A sump permits water detection and sampling. Manual loading is normally used for this low-level waste.

(b) The higher-level radioactive wastes [1 Sv/h, (100 R/h)] such as cartridge filters and ion exchange resins, are stored in vertical, concrete tile holes (Figure 3). Loaded holes are backfilled with high-slump concrete to form a monolithic structure.

(c) Above-ground concrete Quadricells (Figure 4) are designed for storage of bulk resins and highly radioactive reactor waste components. Each Quadricell has two independent concrete barriers, one outer structure (6 meters by 6 meters) separated into four cells and four inner cylindrical concrete vessels that house the waste material. Being above ground, this storage system is independent of site, and additional storage capacity can be readily added. The Quadricell is capable of withstanding credible earthquakes and is resistant to impacts.

(d) A fourth type of storage system, the low-level storage building (LLSB), is used to store wastes retrieved from other facilities that have decayed to yield less than 10 mSv/h (1 R/h). The pre-

FIGURE 2. SHALLOW SUB-SURFACE STORAGE: MULTIPLE ENVELOPES OF CONTROL

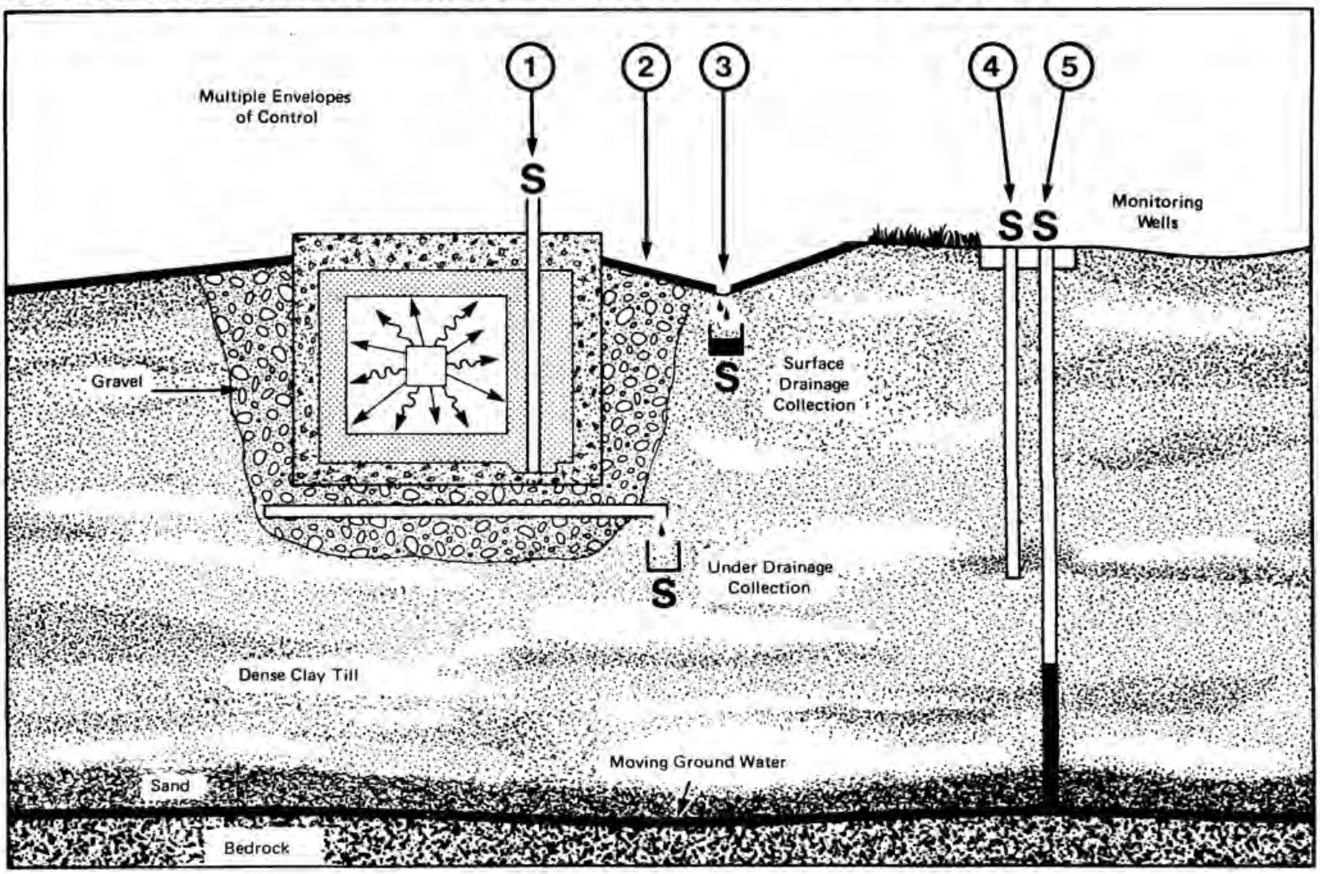
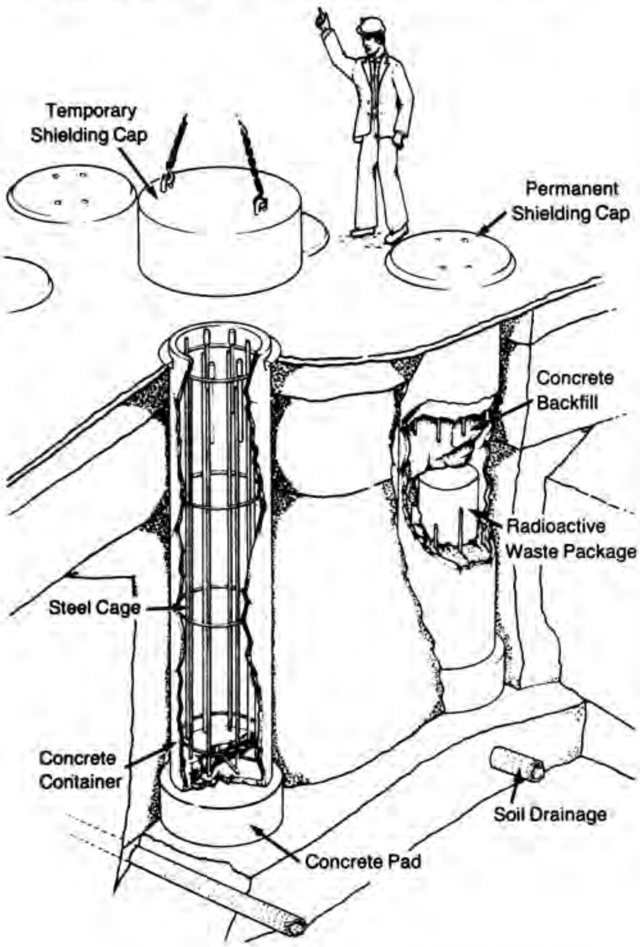


