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RADIOACTIVE WASTE STORAGE AND DISPOSAL:

THE CHALLENGE

by

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INTRODUCTION

Whether they involve materials which are radioactive, carcinogenic, mutagenic, un-aesthetic or just plain odiferous, the waste disposal practices of yesteryear are in most cases not acceptable today. In this field as in many others, our challenge is to cherish and protect future generations by learning from the lessons of the past.

For example, I would imagine that there are many of you here today who, until not too long ago, practiced a method of disposal of domestic waste at summer cottages which seemed like a good idea at the time: you separated tin cans, bottles and other solids from combustible materials, burned the latter on the bonfire and motored - or perhaps even rowed - to the middle of the lake or river for a bi-monthly can-dunking exercise.

Little thought was given to the pollutants dispersed in the atmosphere from the fires (unless you happened to be down-wind from one), and there are now countless lakes and rivers in Canada's cottage country whose bottoms are literally lined with glass, plastic, iron oxide, aluminum, tin, an assortment of other alloys, and the soldering compounds and adhesives which kept the various containers together. For decades to come, these materials will be absorbed into the aquaculture, eventually reaching, and possibly affecting, man. At the very least, sport fishing may be affected.

Added to the foregoing practices were the effects of electrically-operated domestic water systems, whereby wash water and sanitary wastes released into porous, gravelly soils, resulted in the transfer of phosphates and other nutrients to lake waters. The net effect has been the formation of algae in large amounts and a further deterioration of water quality.

Doubtless there are few people who now continue such ecologically questionable practices. The critical anti-pollution commentary of the Sixties as well as the obvious deterioration of certain recreational bodies of water brought home forcibly to most people that what had seemed reasonable, sensible and perhaps even beneficial practices in the past, were no longer any of these things.

There are clear parallels with regard to nuclear waste storage and disposal where we have problems of the past to rectify as well as new concerns which cannot be left to chance solution lest they create an undesirable legacy in their turn.

The rapid growth of the nuclear industry, and the volubility of the critics who have risen to attack it under a variety of motives, have led to increasing public anxiety about the possible effects of the liberation of radioactive contaminants upon man and his environment. In the days when the use of radioisotopes was confined mainly to hospitals and a few industrial concerns, and when the few existing nuclear research reactors were located in remote areas and operated by government agencies, the problem of radioactive residues seemed to be a minor one, if it was thought about at all.

Now the Canadian public is faced with a developing nuclear industry having considerable domestic impact, ranging from the generation of household electricity to the possible presence of an ionization-type smoke detector in one's residence, or a tritium source of dial illumination in a new wristwatch. In these changed circumstances, problems of radioactive waste management have aroused the interest and concern of politicians, the news media and groups concerned with pollution, as well as members of the general public. Some of these groups and individuals, objectors and doubters alike, are well informed, others less so, and the situation is ripe for exploitation by whoever exhibits the most credible, determined leadership.

Even among people who support the nuclear program, there is growing concern that the future development of the nuclear industry will be hampered by an ever-increasing volume of wastes that pose a potential danger to the welfare of mankind. In a recent report, Dr. Robert J. Uffen, Dean of Applied Science at Queen's University and a member of Ontario Hydro's board of directors, echoed many of his contemporaries by stating that "...the waste disposal problem is becoming one of the major limiting factors to the expansion of the peaceful uses of nuclear energy."

There are others who, while not arguing outright with Dr. Uffen's statement, place a somewhat more positive light on the subject. For example, the study popularly referred to as the Hare Report, commissioned by the Energy, Mines and Resources department, states that provided immediate research and development is undertaken, "there are good prospects for the safe, permanent disposal of reactor wastes and irradiated fuel, and we see no reason why the disposal problem need delay the country's nuclear power program."

Indeed, at least amongst the scientific community, an international consensus would seem to have been reached on the viability of safe, environmentally sound answers to the radioactive waste disposal problem. This is exemplified by a report issued in September of last year by the Nuclear Energy Agency of the Organization for Economic Cooperation and Development, whose authors stated: "We have at our disposal the scientific and technical capacity to resolve the problem of waste management satisfactorily, based on measures that have already been explored. This is why, granted that present generations make the necessary efforts, there is no reason to fear that we will leave our descendants with a problem that has not been solved."

