INFO 0062

Publication

Atomic Energy Control Board | Commission de contrôle de l'énergie atomique

Atomic Energy Control Board
Commission de contrôle de l'énergie atomique

P.O. Box 1046
Ottawa, Canada
K1P 5S9

C.P. 1046
Ottawa, Canada
K1P 5S9

PRESENTATION

INFO-0062

ENVIRONMENTAL IMPACT OF URANIUM MINING AND MILLING - A CANADIAN EXPERIENCE

by

A.B. Dory

Atomic Energy Control Board
Ottawa, Canada

Presented to the American
Institute of Chemical Engineers
Detroit, Michigan

August 1981

ENVIRONMENTAL IMPACT OF URANIUM MINING AND MILLING - A CANADIAN EXPERIENCE

Aladar B. Dory, P.Eng.
Atomic Energy Control Board

It is difficult to provide an assessment of a topic as complex as Environmental impacts of uranium mining and milling. The following is therefore only a very sketchy outline of the basic regulatory approaches for their minimization used in Canada.

(1) REGULATORY REQUIREMENTS AND PHILOSOPHY

In the 1950's, when uranium mining and milling first began in Canada on a large scale, tailings storage was handled in the same manner as tailings resulting from all other mining and milling operations. Retention structures (dams) were often built from the coarse fraction of cycloned tailings. Engineering of these dams was minimal and addressed rather short-term stability. Quality control of the actual construction was minimal. Failures of these dams have occurred, resulting in releases of tailings into the environment. Sometimes the waste or tailings material used for the construction of tailings dams had strong acid-generating potential. This, in turn, resulted in acidic seepages with a detrimental effect on the downstream aquatic environment.

As a consequence, the often debated "destruction" of the Serpent River system as a result of uranium mining in Elliot Lake, Ontario, resulted not so much from contamination by radionuclides (e.g. radium-226) as is frequently claimed, but from acidic seepages from the tailings and tailing dams in the watershed area.

As a result of public perception of the level of hazards associated with all aspects of the nuclear industry, the uranium mill tailings are now controlled much more rigorously than other tailings, even though the environmental hazards of uranium mill tailings are generally of the same order of magnitude as those associated with other tailings.

The effects of past tailings management practices unfortunately resulted in loss of credibility for the industry and the regulatory process in the public eye. The restoration of this credibility is one of the most important long-term goals of the industry and regulatory agencies.

The Atomic Energy Control Board (AECB) currently requires that tailings management facilities be sited, designed, constructed and operated in a manner resulting in the exposures of workers and public to radioactive and other contaminants which are:

1) as low as reasonable achievable, social and economic factors being taken into account, below the regulatory limits for releases and exposures; and

2) below the levels which might be set for a specific facility as a result of site specific conditions.

Adherence to the AECB's requirements for tailings management facilities will result in an operation which meets the above criteria. It provides a good base on which to implement measures upon cessation of operations to meet the required standards for the post-operational phase. It is believed that with the implementation of additional measures presently being investigated, they will meet the criteria of "disposal" in the long term. The term "disposal" means a "walk-away" situation, where the facility is so constructed that the environment is protected from unacceptable releases of contaminants without the need for constant surveillance or corrective human intervention. In reality, the totally "walk-away" situation may not be achieved, and some limitation of land-use may have to be maintained.

The use of new technology coupled with appropriate site selection, quality construction and good operating procedures, can ensure that the impact on health, safety and on the environment will be acceptably low over the period of operation. Further, the methods of retention should be compatible with shut-down procedures - namely chemical and physical stabilization of the tailings and the retention structures, which will ensure that any releases to the environment and radiological exposures of man will continue to be within the requirements.

Some concern exists that man-made retention structures (dams) could be susceptible to failures following an extended period of neglect. To minimize the occurrence of these failures, present requirements aim to make the tailings management facilities less reliant on care and surveillance. The dams are required to be "impermeable" to minimize seepage. The impermeability should preferably be achieved by using natural rather than synthetic materials.

In the long term, natural erosion forces, whether resulting in a gradual or sudden transfer of materials, will almost certainly lead to eventual integration of the wastes with the environment. The resulting impact is impossible to predict with certainty but one should not jump to the conclusion that the impact will be catastrophic or even of substantial concern. Innovative methods of tailings placement with good dam design and shut-down procedures can alleviate the concerns of a catastrophic dam failure. In the absence of a catastrophic, natural event, such as glaciation, the integration of the wastes with the environment is likely to be gradual. In the event of such a natural event, the consequences of the wastes are likely to be secondary to that of the event itself.

