Seasonal Change in Snowpack, Soil Water and Stream Water DOC Concentrations in Glacial and Snowmelt Fed Catchments in the Alberta Rocky Mountains

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EXTENDED ABSTRACT

The present study is a contribution to an investigation of the causes of elevated levels of organochlorine contaminants (OCs) in alpine lakes. Organochlorines in alpine catchments are derived from atmospheric long distance transport, and wet deposition, particularly to the seasonal snowpack. Donald et al.(1993) found that fish from alpine lakes contained elevated levels of organochlorine (OC) contaminants. This is explained in part by the increase in deposition of OCs with increasing elevation (Blais et al., 1998). However, it was also found that fish in glacially fed lakes (e.g. Bow Lake) had higher OC concentrations than fish in snowmelt fed lakes (Donald et al., 1993). This suggests that the elevated OC levels in fish from glacial fed lakes are due either to low retention of OCs on soils in glacial catchments and/or high bioavailability of OCs in glacial runoff, relative to snowmelt runoff from non-glacial catchments. Blais et al. (in press) confirmed that a glacial melt stream was the dominant source of OC inputs to Bow Lake (e.g. 97% of HCH load in 73% of runoff).

The objective of this study is to determine whether differences in flow routing between glacial and non-glacial catchments can cause differential retention of OCs on catchment soils and differences in the bioavailability of OCs delivered to Bow Lake. These questions are investigated by comparing the seasonal variation of Dissolved Organic Carbon (DOC) concentrations in streams, snow, and soil waters in the two principal catchments draining into Bow Lake, the Glacial catchment (GL) and the snowmelt-fed Bow River (BR) catchment (Figure 1). The Glacial catchment is 27 km^2, and 41% glaciated. Only 12% of the catchment area is forested, 85% is unvegetated or sparsely vegetated, and 50% of the area consists of nonsoils and 35% of nonsoils and/or Regosols. There are no glaciers in the 17 km^2 Bow catchment. 49% of this catchment is forested, but 30% is unvegetated or sparsely vegetated. The soils are primarily mineral soils with some organic horizons (i.e. 56% Brunisols, Podsols and Gleysols), but 30% of the catchment consists of nonsoils and/or Regosols.

DOC was measured as non-purgable organic carbon (NPOC) by high temperature combustion using a Shimadzu TOC 5000A equipped with high sensitivity Pt catalyst. Stream and soil water samples were filtered on site with glass fibre filters, acidified to pH 2, stored in amber glass vials, and refrigerated. Snow was collected in clean glass jars and stored frozen, samples were melted, filtered and acidified in the lab.

Interpretation of stream DOC is based upon a conceptual model for snowmelt runoff across 3 distinct types of snow-covered surface: till, rock or mineral soils with no organic matter; organic soils and/or vegetation; and glacier ice overlying sediments). Snowmelt can runoff as overland sheet flow or channelised overland flow, shallow subsurface flow, or deep subsurface flow. In the case of snow overlying bare rock or non-organic sediments, snowmelt will not pick up significant DOC regardless of the flow path, and stream DOC should reflect snowmelt DOC concentrations.

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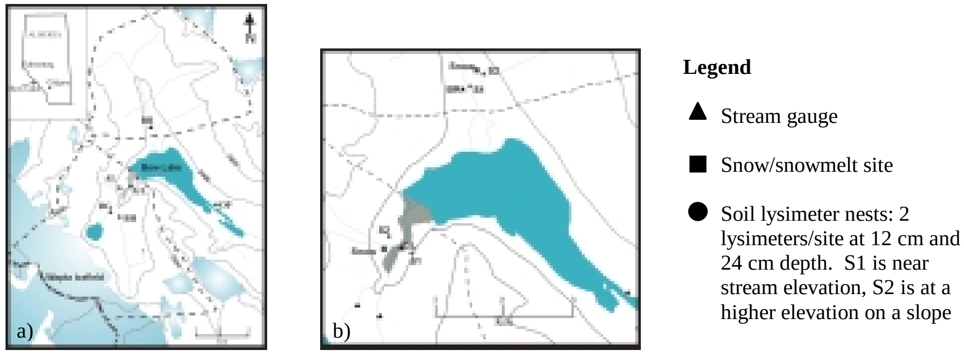

