Using a Long Term Metal Dataset to Spatio-temporally Characterize Pulp Mill Effluent Impacted Sediments 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 m^3 of unconsolidated sediment, impacted by inorganic and organic contaminants (metal[loid]s, polycyclic aromatic hydrocarbons [PAHs], dioxins and furans). This study aimed to characterize metal(loid) impacted sediments to inform decisions for a $89 million (CAD) sediment remediation program, designed to return this aquatic site to a tidal lagoon for tradition use by the PLFN community [2].

Methods: Spatio-temporal variation of metal(loid) sediment concentrations in BH and reference locations (103 samples from 81 stations) between 1992-2015, were assessed with secondary data (government reports, peer-reviewed and grey literature) using geographic information system (GIS) techniques. Metal(loid) sediment concentrations were compared to Canadian freshwater and marine sediment quality guidelines (SQGs) [3]. BH currently operates as a freshwater treatment lagoon, but will be returned to tidal influences following sediment remediation. CCME interim sediment quality guidelines (ISQGs) are equivalent to lowest effect levels, below which contaminants have little chronic or acute effect on biota, probable effect levels (PELs) are equivalent to severe effect levels, above which biota are highly likely to be negatively affected by contaminants [4].

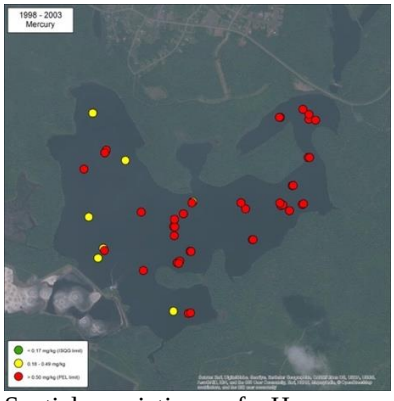

Fig. 1: Spatial variation of Hg concentrations compared to CCME freshwater (green, <0.17 [ISQG]; yellow, 0.18-0.49; red, >0.50 [PEL] mg/kg) SQGs in Boat Harbour sediment between 1998-2003.

Results: Seven metal(loid)s (As, Cd, Cr, Cu, Pb, Hg, Zn) exceeded low effect freshwater (56-88%; n=58-91) and marine (23-91%; n=23-94) SQGs; six (As, Cd, Cr, Pb, Hg, Zn) exceeded severe effect freshwater SQGs (1-63%; n=1-58); and four (Cd, Cu, Hg, Zn) exceeded severe effect marine SQGs (20-54%; n=21-56). Significantly higher Cd, Cu, Pb, Hg and Zn concentrations were measured between 1998 and 2000 (Hg concentrations are shown in Fig. 1), compared to earlier (1992-1996) and more recent (2003-2015) data. Most BH sediment samples (69%) were shallow (0-15 cm), leaving deeper horizons under-characterized. GIS analysis revealed inadequate spatial coverage, presenting challenges for remediation decisions regarding vertical and horizontal delineation of contaminants.

Discussion: Gaps exist in our understanding of sediment metal(loid) characteristics in BH, including spatial (vertical and horizontal), and temporal variation of sediment contamination [5]. Further characterization is required for organic contaminants (PAHs, dioxins and furans). More detailed sampling, is required to better characterize these sediments prior to remediation to enable cost-effective approaches for a decades-old problem.

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References: [1] Hoffman et al. (2015) *Environ Monit Assess* **187**:1-13; [2] Walker et al. (2017) *Ninth Internat Conf Rem Manage Contam Sed, New Orleans, Louisiana;* [3] CCME (2016) *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life;* [4] Walker et al. (2015) *Soil Sediment Contam* **24**:471-493; [5] Hoffman et al. (submitted) *Environ Monit Assess.*