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A PERSPECTIVE ON THE MANAGEMENT OF LOW-LEVEL RADIOACTIVE WASTE

by

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1. INTRODUCTION

The approach to management of Low-level Radioactive Waste (LLRW) is undergoing intensive scrutiny and change, both in Canada and abroad. LLRW includes all radioactive waste exclusive of spent fuel and, mine and mill tailings. The degree and duration of the hazard associated with the LLRW is waste stream dependent and very variable, and must be taken into account in the practices applied to the management of each individual waste stream. The practices applied are largely a function of the end result of the waste management operation; namely, storage versus disposal. The choice of a storage versus disposal option can significantly impact both the operational practices and the costs of waste management for the nuclear industry. This paper is intended to provide a perspective on the status of LLRW management, the requirements for effective LLRW management, the changes and developments in the management of LLRW, the reasons for those changes and developments, and the implications for the Canadian nuclear industry.

2. CURRENT LLRW PRACTICES

2.1 Canadian

The current Canadian waste management practice is interim storage where storage is defined by the IAEA [1] as, "The placement of waste in a nuclear facility where isolation, environmental protection and human control (e.g. monitoring) are provided with the intent that the waste will be retrieved for exemption or processing and/or disposal at a later time;". Storage is an active function that carries with it the longer-term liability of continuing management actions including those actions required to make the transition to disposal.

Waste management practices in Canada are evolving towards disposal which is defined by the IAEA [1] as, "The emplacement of waste in an approved, specified facility (e.g. near surface or geological repository) without the intention of retrieval. Disposal may also include the approved direct discharge of effluents (e.g. liquid and gaseous wastes) into the environment with subsequent dispersion."

In Canada, a policy to move from storage to disposal was first enunciated by Atomic Energy of Canada (AECL) in the 1970s [2] and R&D studies have been underway in AECL since the late 1970s. Ontario Hydro also carried out preliminary R&D studies relevant to disposal in the 1980s. In 1987, the Canadian Atomic Energy Control Board (AECB) issued the Regulatory Policy Statement R-104 [3] which states that; "For the long-term management of radioactive wastes, the preferred approach is disposal, a permanent method of management in which there is no intention of retrieval and which ideally uses techniques and designs that do not rely for their success on long-term institutional control beyond a reasonable period Of time." This policy statement defines the basic regulatory requirements and provides guidelines for their application to achieve acceptable disposal.

Currently in Canada, there are a variety of programs underway that are gathering the information and developing the technology required to achieve disposal. The major waste generators, AECL and Ontario Hydro, have evaluated and documented approaches [4] and options [5] for moving from storage to disposal. The Low-Level Radioactive Management Office (LLRWMO) under Natural Resources Canada is assisting in the development of policies for achieving an effective transition from storage to disposal [6]. AECL is currently in the licensing process for a prototype disposal facility [7] that is designed to handle a certain category of waste. AECL, Ontario Hydro and Hydro Quebec sponsor a CANDU Owners Group (COG) research and development program [8] that is developing the understanding and technology for LLRW disposal to cover the full spectrum of wastes generated in CANDU reactors and research facilities. The Federal Siting Task Force on Low-Level Radioactive Waste is evaluating concepts and sites for disposal of a large volume of historic wastes currently stored in the Port Hope area.

2.2 International

The transition from storage to disposal of solid LLRW is well underway internationally [9, 10]. Permanent disposal facilities based upon either near-surface concrete vaults or subsurface rock cavities have been constructed and are in operation in a number of countries. Near-surface disposal facilities based upon concrete vault systems are in operation in France, Spain and Japan. Sweden is operating the SFR-1 (Swedish Final Repository for Radioactive Waste), a shallow rock cavity system located 50m below the Baltic Sea. Finland also began operating a shallow rock cavity system in 1993. Concrete vault systems are also planned for most of the US state compact facilities. Germany is operating a deep repository in salt and has a program that is well advanced towards deep geological disposal of LLRW in rock. Planning has started for underground repositories in the United Kingdom, Switzerland, Korea and the Czech Republic.

3. Driving Forces for Disposal

The primary driving forces for disposal are to meet the objective of minimizing the burden on future generations and to avoid the liabilities associated with continued interim storage and the transition from storage to disposal. Additionally, as exemplified by the international developments, to put Canadian LLRW management practices in line with modern waste management practices.