The radium in the tailings currently emplaced will remain for many thousands of years. Hence, the ensuing radon gas emissions are likely to render closed-out sites unacceptable for the construction of dwellings and for subsequent habitation. Thus in the long term, in the absence of adequate controls to limit public access and use, people could be subjected to unexpected radiation exposure. Removal of radium and other contaminants from the mill tailings is being considered and investigated as a possible solution to the long-term problems posed by uranium tailings. Whether the tailings could be stripped of radium to the extent that long-term restrictions on land could be avoided is as yet uncertain. The possibility does exist that land-use restrictions will be necessary and will be enforced throughout that period in which institutional controls permit.

The AECB considers the health and safety of workers and members of the public to be of primary concern in the assessment of any proposed mining practice. Of great importance also is the influence these mining practices may have on waste streams, subsequent waste management and, consequently, the environment.

Some of the main activities of the AECB staff at the present concentrate on the following tasks:

a) development of specific radiological health and safety and related regulations for uranium mine-mill and tailings management facilities;

b) development of limits for radioactive contaminants. The establishment of release limits for total Radium-226 is currently underway;

c) development of guidelines for standardization of measuring techniques for various radionuclides in the atmosphere and in liquid effluents;

d) updating of the Board's requirements as formulated in the licensing guides, to keep these in line with new developments;

e) continued encouragement of the industry to lead and participate in research and development programs intended to further optimize present operating practices and to resolve the long-term concerns associated with tailings management;

f) further development of requirements for measures leading to gradual transformation of mill-tailings management to "disposal".

Close-out criteria for uranium mill tailings have been drafted[1], and they are being discussed with the appropriate federal and provincial regulatory agencies, industry and the public;

g) increased participation in public hearings on proposed nuclear facilities.

One important basic philosophical difference in the Canadian approach to the regulation of the nuclear industry, in contrast to other jurisdictions is the AECB's strong commitment to encouraging maximum self-regulation of the industry. The application of this principle results in increased responsibility and accountability of industry management.

(2) ENVIRONMENTAL IMPACT OF URANIUM MINING AND MILLING

To illustrate the extent of the environmental impact of uranium mining, milling and waste management, we have concentrated on the mines in Elliot Lake area of Ontario. This choice was influenced by the international publicity given to this mining area mainly when the negative aspects of uranium mining are illustrated. Mining in this area started in the early 1950's when the regulatory requirements did not yet treat uranium mining in a different way from other types of mining. As a result, the facilities have been developed in a manner which was far short of present regulatory requirements. The environmental impact was particularly worsened by a significant content of sulphides in the ore, resulting in highly acidic effluents from the tailings.

For the purpose of the impact assessment, the radionuclides of main concern are Radium-226 (^{226}Ra) in aquatic releases, and Radon-222 (^{222}Rn), the decay product of ^{226}Ra in the Uranium decay chain for airborne releases. Radon in turn decays through Polonium 218 (^{218}Po-Radium A), Lead 214 (^{214}Pb-Radium B), Bismuth 214 (^{214}Bi-Radium C) and Polonium 214 (^{214}Po-Radium C^1) to Lead 210 (^{210}Pb-Radium D).

(a) Impact on Ground and Surface Water System

The impact of the mines on the ground water is believed to be minimal and very localized. This is an observation which cannot be generalized. The Elliot Lake mines are all underground, relatively deep mines and the geology of the area is such that one cannot really speak of a regional ground water system. However, mines in other areas, with different geological conditions might have a more pronounced impact on ground water. It is even more so when the impact of larger open pit mines is examined. For example, the planned open pit mine at Key Lake in Saskatchewan will require an intentional lowering of the ground water table which would significantly lower the ground water elevation to the distance of several kilometers from the mine. This impact therefore might be in some cases, quite significant, but it is temporary and when mining ceases the ground water table will soon return to its original level.

The impact of the tailings management facilities on the ground water elevation will depend on the design of the retention structures. Limited information exists as to the quality and quantity of seepages from the still operating or dormant tailings facility. It is obvious that during operations, the quality and quantity of seepage is influenced by the permeability of the tailings basin and the design of the system.

