CANADIAN WASTE MANAGEMENT - THE ELDORADO EXPERIENCE

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INTRODUCTION

Canada is a world leader in uranium production. In 1978 it produced 6,803 tonnes of uranium (contained in concentrates), accounting for 20 per cent of the estimated world output of 34,000 tonnes[1,2]. Canadian production centers on two provinces: Saskatchewan and Ontario. Of the six active uranium producers, four are located in Ontario: Denison Mines Limited, Rio Algom Limited, Agnew Lake Mines Limited and Madawaska Mines Limited. Together they accounted for some 55 per cent of the total 1978 shipments. The remainder was shipped by two producers in Saskatchewan: Gulf Minerals Canada Limited/Uranerz Canada Limited and Eldorado Nuclear Limited. In the mid-1980's three large mines in northern Saskatchewan will join these ranks[1].

The first Canadian uranium was produced in 1942 for the Manhattan Project by a then private company — Eldorado Gold Mines Limited.

HISTORY

The Canadian uranium industry was born with Gilbert LaBine's discovery of pitchblende at Great Bear Lake, Northwest Territories, in 1930. By 1933 Eldorado Gold Mines Limited, a private company, was mining and processing the pitchblende for the extraction of radium and silver. In the 1930's radium and its compounds were extensively used in the treatment of cancer and various skin ailments, such as eczema, acne, *etc*. They were also used in research and in the production of luminous paints[3]. In 1936 Eldorado celebrated the production of its first ounce (28.34 g) of radium. To obtain one gram of radium, ten tons of pitchblende had to be refined in the Eldorado Refinery in Port Hope, Ontario. The pitchblende was concentrated from 500 tons of ore in Port Radium, and then shipped by air — the Eldorado Silver Radium Express — at the rate of two tons a day[3,4]. The Port Radium mine was closed in 1940 as a consequence of declining demand for radium.

To produce uranium for the Manhattan Project, the mine was re-opened in 1942. The company was re-named Eldorado Mining and Refining Limited, and in 1944 became a Crown Corporation wholly owned by the Canadian Government. The Port Radium mine, 30 miles south of the Arctic Circle, was in operation until 1960, when mining ceased due to ore depletion. The acid leach mill processed up to 82,103 tonnes of ore in 1958, producing 385 tonnes of yellow cake (U_3O_8). In the closing years of the mine, mill production was supplemented by the reclamation of old radium mill tailings[4,5], which were dredged from Great Bear Lake where they had been dumped during the radium producing years.

Presently, Eldorado Nuclear Limited is involved in the mining, milling, transportation, extraction, refining, and metallurgy of uranium. It operates a mine and mill in northwestern Saskatchewan, 16 km north of Lake Athabasca, on the north shore of Beaverlodge Lake. The major portion of the ore is mined underground in the Fay mine, which is now more than 1.6 km (1 mile) in depth[6]. The remainder comes from incline and open-pit mines. Custom processing is provided for satellite mines.

Milling of the ore is carried out via an alkaline (carbonate/bicarbonate) process, and the product, yellow cake, is flown to Edmonton, Alberta, and shipped by rail to the Eldorado Refinery in Port Hope, Ontario. The Refinery is one of the five in the Western World, and processes all Canadian-mined uranium, as well as some from abroad. Two main refined uranium compounds are produced, namely, ceramic grade uranium dioxide for CANDU reactor fuel, and uranium hexafluoride. The uranium hexafluoride is exported for uranium-235 enrichment and manufactured into fuel pellets for non-Canadian reactors. A second refinery is currently under construction in the Port Hope area.

CANADIAN WASTE MANAGEMENT

To date uranium mining in Canada has produced more than 100 million tonnes of tailings. The combined six operations in Saskatchewan and Ontario produce more than 14,000 tonnes of tailings daily[7]. The current ore grades vary from 0.05 to 0.25 per cent uranium (0.5 to 2.5 kg per tonne of ore). The upcoming northern Saskatchewan mines will process ores containing up to and over 30 per cent of uranium; this is expected to drastically reduce the waste volume associated with these new mines.

Certain geological and climatic features are unique to Canadian waste management. All the mines are located on the Canadian Shield; the bed rock averages 3,200 million years in age, lending tectonic and seismic stability to long-term storage and disposal areas.