The stated objectives of disposal in the Regulatory Document R-104 are to; minimize any burden placed on future generations, protect the environment and protect human health, taking into account social and economic factors. Interim storage, the current LLRW management practice in Canada, cannot meet the first objective since it requires institutional controls (e.g. access control, monitoring, site maintenance, etc.) as long as the wastes pose an unacceptable hazard to the environment and human health or until the wastes are retrieved for disposal. In addition to meeting these ethical responsibilities, the nuclear industry has a business objective of minimizing the liability associated with the long-term management of their wastes. Interim storage followed by retrieval of the waste and transfer to a disposal facility, as opposed to direct disposal, is likely to lead to higher lifetime costs and occupational doses. If the stored wastes were not adequately characterized, segregated and tracked at the time of storage, large costs could be incurred in acquiring, after the fact, the information required to meet the safety case and operational requirements for disposal. As the inventory of stored waste increases, the liability also increases due to the increasing mismatch between the size of the waste management operation required to handle the accumulated inventory of wastes and that required to manage the annual production of wastes.

4. A Comprehensive Approach to Low-Level Radioactive Waste Management

Regulatory approval for operation of a waste management facility carries with it a requirement for a clear statement of the long-term intent since the future safety of the facility depends upon it. For a storage facility, the safety case can be based upon continued operational controls, monitoring and a commitment to future action, namely decommissioning. With current management practices decommissioning is likely to require waste retrieval and transfer to disposal. For a disposal facility, the safety case depends upon our ability to credibly predict the long-term fate of the contaminants contained in the disposed wastes. In order to minimize our future liabilities, both options should follow a comprehensive approach to the management of the wastes, such as illustrated in Figure 1. A comprehensive approach includes: identification of waste streams, characterization of waste streams, waste segregation and classification, waste processing and conditioning, waste routing and tracking and finally waste emplacement. Each step and its significance are described briefly below.

4.1 Waste Stream Identification

One of the most important front-end features of disposal programs, that is common to most countries that have implemented disposal, is the requirement that generators segregate their wastes into identified waste streams. The generator should establish operating envelopes for each stream so that the waste manager can assume that all wastes assigned to a particular stream have common characteristics within a specified range. This is an essential requirement for the safety assessment analysis required for licensing a disposal facility. In addition, waste stream identification together with the subsequent tracking and routing of each waste stream, at the interim storage stage, will reduce overall costs. Additional cost savings will result from the identification of wastes that can be segregated and routed to non-radioactive waste management facilities, and from the avoidance of the potentially large characterization effort that may be required to transfer ill-defined wastes from interim storage to disposal.

4.2 Waste Characterization

The characterization of the radiological properties of each waste stream/waste package must be sufficient to quantify the associated hazard, both at the time of acceptance into a waste management facility (primarily external exposure) and for the future (internal and external exposure resulting from radionuclide release from a facility). As long as the waste remains hazardous, i.e. the time over which some form of protection against radiation dose to humans is needed, safety will be dependent on the local conditions as well as radiological characteristics. The latter point highlights the tight linkage between the disposal strategy chosen and the anticipated waste characteristics.

Characterization can require extensive and costly analysis or it can be relatively straightforward depending upon the source of the waste and the degree to which the source of the waste limits the radionuclide content of the waste. For example, waste from a laboratory in which only one pure radioisotope has been used will not require extensive analysis. At the other extreme, waste from a hot cell used for a variety of operations with nuclear fuel and with the potential to concentrate some radionuclides relative to others, will require extensive analysis.

For most LLRW, the relative hazard of the non-radiological components is not expected to be significant compared to that from radioactivity. However, the non-radiological hazardous components of the waste will need to be considered and may be significant in some cases.

4.3 Waste Segregation and Categorization

Waste segregation and categorization are tightly linked in a feedback loop with waste characterization. The ultimate objective is to ensure that waste streams with differing characteristics are not mixed in such a way that the costs for characterization are driven up and the safety case is jeopardized. For example, if a large volume waste stream containing a single short-lived radionuclide is mixed with a small volume of waste containing long-lived radionuclides, the entire volume will require much more extensive, and expensive characterization. The addition of the long-lived radionuclide may also necessitate more elaborate performance assessment to demonstrate that the long-lived radionuclides do not create an unacceptable hazard. Appropriate segregation of wastes is critical not only for disposal but also prior to interim storage in order to avoid the associated liability in the future.