The reason for optimism in consideration of the radioactive waste management question lies in the fact that knowledge in this field is more advanced than is popularly supposed. The problem that actually exists is how to choose the most economically effective method for disposing of the wastes in the interests of public health and safety, and protection of the environment. Indeed, economics aside, the whole question of disposal of radioactive wastes cries out for a demonstration project.

GENERATION OF RADIOACTIVE WASTES

Radioactive waste is currently generated in the nuclear fuel cycle, in nuclear research, and in the production and use of radioisotopes. These wastes may be generated in solid, liquid or gaseous form.

In the nuclear fuel cycle, waste is produced at all stages, beginning with the large volume of uranium mine and mill tailings contaminated with the natural decay products of uranium. Then there are the wastes from uranium refining and fuel fabrication plants, most of which are low in radioactivity but have a long half-life as well as chemically toxic qualities in the case of refinery wastes. Finally, there are wastes from nuclear power reactor operations.

Reprocessing of spent fuel would be another source of radioactive waste, but at present, reprocessing is not practiced on other than a bench-scale research basis in Canada.

The radioactive wastes created during the mining, milling, refining and fuel fabrication stages of the nuclear fuel cycle are small in unit radioactivity but large in volume compared to that generated in the fuel irradiation stage. This waste contains decay products of natural uranium, some of which are radioactive. Of these, radium is the most hazardous and some health authorities consider it to be more deleterious in its effects than plutonium. Radium also gives rise to radon gas whose daughter products can cause lung cancer.

In the past decade, with the increased awareness of, and concern about, environmental impact, the effluents and gaseous derivatives from the mine waste and mill tailings areas have come under increasing scrutiny because of the potential hazards mentioned above. Elliot Lake, Uranium City, Bancroft and Port Hope are examples of unsatisfactory waste management and the impact of low-level wastes on the population and the environment.

The environmental and health agencies have been involved in the regulatory control of the effluents, having established receiving-water quality objectives or concentration limits for these materials in the effluents.

From the Board's point of view, uranium mill tailings facilities are considered to be nuclear facilities, and, as such, are licensable under the Atomic Energy Control Regulations.

The licence may specify any terms and conditions the Board considers necessary in the interest of the health and safety of the facility workers and the general public.

It must be remembered that hundreds of millions of tons of tailings and mine waste are going to be around for a very long time. Most of these wastes contain significant quantities of radioactive and acid-forming materials and are subject to all natural processes which could mobilize these contaminants and distribute them in the surroundings.

In this regard, an American Physical Society study group on nuclear fuel cycles and waste management recently concluded that: "For long-term waste management, the hazard associated with radium is more significant than that for plutonium. In addition, for regional population exposure, radionuclides in uranium mill tailings are potentially at least as important as the actinide chain elements in high-level waste; the relative accessibility of mill tailings contrasts with the isolation proposed for other actinide-containing wastes."

In a nuclear power reactor station, almost all the radioactive material is contained within the fuel and consists of solid and gaseous by-products from fission reactions occurring within the fuel. The radioactive substances such as plutonium that are formed as a result of neutron capture by the fuel material are also contained within the fuel. Other neutron activation products are formed in the coolant, moderator, reactor structures and gas systems.

More than 99% of the radioactive waste from nuclear power stations is contained in the used fuel bundles - the nuclear "ashes" discharged from the reactors. In appearance, apart from surface staining, a used bundle is identical to fresh fuel. It has spent about a year and a half in the reactor core, and about 1.5% of the 20 kilograms of fuel per bundle has undergone a change. Each bundle, about the size of a fireplace log, has generated enough heat to warm a family dwelling in northern Canada for about 100 years.

Although most of the fission and activation products formed in the fuel remain inside the sealed fuel elements, small amounts leak into the reactor coolant. The radioactive material in the coolant is continually removed by filters and ion exchange resins which periodically require replacement and thus add to the radioactive waste. Some radioactive material, however, remains attached to the piping and other components. Decontamination of these components may be necessary from time to time to permit routine maintenance, and this produces additional radioactive waste in the form of filters and ion exchange resins used in the clean-up procedure.