The mines are generally located in wet and temperate areas, such as the Elliot Lake region (Northern Ontario), and semi-arid regions (Beaverlodge area, Saskatchewan). Both areas abound in natural lakes, some of which have been used for the temporary or long-term storage of tailings. To suit engineering designs, these lakes, swamps and natural basins are sometimes dammed and artifically raised[7,8,9,10].

Thorium is a major constituent of Elliot Lake ores. Prior to discharge, all liquid wastes are limed, precipitating the thorium into solid tailings[7].

The liquid effluents from tailings areas contain various radionuclides of concern, *e.g.*, radium-226, lead-210, polonium-210, thorium-230, *etc.* All Canadian mines reduce the levels of radium-226 in the effluent by treating with barium chloride, and co-precipitating as barium-radium sulphate[11]. The co-precipitate settles in natural or man-made ponds, or is sand-filtered and collected for further long-term storage.

FEDERAL AND PROVINCIAL EFFLUENT GUIDELINES FOR RADIUM-226

The Federal authorized level for uranium mines and mills effluent discharges is 10.0 pCi/L dissolved radium-226. The "dissolved" is an arbitrary designation for samples filtered through a three micron filter[12]. The control level is the maximum authorized monthly arithmetic mean of the discharge.

For tailings pond discharges the Provincial Governments of Saskatchewan and Ontario have 3 pCi/L of dissolved radium-226 as the objective[11]. The Atomic Energy Control Board (AECB) of Canada is considering the proposal of 10 pCi/L <u>total</u> radium as a target guideline for tailings pond discharge[11].

No Canadian equivalent of the U.S. Uranium Mill Tailings Radiation Control Act (1978) has been promulgated yet[13,14].

BEAVERLODGE WASTE MANAGEMENT

Eldorado's Beaverlodge operation is subject to long periods of extremely cold weather. The yearly mean temperature for 1952-1970 was -3.7°C, and for the month of January, -27°C. Frost-free days average 139 per year, with 2,000 hours of sunshine (mostly in the Summer months). Precipitation averages 186 mm for April-September, and 156 mm for October-March periods. Evaporation averages 360 mm per year[15].

The lake systems of the area drain into Lake Athabasca to the south of Beaverlodge Lake.

Tailings and Mine Water Management

The principal extraction circuit of the mill is a carbonate/ bicarbonate leach which yields high grade yellow cake. It is the only alkaline leach mill in Canada. Due to the high pH of the liquid discharge, no liming is necessary.

A much smaller acid leach circuit handles the pyrite-containing ore (2-3 per cent of total) produced by flotation concentration. The tailings are combined with those from the alkaline leach and discharged.

The mill tailings are about 75 per cent -200 mesh, at 21 per cent solids. In 1979 the mill discharge averaged 760 tonnes per day, for a seven day week. The coarse fraction is separated from the slimes in a Dorrclone Plant and used as backfill; the slimes are discharged to Fookes Lake, which acts as a settling pond.

The mine water consists mainly of underground water and water used in drilling and general mining operations as dust suppressant. The Fay mine water also contains the seepage from backfill. The Fay mine water is treated with barium chloride and discharged into Minewater Lake which acts as a settling pond. The Dubyna mine water treatment is self-contained, and post-treatment settling occurs in underground engineered sumps prior to discharge to Dubyna Lake. The Beaverlodge tailings treatment system is shown in Fig. 1.

Backfill

Backfilling has come to be recognized as a viable alternative or supplement to surface disposal of tailings, both in the United

States and Australia[16,17]. Eldorado is the only Canadian operation which uses backfill as a partial disposal of tailings in its underground operation in the Fay mine.

The mill tailings and mill waste water are collected in the mill, continuously sampled, and then pumped through a 20 cm plastic line, at 21 per cent solids to the Dorrclone Plant. The coarse fraction, at 60 per cent solids, is conveyed underground after the addition of water as a carrying medium. In 1979 backfill averaged 304 tonnes per day, or about 40 per cent of the total tailings. Depending on custom ore processed, the percentage may be as low as 27 per cent of the total[18]. Presently cement-mixed backfill is being tested in the Fay mine, the sand to cement ratio is 30:1.

