MIGRATION AND CONTAINMENT OF LEACHANTS FROM URANIUM TAILINGS PONDS

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ABSTRACT

Two provinces, Saskatchewan and Ontario, are the major uranium producers in Canada. Prior to 1975 approximately one hundred million tonnes of tailings were deposited over a surface area of more than 50 km^2 [1]. All of these tailings were placed into conventional confinement structures, predominantly tailings ponds with permeable embankments. The new regulations put forward at the beginning of 1980 for the design and operation of uranium waste management systems are to provide permanent confinement of all solid waste materials and also require that the liquid wastes are free from contaminants.

INTRODUCTION

Two provinces, Saskatchewan and Ontario, are the major uranium producers in Canada. In Saskatchewan the first uranium was discovered in 1934 and production began in 1953 [4]. By 1957 there were seven active mines in Saskatchewan and in Ontario, in the Elliot Lake area, thirteen mines were producing uranium from underground ore bodies. In the 1960s, due to dwindling demand for uranium, many mines had ceased operation and the abandoned waste piles and tailings ponds are still a major concern and hazard to the environment. In the middle of 1970 a new generation of mines was brought into production mainly in the province of Saskatchewan because of new discoveries of high grade uranium ore in that region. These new developments had to satisfy strict and safe environmental requirements imposed by both provincial and federal agencies. Uranium production is subjected to annual licensing, monthly inspections and to frequent checks of water quality of the disposed waste liquids. In addition new operations will undergo public scrutiny from concerned groups. The new objectives put forward for the design and operation of uranium waste management systems are to provide permanent confinement of all solid waste materials with adequate factors of safety to ensure long term stability; to eliminate all potential seepage pathways; to ensure that contaminated liquid will be intercepted and contained until such time as it can be recycled or treated to remove contaminants and render it acceptable for discharge; to provide an integrated layout of the mill, water reservoirs and tailings storage facility which would ensure that all accidental spillages of contaminated materials were contained; and to provide a safe and efficient decommissioning system. The primary concern in tailings management focuses now on the close-out or decommissioning aspects of uranium mines.

Another important consideration of tailings management in Canada has been the treatment of the liquid effluents. In the past the treatment systems involved the addition of lime to lower the acidity and the addition of barium chloride to remove Radium 226. Little attention has been paid to other toxic substances which are usually present in the uranium oxide production, such as arsenic, iron, nickel, ammonia, cobalt, copper, zinc, molybdenum, lead, vanadium and in many cases florium and selenium. In order to prevent these minerals from reaching the environment, control and treatment methods are applied, such as impervious and semi-impervious liners for tailings ponds; ion exchange and neutralisation of toxic ions; cut-off techniques for seepage water; installation of horizontal and vertical drains; earth covers over waste ponds; subaerial and deep pit disposals and subaqueous deposition of tailings. It must be kept in mind that Canada has extreme climate conditions, where temperatures of +35°C in the summers and -45°C during the winter periods are the rule rather than the exception. The mean annual precipitation ranges from 400 to 600 mm of which less than half will be lost due to evaporation.

GEOHYDROLOGY

The majority of the Canadian uranium mines are located within the Canadian Shield, a complex ancient rock mass of which the oldest formations are more than two billion years old. These ancient granites are overlain and interfolded by a series of metamorphosed, deformed and recrystalized sediments which were derived from the parent rock. The surface of these Precambrian rocks have been extensively scoured by glacial erosion and are covered with a thin layer of glacial and post-glacial sediments. The drainage pattern in the Canadian Shield is irregular and is interspersed with many lakes at various elevations. Many of these lakes are not connected to one another or to waterways. The quality of the lake water is generally good with pH values ranging from about 5.5 to 8, except in muskeg areas and peat bogs where values as low as 3 have been measured [3]. These lakes provide ample recharge for the groundwater regime. The bedrock is generally fractured to a certain depth and must be considered permeable and also is in many cases under artesian pressure creating an upward gradient.

