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ASSESSMENT OF ENVIRONMENTAL IMPACT OF PORT HOPE HARBOUR'S RADIOACTIVELY CONTAMINATED SEDIMENTS

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INTRODUCTION

In 1976 the Federal/Provincial Task Force on Radioactivity was established to respond to the need for action by government to assess the extent of radioactive contamination of the Town of Port Hope, devise a plan for removing the contaminated material and ensure that the plan was implemented. The Atomic Energy Control Board (AECB) carried out an intensive radiological survey of buildings, both public and private, to determine ^{222}Rn levels. Where the levels were found high enough to create a human health hazard, the AECB directed the removal of ^{226}Ra contaminated soil to a disposal site at the Chalk River Nuclear Laboratories of Atomic Energy of Canada Ltd.

It was known at this time that the sediments of the Turning Basin of Port Hope Harbour were contaminated with ^{226}Ra from earlier operations to extract this radionuclide from uranium ore at Eldorado Nuclear Limited's site but the extent of this contamination was not well defined. The Task Force requested Environment Canada to organize a wider survey of the harbour in cooperation with Ontario Ministry of the Environment (MOE) and report back with an assessment of the situation in order to complete the picture of environmental contamination in Port Hope.

This survey was carried out by MOE in 1978 and the results are presented, along with earlier surveys of sediment and water in the harbour, in a report by the Ontario Regional Office of Environmental Protection Service, Environment Canada (1). The present report attempts to assess the environmental impact of the contaminated sediments based on the data

presented in (1), pointing out where more data is required before a decision can be made on what remedial measures should be selected to completely alleviate any impact.

Sediment ^{226}Ra Concentrations

In 1932 Eldorado Gold Mines Ltd. began the very chemically complicated task of extracting pure ^{226}Ra from high grade pitchblende ore concentrates shipped to their plant at Port Hope from the Port Radium mine on Great Bear Lake. The tremendous value of this radionuclide both monetarily and in the practice of what would become known as nuclear medicine was the incentive for the company to start up this operation during a period of economic depression. The process produced more waste than the original concentrate, about 10 tonnes per gram of ^{226}Ra, containing uranium, arsenic and ^{226}Ra residues. This was stored onsite around the harbour until 1942 when the federal government directed the company to extract uranium also from the Port Radium ore. Wastes were moved offsite to Monkey Mountain, Wellcome and Port Granby after expropriation of the company in 1944 by the federal government.

It was most likely during this early period of onsite waste storage that the harbour became contaminated. The results of the 1978 survey of the sediments by MOE and Ontario Ministry of Labour (MOL) show that the whole of the Turning Basin contains ^{226}Ra in the bottom sediments with the highest concentration at the west side (1).

The first detailed survey of the bottom sediments of the Turning Basin was carried out by MOE and MOL in 1968. Nine sediment cores, each 20" in depth, were taken in the western part of the Turning Basin, sectioned and analyzed for ^{226}Ra. The results from all cores show that extremely high concentrations of ^{226}Ra occur in the sediments and extend to the water/sediment interface. In one core, the concentrations increased from 5,000 pCi per gram at the surface to 15,000 pCi per gram of dried sediment between 15" and 20" below the surface. This latter value is 30 times higher than the average concentration in uranium mine tailings.

A second survey was carried out by MOE and MOL in 1971 when more and deeper cores were taken. Each core was measured at 1" intervals for γ-radiation from the ^{226}Ra and profiles of ^{226}Ra relative concentrations were constructed. These profiles again show the highest concentrations in the centre of the western half of the Turning Basin with the deepest penetration being 33". The maxima however are at 12" and 23". Obviously the radium-containing sediment does not consist entirely of waste deposited in the harbour but consists of fine-grained material constantly being supplied to the harbour from storm drains and from the Ganaraska River which has mixed with the radioactive waste since the middle 1930's.

It is possible to estimate a mean sediment accumulation rate from the bottom profiles of Port Hope Harbour provided by Public Works Canada for 1911 and 1977. From these profiles it can be seen that the western half of the Turning Basin has accumulated about five feet of sediment in 66 years for a mean accumulation rate of about 0.9" per year. As the deepest penetration of ^{226}Ra in the sediment was about 33" in 1971 it would

correspond to the year 1934, close to the start of ^{226}Ra production at the site. The maxima at 12" and 23" in the station 3 profile (Appendix E in reference 1) are probably due to resuspension of the bottom sediment by violent storms followed by slower settling of the finer muds which would contain the highest concentrations of ^{226}Ra.