Research and modelling work undertaken during Ontario's Environmental Assessment Board hearings on the expansion of uranium mining in Elliot Lake[2] has indicated that with minimal close-out measures the seepage from Elliot Lake tailings will carry about 1.5 - 1.85 Becquerel* per litre (Bq/L) of ^{226}Ra. The quantity of this seepage will depend on the effectiveness of measures to facilitate a speedy run-off of precipitation from the tailings without ponding causing significant percolation through the tailings.

This concentration of ^{226}Ra in the seepage should not have a significant impact on the ground water quality provided proper close-out measures minimize the quantity of the seepage. However, the chemical composition of the ore-tailings might result in more significant impacts (acid, heavy metals and other chemicals).

---

* 1 Becquerel (Bq) - 1 distintegration per second

Observations at one dormant tailings area failed to indicated any movement of the ^{226}Ra plume in the local ground water system since the early 1960's. At this facility the tailings have been left in a natural lake with no close-out measures implemented when the operations ceased.

More information is available on the amount of ^{226}Ra released in the effluents to the surface water system. Annual reports published[3] indicate the amount of ^{226}Ra released from Ontario uranium mines into the Great Lakes watershed. The releases from the facilities of the Elliot Lake area are the most significant. The latest available data indicate that there were about 4×10^{10} Bq of total ^{226}Ra (about 2.7×10^{10} Bq as dissolved) * released in 1979 from the Elliot Lake area facilities into the Serpent River. Since there is no control in place after the effluent leaves the individual facility, we should make the conservative assumption that eventually the whole amount of ^{226}Ra released would likely become dissolved and available for entering the food chain. Furthermore, the sulphuric acid originally generated from the sulphides in the tailings and entering the Serpent River system resulted in the whole system becoming uninhabitable for fish. Chemical treatment of the effluents over a period of several years has resulted in the gradual decrease of ^{226}Ra and increase of pH and the gradual return of fish. The present concentration of ^{226}Ra in the Serpent River at the inflow to Lake Huron varies between 0.04 - 0.33 Bq/L. The average concentration of ^{226}Ra in the fish observed is 0.26×10^{-2} Bq/g. The Canadian recommended limits for ^{226}Ra in drinking water are 1 Bq/L for a maximum acceptable concentration and 0.1 Bq/L as a target concentration[4].

In light of the national guidelines and of the recommendations of the International Commission for Radiological Protection (ICRP) dealing with ^{226}Ra levels in drinking water, the impact of releases from uranium mine-mill and tailings management facilities is not alarming. On the other hand, since there is no scientifically proven threshold to the health effects of radiation, concerted efforts are continuing to reduce these releases to levels as low as reasonably achievable, economic and social factors being taken into consideration (the ALARA principle).

---

* Dissolved ^{226}Ra in this case is defined as ^{226}Ra passing through a 1.2 micron filter.

(b) Impact on Air Quality

The impact of uranium mine-mill facilities on air quality results from mine exhausts, open pits, mill ventilation exhausts and emissions from the tailings masses. For the purpose of this presentation, we will deal only with ^{222}Rn and its daughters as the releases of non-radioactive contaminants either from the mine-mill exhaust or the tailings are not unique to uranium mining.

Contamination resulting from long-lived radionuclides in the airborne dust has not yet been studied extensively in Canada; therefore, it cannot be assessed thoroughly at this time. Results of limited surveys in the Elliot Lake area, however, analysed for Gross alpha, Gross beta, ^{226}Ra and uranium indicated that the majority of samples were in most cases below the detection limits for the above parameters and in most cases, the maximum values were only slightly above the detection limit. Measurements of total suspended particulate matter at one townsite in the Elliot Lake area in close proximity to dormant tailings for the years 1977 to 1980* were as follows:

Annual Geometric Mean (ug/m^3)				Maximum Reading (ug/M^3)				Air Quality Criteria (Ontario - ug/m^3)	
1977	1978	1979	1980*	1977	1978	1979	1980*	24 hrs.	Annual Geom. Mean
16	15	20	23	67	108	64	82	60	120

* 1980 data to September only

There is one main feature common to all Canadian tailings facilities which makes them different from those in the United States. The Canadian tailings are saturated with water. This is obviously the main reason that the problems of radon-radon daughter emissions from the tailings are far less serious in Canada than they are in the U.S. Water saturated tailings dramatically slow down the radon percolation rate and experience indicates that only radon generated in the top 10-20 centimeters of the deposited tailings reach the surface.