REGULATIONS AND REQUIREMENTS

Before 1970 the only consideration given to tailings containment was that imposed by the natural features of the topography and economic considerations. In recent years uranium tailings management issues have assumed a high public profile resulting in several open hearings and enquiries. Regulating the uranium industry involves both provincial and federal authorities. In 1946 the federal government passed "The Atomic Energy Control Act" which was prior to 1975 aimed mainly to control the production and management of uranium products. After 1975 much higher emphasis was placed on protecting the Canadian environment. Both the Atomic Energy Control Board (AECB) and the provincial environmental departments began exercising much stricter controls over the environmental effects and hazards caused by the uranium industry. The new regulations imposed on the production of uranium must be interpreted also with regard to the present economic conditions, keeping in mind that the price of uranium oxide is less than half what it was several years ago. The present regulations for the uranium industry cover the environmental control of uranium development from a detailed exploration stage, through construction, operation and the abandonment-reclamation phases. The regulations include design and construction requirements, contingency procedures, reclamation and abandonment requirements, effluent quality standards, air quality standards, and monitoring requirements. Some of the regulations will be referred to in the following sections. Table 1 gives some of the discharge limits for effluent from uranium tailings storage facilities presently used by the province of Saskatchewan [4].

TABLE 1. DISCHARGE LIMITS OF EFFLUENT

Substance	Max. Conc. Monthly Mean	Max. Conc. Composite Sample	Max. Conc. Grab Sample
Total Suspended Solids (mg/L)	25.0	37.5	50.0
Uranium (mg/L)	5.0	7.5	10.0
Radium 226 (Dissolved) (mg/L)	0.37	0.74	1.1
Arsenic (mg/L)	0.5	0.75	1.0
Copper (mg/L)	0.3	0.45	0.6
Lead (mg/L)	0.2	0.30	0.4
Nickel (mg/L)	0.5	0.75	1.0
Zinc (mg/L)	0.5	0.75	1.0
pH (Minimum)	6.0	5.5	5.0

In the above table a "Composite Sample" means a quantity of effluent consisting of a minimum of 3 equal volumes of effluent collected over a period of not less than 7 hours and not more than 24 hours. A "Grab Sample" is a volume of effluent collected at any given time. In Ontario the Ministry of Environment is presently developing "Guidelines for the Discharge of Radionuclides to Surface Waters" in which limits of concentrations of radioactive materials will be given at the point of discharge.

DISPOSAL TECHNIQUES

In the past disposal of radioactive waste should rather be considered as storage where the spoil material is left as waste piles or tailings embankments with little control to prevent further pollution of the environment either by contaminents infiltrating into the ground, as run-off or as airborne pollutants. Disposal has now been redefined [3] as a method of dealing with wastes for which there is no intention of retrieval with the added requirement that the method used should not rely for its integrity on continued human involvement. In accordance with this new meaning of disposal several novel techniques of tailings disposals have been proposed to limit or prevent future misuse of the tailings after the mine has been "closed-out." These new placement technologies emphasize the ultimate disposal without the need for further maintenance of the containment system.

Open Pit Disposal

This is a fairly new technology and has been used for the Rabbit Lake mine extension in Saskatchewan [4]. The scheme consists of depositing the filtered and treated tailings in a mined-out open pit. The slopes of the pit are lined with a highly permeable waste rock material as shown in Fig. 1. This filter will act as a hydraulic barrier minimising the interaction between the tailings porewater and the groundwater regime. Furthermore, since the tailings are redeposited in a dry state below the water level of the pit, there will be hardly any need for landuse controls and radon emanation and gamma emmission will be extremely low. Since ammonia in the effluent had been of concern; ammonia was eliminated from the extraction process. The pervious filter material acts as a hydraulic short circuit and any water and dissolved contaminants will radially drain to that zone. The water will be collected at the base of the pit and can be further treated if necessary. This system is rather self-contained and should not disperse any contaminants into the environment after abandonment of the mine operation.

Coning or Stacking Method

This method is presently evaluated in the Elliot Lake area in Northern Ontario. Coning involves the placement of tailings in a rather dry state, that is, the solids in the tailings are about fifty to sixty per cent and the storage capacity for a given area is increased correspondingly. The tailings are stacked or coned to a high point at the central area of the disposal site and gently sloped towards the edges. The sloped topography will cause the precipitation to run off rather than infiltrate. This is an important consideration for Canadian climates where net-precipation exceeds evaporation by more than fifty per cent. All of the technical aspects have not been fully evaluated yet especially with regard to long-term management.