Leaks from the coolant system may result in some radioactive material becoming airborne inside the reactor building. The ventilation system is designed to prevent the spread of this material within the building and to clean up the exhaust air leaving the reactor building. The filters and charcoal absorbers used are periodically replaced and are therefore another source of radioactive waste, although the levels in these cases are very low.

Other sources of radioactive waste associated with the operation of reactors include contaminated scrap, tools, protective clothing, rags, mops and paper. These wastes arise mainly from routine maintenance and from the cleaning up of minor leaks, and their radioactive content is usually very low.

WASTE MANAGEMENT PRINCIPLES

In all waste management considerations, the AECB distinguishes between storage, which is a method of containment with the intention and the provision for retrieval, and disposal which is a form of management in which there is no intent to retrieve but which, more importantly, does not rely for its integrity on the continued need for human intervention whether this be for treatment, monitoring or restriction of access.

Storage is essentially a temporary measure and generally requires some form of surveillance. Disposal is intended to be a permanent step and, because of this, the concern for viability in the long term is paramount. If we cannot convince ourselves that the long term goals can be met then obviously we remain in a storage situation. This situation will remain, with all the implications of continued surveillance, until an acceptable method of disposal is found, or in some instances until a decision is made to commit radioactive materials to disposal by methods known but not yet invoked.

There is a key ground rule which applies in radioactive waste management, one which is accepted internationally as the basis for limiting all exposures to ionizing radiation. This is stated by the International Commission on Radiological Protection in the following way: "...all doses (will) be as low as reasonably achievable, economic and social considerations being taken into account, and any unnecessary exposure (will) be avoided".

In light of the concerns for biological health, radioactive waste management has developed as a methodology which embraces all the things that are being done to ensure that radioactive materials are always handled, stored and disposed of in such a way that only insignificant amounts could ever escape to the environment, and that the rate of any escape is acceptable.

Because of the long radioactive decay time and the initially high concentration of some of these materials, this is a demanding exercise. But it is not just a technical matter; it has policy implications at all levels of government - provincial, federal and international. Moreover, the time scales involved raise questions about the responsibilities we have towards future generations.

FUEL CYCLES AND STORAGE TECHNIQUES

Waste management strategies and techniques are significantly altered by the choice of fuel cycle.

At present, CANDU reactors are operated with natural uranium fuel. No credit is taken in the fuel cycle for the value of the plutonium in the spent fuel, but in truth it is a significant resource in its own right. The plutonium has an energy content approximately equal to that of the uranium-235 originally in the fuel. At some time in the future it may become economic or indeed necessary to reprocess the uranium fuel, extract the plutonium and recycle it.

Uranium-238 as a "fertile" material has also a high potential energy content. While this isotope is a "waste" for the CANDU reactor, it is a potentially valuable resource for conversion to plutonium in other reactor systems, notably the fast breeder reactor.

At present, spent fuel is stored in facilities from which it can be retrieved for reprocessing if and when necessary. If reprocessing is never implemented, the spent fuel would eventually be put in a disposal facility. From that time on, used fuel from a reactor would be moved, after cooling, directly to the disposal site.

If reprocessing does become part of the fuel cycle, the plutonium would be fabricated into fuel and returned to the reactor. The residual wastes would contain three principal kinds of materials: fission products, actinides (transuranics other than plutonium), and depleted uranium. These wastes would require careful disposal.

PRESENT WASTE MANAGEMENT

Ore Tailings

The tailings from uranium ores are traditionally discharged to ponds adjacent to the mills. The concern with these wastes stems from their large volumes and from the potentially hazardous nature of the long-lived radium-226 and other associated radionuclides which can become distributed in the environment by wind and water effects. It is possible that this concern can be reduced by increasing the thickness of earth cover over the tailings piles and revegetating the soil to lower the release of radon gas and windblown tailings dust, and by providing well-engineered drainage and collection from the storage areas.

