A field study using the stable isotopes of oxygen and hydrogen to calculate evaporation

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Evaporation from a large tundra watershed (850 km^2) was examined in central District of Keewatin, N.W.T. (64°41'N; 97°03'W), as part of a pioneer water balance study at this arctic site. The ^{18}O and ^{2}H compositions of precipitation, surface waters, and groundwaters were monitored during the summers of 1988 and 1989 to trace their movement, mixing, and evaporation within the flow system. This work was conducted in conjunction with an evaporation-pan study. An isotope mass-balance technique was applied to the combined data set in order that the annual vapour losses could be calculated for the study area.

The importance of evaporation in this part of the arctic is readily discerned from the ^{18}O and ^{2}H contents of the lakes and ponds. The effects of this process are qualitatively identified on a $\delta^{18}O$ versus $\delta^{2}H$ diagram, with respect to the Global Meteoric Water Line (GMWL; $\delta^{2}H = 8\delta^{18}O + 10$). The enrichment signals that are preserved in these surface waters characterize a well-defined evaporation line described by the relation $\delta^{2}H = 5.5\delta^{18}O - 49$.

To calculate evaporation (E) from the isotopic data, the bulk composition of the derived moisture, δ_e, must be determined. The theoretical values of δ_e were computed for both isotopes through analysis of their slopes of isotopic enrichments in the evaporating-pan water, with respect to the fraction of water that remained. These estimates were refined by relating them to the evaporation line, which describes the true behaviour of these isotopes during evaporation in the natural environment. E is then calculated from a water balance equation and its related isotopic expressions.

The calculations indicate that evaporation is of variable importance at different levels in the drainage system. Small tundra ponds with limited surface inflow or outflow are strongly enriched in both ^{18}O and ^{2}H (up to -12 ‰ $\delta^{18}O$ and -113 ‰ $\delta^{2}H$), relative to mean annual precipitation ($\delta^{18}O$ = -22.7 ‰, $\delta^{2}H$ = -174 ‰), and as much as half of their water output can be lost to evaporation. Conversely large and well-drained lake ($\delta^{81}O$ = -20.6 ‰, $\delta^{2}H$ = -158 ‰), loses only 10% or less of its annual water budget as vapour.

Results obtained from this project demonstrate the viability of gauging evaporation and studying water balance with the stable isotopes. Techniques developed in this study can also be applied to a variety of hydrological problems associated with mining and tailings management. This work would be particularly useful for defining the long-term water balances of mine sites, permitting assessments of the long-term capacities of tailings ponds and evaluations of water inflow problems.

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