Extensive measurements of radon daughter concentrations have been taken in and around Elliot Lake in 1979 and 1980. The following is the summary of the results:

	Location (see figure 1)	Radon Daughter Concentrations in Working Levels (WL)*		
		Average	Minimum	Maximum
1)	About 60 metres between two exhaust shafts	0.0660	0.0010	0.4740
2)	300 metres from exhaust shaft	0.0080	0.0000	0.1110
3)	400 metres from exhaust shaft	0.0012	0.0010	0.0020
4)	1500 metres from exhaust shafts	0.0010	0.0000	0.0030
5)	100 metres from an operating tailings facility	0.0028	0.0000	0.0038
6)	A townsite 600 metres from dorman tailing facility	0.0024	0.0008	0.0059
7)	A townsite between exhaust shafts, mill exhaust and tailings, minimum distance 1000 metres	0.0071	0.0006	0.0150
8)	Elliot Lake Municipal Building - no evident source of radon daughters within 2000 m.	0.0008	0.0003	0.0012
For Comparison:				
	City of New, York, U.S.A.	0.0007 [5]	-	-

The above indicate that the impact, although quite significant in close proximity to the source, quickly diminishes within a few hundred metres. There is little flexibility in measures to reduce exhaust from the mine or mill as the protection of health of the workers demands speedy removal of radon daughters from the working places. However, measures could be implemented to reduce radon and radon daughter emissions from tailings. It is reasonable to assume that these measures would also reduce gamma radiation fields over and in the vicinity of the tailings, which at the present, with no covering of the tailings, are about three times the natural background in the area.

(c) Perceived Impact

Mistakes committed in the past and the traditional reluctance of mining companies to talk openly to the public have resulted in the loss of credibility of the uranium mining industry and indeed the whole of the

---

* Working Level (WL) - unit of radon daughter concentration
$1 \text{ WL} = 2.08 \times 10^{-5} \text{ Jm}^{-3}$

nuclear industry. The general population is subjected to well publicized views of the critics of the nuclear industry which capitalize on the mistakes of the past, without the benefit of facts from the other side of the issue. This naturally results in a biased picture of the industry. As a consequence of the nuclear industry's development from the tool of mass destruction, the health hazards associated with radiation are generally overstated. Society is generally willing to accept considerable risks (voluntary or involuntary) associated with every day life, but is not willing to accept readily radiation risks associated with the nuclear industry even though they are by one or two orders of magnitude lower. A long and difficult process of complete openness of the industry and regulatory agencies in giving the public total and true information is therefore necessary to regain public confidence and acceptance of uranium mining and of the entire nuclear industry.

3. CONCLUSION

The mandate of the AECB is to ensure that any nuclear facility, which is to be developed, meets the regulatory requirements. With regard to the development of new facilities, the AECB is now involved from the early planning stages through the development of the mine-mill facility. As a result of this involvement, new facilities (including tailings management) are designed and developed to a much higher standard than previously.

New criteria regarding site, construction and retention structure quality and technical specifications have been developed. Present technology and practices are sufficiently advanced to ensure the safe operations of uranium tailings management facilities - in the present, and with minimal effort, as far into the future as institutional controls may be reasonably assured. There are still unanswered concerns for the longer term and these concerns are being addressed by the industry and government. Our confidence that these concerns can and will be resolved within the foreseeable future is the main justification for allowing new tailings facilities to be developed.

REFERENCES

1. Atomic Energy Control Board Consultative Document C-1, Proposed Regulatory Guide, "Long Term Aspects of Uranium Tailings Management", Issued for Comment January 8, 1981.

2. The Expansion of the Uranium Mines in the Elliot Lake Area, Ontario, Environmental Assessment Board Hearings, 1976-1979.

3. Great Lakes Water Quality Board Report to the International Joint Commission, Appendix D, 1975, 1976, 1978, 1979.

4. "Guidelines for Canadian Drinking Water Quality 1978", Canadian Government Publishing Centre, 1979, Catalogue No. H48-10/1978.