4.4 Waste Processing

In addition to the radiological properties of the waste, the waste volumes and form can significantly impact the storage or disposal strategy and costs. The storage or disposal concept chosen, the facility size and location will all be influenced by the volume of waste to be handled. The costs of waste processing to achieve volume reduction through compaction or incineration needs to be evaluated against the costs for provision of a larger space for storage or disposal.

Waste processing is also applied to alter the chemical and physical form of the waste. The form of the waste can be one of the most important factors controlling the release rate of hazardous materials from the waste. This is important since the performance of a waste repository is characterized by the magnitude of the release rate of critical contaminants. For example, since most contaminant release from a waste will be water borne, control of the rate at which waste and water interact can be a controlling factor in the rate of release of particular contaminants. The interaction of water and waste will be a function of the stability, water permeability and chemical reaction with the contaminants. All of these factors are waste form dependent.

A further barrier to migration of the radioactivity contained in the waste can be the packaging or container. The dominant role of the container is to prevent release of radioactivity during handling. Because of its limited durability, the container is not usually a significant factor in the release of long-lived radionuclides after emplacement. However, for the more mobile radionuclides, such as tritium and radioiodine, the container may sufficiently restrict diffusion from the waste into the surrounding backfill to materially reduce the overall release.

4.5 Waste Emplacement - Storage or Disposal

The characteristics of the waste will determine its acceptability for management in any particular facility. The relative importance of the various characteristics (contaminant content and concentrations, physical/chemical form and leachability, packaging, etc.) will depend on the safety philosophy applied in the design of the waste management facility, most critically the final disposal option chosen. The disposal option chosen will, in turn, be based on an integrated evaluation of the total system that includes; the waste inventory to be placed in the facility, the engineered design characteristics of the facility, and the characteristics of the site in which the facility is placed, as shown in Figure 2. The safety evaluation of the total system must include operational and public safety. Operational radiation safety can be achieved through good practice and external radiation monitoring; however, public safety needs to take into account the potential exposure pathways for the time period over which the wastes remain hazardous. For storage, monitoring can be used to assess public impact but it does not provide a measure of future impact. A predictive capability through performance assessment models is required to assess public safety in the long-term.

5. Performance Assessment

Performance assessment is the integrator to assess the long-term safety of a disposal facility after institutional control activities (maintenance and monitoring) have deteriorated or been discontinued. Performance assessment is achieved through the use of a computer model that mathematically describes the relevant, specific features of the disposal system, as discussed in Section 5. The following series of steps are generally followed in the performance assessment process: identify features, events and processes (FEPS) that could impact safety; define combinations of FEPS (scenarios) that may be relevant: identify scenarios that are potentially important for consequence analysis for the specific facility; develop, verify and validate models, databases and computer codes for analysis of the disposal system; calculate the safety consequences of relevant scenarios; identify uncertainties in the results and the most important parameters (sensitivity analysis); and finally compare results with relevant standards and criteria.

The steps leading to the final performance assessment should be an iterative process with design in order to drive the design to maximize present-day and future safety, and to minimize costs.

6. Summary and Conclusions

In Canada, a comprehensive approach to LLRW management has not been achieved. Many of the issues discussed above will require substantial work to fully resolve. Technology development programs are in progress but progressing slowly, to acquire the knowledge required to make sound decisions towards implementing optimized waste management practices for LLRW. AECL is well advanced towards building a prototype disposal facility for a portion of their waste streams. Licensing and operation of the prototype facility will provide valuable guidance on the development of safety cases for licensing other disposal facilities and for the practical aspects of implementing a disposal operation that takes into account the many developments required to achieve the comprehensive approach discussed in Section 4.

Waste acceptance criteria must be carefully developed to ensure disposal safety for both workers and the public, and to ensure that cost-effective, efficient operational procedures are applied to wastes from all generators. Any additional requirements placed on waste generators must yield safety or economic benefits. An additional benefit expected from the work on waste characterization and categorization is the ability to substantially reduce the amount of waste that goes into radioactive waste management facilities by segregating out those waste streams that are "non-radioactive".

