ADVANCES IN RADIOACTIVE WASTE MANAGEMENT FROM AN INTERNATIONAL PERSPECTIVE

K.E. Nash
Ontario Hydro Nuclear, Canada

G.R. Simmons
Atomic Energy of Canada Limited, Canada

INTRODUCTION

Nuclear generated electricity, is an important world energy source, currently providing 17% of the world electricity supply. Nuclear energy can be a significant part of the solution to national and international environmental problems such as air pollution and climate change. The main basis for this is the absence of polluting gas emissions namely, NO_x, SO_x and CO_2. Nuclear power is considered by most people in the industry to be a sustainable energy source.

Many studies have shown that the environmental externality costs of nuclear power production are low compared to other forms of energy generation. For many years the industry has invested its resources in developing comprehensive and permanent waste management solutions and has included all back end costs into its pricing structure. In this respect the industry has been a leader in sustainable development and full cost accounting, well before these reached their current prominence. A comprehensive solution to the problem of nuclear waste, especially related to high level waste has not yet been reached. Critics of nuclear power use this fact to argue that nuclear power is not a sustainable energy source.

The purpose of this paper is to examine the extent to which advances in radioactive waste management have been made, and what advances remain to be made, to position nuclear power to meet the energy supply and environment challenges ahead.

INTERNATIONAL PERSPECTIVES ON RADIOACTIVE WASTE MANAGEMENT

The Radioactive Wastes from Nuclear Power Production

The radioactive wastes arising from nuclear energy are managed in several steps including storage, processing, transportation and eventual permanent disposal. The wastes can be generally categorized as: uranium mine and mill tailings; low level and intermediate level radioactive wastes and high level wastes. Low and intermediate level wastes arise from fuel manufacturing and used fuel reprocessing, nuclear power plant operation and decommissioning activities. These wastes are mostly short-lived, but consist of long-lived waste components. High level waste is either used fuel or the by-products from the reprocessing of used fuel.

Management strategies for radioactive waste vary among countries. The quantity and characteristics of the radioactive wastes arising in each country depends on the fuel cycle adopted, number and type of fuel cycle facilities established within each country and whether they are sized to meet domestic requirements or the requirements of a larger market. For example, does the country have an indigenous uranium mining and milling industry, uranium conversion industry, uranium enrichment facilities, fuel fabrication facilities or used fuel reprocessing facilities, or does it rely on external suppliers for some or all of these materials and services?

Significant success has been achieved in all countries with nuclear programs in storage, processing and transportation of radioactive wastes. The progress in permanently managing radioactive wastes varies from

country to country depending on the state of development of the nuclear program in the country and on decisions made by the governments and the owners of the wastes. For example, utilities in China, France, India, Japan, and the United Kingdom send their used fuel to reprocessing facilities and are, or will have to, manage the solidified wastes resulting from reprocessing. Canada, Finland, Hungary, Spain, Sweden, and the United States of America do not plan to reprocess their used fuel and have programs to develop repositories for the direct disposal of used fuel. Alternatively, some countries are not currently pursuing any form of high level radioactive waste disposal. Holland and Italy currently rely on long-term storage of used fuel and the United Kingdom currently relies on long-term storage of solidified reprocessing waste. The countries that reprocess or plan to reprocess their used fuel recognize the need for a geological disposal facility for high level waste, long-lived low and intermediate level wastes and eventually recycled fuel that is not suitable for additional reprocessing.

Nuclear Waste Disposal

Although many countries plan to have geological disposal facilities for high level radioactive wastes and long-lived radioactive wastes, there have been no such facilities licensed. Some countries, such as Germany, the United Kingdom and the United States of America (USA), are planning separate repositories for the disposal of high level radioactive wastes, and long-lived low and intermediate level wastes. The Konrad Repository (Germany) and the Waste Isolation Pilot Plant (USA), planned for low and intermediate level wastes, are fully constructed and are in the final stages of licensing to allow them to receive wastes. In the United Kingdom, Nirex Limited had selected a site in West Cumbria for a repository but were unable to secure planning permission to proceed with the Rock Characterization Facility necessary to complete the site characterization.

In Germany (Gorleben repository project) and the USA (Yucca Mountain Characterization Project) sites have been selected and are being characterized for the disposal of high level radioactive wastes. Neither project has progressed to the point of submitting a licence application and both projects are experiencing strong public resistance.

Other countries, such as China, Finland, France, Hungary, Sweden, and Switzerland, have developed the technology for siting a geological repository and are actively seeking a site for the disposal of long-lived low and intermediate level wastes and high level wastes. There has been public resistance to many of these siting initiatives (e.g., negative results of community acceptance referenda in the Storumen and Mala municipalities in Sweden).