It follows that the method of tailings management now in use must be considered as storage. The reason for this is simply that we could not at the present moment walk away from a tailings pile with no further provision for supervision. In addition, it is unlikely that we would ever be able to do so without significant improvements to current procedures. Just what would be required to ensure the long term suitability of tailings management methods is a subject now under intensive study by the AECB and others.

The most attractive approach to the problem of radium (and other contaminants) in tailings would be removal prior to the discharge of the tailings to their retention ponds. If this were feasible, many of the long term problems would disappear. This approach is currently the subject of greatly increased attention by the AECB and others, including EMR's CANMET, the Environment Canada laboratories at Burlington, Ontario, and a number of mining companies.

The Board considers the ultimate goal in the management of tailings to be their conditioning and emplacement in such a manner that continuous treatment and surveillance would be unnecessary.

Non-Fuel Reactor Wastes

Non-fuel reactor wastes (ion-exchange resins, filters, cleaning materials, clothing, etc.) are stored in concrete trenches or in "tile holes" - concrete pipes set vertically in the ground. In many cases, the waste is treated either for conversion to solid form or for volume reduction prior to its emplacement in storage. AECL and Ontario Hydro are currently studying and developing improved techniques of volume reduction involving incineration, reverse osmosis, and evaporation.

As with all reactor wastes, the most desirable course of events would permit their removal to a central, or regional waste management centre, for disposal.

Spent Fuel Waste

A 2000 megawatt power station - the size of Ontario Hydro's Pickering - is fed about 40 fuel bundles (approx. 3/4 ton) per day and discharges an equal amount of spent fuel. (A coal-fired station of the same size would require about 400 carloads of coal daily and would yield about 20 carloads of ashes per day in addition to its solid and gaseous stack effluents. It is evident that the volume of waste arising from fuel consumption is much smaller for the nuclear station. However, although coal ash is far from being innocuous, the nuclear waste must be handled with much greater care.)

The discharged fuel from all Canadian reactors, and in fact most reactors in the world, is stored under 3 to 4 metres of water in deep, water-filled pools constructed with thick concrete walls lined with stainless steel.

A nuclear power station may be designed with sufficient pool capacity to store all the spent fuel produced over its expected 30-year service life. Alternatively, the spent fuel could be shipped from the power station to a central pool site for storage, if indeed such central facilities existed.

A pool is an elementary storage technique, but it does have advantages. The waste is contained within the fuel sheath which is corrosion resistant. If a fuel defect does occur, the small amount of activity escaping is retained within the pool water, from which it can be extracted if desired.

The pool's stainless steel or fibreglass-epoxy liner and double-layered concrete are a further barrier.

To date, Canada has amassed more than 25 years of experience with storage of spent fuel and other radioactive components in pools, and there has never been a significant escape of activity, or an accident of any magnitude.

Dry Storage

Atomic Energy of Canada Limited and Ontario Hydro are studying alternatives to pools for storage of spent fuel. One scheme selected for development is the concrete canister concept, a system employing holding vessels about 5 metres high and 2.5 metres in diameter. The fuel is stored dry in small quantities, 220 bundles per canister, in a steel can which is welded shut and surrounded by lead and concrete shielding.

The fuel is cooled by radiation and conduction to the concrete shell, and then by conduction through the concrete. The concrete is cooled by natural air convection over the outer surface. One canister will hold about 4.5 tons of fuel, about a week's production from a station the size of Pickering.

The canister appears to have some advantages over pool storage. Once the fuel is in place, it needs minimal surveillance, essentially no maintenance, and produces no secondary wastes such as the filters needed to remove radioactive materials from the water in spent fuel bays. However, there may be problems due to the temperature gradient across the wall of the concrete flask, and with defective fuel. AECL's program is designed to quantify both advantages and disadvantages so that an objective comparison can be made.

The immediate value of the canister development program will be to provide an evaluated and demonstrated concept to which the water-filled pool storage can be quantitatively compared. If the demonstrations are satisfactory and the design study shows that significant advantages can be gained, canisters rather than pools could be the preferred storage concept for facilities to be built in the late 1980's.

