CHEMISTRY OF A TEMPERATE POND'S DECAYING WINTER COVER

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Introduction

During the decay of a lake's winter cover, it has been suggested that the impurities, such as nutrients, ions and particulate matter, incorporated into the ice during growth, are directly annexed into the water column (Barica & Armstrong 1971; Gröterud 1972b; Jones and Ouellet 1983). This study was undertaken to monitor the migration of ions within the ice cover, during the decay period. The chemical parameters considered were specific conductance, total alkalinity, and the major ions of calcium, sodium, magnesium and potassium. Pathways taken by these ions were determined for two locations on an ice cover (margin and centre), from cover blocks removed during the decay period.

The study area was Curtis Pond (44°19'N, 78°18'W); an eutrophic temperate pond, in an urban setting, in the eastern section of the City of Peterborough, Ontario, Canada. The pond of calcareous waters, has a surface area of 1.92 x $10^4 m^2$, a maximum depth of 2.5 m and a volume of 2.31 x $10^4 m^3$ (Campeau 1979; Kingsbury 1983).

Methods

Ice blocks were removed from the two sampling sites at four different times; Peak Ice Conditions (P.I.C.) on February 14, 1983, P.I.C. + 20 days, P.I.C. + 32 days and P.I.C. + 38 days. Once the blocks were removed from the ice cover, they were stored in a freezer until analyzed.

Prior to analysis, the ice blocks were sectioned horizontally at five cm intervals downward from the black ice/white ice interface. The white ice was segmented between event layers, not more than four cm apart. The sample sections were rinsed with deionized water, and triple bagged. The bagged samples were melted and were chemically analyzed using standard proceedures. Vertical ion profiles were plotted against ice block depth (denoting the air/ice interface as 0 cm) for both sample locations. For more details on methodology, see Kingsbury (1983b).

Results

The sample sites chosen each represented different, but typical, formation patterns of a lake ice cover. Sample site E was situated on the margin region of the pond cover, and during the ice cover development it was associated with a major slushing event. This event (February 4, 1983) created a well-defined "slushed" white ice layer, on top of the existing white ice. Sample site Ø, located in the central region of the ice cover, was not affected by this slushing, and its subsequent white ice development was influenced by atmospheric sources only.

A general downward ion migration pattern was noted during the decay period within the ice cover, based on specific conductance profiles (see "A" in Figures 1 through 4). All examined ions followed this pattern to various degrees for both sample locations, through greater ion concentrations were associated with the margin.

The P.I.C. profiles (Fig. 1) show large concentrations of ions in the upper portions of the ice cover. The highest concentrations are found in the white ice layer with relatively high concentrations occurring in the upper black ice layers. The ion concentrations

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then decrease in the black ice, with increased depth, to values near zero.

The P.I.C. + 20 days profiles (Fig. 2) illustrate an unimodal curve, with the peak occurring below the surface in the upper layers of the black ice. Above this peak, the ion concentrations slowly decline towards the air/ice interface, to concentrations lower than originally noted in the white ice at P.I.C. Below the peak, overall ion concentrations are greater than at P.I.C., with the concentrations decreasing with depth downward into the block.

In Fig. 3, the P.I.C. + 32 days profiles indicate a multimodal curve. A bimodal curve is noted in the black ice, with the maximum ion concentration (in the black ice) occurring in the upper peak. An ion increase is also apparent for most of the profiles at the surface of the ice blocks.

P.I.C. + 38 days profiles (Fig. 4) were taken just before complete decay of the cover, which occurred on P.I.C. + 40 days. They show a low ion concentration at the surface of the cover, which increases to a maximum at the bottom of the ice block, for most of the ions examined.

Total alkalinity (see "B" in Figures 1 through 4) profiles also follow the previously mentioned patterns during the decay period.

Discussion

Though the winter of 1983 was a low snow year in the study region, all three cover components (snow, white ice and black ice) were present during the winter, and indicated the winter cover patterns normally exhibited by a developing ice cover. Thus it is believed that the results are reasonably typical of a temperate ice cover's development and decay.

With regard to the ion profiles, temporal patterns can be noted during the decay period for both the margin and centre ice cover. The decay pattern suggests the following scenario occurring in the ice cover of the pond.

