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# *INVENTORY OF RADIOACTIVITY IN OTTAWA RIVER-BED SEDIMENTS NEAR THE CHALK RIVER LABORATORIES*

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AECL's Chalk River Laboratories (CRL) are situated on the Ontario side of the Ottawa River about 200 km NW of the City of Ottawa. Since 1947, water for cooling CRL's research reactors has been piped from and returned to the Ottawa River. From 1952 to the present time, cooling water has been discharged through the Process Sewer at a rate of 1.5 to 2 $m^3/s$. The Outfall, which is the discharge from the Process Sewer, is in 18 m of water, 65 m offshore. Flow is directed toward the river surface through three "diffuser vents," creating a turbulent swirl at the surface and maintaining a patch of open water in winter. In addition to cooling water, the Outfall has, over the years, included small additional effluents from a heavy water recovery plant, a decontamination centre and a waste treatment centre. Although the effluent has been monitored and has met applicable regulatory requirements, investigations of the riverbed near the Outfall revealed radioactivity. In 2001, a riverbed reconnaissance and a detailed coring program were initiated for the purpose of determining the inventory of residual radioactivity.

The reconnaissance was performed by towing a gamma probe along the bottom of the river behind a boat moving 1 m/s. Visualization of gamma-activity and electrical conductivity in real time allowed higher density of data collection in areas of greater radiation. Areas having greater-than-background concentrations were identified in water 8- to 30-m deep within a 400-m by 200-m "target-area," located near and downstream of the Outfall. Upstream and lateral edges of the target-area were within a factor of two of background.

The reconnaissance data were used to create a semi-quantitative, contour map of riverbed radioactivity. The map showed, in general, a smooth transition from areas of greater radioactivity to areas of less radioactivity. The map was used to guide the coring program and improved the rationale for interpolation between cores.

Cores of the riverbed were 7-cm in diameter and 15- to 43-cm in length. A total of 70 locations were cored within a 19-km reach of river. Forty-two of these locations were near or within the target-area. The cores were sliced at 1-cm-thick intervals from surface to 15 cm depth and at greater intervals with depth, providing over 1400 samples for measurement of gross beta radioactivity. Specific isotopes were identified using gamma-ray spectrometry.

Considering the river width (850 m), mean depth (~13 m) and flow (maximums < 4700 $m^3$ /s, annual means ~ 800 $m^3$ /s and annual minimums as low as 77 $m^3$ /s), average cross sectional currents along the riverbed in this region would be expected to be small (0.5 to 31 cm /s) and deep-water, bottom currents even smaller. It was not surprising, therefore, that the sediment was a silty clay (e.g. 10% very fine sand, 25% silt and 65% clay) in water more than 8-m deep. Orange-brown, somewhat-flocculent, oxidized material comprised the top 0.5 to 1 cm of each core. Black streaks and the faint odour of $H_2S$ were generally encountered within the underlying grey, silty clay, and these features indicated reducing conditions below 1 to 1.5 cm in the sediment. Subtle variations in grey colour suggested horizontal laminae on a scale of 1 or 2 mm, and this may be evidence of minimal perturbation by benthic fauna and currents.

Target-area sediments were similar to the sediments found elsewhere in the river, with notable exceptions: Within 15 or 20 m of the outfall and in the upper 10 cm of sediment, cores contained small droplets of dark brown oil, occasional white or terra cotta granules and bits of paint and rust-like materials up to 5-mm in length. Within about 5 m of the outfall, the topmost sediment was mainly comprised of medium to coarse sand, and was underlain by fine-grained river mud.

Vertical profiles of radioactivity showed that all man-made radioactivity was in the upper 15 cm of sediment, with as many as four distinct peaks. Maximum values commonly occurred between 2 and 10 cm. Radioactivity in the target area was usually lower in the top centimetre, suggesting less radionuclide deposition in the past decade or so. Upstream cores, and at all core locations below 15 cm depth, sediment radioactivity was 1.0 to 1.3 Bq/g, which was considered background. Downstream of the target-area, the upper 15-cm of riverbed usually contained 1.3 to 2 Bq/g. Near the Outfall, the maximum gross-beta measurement was 480 Bq/g. In order of abundance, the principal nuclides were $^{137}Cs$, $^{60}Co$, and $^{90}Sr$ with smaller amounts of $^{152}Eu$, $^{154}Eu$ and $^{241}Am$.

An inventory of radioactivity in the target-area was based on average values for the upper 15, 1-cm slices of sediment at each core location, which were contoured in plan view. The area of each contour was multiplied by its contour value and then summed, giving an estimated total inventory of $4 \times 10^7$ kBq.

As a measure of potential ecological impact, target-area sediments were collected to a depth of about 10 cm using a Ponar dredge and tested for toxicity and inhibition of growth and reproduction using a macro-invertebrate bioassay. No detrimental effects were observed.

Taken together, the results suggested that the period of NRX reactor operations at CRL, which ran from 1947 to 1992, coincided with the approximate beginning of the riverbed radioactivity. Because lower concentrations of radionuclides were generally found in the upper centimetre of sediment, recently deposited material appeared to reflect cleaner CRL operations in the past decade.