Final Report

Churchill River soil flux core experiments
October 2017

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Project significance and background:

Methylmercury (MeHg) is produced at elevated levels in newly-flooded soils, and prior research has shown that this is related to soil organic carbon content (Calder et al., 2016). New hydroelectric developments and reservoir creation are being proposed in many ecosystems, but little data exists on whether the MeHg flux from flooded soil varies according to flooding duration, carbon content and/or season. This information is essential to assess the environmental and human risks prior to reservoir creation. We have conducted MeHg flux core experiments to address this knowledge gap for a hydroelectric power development under construction near Muskrat Falls on the Churchill River (Labrador, Canada),

In previous flux core experiments (June 2013) using Muskrat Falls pre-flooded soil with leaf litter layer removed, we observed a 14-fold increase in water MeHg concentration after only 5 days of incubation (120 to 170 pmol m^{-2} d^{-1}; Schartup et al., 2015). Additionally, winter flux core experiments (Dec 2016 to Jan 2017) were conducted with pre-flooded soil from three sites, and leaf litter layer or litter layer and top 5 cm were removed from cores from two sites. The MeHg flux was 10 to 20 times lower than in June 2013, and there was little temporal change in water concentration (46 days). As anticipated, MeHg fluxes were consistently low for soils sampled and incubated under cold season conditions. These results suggest that the initial increase in reservoir water levels during the cold season had negligible effects on MeHg production.

Methods:

Oct 2017 flux core experiments conducted at the Labrador Institute in North West River. MeHg flux experiments were conducted at 22^0C during Oct 2017 with Churchill River soil cores (Figures 1 and 2) collected on 16 and 17 Oct 2017 (6 to 7^0C water temperature). Experiments included pre-flooded (soil never exposed to river water), wet bog, burned and flooded soils (Figure 3, Table 1). Soils were flooded for a total of 42 days at a water level greater than or equal to the 21.8 masl (meters above sea level; M. Biasutti-Brown communication with Nalcor). However, the days greater than 21.8 masl were all during Mar and Apr 2017, possibly mostly ice cover, and the reservoir had been raised to this level within a day or two of soil core collection. Flooded cores from both Upper Brook (UB) and Edward's Brook (EB) were manipulated by removing the leaf litter layer (OL) or by removing the litter layer and the top 5cm of soil. Three cores were incubated for each site and manipulation (2 cores for each pre-flooded site). Overlying water was sampled daily for 6 days, was replaced with fresh Churchill River water daily, and water quality measurements (temperature, conductivity, dissolved oxygen, pH) were made daily before water changes.

Figure 1. MeHg flux core experiments using battery powered mixing heads at the Labrador Institute, North West River, October 2017.

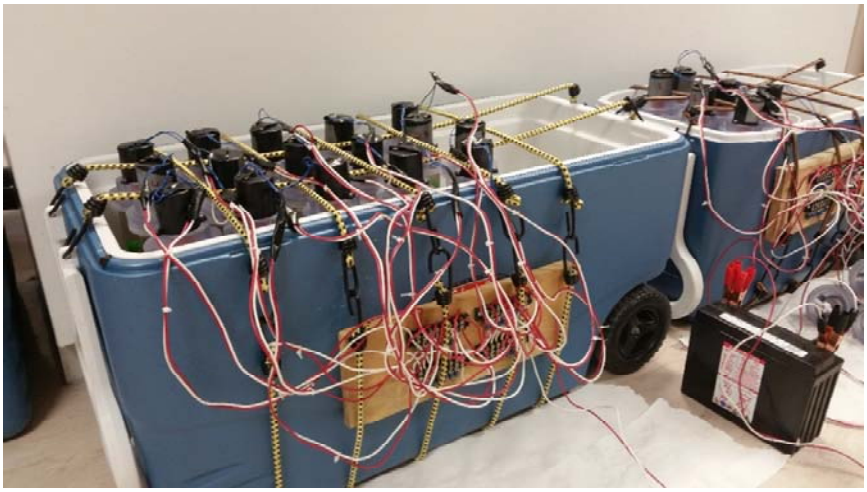

Figure 2. Flux core water changes using peristaltic pumps with silicone tubing, and water sample filtration using 0.45 µm cartridge filters.