Many countries, such as the Czech Republic, Finland, France, Germany, Japan, Spain, Sweden, and the United Kingdom, have established and licenced permanent disposal facilities for short-lived low level and intermediate level radioactive wastes. These facilities, either surface, near-surface or underground, are operating successfully. The next challenge will be to obtain the public support and regulatory approval necessary for the permanent closure of these types of facilities when the decision is made to stop placing additional waste in the facilities. France has one short-lived low-level disposal facility that is no longer accepting waste and is being prepared for eventual closure under institutional control. There is public resistance in many countries to the siting of new short-lived low and intermediate-level waste disposal facilities.

The mine and mill tailings have a large volume and are generally managed and decommissioned on site. They are generally kept in open uncontained piles, or behind dams or dikes with solid or water cover. This has resulted in the release of small amounts of radon to the environment which has not resulted in significant exposures to the public. Techniques for reducing the release of radon from tailings are available and are gradually being implemented. These include capping with silt or sand, multi-layer capping with additional erosion protection and disposal below ground with a clay cap.

Decommissioning

The approach to decommissioning nuclear reactors varies among the reactor owners. The timing of decommissioning is generally either immediately after station shutdown, as proposed in Sweden and the United States, or after many years of safe storage to allow radioactivity to decay before decommissioning as proposed in the United Kingdom and Canada. The radionuclide concentrations and the total radionuclide inventories in the waste from decommissioning of the nuclear power reactors and the fuel cycle facilities will vary depending on the timing of the decommissioning activities. In either case, however, there will be wastes classified as both short-lived and long-lived low and intermediate level radioactive wastes and they would be directed to the appropriate disposal facilities.

The Challenge in the Management of Radioactive Waste from Nuclear Power Production

The overall report card on the status of nuclear waste management can be summarized as follows.

- Solutions have been implemented and licenced for the decommissioning of uranium mines; management of mine and mill tailings; storage, processing and, in many cases, disposal of low level wastes; and the reprocessing of used fuel.
- Solutions have not been found for the permanent disposal of high level wastes (i.e. used fuel or the by-product radioactive waste arising from reprocessing) or long-lived intermediate level waste.

In some countries there is difficulty in expanding or establishing low level radioactive waste disposal facilities.

There is a growing scientific consensus that high level and long-lived intermediate level waste can be safely disposed of. Several countries have developed concepts, and in some cases detailed designs, for the necessary facilities. Many countries have prepared long-term safety assessments to show that these facilities would satisfy current safety criteria. Technology exists for low level waste disposal. Finding a solution for permanent disposal of radioactive wastes is mainly a social-political issue.

CANADA'S PROGRESS IN RADIOACTIVE WASTE MANAGEMENT

Introduction

In Canada, electricity is produced at five nuclear generating sites comprising of CANDU reactors. Twenty are owned by Ontario Hydro and one each by New Brunswick Power and Hydro Quebec. The total installed capacity is 13 760 MWe. Nuclear generated electricity accounted for about 16% of Canadian electricity production in 1996. Within the provinces, in 1996 the nuclear generated electricity accounted for 54% of Ontario's electricity, 3% of Quebec's electricity and 30% of New Brunswick's electricity.

Atomic Energy of Canada Limited (AECL) is a vendor of CANDU reactors, provides research and development and services for CANDU reactors, and owns several research reactors, including three demonstration power reactors that are shut down. There are also six universities and two other organizations in Canada that have small (<20 kW thermal) research reactors.

Waste Arising

It is projected that the total radioactive waste produced over the lifetime of the 22 Canadian power reactors will comprise approximately:

- 70,000 tonnes of used fuel;

- 100,000 m^3 of low level operational waste;
- 6000 m^3 of intermediate level operational waste in the form of carbon-14 contaminated resins and other material; and
- 200,000 m^3 of decommissioning low and intermediate level wastes.

Over 99% of the radioactivity in these wastes are in the used fuel.

Most of these wastes are currently stored at generating stations where they were produced. Canada has developed dry storage systems for used fuel. Ontario Hydro has adopted a dry concrete cask system, and AECL has supplied its dry storage canister system to New Brunswick Power and its more recent modular, air-cooled canister storage system, MACSTOR, to Hydro Quebec.

Ontario Hydro centrally stores low and intermediate level wastes at its Bruce Nuclear Power Development. Hydro Quebec and New Brunswick Power store their low and intermediate level wastes at their nuclear power stations. AECL stores operational and decommissioning wastes from its demonstration nuclear power reactors, now shut down, at its Chalk River Laboratories.

Long Term Financial Liabilities

Hydro Quebec, New Brunswick Power and Ontario Hydro have been setting aside funds from revenues for the past 15 years for the long-term management of nuclear waste and for decommissioning. The combined utility liability is estimated to be $20 billion, of which 90% is associated with Ontario Hydro's nuclear program. Waste management related to AECL's development activities is an additional liability.