5. Based on measuresments in 1973-1974 - Sources and Effects of Ionizing Radiation, United Nations Scientific Committee on the Effects of Atomic Radiation, 1977 Report to the General Assembly, with Annexes, (UNSCEAR 1977), United Nations, New York, 1977.

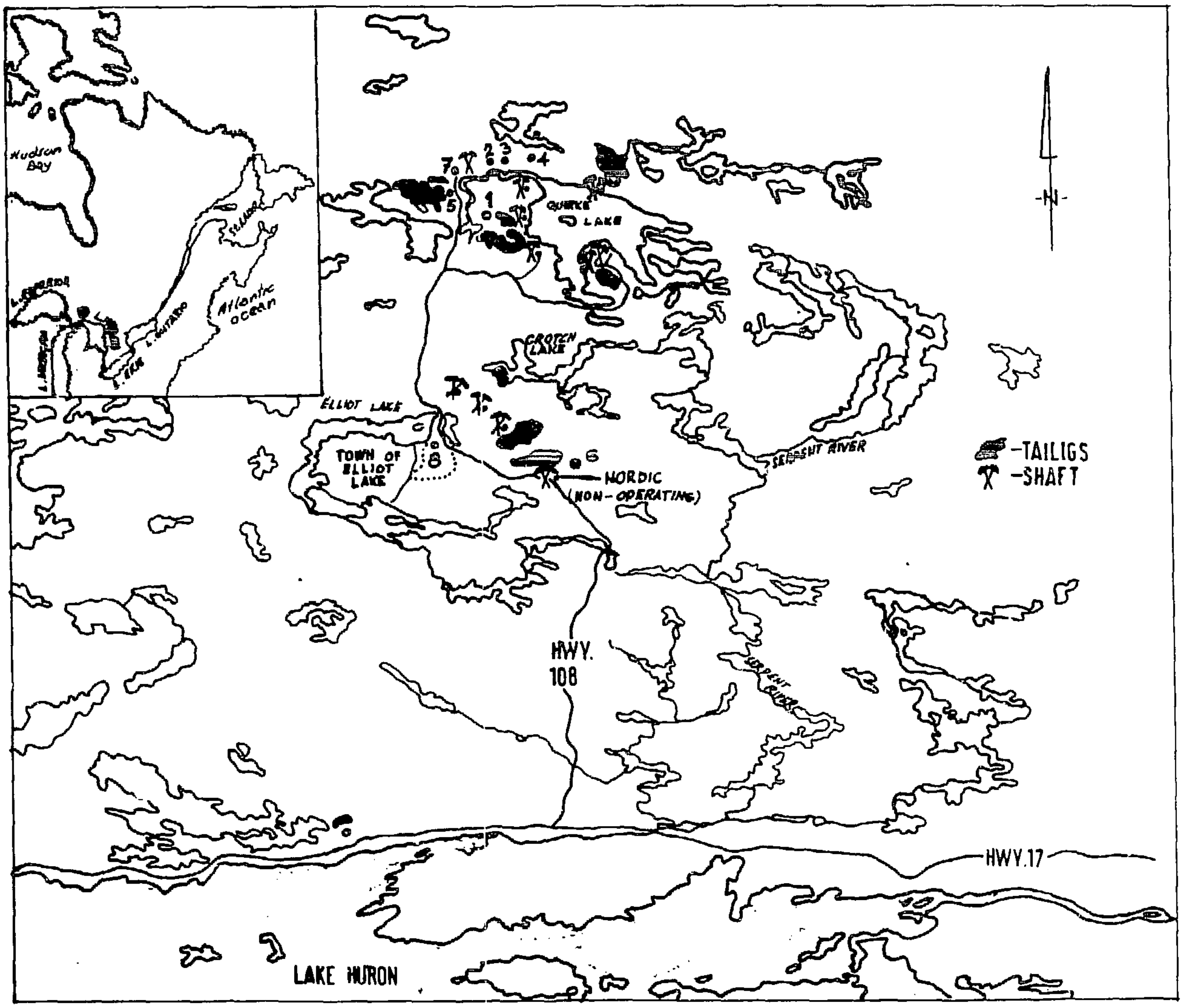

FIGURE 1 - ELLIOT LAKE AREA