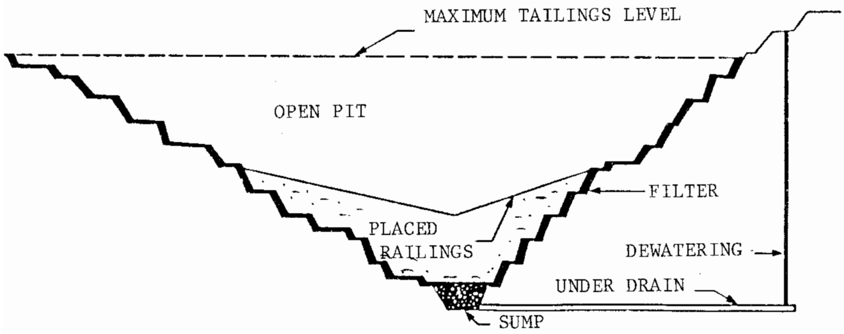

FIGURE 1. RABBIT LAKE DEEP PIT DISPOSAL

Sub-Aerial Deposition

This method has been first tried at the Key Lake Uranium Mine in northern Saskatchewan and the storage facility was designed to achieve a partially saturated, drained, and consolidated tailings contained by circumferential dikes. The scheme at Key Lake is shown in Fig. 2. Before tailings deposition a clay seal (Bentonite) was constructed over the whole area and a filter blanket is incorporated overlaying this seal which will collect all free draining liquids to a collector sump. The sub-aerial technique of deposition where the tailings are placed in thin layers will result in a laminar structure with the highest possible density and lowest vertical permeability. The horizontal permeability is many times greater than the vertical one, resulting in a predominant horizontal flow pattern within the tailings. This method needs to be carefully studied especially during the long cold winter months where the tailings are

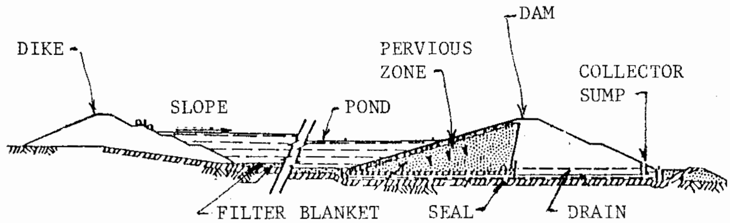

FIGURE 2. KEY LAKE LAYERED TAILINGS DISPOSAL

subjected to freezing and deposition of tailings in thin layers is not possible. The effect of the discontinuity between winter and summer placements has to be monitored over several years before a final judgement can be made.

Deep Lake Disposal

Several years of studying the concept of deep water tailings disposal have been undertaking at the Quirke Uranium Mine in northern Ontario. Quirke Lake, with serveral connecting basins, is quite a large lake and has a depth of approximately 140 metres and could accommodate in the order of 500 million tonnes of tailings [1,3] while still maintaining a free water body of at least 30 metres above the tailings. The deep lake disposal technique seems to have several advantages one of which is the inhibition of Radon and gamma emanation. The second advantage would be that tailings will eventually be covered by natural lake sediments and thereby minimizing the interaction of the tailings with the overlying lake water. Opponents to this scheme argue that the short-term and long-term interaction of the various contaminants with the lake water is not well understood. This interaction could be critical at Quirke Lake since the volume of water flowing through the lake is about 4000 L/s and, therefore, could cause pollution of the downstream lakes and rivers [2].

Unfortunately, there has not been a setting in Canada or any other part of the world which is similar to the Quirke Lake disposal site. Hearings on that subject are presently held to evaluate this disposal option. One of the main difficulties being faced is that the time necessary for a proper evaluation and approval is considerable while Quirke Mine must make a decision very soon on how to dispose the tailings from the ongoing mine operation. A schematic diagram of the deep lake disposition scheme is shown in Fig. 3 indicating the various interacting components involved.

TOXIC ELEMENT MOVEMENTS

The problem of toxic element dispersion associated with uranium tailings can be divided into three parts all of which are interrelated. Solid pollutants which are either deposited as solid particles or suspended in liquid, dissolved contaminants in the form of ions, and airborn pollutants.

Airborne Pollutants

Radon is considered the controlling contaminant for airborne release. Current levels of radon emission from uranium tailings is in the range of 100 to 700 pCi/m^2 sec and proposed regulations in Canada should keep the level within 100pCi/m^2 sec [5]. The present limit enforced by the Environmental Protection Agency (EPA) in the United States of America is 20 pCi/m^2 sec. In order to achieve either control levels the tailings should be covered with a certain thickness of soil. In general, there is no reliable annual emission averages for most closed-out sites in Canada, but measurements are presently carried out at some active sites as

