COMPARISONS OF DISSOLVED CHEMICAL CONCENTRATIONS IN ARIZONA SNOWPACKS AND SMOWMELT STREAMFLOW

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Although magnitudes of concentrations of chemical pollutants in snowpacks elsewhere have been reported (Johannessen and Henriksen 1978, Colbeck 1981, Kling and Grant 1984, Berg and Woo 1985, Farnes 1985, Kotturi and Richards 1985, Laird et al. 1986, Roos 1988), those in Arizona snowpacks have only recently been known (Ffolliott and Lopes 1993). The dissolved chemical concentrations reported in this study provide some insight into the potential quality of snowmelt water, the primary source of streamflow in the region. To further study the relationships between the concentrations of chemical constituents in snowpacks and those in snowmelt streamflow, the chemical concentrations reported by Ffolliott and Lopes (1993) are compared in this paper to concentrations of similar chemical constituents in snowmelt streamflow (Ffolliott 1990).

Description of the Study

Dissolved chemical constituents in snowpacks and subsequent snowmelt streamflow were measured on a small-scale watershed basis in earlier investigations to define these relationships on the Heber watersheds in north-central Arizona (Ffolliott and Baker 1977). The results obtained in this (unpublished) study suggested that the two sets of chemical concentrations were statistically similar, although sampling was too limited in time and space to draw meaningful inferences.

The possibility that concentrations of dissolved chemical constituents in snowpacks on watersheds might be similar to those found in snowmelt streamflow also formed the hypothesis that was further considered in this present study. The hypothesis could not be evaluated directly, however, because the two data sets were collected independently of each other. Nevertheless, the results obtained might help to refine the hypothesis for future evaluation.

Source data were collected on, and adjacent to, the Beaver Creek watersheds, the Heber watersheds, and the Thomas Creek watersheds, located along the Mogollon Rim in north-central Arizona. The Beaver Creek watersheds, situated about 80 km south of Flagstaff, were established to evaluate the effectiveness of silvicultural treatments in ponderosa pine forests on volcanic and cinder parent materials relative to water yield and other multiple use values (Baker 1983). The Heber watersheds, about 20 km south and southwest of Heber, were established to obtain information on the multiple use values of ponderosa pine forests on sedimentary parent materials (Ffolliott and Baker 1977). The Thomas Creek watersheds, located 25 km south of Alpine, were established to study the effects of silvicultural treatments on water yield and other forest-based resources in high-elevation mixed conifer forests (Gottfried 1991). The study sites, sampling techniques, and laboratory procedures used to determine the concentrations of dissolved chemicals in the snowpacks and snowmelt streamflow have been described in earlier publications (Ffolliott 1990, Ffolliott and Lopes 1993) and are not reiterated here.

Results and Discussion

Some of the dissolved chemical constituents sampled in this study were found in concentrations below the detectable limits of laboratory procedures. For example, concentrations of nitrate (NO_3) from all of the sampling sites could not be detected in the laboratory and were therefore not included in statistical summaries. Concentrations of fluorite (F), chloride (Cl), and sulfate (SO_4) were too low for detection at some sampling sites, although the estimated means and standard errors of these chemicals are included in Tables 1 and 2 after making the necessary adjustments in the sample sizes. Means and standard errors of the other chemicals were calculated from the total sample.

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Concentrations of the dissolved chemicals sampled in Arizona snowpacks (Table 1) were similar to those reported elsewhere (Berg and Woo 1985, Colbeck 1981, Johannessen and Henriksen 1978, Kotturi and Richards 1985, Laird et al. 1986), considering the differences in sampling techniques and laboratory procedures. There were no sites sampled with higher than "normal" concentrations of dissolved chemicals, based on the observed normal frequency distributions of these concentrations (Ffolliott and Lopes 1993). There were no outlying data points.

Table 1. Means and standard errors of pH and concentrations of dissolved chemicals in the snowpacks, sampled in milligrams per liter (from Ffolliott and Lopes 1993).

Constituent	Mean ± Standard Error
Na	1.30 ± 0.524
Ca	0.234 ± 0.0561
Mg	0.065 ± 0.0198
F	0.122 ± 0.0125
Cl	1.07 ± 0.373
SO_4	0.707 ± 0.144

Table 2. Means and standard errors of concentrations of dissolved chemicals in the snowmelt streamflow from forested watersheds, in milligrams per liter (from Ffolliott 1990).

Constituent	Beaver Creek	Heber	Thomas Creek
Na	3.20 ± 0.068	1.67 ± 0.116	2.87 ± 0.083
Ca	7.33 ± 0.129	9.26 ± 1.16	7.86 ± 0.197
Mg	2.99 ± 0.040	1.86 ± 0.121	2.86 ± 0.071
F	0.471 ± 0.002	0.095 ± 0.009	0.108 ± 0.004
Cl	2.87 ± 0.112	2.19 ± 0.119	2.27 ± 0.081
SO_4	16.8 ± 0.450	10.2 ± 0.830	6.06 ± 0.268

Concentrations of some of the studied dissolved chemicals in the snowpacks (Table 1) were lower than those reported in the snowmelt streamflow from forested watersheds (Table 2). However, these exceptions were inconsistent and likely inconsequential. Concentrations of the dissolved chemical constituents were low in both instances.

Comparisons of concentrations of the dissolved chemicals in the snowpacks sampled and those in snowmelt streamflow from forested watersheds, with water quality criteria proposed by the U.S. Environmental Protection Agency and the Arizona Department of Environmental Quality, indicated that levels of acceptability for aquatic life, irrigation, and public water supplies are not exceeded. Levels of acceptability for some constituents have not been listed or prescribed.

Conclusions

To directly link the contributions of the dissolved chemicals in snowpacks to the chemistry of subsequent snowmelt streamflow, a more thorough study of the relationships between snowpack chemistry and the chemistry of snowmelt streamflow on a watershed basis is needed. It will be necessary to sample snowpacks on a watershed throughout the intermittent snowpack accumulation and melt cycles commonly observed in Arizona, and the resultant snowmelt streamflow on the same watershed. Additionally, the importance of geologic weathering interacting with land-use practices, and snowpack amount and timing (pattern) of snowmelt streamflow must be determined (Stottlemyer 1987). Long-term monitoring of these processes is required.

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