Initiation of disposal operations need not wait for full development of all of the requisite knowledge and technology, the liability associated with a protracted transition from storage to disposal could be substantial. An implementation strategy that will facilitate regulatory acceptance of an early transition to disposal would be advantageous to the Canadian nuclear industry. The European model of a national strategy implemented by a national organization may be the most expeditious means of achieving early disposal. Indeed it may be imposed on the industry if the Canadian nuclear industry does not itself take the initiative to define a joint strategy, pool resources, and get on with the job. Careful development and implementation of a strategy for disposal of LLRW will move the industry into the modern world of waste management practices and should yield economic benefits in the long-term.

References

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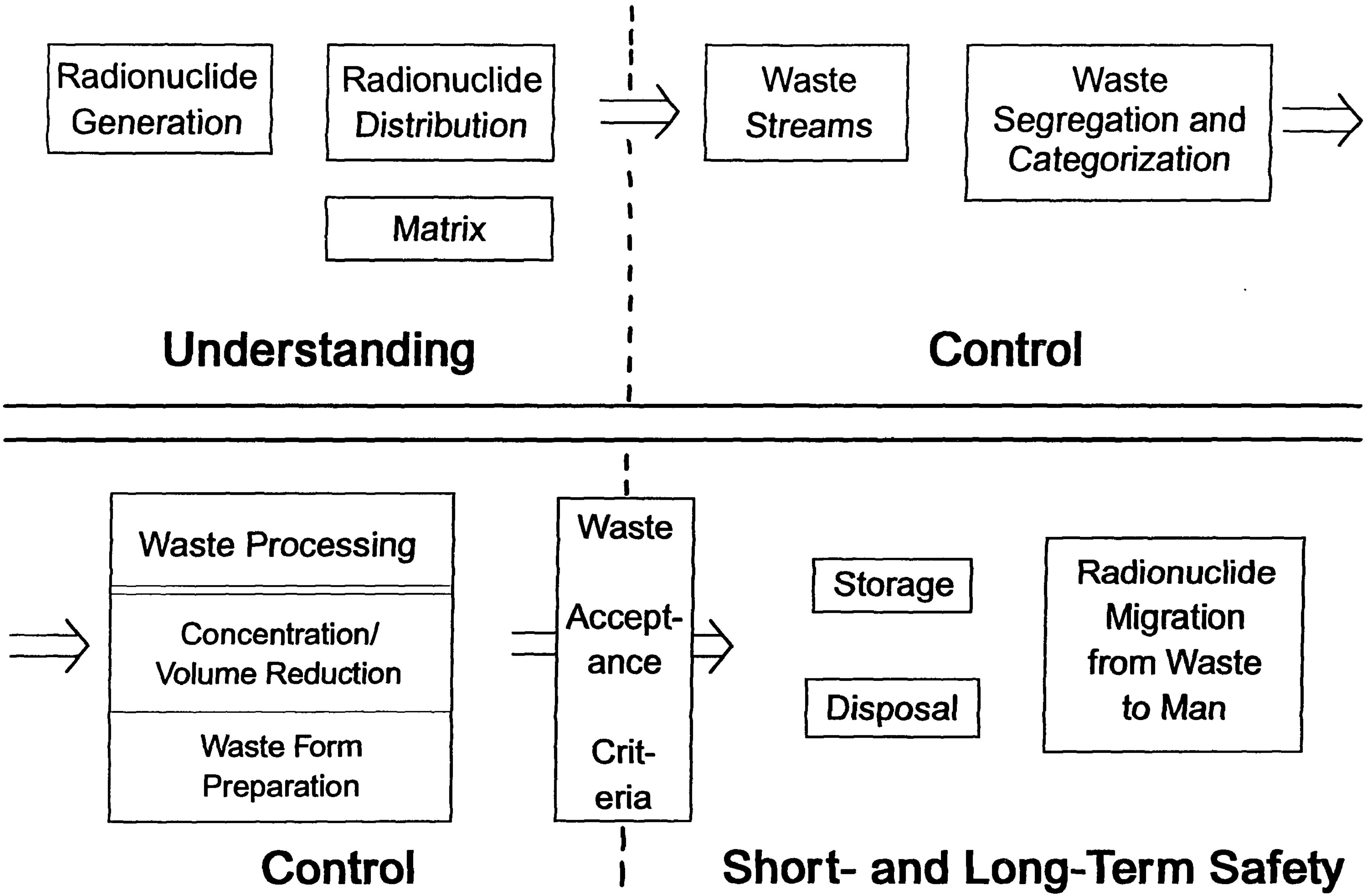