The mining method used is cut and fill stoping. When a stope reaches 7.2 m in height, the bottom is mucked out, a barrier "dam" constructed and backfilled to a height of 4.2 metres. This is then covered with 0.6 m of cement-mixed backfill to stabilize the stope floor and minimize radon exhalation. The percolation rate of the backfill is 10 cm/h, and the water thus produced is incorporated into the mine water of the lower levels.

Daily, 197 tonnes of tailings by-pass the Dorrclone Plant and are discharged with the 259 tonnes of slimes (10 per cent solids) into Fookes Lake. The pH of the slurried tailings is 8.5-9.0. Table I presents the solids and solution content of radium-226 in the mill tailings, backfill, and treatment tailings[19,20].

TABLE I. Radium-226 Content in Tailings and Backfill.

	+200 mesh pCi/g	-200 mesh pCi/g	Solution pCi/L
Mill Tails	190	910	70
Backfill	130	150	38
Treatment Tails	1180	705	90

Two radium-226 mass balances were undertaken in 1978-79 in the mill and the Dorrclone Plants, the first balance of its kind in Canada[19,20]. The results indicated that almost 83 per cent of radium-226 is associated with the -200 mesh fraction. Backfilling partially solves the disposal problem of mill tailings but not that of radium-226. The backfilled tailings are expected to reintegrate with the subterranean environment over the ages, thus providing *de facto* disposal.

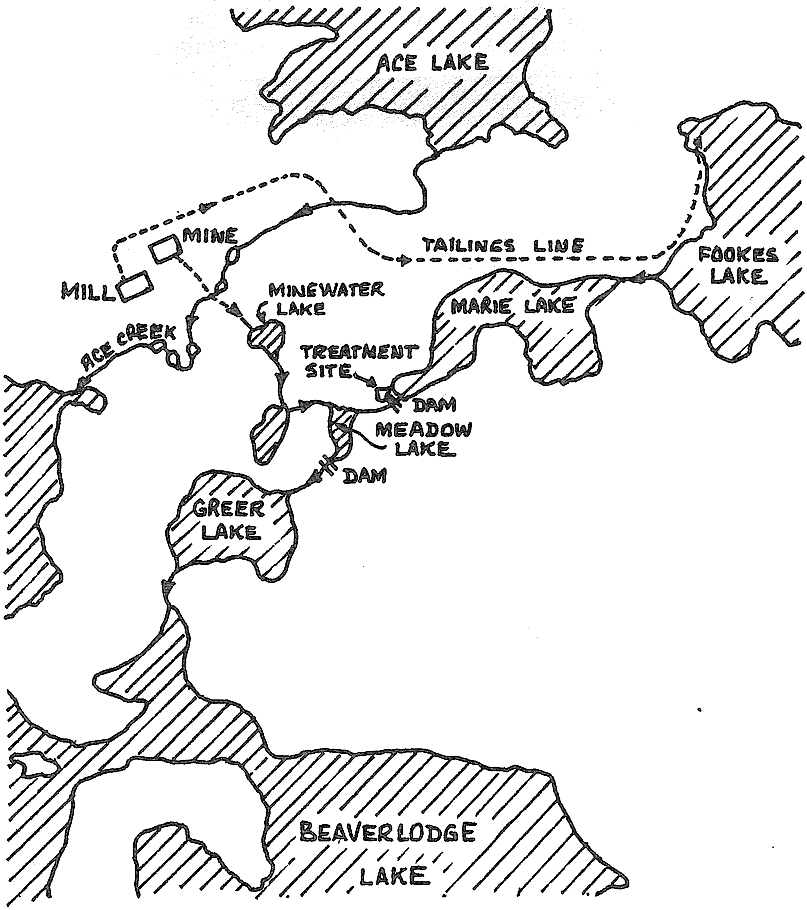

FIG. 1. BEAVERLODGE EFFLUENT SYSTEM

Liquid Effluents from Tailings Storage

The tailings that by-pass the Dorrclone Plant and the slimes flow by gravity through a 25 cm plastic line and a 25 cm wooden stave line to the long-term storage area which consists of a three lake system, as shown below in Fig. 2.