Figure 1. a) Stream gauge sites at Bow Lake. BR: Bow stream, GL: Glacial stream, OF: lake outflow, AL: Alpine stream, BH: Bow Hut stream, BG: Bow Glacier stream. b) Snow and soil lysimeter Site map

Where snow overlies organic soils and/or vegetation, overland flow could leach DOC from surface litter, leading to increases in stream DOC. Subsurface flow through shallow soil horizons would flush DOC-rich soil water to the stream (Boyer et al. 1997). Deep subsurface flow would not alter stream DOC appreciably since DOC from shallow soil horizons will be flushed downwards and then consumed by microbial activity and/or adsorbed onto deeper soil horizons. Snowmelt runoff over glacier ice will be channelised before entering the glacier and may never infiltrate subglacial sediments, so runoff should not acquire DOC along this flow route.

DOC was much higher in the Bow stream (0.4-2.1 ppm) than in the Glacial stream (0.2-0.8 ppm). DOC in the Bow stream showed a clear and consistent seasonal pattern, with DOC in peaking at the very start of the melt, prior to the peak in stream discharge. The Glacial stream showed a smaller seasonal increase in DOC coincident with initial increases in stream discharge, but the shape and timing of the seasonal pattern of DOC in the Glacial stream was less well defined (Figure 2).

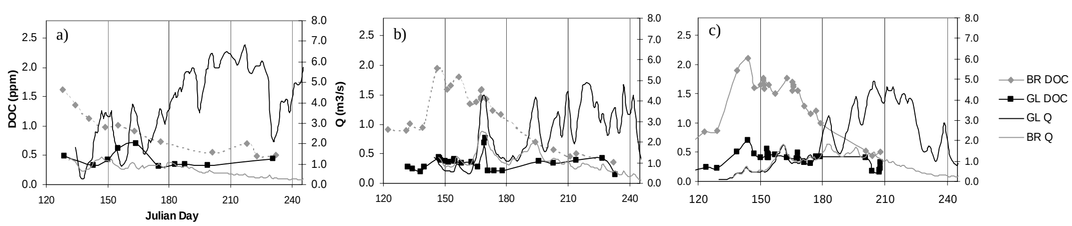

Figure 2. Stream DOC concentrations and discharge (Q) in the Bow and Glacial streams May-August (a) 1998 (b) 1999 (c) 2000

The snow melt (mean 0.57ppm +/-0.42 at the Bow site, and 1.70+/-1.54 for the Glacial site) was enriched in DOC relative to the snowpack (0.28 ppm +/-0.12 and 0.41ppm+/-0.18 for the Bow and Glacial sites, respectively). The enrichment was usually greatest in the first fraction of the melt, but a very high concentration of DOC was also recorded in a melt fraction near the end of the melt season at the Glacial site (Figure 3). The data suggest that snowmelt can contribute to the spring rise in DOC. For the Bow stream, snowmelt is unlikely to be able to account for the whole of the increase in stream DOC but, for the Glacial stream it is difficult to rule out the possibility that it is largely responsible for the increase in stream DOC.

