

Characterization and spatial distribution of organic contaminated sediment from historical industrial effluents to inform remediation decisions

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Introduction: A bleached kraft pulp mill in Nova Scotia, Canada, has discharged effluent wastewater into Boat Harbour (BH), a former tidal lagoon within Pictou Landing First Nation (PLFN), since 1967 [1]. Fifty years of effluent discharge to BH has created >170,000 m³ of unconsolidated sediment, impacted by inorganic and organic contaminants (metal[loid]s, polycyclic aromatic hydrocarbons [PAHs], polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans [PCDD/Fs]). This study characterized PCDD/F and PAH impacted sediments to inform decisions for a \$133 million (CAD) sediment remediation program, designed to return this aquatic site to a tidal lagoon for traditional use by the PLFN community [2].

Methods: We reviewed over 200 reports focusing on relevant sediment data from 1992 to 2015 (12 reports). Because studies were often conducted by third parties, sampling methods (grabs, cores, discrete and composite sampling), and sampling depth (shallow vs. deep sampling) varied widely. These challenges were addressed by grouping studies employing similar techniques (e.g., shallow composite grabs were grouped with studies using shallow coring devices) [2]. This study: (i) compared PCDD/F sediment toxic equivalent (TEQ) concentrations and PAH sediment concentrations to sediment quality guidelines (SQGs) [3]; (ii) sorted data according to vertical delineation and method of collection; and (iii) identified potential sources of contaminants and identify gaps in long term monitoring data to help inform future remediation management decisions.

Results: Sediment PCDD/F concentrations exceeded severe effect thresholds over the entire period posing severe ecological health risks and have persisted in Boat Harbour despite implementation of *Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations* in 1992 (Fig. 1). PAH concentrations varied greatly, likely due to inconsistent sampling techniques. Five individual PAH compounds frequently exceeded severe effect thresholds, in contrast to total PAHs, which were below severe effect thresholds. Forensic analysis using PAH diagnostic ratios suggests pyrogenic PAHs (derived

from wood products and coal combustion) were the primary source.

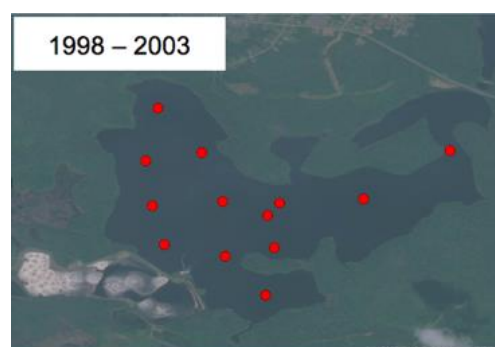


Fig. 1: Spatiotemporal variation of PCDD/F TEQs concentrations for fish compared to CCME freshwater and marine SQGs (green, <0.85 [ISQG]; yellow, 0.85-21.50; red, >21.50 [PEL] pg/g) in Boat Harbour sediment between 1998-2003.

Discussion: Results revealed large data gaps in our understanding of sediment characteristics in Boat Harbour. Gaps include temporal and spatial (vertical and horizontal) variation, creating challenges for accurate delineation of sediment contaminants. Deeper horizons were poorly characterized compared to shallow sediments (0-15 cm). Overall, spatial coverage across Boat Harbour was inadequate. More detailed sampling is required to better characterize these sediments prior to remediation. Because of severe ecological health risks associated with high sediment PCDD/F concentrations, remediation of the entire sediment inventory along with an ecological risk assessment is recommended.

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References: [1] Hoffman et al. (2015) *Environ Monit Assess* **187**:766; [2] Hoffman et al. (2017) *Environ Monit Assess* **189**:257; [3] Walker et al. (2015) *Soil Sediment Contam* **24**:471-493.