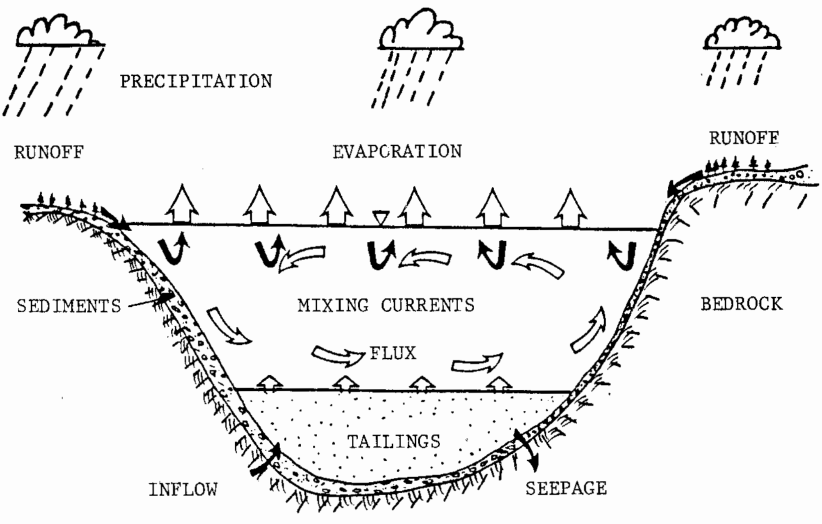

FIGURE 3. UNDERWATER TAILINGS DISPOSAL SCHEME

reported by Bigu et al. [5]. The importance of soil cover on the reduction of radon emission is shown in Fig. 4. For example, if the emission of radon from a tailings area is in the order of 100 pCi/m^2 sec and it should be reduced to an admissable level of 20 pCi/m^2 sec, a 2 metre thick soil cover is needed. An emission value of 600 pCi/m^2 sec would require a 4 metre thick earth cover.

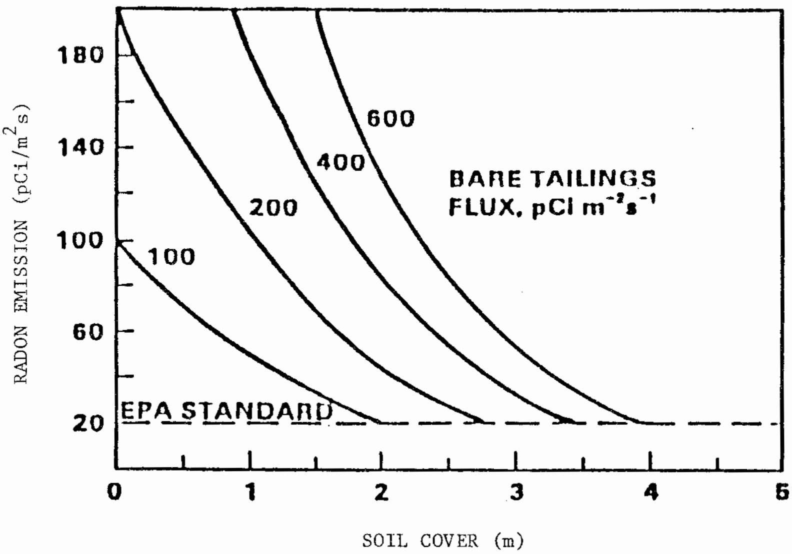

FIGURE 4. THE INFLUENCE OF EARTH COVER ON RADON EMANATION

Canadian authorities propose to limit gamma radiation to about 50 µR/h measured at one metre above the uncovered tailings [5]. Typical gamma fields above uranium tailings are in the order of 1000 µR/h [2]. In general, meeting the required emission levels for radon by implementing an earth cover will also comply with the gamma emission standard. Wind-blown radioactive dust and solid particles will also be eliminated once the soil cover is in place.

Radioisotopes in Effluent

The most common radioactive pollutant in liquid effluents is radium 226. Several pilot plants are presently in operation in Canada to study effective means of radium removal. So far, the most promising method is by using a multi-layer filtration technique which can achieve concentrations levels of less than one Becquerel per litre. This is less than the present standard for drinking water. This, understandingly, has led to considerable confusion over effluent standards for uranium mill operations and water quality standards for human consumption.

Radioactive seepage leaving the tailings pond area can be intercepted by the various cut-off methods and movement of toxic substances or radionuclides can be monitored very effectively by sampling from observation wells located downstream from the cut-off. Any effluent which does not comply with discharge standards can be pumped back to the pond area. Figs. 5 and 6 show a tailings disposal system where considerable down-valley seepage had occurred. After a grout curtain was installed under the embankment, little or no movement of effluent could be measured. The decrease in concentration of uranium, radium and other radionuclides and metal ions were dramatic as had been verified by regular sampling from monitoring wells (Fig. 6).