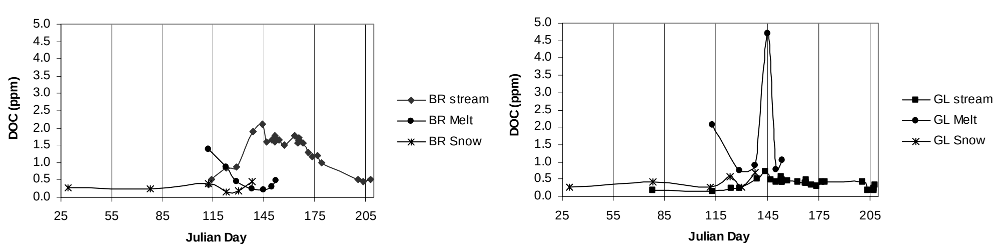

Figure 3. Snow, snow melt and stream DOC in the Bow River (BR) and Glacial (GL) catchments in 2000

To minimise contamination and disturbance of the surrounding snowpack, soil lysimeters were not sampled until the snowpack at each site was very thin (<25 cm). All the soil waters, except for BR-S1 12cm, had similar seasonal trends (Figure 4), with low DOC in June (5-10 ppm), and high DOC in July (20-40 ppm). The high DOC in July suggests that there is a build up of DOC in the late summer and fall (due to microbial activity), and the low DOC concentrations in June suggest that the high DOC water that forms in summer is flushed from soils in the following spring and contributes to the seasonal DOC peak in runoff.

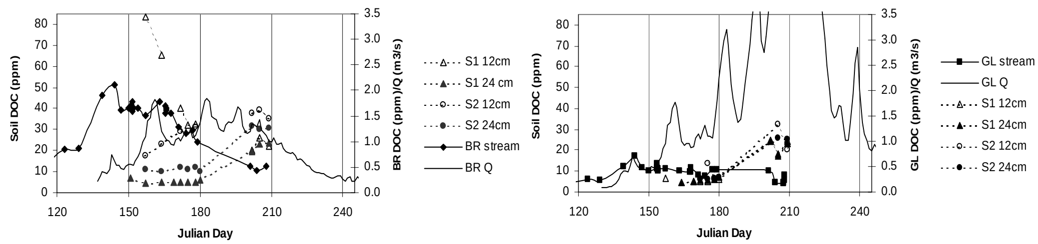

Figure 4. Soil water DOC concentrations in the Bow (BR) and Glacial (GL) catchments. Soil DOC is plotted against the left y-axis, while stream DOC and discharge (Q) are plotted on the right y-axis.

Seasonal trends in stream DOC for the three years and the soil DOC in the Bow catchment suggest that DOC was flushed from soils and snow at the onset of snowmelt and reached the stream mostly via shallow subsurface flow. The prolonged high DOC concentrations in the Bow stream likely reflect the flushing of soils as snowmelt is initiated at progressively higher elevations in the catchment. The routing of snowmelt through shallow soils in the Bow catchment could lead to significant retention of organochlorine contaminants on soil organic matter. This could account for the low concentrations of organochlorines in this stream (Blais et al., in press). The DOC flushed from the soils to the stream also provides a source of organic ligands that could limit the bioavailability of contaminants from this tributary (NB this coincides with early snowmelt when OCs are being released to runoff). Snow and soil lysimeter experiments suggest that similar processes occur in the forested areas of the Glacial and Bow catchments (i.e. flushing of soil DOC). However, the amounts of DOC in the streams and the seasonal patterns are very different. This likely reflects either the lack of DOC sources in the non-forested parts of the catchments or a flow routing effect, whereby most runoff does not come into contact with these sources, which, in the Glacial catchment, is likely to be channelisation of runoff in the ice covered areas

In summary, the Bow stream DOC concentrations suggest that much of the runoff in this catchment has had significant contact with organic soils, so contaminants in the snowpack are likely to be retained on catchment soils. Also, OCs that reach the stream may bind to dissolved organic ligands, thus reducing their bioavailability. Although it is not clear whether it is due to flow routing or the lack of organic sources in the catchment, the Glacial stream DOC concentrations suggest that most of the runoff in this catchment has had limited contact with organic soils. Therefore, contaminants from the snowpack are less likely to be retained on catchment soils and more likely to reach the stream. Furthermore, the low DOC concentrations in the Glacial stream waters mean that OCs that reach the stream are less likely to bind to organic ligands and thus reach the lake in a more bioavailable form.

References

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