DISPOSAL

Storing wastes on an interim basis is not technically difficult. However, for the longer term we need to provide new engineering concepts. We could continue to use man-made structures built on the surface of the earth. However, such structures deteriorate with time, and to ensure isolation of the waste, would have to be replaced on a planned-maintenance basis. This places a burden on future generations, and cannot therefore be considered disposal.

The option that appears to hold the best prospect for achieving health, safety and long-term responsibility objectives is the use of deep, geologic formations that are known to have been stable over geologic timescales. The surrounding rock provides a heat sink for cooling, the overburden provides almost infinite shielding and isolation from the biosphere, and it is difficult to think of anything, including ice ages and meteorites, which would remove this protection in a catastrophic fashion.

Salt beds, some of which are millions of years old, are one type of geologic formation which has been investigated extensively in the USA and Germany for nuclear waste disposal, and they are not being ignored in Canadian research.

Since salt is highly soluble in water, the existence of a bed indicates the absence of flowing groundwater from the time that the bed was laid down. This is a very attractive feature since seeping groundwater appears to be the main mechanism by which radioactive waste might be transferred from its burial place. Further protection against this possibility can be afforded by disposing of the waste in a highly insoluble form such as being incorporated in glass.

A great deal is known about all the relevant properties of halite deposits for waste disposal, far more than about any other formations. However, it is recognized that other types of rocks may be equally suitable, but the necessary research and development have not yet been done.

Monolithic rock formations in regions such as the Canadian Shield have also been proposed for waste disposal. These formations have not been extensively studied for this purpose, but appear to offer the degree of long-term isolation required.

The Geological Survey of Canada is engaged, with AECL, in studies which will enable them to identify the more promising geologic formations. Very recently, AECL announced a major initiative in this experimental program: test borings will be conducted beginning this summer in suitable formations located at its two research establishments, Chalk River Nuclear Laboratories, and Whiteshell Nuclear Research Establishment.

In the process of selecting a suitable site or sites, formations will be evaluated in the context of general requirements such as the following:

(1) The rock should have low economic value and not be close to other formations with actual or potential economic value;

(2) The formation should be large, accommodating a buffer zone of significant size;

(3) The formation should have high integrity with a minimum of cracks, faults and joints;

(4) The formation should be in a zone of low seismic activity;

(5) The formation should be either impervious to or isolated from moving groundwater.

Besides these factors, there are a number of other detailed considerations including the desirability that the formation be homogeneous and relatively free of internal stresses. The excavation of the cavity, the emplacement of the material and the heat load it generates will all place new stresses on the rock. It will have to be shown that the emplacement could not have any significant effect on the macroscopic stability of the formation, and that the effects of future glaciation are acceptable.

Deep disposal in hard rock (e.g., granite) appears a promising alternative. The size of the Canadian Shield, the low economic value of granite and the presence of the Shield in much of northern and eastern Ontario, with that province being the principal user of nuclear power in this country for the next twenty-five years, are factors which argue strongly in favour of a location in the Shield.

CONCLUSION

In summary, and speaking from the regulatory viewpoint, I would have to say that the storage and eventual disposal of radioactive waste from any point in the fuel cycle subsequent to the mine-mill stage appears to be technologically and environmentally viable. Many of the procedures and techniques are already in use.

We are, of course, most anxious to see progress in the demonstration of ultimate disposal concepts. An interesting speculation is whether or not the AECB would consider withholding reactor licence approval in order to prompt this action.

Such flexing of the regulatory muscle has its place, as witnessed by significant improvements the Board has been able to encourage in waste management practices at the high-volume stages of the nuclear fuel cycle, particularly in the refining stage.

In truth, the field of waste management is the most challenging one facing us today. It will require research dollars, continued cooperative efforts by government and industry, and strengthened legislation and regulations to ensure that future waste management practice does not repeat the errors of the past.

But with the cleaning up of a number of waste storage and disposal acts, plus the closing of the fuel cycle loop by permanent deposition of wastes underground, we will have achieved a balanced arrangement with nature: from the ground we will take a little of the naturally occurring radioactivity, put it to work, and then return it from whence it came. The remarkable thing to contemplate is that through man's ingenuity and genius, the environment should be better protected from these sources of radiation than if they had been left untouched, subject to the caprices of the natural ecological system.

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