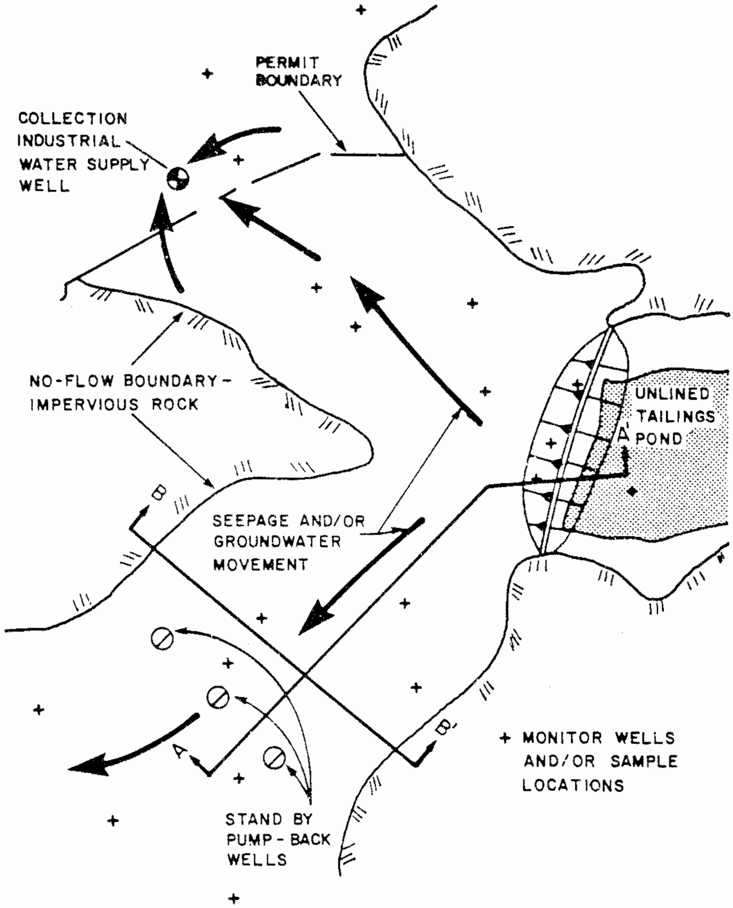

FIGURE 5. SEEPAGE FROM AN UNLINED TAILINGS POND

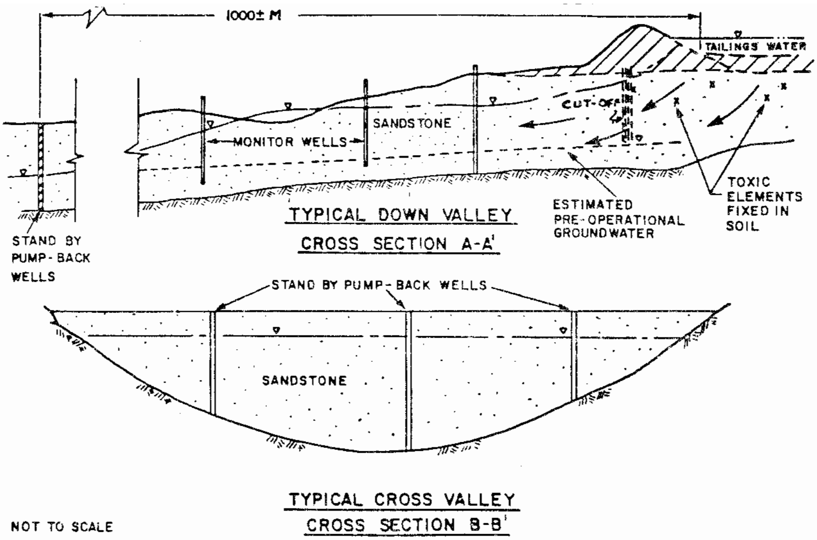

FIGURE 6. SECTION THROUGH TAILINGS DISPOSAL SYSTEM

CONCLUDING REMARKS

Several novel techniques of tailings disposal systems which are presently evaluated in Canada have been discussed in this paper. New technologies carry with them certain elements of uncertainty and risk. Historically, regulatory agencies have held the industry fully responsible if a disposal system failed or became deficient for whatever reason. These constraints make industry reluctant and cautious in adopting new and unproven methods. This reluctance can however be overcome by a closer co-operation and consultation between the various agencies involved, the owner of the mine and the general public. By continuing the refinement of control requirements and criteria, safe and cost efficient uranium tailings disposal systems can be achieved whereby the interests of industry control agencies and the public are integral parts.

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