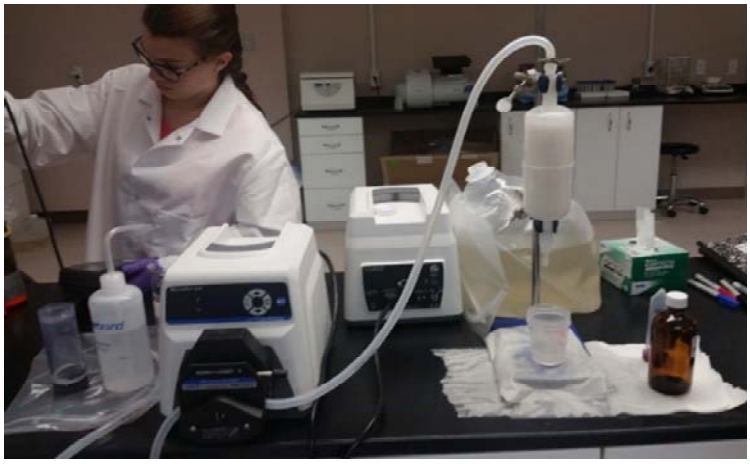

Figure 3. Map of Churchill River soil core sites sampled in Oct 2017 (green labels).

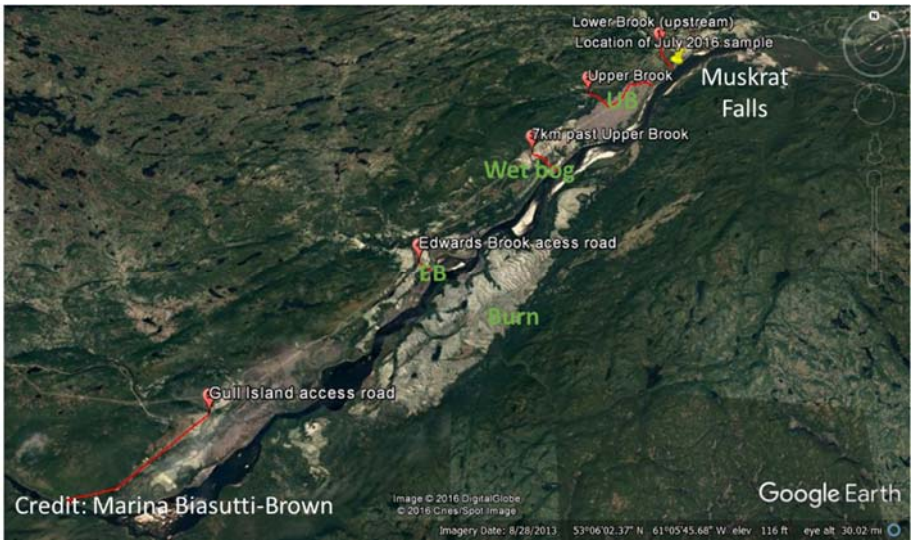

Table 1. Churchill River soil sampling site names and experimental abbreviations (sampled Oct 2017).

Site type	Flux core experiment in NWR (Oct 2017)
Pre-flood	Upper Brook (PF-UB), Edwards Brook (PF-EB)
Flooded	Upper Brook (F-UB), Edwards Brook (F-EB)
Burned	South of river near Edwards Brook
Wetland	Wet bog from 7 Km past UB
Flooded core manipulations	Leaf litter layer removed (F-OL-UB, F-OL-EB) Top 5 cm soil removed (F-5cm-UB, F-5cm-EB)

Results:

1) Flooded soil cores collected in Oct 2017 (6 to 7 ^{0}C water temperatures) had MeHg fluxes three times higher (2 to 70 pmol m^{-2} d^{-1}) than pre-flooded soils (Figure 4, Tables 2 and 3).

2) Pre-flooded soil fluxes (6 to 22 pmol m^{-2} d^{-1}) were similar to Dec 2016/Jan 2017 pre-flooded fluxes, but wet bog fluxes (0 to 2 pmol m^{-2} d^{-1}) were lower than measured previously.

3) Mean MeHg flux ratios (flooded:pre-flooded) were 3.4 and 2.2 for EB and UB sites, respectively. Burned site soil flux was lower than the flux for EB pre-flooded soil (0.4 mean flux ratio), and fluxes at the burned site were low compared to flooded soil.

4) Reduced dissolved oxygen (DO) in overlying water for pre-flooded and flooded cores from UB and EB (Supporting Information) indicate soil oxygen demand and microbial activity for these sites, but not necessarily the activity of methylating bacteria (methylate ionic Hg^{2+} to CH_3Hg^{+}).