Figure 1: A Comprehensive Approach to LLRW Management

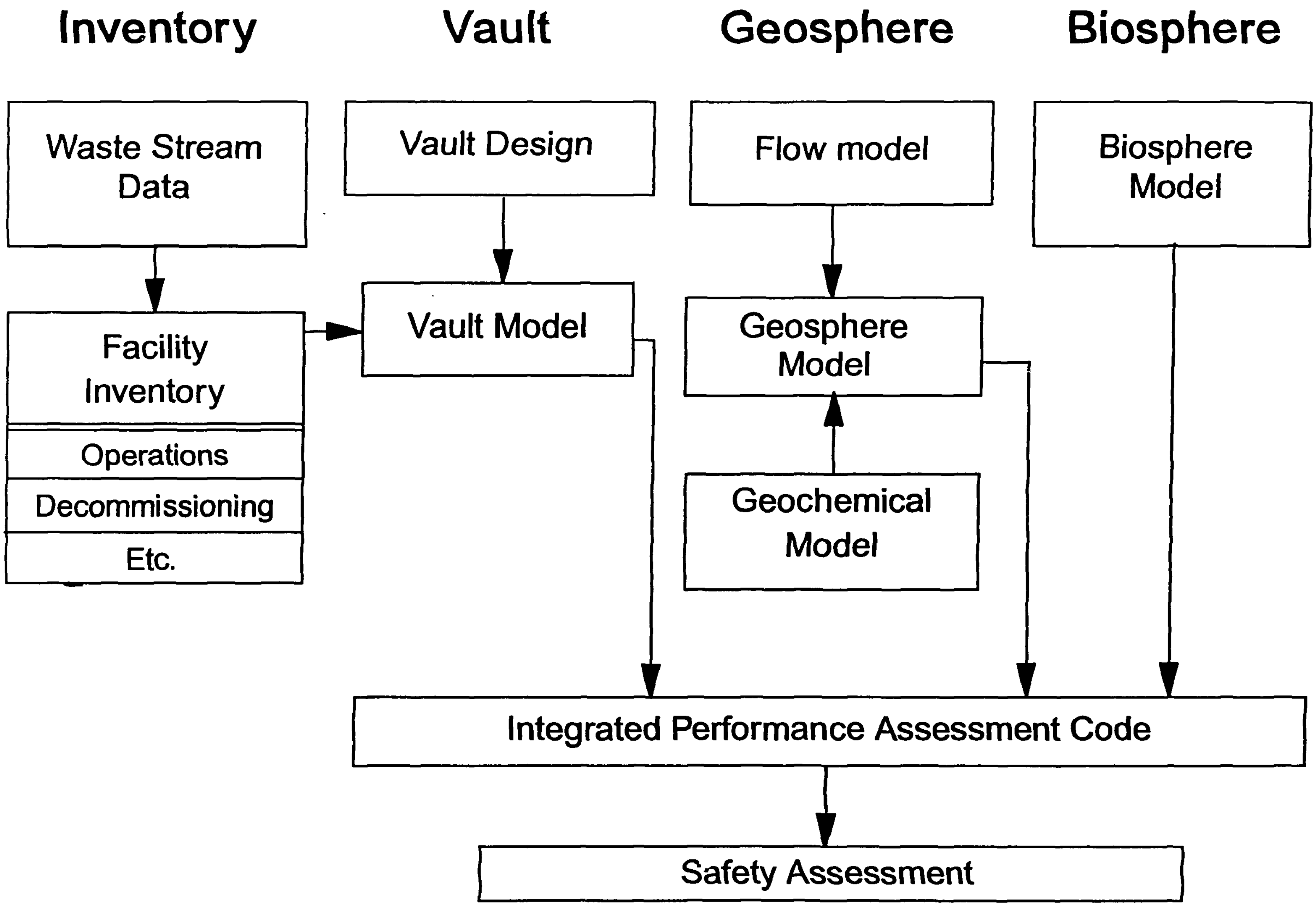

Figure 2: Disposal Facility Design and Performance Assessment