Nuclear Waste Disposal

A major part of the nuclear waste management in Canada has been the Nuclear Fuel Waste Management Program, which was established by the governments of Canada and Ontario in 1978. Under this program, AECL has developed a concept and the technology for deep geological disposal of used fuel in the plutonic rock of the Canadian Shield and Ontario Hydro has provided financial and technical support. AECL's disposal concept has been under review by a federal environmental assessment panel since 1989 and the panel recently published its recommendations to the Government of Canada on the safety and acceptability of the concept.

In preparation for the panel review, Ontario Hydro consulted its major stakeholders in 1995 and concluded that it should proceed toward the disposal of used fuel provided this was the direction decided by a federal government following submission of the federal environmental assessment panel report.

The federal environmental assessment panel, however, has concluded that, although the safety of the AECL concept has been technically demonstrated for a conceptual stage of development, disposal must have broad-based public support before work to find a potential site may proceed. One of the main recommendations of the panel is that a nuclear fuel waste management agency be created to manage and coordinate the full range of activities related to long term management of nuclear fuel waste.

In 1996, the Federal Government of Canada issued a Radioactive Waste Policy Framework that established that:

- The waste producers and owners are responsible, in accordance with the principle of "polluter pays", for the funding, organization, management and operation of disposal and other facilities required for their wastes; and

- The federal government has the responsibility to develop policy, regulate, and oversee producers and owners to ensure that they comply with legal requirements and meet their funding and operational responsibilities in accordance with approved waste disposal plans.

Government decisions on the long-term management of nuclear fuel waste following the federal environmental assessment panel review have not been announced.

The low and intermediate level radioactive wastes arising from nuclear electricity production are collected, processed and stored by the waste producers. Similarly, the wastes from research to support the technologies for producing nuclear generated electricity, are stored at AECL's research laboratories. Radioactive wastes from other industrial, medical and agricultural uses are collected and stored at AECL's Chalk River Laboratories.

The tailings from uranium mining and milling operations are gathered and stored by the operators of the facilities. For some wastes that are radioactive but relatively small in volume, the wastes are packaged and stored for transfer to licenced disposal facilities when these are available. For larger volume wastes, such as the mine tailings, it is impractical to consider moving them to another location. These wastes are stored in controlled facilities such as tailing ponds near the point of generation. These tailings ponds must be maintained and controlled until the hazards associated with the contents are below the clearance levels for such materials.

Decommissioning

After a generating station reaches the end of its service life, it will be placed in a safe condition for at least 30 years to allow radioactivity to decay, after which it will be dismantled. It is anticipated that decommissioning of each station will take about 10 years, and that decommissioning of all currently existing Ontario Hydro reactors will be completed by 2072.

CONCLUDING REMARKS

For nuclear power to be an accepted sustainable technology, a complete solution to nuclear waste management must be available. There are proven and licenced technologies for the safe storage of the radioactive by-products from nuclear power generation. However, there has been limited success in the siting, licensing, operation and closure of disposal facilities. Facilities have been sited and licensed for the disposal of low level radioactive wastes. In a few cases, low level radioactive waste disposal facilities have been closed and are being placed in a disposal state using institutional controls. Facilities have been sited and constructed and are near to receiving a license for the disposal of long-lived intermediate level radioactive wastes. While progress towards siting a high level waste repository has been made in several countries, none have yet reached the licensing stage. Some countries have opted for above ground long-term storage and are doing little or nothing to pursue permanent disposal. To maintain nuclear power as a viable alternative to meet the energy supply and environmental challenges of the next century, it will be important that governments and the nuclear industry work together to develop a socially, financially and environmentally acceptable solution to long term nuclear waste management.

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In preparation for the panel review Ontario Hydro consulted its major stakeholders in 1995 and concluded that it should proceed toward the disposal of used fuel subject to the federal review confirming safety and acceptability of the concept.

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International Perspective

The long-term waste management strategies vary from country to country. Utilities in China, France, India, Japan, and the United Kingdom send their used fuel to reprocessing facilities and will have to manage the solidified wastes from reprocessing. Finland, Hungary, Spain, Sweden, and the United States of America do no plan to reprocess their used fuel and have programs for the direct disposal of used fuel waste. Holland and Italy currently rely on long-term storage of used fuel and the United Kingdom currently relies on long-term storage of solidified reprocessing waste. Those countries that rely on reprocessing recognize the need for a disposal facility for high-level waste.

Many countries have established permanent disposal facilities for low-level radioactive wastes including Czech Republic, Finland, France, Germany, Japan, Spain, Sweden, and the United Kingdom.

The approach to decommissioning of nuclear reactors varies among the reactor owners. The timing of decommissioning is generally either immediately after station shutdown, as proposed by Sweden and the United States, or after many years of safe storage to allow radioactivity to decay before decommissioning, as proposed by the United Kingdom and Canada.

Commentary

The paper will close with a discussion of the role of radioactive waste disposal in supporting nuclear as a sustainable energy technology and the steps that could be taken internationally to enhance the potential of implementing all aspects of radioactive waste disposal.