At peak ice conditions, the white ice and upper layers of the black ice contain greater ion concentrations than the lower portions of the ice cover. This is due to slush-produced white ice and to poor exsolution during the initial, rapid, stages of black ice growth.

On the P.I.C. + 20 days, the surface ion load has moved downward into the cover creating a maximum concentration peak (within the upper quarter of the ice cover), associated to the depth of initial candling of the cover.

An interesting development occurred on P.I.C. + 32 days, with a multimodal profile being exhibited by the ice cover. For most of the profiles, a bimodal curve was present in the black ice, attributed to the addition of ions from adjacent terrestrial sources, accounting for the upper peak and surface increase.

The last sample period, P.I.C. + 38 days, indicates that the major ion loads had migrated to the bottom of the ice cover, with complete candling of the ice cover. At this time, the ions were probably in the process of being annexed into the water column.

The margin region of the ice cover follows the previously mentioned migration pattern for the measured chemical parameters. However, in the centre profiles, only specific conductance, total alkalinity and calcium completely follow the migration pattern. Temporally, magnesium sodium and potassium profiles exhibit a similar pattern, but, after the addition of ions on P.I.C. + 32 days, the ion migration is not as great into the ice cover until complete cover decay.

A possible explanation for the difference between the two sites is based on their relative ion concentrations. Gröterud (1972a) has shown that the margin regions of an ice cover contain greater concentrations of ions than the centre. This was also noted at Curtis Pond. The margin region, with its relatively pronounced white ice development, had a greater ion concentration moving through the cover, than was being received from other sources. This created the well-defined downward migration pattern observed in the margin profiles. The centre, which only receives atmospheric inputs, has, as would be expected, the highest concentrations remaining at the surface, due to the relatively constant supply. Also, the atmospheric inputs had a higher ion concentration than the migrating cover ions. This is shown in the less pronounced migration pattern of the centre profiles. Once complete candling of the ice cover occurs, the ion load quickly travels through the cover and into the water column.

In conclusion, ions originally incorporated into the cover migrate downward through the ice, with time, and are annexed into the water column. During the melt period, terrestrial ions entering the ice cover also exhibit a downward migration pattern, following the original cover ions.

Acknowledgements

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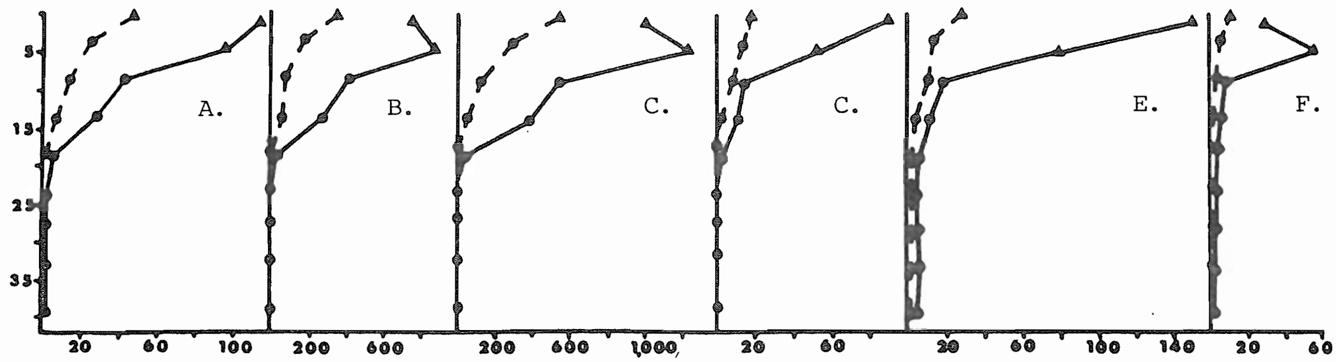

