ACIDIFICATION POTENTIAL OF SNOWPACK IN SIERRA NEVADA

Discussion by Roger C. Bales, Member, ASCE, Mark W. Williams, and Ross A. Wolford

This paper presents an erroneous evaluation of the potential for basin acidification from the storage and release of solutes in Sierra Nevada snowpacks. The authors conclude that the rate of anion release from the snowpack during spring melt in Eastern Brook watershed is 1.4 eq ha⁻¹ d⁻¹, and that this quantity can serve as a measure of the potential of the snowpack to acidify surface waters. They further conclude that due to a slower melt rate and cleaner precipitation, this value is one-tenth that for Woods Lake in New York. They imply that the potential for acidification of surface waters from snowpack runoff in the Sierra Nevada is therefore much less than at Woods Lake.

We are concerned that this paper will result in an inaccurate and false evaluation of the acidification potential for headwater basins in the Sierra Nevada. We illustrate our objections with data from Emerald Lake watershed (ELW) in the southern Sierra Nevada, one of the basins cited in this paper. Melack and Stoddard (1991) have shown that ELW is representative of granitic basins in the Sierra Nevada.

We offer five main criticisms on their approach and conclusions. First, an anion release rate, especially when averaged over times longer than a few days, is an insufficient and inappropriate measure of acidification potential for surface waters in the Sierra Nevada, because: (1) an ionic pulse of solutes in snowpack spring runoff may have a low anion release rate, yet result in acidic conditions in streams; and (2) temporal differences in the initiation and magnitude of snowmelt runoff will result in significant anion release rates across a watershed. The first fraction of snowpack runoff often

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at least some cases, appear to be inappropriate for Brook watershed (e.g., parameters describing ion release pack). It is our position that use of a well-parameterized model of the integrated snowpack and other watershed models provide insight into watershed response and to estimate conditions different from those used to validate the model data and assumptions used in the calculations must be appropriate for the specific area under study.

Fifth, the authors validate the chemical portion comparing the chemical content of one sampling date (simulated results). Chemical inputs to the model were deposition samples collected at and near the modeled sites, wet and dry deposition throughout the accumulation season stored solutes in meltwater (e.g., Bales et al. 1990). We show examples that the chemical storage in the snowpack on that date was equal to the chemical inputs from wet and dry deposition and was considered a trivial error. Running a large model through a window that does not include the date that proves little except that perhaps the overall dry deposition and leaching estimates leading up to the snowpack to reach approximately the same chemical state.

APPENDIX. REFERENCES


Closure by Carl W. Chen and Luis E. Gomez, M.

The discussers objected to our conclusion that the area in the Sierra Nevada mountains is lower than at Woodland mountains of New York. They state that our analyses of the headwater basins in the Sierra Nevada model was to model the response of peak snowmelt (2.6 and 1.1 cm day$^{-1}$, respectively). This calculation further supports our first point, in that anion-release rates vary considerably during snowmelt; the highest anion-release rates are not associated with the highest stream concentrations.

Fourth, the data and parameters used to drive the Integrated Lake-Watershed Acidification Study (ILWAS) model were not documented, and, in

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Peak daily $\text{NO}_3^-$ and $\text{SO}_4^{2-}$ concentrations in snowpacks in ELW in 1987 were each about 30 $\mu$eq L$^{-1}$, of anions for a snowpack melting at a rate of 0.6 mm of water 6.6 eq $\text{h}^{-1}$, 4.5-fold greater than the rate calculated by the $\text{W}$ of 0.8 eq $\text{h}^{-1}$. Furthermore, in 1986 the initiation of snowmelt in each northern aspect (Williams and Melack 1989). Stream $\text{NO}_3^-$ concentrations were highest at the initiation of snowmelt in each ELW therefore increased the time span that the anionic concentrations were elevated by the initial pulse. The question of the term or average anion release rate—should be used to evaluate potential effects on aquatic systems on the spatial and temporal scales considered. At the time we observed to be several the average (Bales et al. 1991 higher than observed for the watershed as a whole.

The watershed comparisons of the acidification potential from surface waters without accompanying comparisons of potential anions. At present deposition levels, acid-neutralizing capacity in ELW varies from seasonally maxima of $-10 \mu$eq L$^{-1}$ to a mean of $-10 \mu$eq L$^{-1}$, thus very sensitive to acid deposition, i.e., to negative ANC. NC of ELW streams during snowpack runoff is due in part to strong-acid anions released from the snowpack (Williams et al. 1991). Some soil-solution ANC values were during snowmelt runoff. Therefore, even small increases in concentration of strong-acid anions from the snowpack have an effect on the pH below zero and cause episodic acidification of ELW and other granitic basins in the Sierra Nevada. The heavily parameterized, discrete time step, material model (Chen et al. 1983) is unnecessary to estimate average annual, but in fact lends an undue aura of sophistication, actually a rather simple estimate. A simple measurement of the change in snowpack ion and water contents during used to estimate melt rate and anion release. Peak anion concentration from snowpack runoff during the first snowmelt in 1986, and 1987, when stream anion and nitrate were highest (snowmelt rates of 0.67 and 0.25 cm dy$^{-1}$, respectively). Peak anion-release rates were 1.7 and 2.6 mm day$^{-1}$, and came later, coincident with peak snowmelt (2.6 and 2.6, respectively). This calculation further supports our first conclusion: rates vary considerably during snowmelt; the peak rates are not associated with the highest streamflow.

The discussors objected to our conclusion that the acidification potential in the Sierra Nevada mountains is lower than at Woods Lake in the Adirondack mountains of New York. They state that our analysis is erroneous. They claim that the headwater basins in the Sierra Nevada are very sensitive to acidification. To support their claim, they show data from Emerald Lake watershed (ELW).

We stand behind our conclusions. The discussors have not shown any

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