FIGURE 3. RADIOACTIVE WASTE TILE HOLE



fabricated, concrete structure is designed as an unheated building, but includes a CO_2 fire system, smoke detection equipment, and a forced-air ventilation system. 6600 m^3 of waste can be stored in prepackaged, self-stacking containers.

PERFORMANCE

The experience at the OH waste management facility to date has been excellent. Figure 5 represents the wastes by category that have been processed by the plant, with radiation levels between 0.06 and 0.12 mSv/hr (6 and 12 mR/h).

DEVELOPMENT OF PERMANENT WASTE DISPOSAL

The three major components of the AECL disposal development program will be discussed in the order:

(a) safety assessments to justify acceptance of the proposed technology by both the regulating bodies and the public

(b) underground emplacement methods that are appropricate for permanent disposal in available geological settings

(c) waste processing methods to reduce the waste volumes and produce well-defined, stable waste forms that assist radionuclide immobilization.

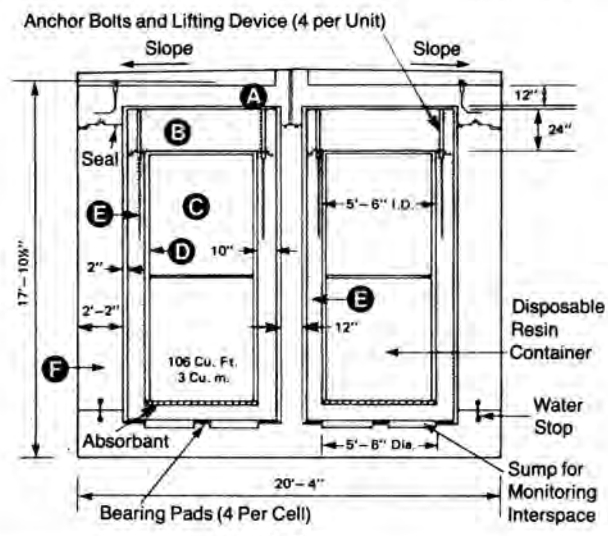
Basically, the safety assessment must predict the impact of the managed waste on the public, the workers, and the environment in relation to accepted criteria.

The assessment must predict the performance of the disposal system and evaluation of the uncertainties in both the system and the prediction. The performance of the system will depend on the concept chosen, the character of the site where it is applied, the engineered features of both the disposal facility and the packaged waste emplaced in it, and the radionuclide content and form in the waste. In the assessment methodology being developed for LILW disposal in Canada, each of these factors is being modelled in detail. Models and submodels will be combined in a modification of a code known as SYVAC (System Variability Analysis Code),[8] which has been developed for fuel waste disposal. This code can be used for either probabilistic or deterministic assessments, and is thus very useful in determining the uncertainties in the predictions. The analysis will affect the choice of the disposal concept, its design and siting in order to achieve a system that can be predicted with acceptably low uncertainties, and that has a very small environmental impact.

The safety assessment program is being applied first to disposal on the CRNL property of future LILW arisings, as well as the current inventory of wastes already in storage there. Two disposal concepts are being investigated assuming a maximum of assured land-use control for 100 years; they are intrusion-resistant, shallow land burial (SLB), and emplacement in a shallow rock cavity (SRC).

An SLB facility at CRNL would likely be located in stabilized dune sand. The sand is free-draining, and