An estimate of the total quantity of ^{226}Ra in the sediments can be made by assuming that an area on the west side of the Turning Basin, extending for about one quarter of its total area, is contaminated to a depth of 24" at a concentration of 5,000 pCi per dry gram. Further assuming a dry solids content of 0.1 gram per cm^3, which is about average for lake sediments, the total ^{226}Ra loading would be 2 Ci.

Radionuclide Pathways

In attempting to assess the impact of this radioactive source on the local ecosystem, one soon finds that, except for the extent of the sediment contamination, the data base for other environmental compartments is sparse. The immediate interface is between a sediment particle and the sediment pore water, across which the ^{226}Ra and daughter products have to diffuse. Although no direct measurements have been made on the pore water, MOE has reported results of ^{226}Ra analyses of benthic organisms which live in the sediments and take up nutrients from the pore water (2). Turbificid worms showed concentrations of ^{226}Ra up to 460 pCi per dry gram while chironomids (midge larvae) contained up to 110 pCi per dry gram. Results of analyses of the worms might be high due to the presence of sediment in

the gut but the chironomid analyses should not be subject to this interference. It is clear that ^{226}Ra is diffusing to the pore water where it is bioaccumulated in chironomids but insufficient data is available to determine its concentration or that of ^{210}Pb, a 22 year half-life daughter of ^{226}Ra.

The sediment pore water also disperses to the water overlaying the sediments which is the major transport medium in aquatic ecosystems. ^{226}Ra entering the water of the Turning Basin would be transported to the harbour mouth and Lake Ontario where it could reach the intake of the Port Hope drinking water treatment system or be taken up by fish swimming through the area. It would appear that this pathway does not constitute a major route for the transfer of ^{226}Ra from the undisturbed sediment. Monitoring of the water in the Turning Basin, in the channel to it, in the harbour mouth and in the lake outside since 1967 has shown a range of average annual values from 1 to 12 pCi/l (Tables B to J in Reference 1). However,within the harbour the majority of values lie between 1 and 3 pCi/l while out in Lake Ontario they are generally less than 1 pCi/l. Ontario's guideline for surface water is 3 pCi/l ^{226}Ra whereas the 1978 US/Canada Great Lakes Water Quality Agreement objective of an annual dose commitment of 1 mrem converts to 1.3 pCi/l ^{226}Ra. This latter objective should be met in Lake Ontario at the harbour mouth. As the aqueous waste discharge from ENL shows a range in values of 2 to 5 pCi/l (Table A, Reference 1) similar to the harbour values, it is impossible to determine whether any significant transport of ^{226}Ra does in fact occur from the sediments to the harbour water.

Uptake of ^{226}Ra from water by freshwater fish through the gill structure is a less important mechanism than uptake through the food chain. Fish spending long periods of time in the Turning Basin could bioaccumulate ^{226}Ra by feeding on chironomids which were contaminated by ^{226}Ra. Rainbow trout spawn in the Ganaraska River and could conceivably feed in the Turning Basin. Analyses of rainbow trout for ^{226}Ra from the 1976 run showed a wide range of values with the highest being 71.5 pCi/kg fresh fish (3). Yellow Perch and White Sucker taken from the same location in 1981 had a similar range of values, with the maximum being 140 pCi/kg (4). These values are low compared to the range of about 500 to 1000 pCi/kg fresh fish measured in fish caught in a contaminated river below a uranium mill in Colorado (5) and probably represent background concentrations.

Another pathway to the human food chain would be via waterfowl feeding on minnows, plankton, weeds and benthic organisms. There are no data available on concentrations of ^{226}Ra in ducks or geese which might feed in the Turning Basin. However, it is not likely that they would be elevated since levels in plankton are only slightly higher than background (2) and the general high level of pollution in the Basin is not conducive to biological productivity.