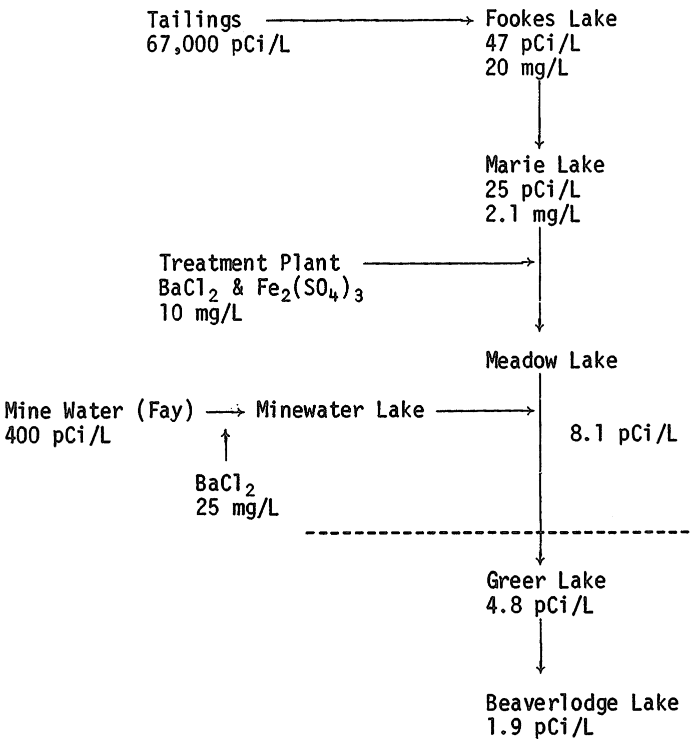

Fig. 2. The Tailings and Mine Water Treatment System. (1979 average of total radium-226 levels)

The tailings are discharged at the furthest end of Fookes Lake at the present rate of 110,000 m^3 annually. Fookes Lake, with a capacity of 9.17 x 10^6 m^3, acts as a primary settling pond. Only 0.002 per cent of the original solids overflow into the next lake in the system — Marie Lake. The Fookes Lake overflow averaged 47.0 pCi/L total radium-226 for 1978, with 20 mg/L solids. Marie Lake acts as a secondary settling pond, and its overflow contains 2.1 mg/L solids; in 1979 total radium-226 content averaged 25 pCi/L. The Marie Lake overflow is treated with barium chloride and ferric sulphate to further reduce the radium-226 content. The rate of addition for $BaCl_2$ and $Fe_2(SO_4)_3$ is 10 mg/L of effluent. Ferric sulphate, a flocculent, is added only from November to April, when radium levels are higher, to improve the settling properties of the barium-radium sludge[21]. The phenomenon of high total radium-226 levels starts prior to the freezing of the surface waters, and has been observed further south in the Elliot Lake region.

Barium Chloride Treatment

The barium chloride and ferric sulphate solutions are made up with Marie Lake water, and are simultaneously added to its overflow. A series of wooden baffles ensures thorough mixing. Meadow Lake also received the treated Fay mine water overflow, and hence acts as a sludge settling pond for both tailings treatment sludge and mine water treatment sludge. The discharge from Meadow Lake, Eldorado's last point of control, and from Greer Lake into Beaverlodge Lake, are sampled weekly.

Mine Water (Fay Mine)

The mine water is collected in sumps and allowed to settle. Water from the first two levels of the Fay mine is processed in the mill for the recovery of uranium values. The settled solids from the underground sumps are hoisted in skips and discharged in slurry form to Minewater Lake.

The mine water is treated with barium chloride at the addition rate of 25 mg/L.

Mine Water (Dubyna Mine)

The Dubyna mine is an incline mine, where the mine water is collected in sumps on the lowest level. The suspended solids are pre-filtered with a sand filter, and then treated with barium chloride and ferric sulphate; addition rates are 25 mg/L each.

Revegetation

Revegetation studies have been undertaken for the past four years on exposed tailings, to assess the feasibility of stabilization of the Fookes Lake tailings with legumes and grasses. The legumes used in the test plots are Cicer Milkvetch, Birdsfoot Trefoil, and White and Yellow Sweet Clover; the grasses are Red Fescue, Kentucky Bluegrass, Timothy, Meadow Foxtail, *etc.* Combinations of several species of grass provided up to 90-95 per cent ground coverage. Best results were obtained when the plots were mixed with peat to a depth of 12 cm, averaging three per cent organic content. The legumes required continued fertilization for sustenance[22].

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