FIGURE 4. THE QUADRICELL STORAGE FACILITY

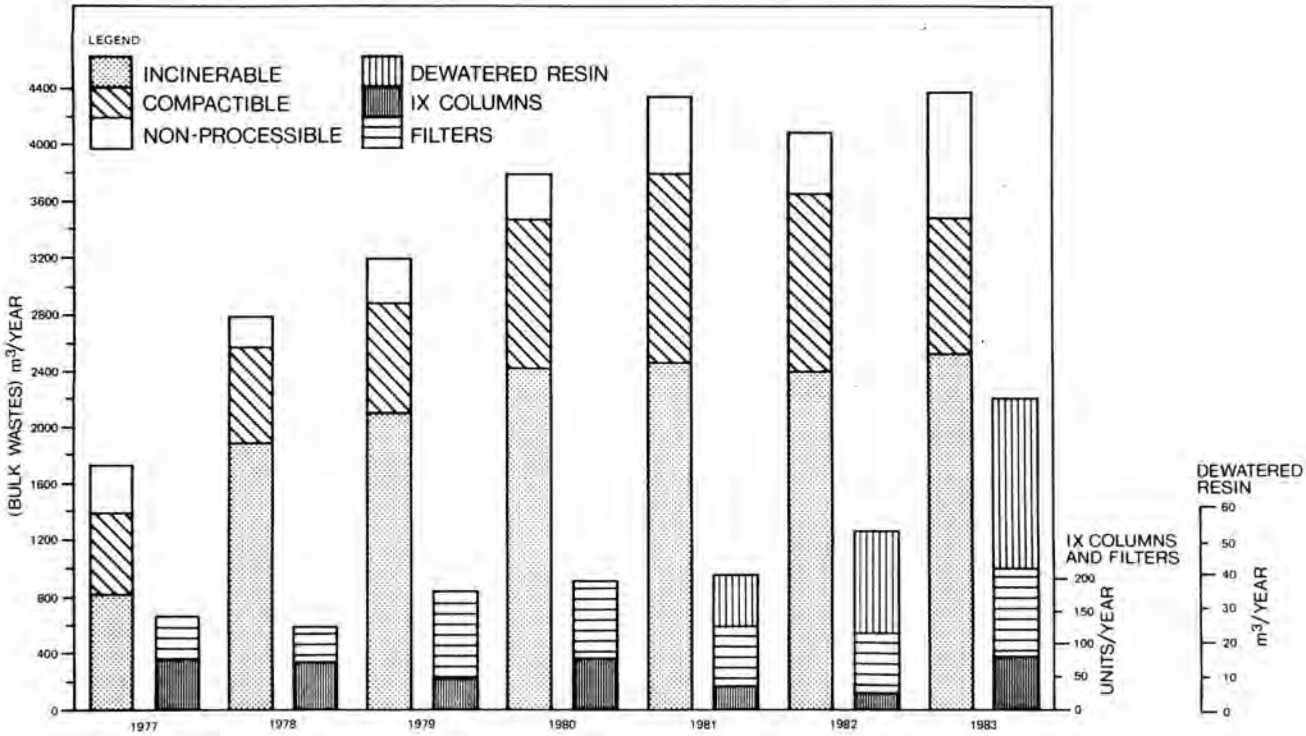


Section

Legend:

- A Outer Concrete Cap
- B Inner Concrete Cap
- C Dewatered Resin
- D Disposable Steel Container
- E Inner Concrete Cylinder
- F Outer Concrete Structure

FIGURE 5. ANNUAL WASTE RECEIPTS AT THE BNPD RADIOACTIVE WASTE OPERATIONS SITE



groundwater velocities are significant. Although the retention properties of the sand for radionuclides are only fair to good,[9] more than 30 years of experience of monitoring underground, radioactive plumes has produced a large base of knowledge of local migration characteristics.

Containment in an SLB facility would be provided mainly by engineered features. In one proposed design,[10] the emplaced waste is bounded in the trench by concrete walls on the sides, a thick concrete cap that resists both water infiltration and biological intrusion, and a permeable but adsorptive floor above the water table, which prevents water accumulation but retards radionuclide migration. Within the trench, some or all of a selection of immobilized waste forms, high-integrity containers, and buffering backfill materials can be combined to ensure only a very slow release of radionuclides should significant water enter the trench.

Much of the CRNL property is exposed Precambrian crystalline rock in which an SRC facility could be excavated by standard hard-rock mining methods.[11] Considerable characterization of the rock has already been done[12] as part of the geoscientific research for the NFWMP. Additional work is being done to identify potential locations for an SRC at depths of less than 200 metres. Since much of the rock has a moderate fracture density, containment in an SRC would also rely largely on engineered features. As with the SLB facility, the design of an SRC facility would match a combination of waste properties and containers, along with buffer and backfill materials, to limit the release of radionuclides. The rock cover would ensure that future inadvertent intrusion was very unlikely. A preliminary design study of possible cavity layouts and their costs has been reported.[11]

Experimental studies of the behaviour of waste forms and backfill materials, singly and in combination, are underway to form a base for modelling of potential radionuclide release.

VOLUME REDUCTION

AECL has used laboratory pilot-plant development[7] of many years to design and construct a waste treatment center (WTC) at CRNL, which contains a controlled-air incinerator, a waste baler, an ultrafiltration, reverse-osmosis plant for concentrating aqueous wastes, and bituminizing systems for immobilizing the resultant ash and concentrates (Figure 6). For the past two years,[13] the incinerator and baler have successfully processed essentially all of CRNL's solid LLW. The aqueous processing plant is currently being commissioned, and construction of the bituminization systems is nearing completion. To provide processing systems appropriate to a wide range of waste types and production rates, developments are continuing on supplementary treatments such as pyrohydrolysis[14] and alternative immobilizing matrices.[15] Processes will be available for both fixed installations and mobile units.