5) For flux core soils collected during Dec 2016/Jan 2107, removing the OL and top 5 cm of soil clearly reduced organic matter (loss-on-ignition; proxy for organic matter) and total Hg. However, flooded soils collected in Oct 2017 that were manipulated to reduce organic matter produced MeHg fluxes in the same range (7 to 75 pmol m^{-2} d^{-1}) as flooded soils at EB and UB sites (Figure 5).

6) The average manipulated:flooded flux ratio was 0.8 to 1.1 for OL-removed cores and 1.1 to 1.3 for 5 cm-removed cores.

Figure 4. Churchill River soil flux cores incubated from 18 to 24 Oct 2017 (22 ^{0}C). Average MeHg flux (pmol m^{-2} d^{-1}; ± SD, n=3 cores; 2 cores at pre-flooded sites) through 6 water sampling days. Average flooded and burn site to pre-flooded site ratios are shown in red.

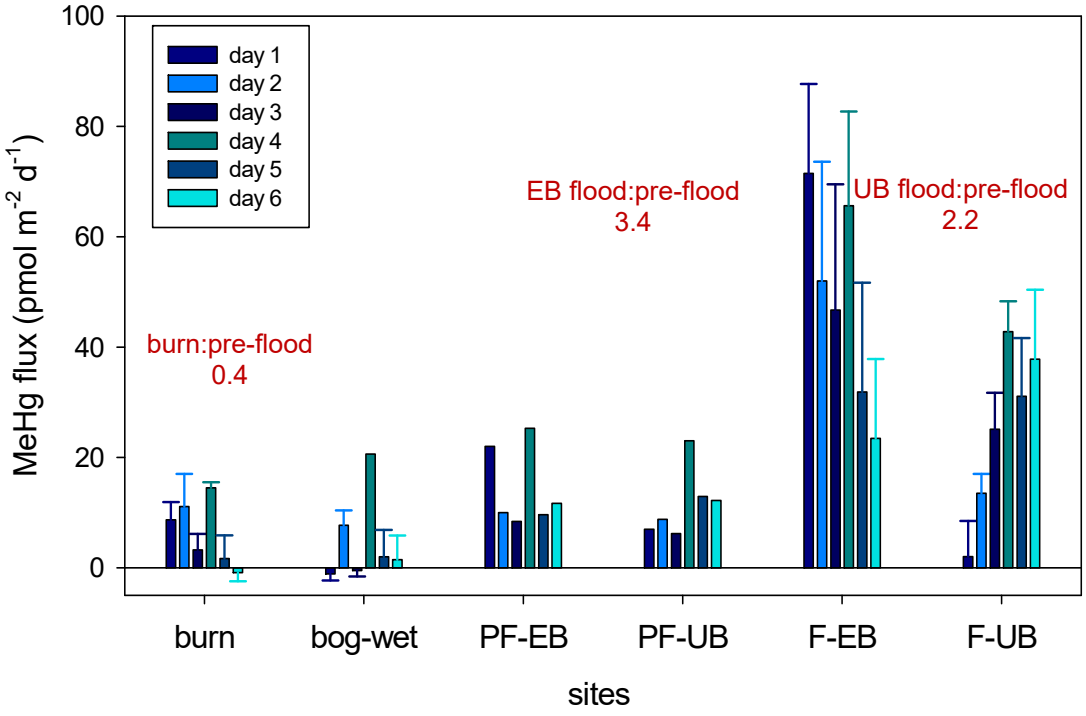

Figure 5. Churchill River soil flux cores incubated from 18 to 24 Oct 2017 (22 ^{0}C). Average MeHg flux (pmol m^{-2} d^{-1}; ± SD, n=3 cores; 2 cores for pre-flooded sites) through 6 water sampling days. Average manipulated to flooded site ratios are shown in red.