Fig. 1. P.I.C. ion profiles. T.ice (cm): margin 42.0, centre 42.5

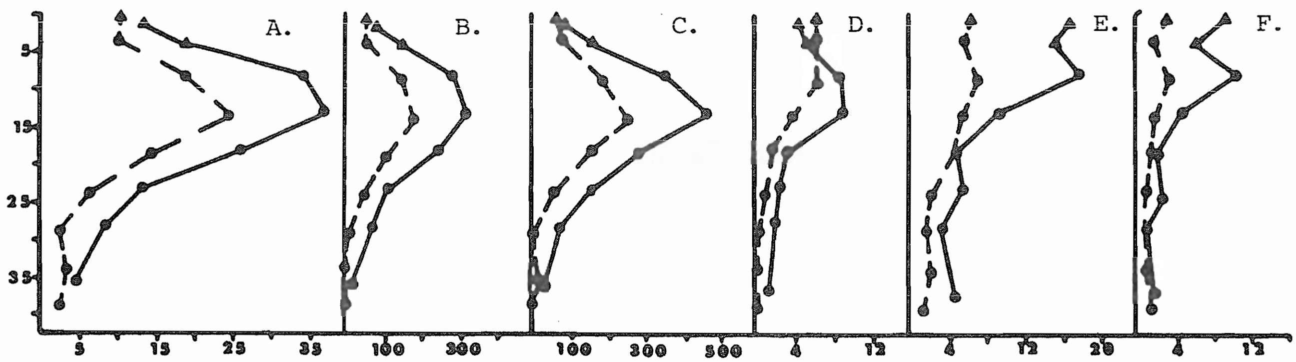

Fig. 2. P.I.C. + 20 days ion profiles. T.ice (cm): margin 40.0, centre 42.0

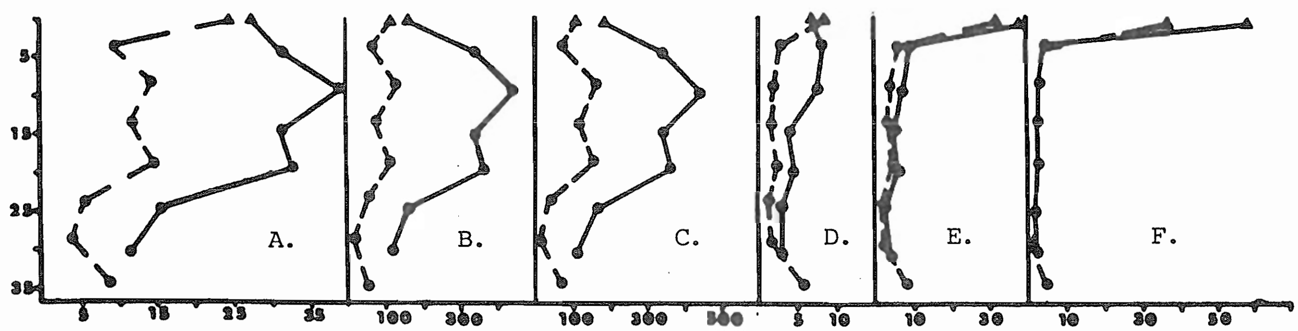

Fig. 3. P.I.C. + 32 days ion profiles. T.ice (cm): margin 36.0, centre 37.0

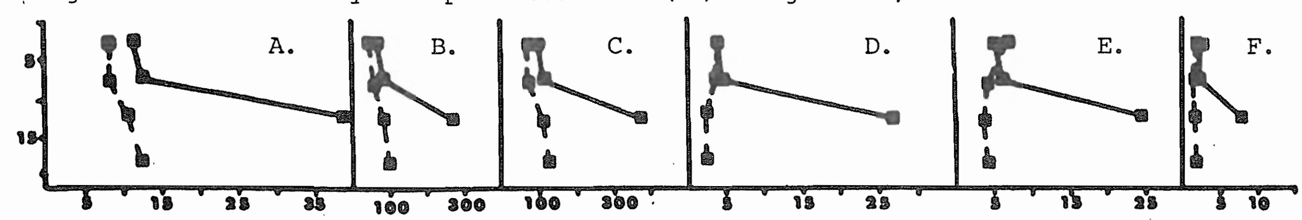

Fig. 4. P.I.C. + 38 days ion profiles. T.ice (cm): margin 15.0, centre 23.0

Note: A- specific conductance, B- total alkalinity, C- calcium, C- magnesium, E- sodium, and F- potassium, with sample site E (margin) profile being denoted by (•——•) and sample site Ø (centre) profile as (•– –•), triangle values (▲) represent white ice, dots (•) are black ice; squares (■) denote undistinguishable ice type; T.ice- total ice block thickness.