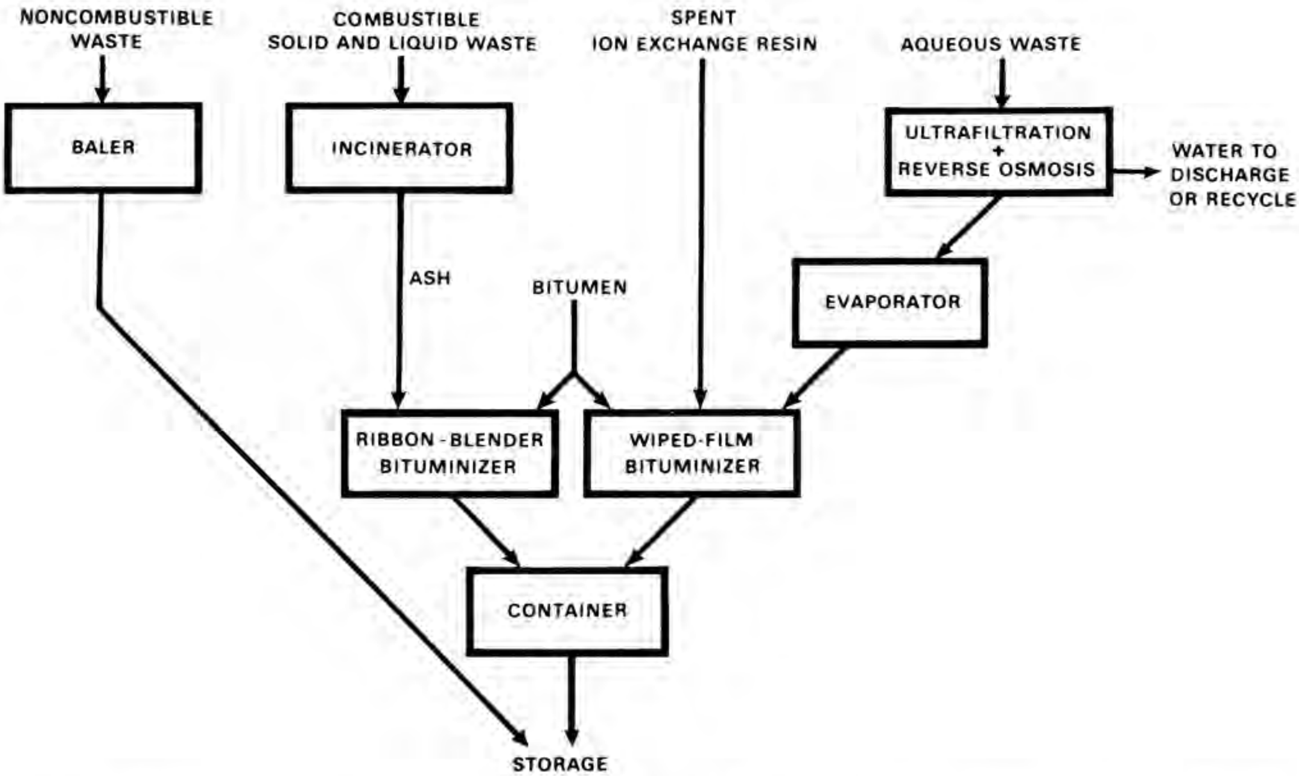
CHARACTERIZATION

AECL and OH have been developing[5] measurement methods to identify the concentrations, quantities, and chemical nature of nuclides before waste processing. These studies are described in another paper at this conference.[16]

RELEVANCE TO OTHER COUNTRIES

The technology described in this paper was developed by AECL and OH to enable the establishment of safe, effective, and efficient management system for all Canadian LILW. The particular combination of waste characterization, processing for volume reduction and immobilization, and packaging can be optimized depending on whether the immediate emplacement is to be one of storage or disposal. In each case, a complementary

FIGURE 6. CRNL WASTE TREATMENT CENTER BASIC FLOWSHEET



knowledge of the factors and design features on which the safety of the facility is based can assist in defining an overall management strategy that balances the needs of safety and the costs of each component in the system, which contributes to its fulfillment.

The base of these studies makes them applicable to other situations of waste properties, management criteria, and licensing limitations. London Nuclear is working closely with both AECL and OH to apply this capability to other systems.

The full range of project management, design, construction and operational services, and experience in the radioactive waste management area are available to other utilities and consultants.

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