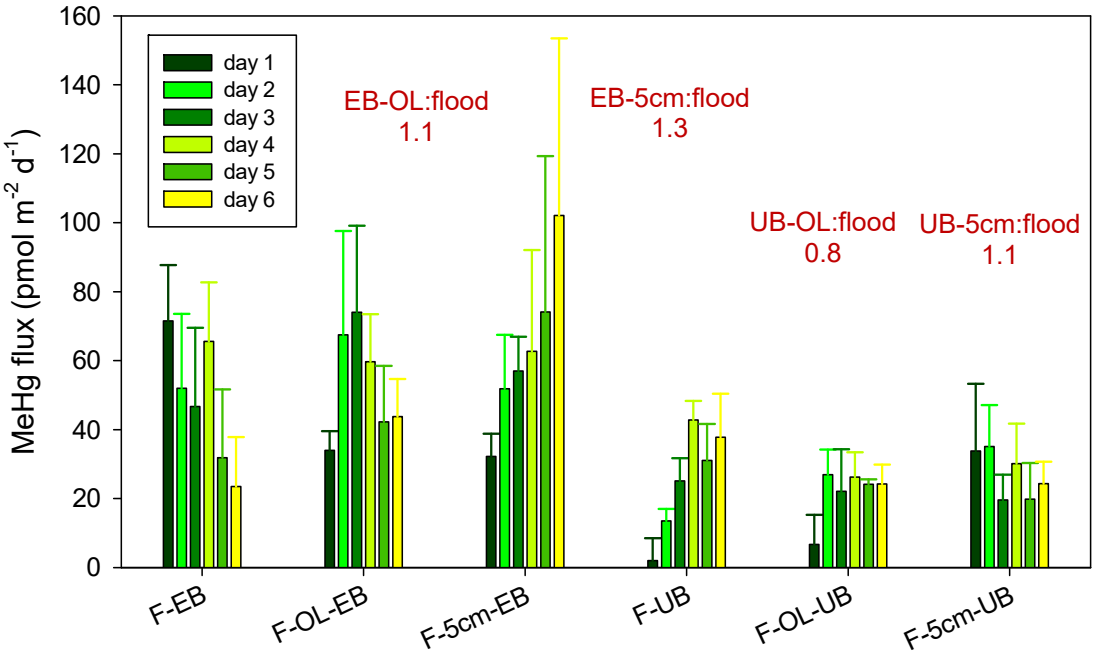

Table 2. Churchill River soil flux cores incubated from 18 to 24 Oct 2017 (22 ^{0}C). Average MeHg flux (pmol m^{-2} d^{-1}; ± SD) for 24 hr incubation periods with 3 cores (2 for pre-flooded sites) for each site and manipulation. Burned and flooded to pre-flooded flux ratios and manipulated to flooded flux ratios in parentheses. (note:[1] overall SD calculated by propagation of errors)

Sampling interval	MeHg flux sites				MeHg flux flooded soil		MeHg flux flooded soil manipulations			
	PF-UB	PF-EB	Burn	Bog-wet	F-UB	F-EB	F-OL-UB	F-OL-EB	F-5cm-UB	F-5cm-EB
Day 1 10/19/17	7.0	22.0	8.7 ± 3.2 (0.4)	-1.1 ± 1.2	2.0 ± 6.5 (0.3)	71.5 ± 16.2 (3.3)	6.7 ± 8.6 (3.4)	34.0 ± 5.5 (0.5)	33.8 ± 19.5 (17.1)	32.2 ± 6.6 (0.4)
Day 2 10/20/17	8.8	10.0	11.1 ± 5.9 (1.1)	7.7 ± 2.7	13.5 ± 3.5 (1.5)	52.0 ± 21.6 (5.2)	26.9 ± 7.3 (2.0)	67.5 ± 30.1 (1.3)	35.1 ± 12.0 (2.6)	51.8 ± 15.7 (1.0)
Day 3 10/21/17	6.2	8.4	3.2 ± 2.9 (0.4)	-0.1 ± 1.1	25.1 ± 6.6 (4.0)	46.7 ± 22.8 (5.6)	22.1 ± 12.2 (0.9)	74.0 ± 25.1 (1.6)	19.6 ± 7.3 (0.8)	57.0 (1.2)
Day 4 10/22/17	23.0	25.3	14.5 ± 1.0 (0.6)	20.56	42.8 ± 5.5 (1.9)	65.6 ± 17.1 (2.6)	26.2 ± 7.2 (0.6)	59.7 ± 13.8 (0.9)	30.1 ± 11.6 (0.7)	62.7 ± 29.4 (1.0)
Day 5 10/23/17	12.9	9.6	1.7 ± 4.2 (0.2)	2.0 ± 4.9	31.1 ± 10.6 (2.4)	31.9 ± 19.8 (3.3)	24.1 ± 0.9 (0.8)	42.6 ± 16.3 (1.3)	19.8 ± 10.5 (0.6)	74.1 ± 45.2 (2.3)
Day 6 10/24/17	12.2	11.7	-0.9 ± 1.6	1.5 ± 4.4	37.8 ± 12.6 (3.1)	23.5 ± 14.4 (2.0)	24.2 ± 5.6 (0.6)	43.8 ± 10.9 (1.9)	24.4 ± 6.3 (0.6)	102 ± 51.4 (4.4)
Overall ave ± SD[1]	11.7	14.5	6.4 ± 8.6	5.1 ± 7.3	25.4 ± 20.0 (2.2)	48.5 ± 46.2 (3.4)	21.7 ± 19.0 (0.8)	53.5 ± 46.3 (1.1)	27.1 ± 29.4 (1.1)	63.3 ± 76.3 (1.3)