No information is available on the loss of ^{222}Rn, the 3.8 day half-life gaseous decay product of ^{226}Ra, from the sediment which theoretically could diffuse rapidly through the water column to the atmosphere, creating a hazard for people in the vicinity. In practice, ^{222}Rn remains in place in consolidated lake sediments as does the further decay product, ^{210}Pb (6).

Although γ-ray emissions from the sediments are normally shielded by the water, there remains the possibility individuals could contact contaminated sediments directly and the boating public are presumably most at risk in this regard. Anchors pulled up from the bottom could carry sediment with them into boats, where it would dry out and become a hazard. It is also possible that visiting sailors unaware of the hazard might dive in the Turning Basin to inspect a damaged hull and become contaminated.

Assessment of Environmental Impact

The condition of the Turning Basin in Port Hope Harbour is akin to that of a uranium mill settling pond where ^{226}Ra leached from mill tailings is precipitated by addition of $BaCl_2$ and lime. While the concentration of ^{226}Ra in the water flowing out of a mill settling pond is about 10 pCi/l, that in the Turning Basin is indistinguishable from the current effluent from ENL's operations of about 4 pCi/l. The age of the ^{226}Ra contaminated sediments is probably 40 years and, although redistribution of the sediments has occurred during the period, the ^{226}Ra appears to be strongly absorbed. Monitoring of ^{226}Ra levels throughout the harbour and Lake Ontario since 1967 has shown no trend to levels above Ontario's water quality guidelines. Although benthic organisms show high levels of ^{226}Ra, there is no evidence that fish at the next trophic level show enhanced concentrations of ^{226}Ra. It would appear that the ^{226}Ra contamination in Port Hope Harbour sediments is having very little effect on the aquatic ecosystem and is not impacting on the human food chain.

A potential risk to human health exists from direct contact with the sediments. At present, the critical group is the membership of the Port Hope Yacht Club who are the major users of the Turning Basin. Dredging of the Turning Basin and impounding of the dredge spoil onshore would expose a wider group to risk. Leaching of ^{226}Ra from impounded sediments could contaminate water supplies and air-borne dried sediment would create a risk from inhalation. Fisheries and Oceans Canada which has jurisdiction over the operation of the harbour through its Small Craft Harbours Branch, Ontario Region, has analyzed sediment samples from the harbour for contaminants other than radionuclides. On the basis of high Pb, As and PCB levels they have recommended containment of dredge spoils but feel an indepth study is warranted before a final decision is taken (7).

Future Planning Options

Since the health hazard to the community is minimal at the present time, no major remedial measures appear to be necessary in the short term but there is a need for investigative research and development to aid in deciding the future disposition of the sediments. To ensure that there is no trend to higher concentrations of ^{226}Ra in the waters of the harbour, the present monitoring program needs to be continued with an increase in the sampling rate and better sensitivity in the ^{226}Ra analysis. Also, to minimize the risk to human health, consideration should be given to isolating the Turning Basin by stopping public access by road and water. This would involve relocation of the Port Hope Yacht Club's docking facilities.

Future options for whichever government agency, federal or provincial, takes reponsibility for permanent disposal of the sediments involve either removal to an acceptable disposal site or filling in the Turning Basin with material impervious to water. The first of these options awaits federal/provincial agreement on an acceptable disposal process followed by selection of an approved site. The technical difficulties inherent in safely transporting very large quantities of hazardous material and public opposition to locating waste disposal sites near communities almost certainly places the possible use of this option into the twenty-first century. The suitability of the filling-in option cannot be evaluated right now because of lack of information on the hydrogeology of the harbour and its surroundings, insufficient data on levels of all contaminants in the sediments and their leachability by groundwater and no data on ^{222}Rn emanation rates.

In deciding the future of Port Hope Harbour it should also be borne in mind that ENL is planning a new and enlarged UF_6 conversion plant for its Port Hope site while phasing out the UO_2/UO_3 plant. If future action is to be taken to permanently isolate Turning Basin sediments, then ENL and the Atomic Energy Control Board should consider relocation of the proposed UF_6 plant cooling water discharge which currently is planned to replace the present UO_2/UO_3 plant discharge. Since the water quality of this effluent will be far superior to that of the existing UO_2/UO_3 plant, it could be discharged directly to Lake Ontario. If this was done, there would be no concern over the heated effluent interfering with the Ganaraska fishery.

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