Table 3. Churchill River soil flux cores incubated from 18 to 24 Oct 2017 (22 ^{0}C). Average overlying water concentrations (fM; ±SD) for 24 hr incubation periods with 3 cores (2 for pre-flooded sites) for each site and manipulation. Ratios of current day to day 1 concentrations in parentheses. (note:[1] overall SD calculated by propagation of errors)

Sampling interval	MeHg (fM) sites				MeHg (fM) flooded soils		MeHg (fM) flooded soil manipulation				Change water
	PF-UB	PF-EB	Burn	Bog-wet	F-UB	F-EB	F-OL-UB	F-OL-EB	F-5cm-UB	F-5cm-EB	
Day 1 10/19/17	213	343	232± 31	154 ± 5	182 ± 39	558 ± 129	207 ± 53	362 ± 46	404 ± 105	376 ± 20	160
Day 2 10/20/17	171 (0.8)	196 (0.6)	219 ± 52 (1.0)	170 ± 13 (1.1)	221 ± 31 (1.2)	455 ± 129 (0.8)	287 ± 53 (1.4)	507 ± 109 (1.4)	354 ± 60 (0.9)	436 ± 49 (1.2)	121
Day 3 10/21/17	199 (0.9)	220 (0.6)	175 ± 25 (0.8)	156 ± 7 (1.0)	363 ± 62 (2.0)	424 ± 170 (0.7)	349 ± 109 (1.7)	658 ± 104 (1.8)	281 ± 51 (0.7)	518 ± 17 (1.4)	155
Day 4 10/22/17	293 (1.4)	313 (0.9)	230 ± 23 (1.0)	248 ± 26 (1.6)	442 ± 24 (2.4)	580 ± 122 (1.0)	304 ± 51 (1.5)	492 ± 76 (1.4)	317 ± 54 (0.8)	556 ± 128 (1.5)	105
Day 5 10/23/17	242 (1.1)	208 (0.6)	150 ± 33 (0.6)	158 ± 31 (1.0)	376 ± 52 (2.1)	322 ± 127 (0.6)	323 ± 24 (1.6)	439 ± 92 (1.2)	281 ± 63 (0.7)	609 ± 175 (1.6)	147
Day 6 10/24/17	221 (1.0)	240 (0.7)	136 ± 13 (0.6)	156 ± 26 (1.0)	426 ± 68 (2.3)	280 ± 102 (0.5)	316 ± 30 (1.5)	453 ± 71 (1.2)	322 ± 40 (0.8)	816 ± 189 (2.2)	148
Overall ave ± SD[1]	223	254	190 ± 78	174 ± 51	335 ± 120	441 ± 322	298 ± 147	485 ± 210	326 ± 161	552 ± 293	139 ± 22

Conclusions:

1) MeHg fluxes from soil cores collected in Oct 2017 that had been submerged for approximately 42 days were about three times higher than those observed from pre-flooded soil.

2) Churchill soil core pore water experiments conducted at Harvard University in August 2017 indicated that there is measurable MeHg production in pore water with greater flooding time (161 days), and that MeHg production is greater in the summer than in the fall.

3) Removing the leaf litter layer or top 5 cm of soil (organic matter) did not lower MeHg flux from flooded soils in Oct 2017. Harvard pore water experiments (Aug 2017) also showed higher pore water MeHg concentrations below 5cm.

4) MeHg flux core experiments are useful for comparing the effects of different environmental conditions, such as duration of flooding and soil organic carbon content, but the magnitudes of fluxes should not be used to infer impacts on ecosystems.

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