Using stable water isotopes as tracers to develop a conceptual model of the source waters connected to streams within the Pemigewasset River watershed, NH.

Kristin Brandt, Graduate Student and
Candidate for MS in Environmental Science and Policy
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Understanding the hydrology of a system is necessary to understand the expression of human impacts in streams. Once a month for six months in 2011 (April – September), I sampled 62 sites throughout the Pemigewasset River watershed, NH (~1610.12 km^2). At each site I collected water samples for stable water isotope analysis along with *in situ* measurements of specific conductivity. This data enabled me to determine changes in source waters to the rivers (hydrologic connectivity) and the effect this had on the expression of road salt pollution in the rivers.

The use of road salt as a deicer has increased since first applied in the 1940s. In the winter of 1941-1942, New Hampshire became the first state to adopt a policy of using salt to deice roads (TBR 1991). Today, average road salt application load for the Interstate-93 corridor in New Hampshire is 24.9 tons per lane mile (Mullaney et al. 2009). Understanding how road salt enters groundwater and surface waters is essential to mitigating road salt contamination impacts to both environmental and human health.

Hydrologic connectivity refers to how surface waters are connected to subsurface water flows (Stieglitz et al. 2003). This relationship can easily be identified by using stable water isotopes. Stable water isotopes of deuterium (^2H) and oxygen-18 (^{18}O) are useful tracers in hydrologic systems. Previous studies have used them in the separation of hydrographs, calculating residence times, and simply understanding the hydrology of a system (Hooper and Shoemaker 1986; Soulsby et al. 2006; DeWalle et al. 1997). Since different water sources (precipitation, snowmelt, soil water, groundwater) can have specific isotopic signatures, using a simple mixing-model can show which source is connected to a stream at any given time.

Using stable water isotopes as tracers, I was able to develop a conceptual model of the source waters connected to streams within the Pemigewasset River watershed, NH. My model shows that in this system, soil water tends to be recharged by precipitation (generally in the form of rain). Precipitation recharges soil water by infiltration and percolation. Infiltration is how the water enters the soil surface and occurs with a combination of gravity and capillary action. The subsequent downward movement of water through the soil is known as percolation (Brooks et al. 2003). Snowmelt also recharges soil water in the winter, but by summer it has “moved on” to recharge groundwater. Any residual snowmelt left in the soil water is isotopically “overpowered” by the rainfall recharge.

Snowmelt is the main source of groundwater recharge in New Hampshire (Buttle and Sami 1990). Precipitation also plays a minor role in recharging groundwater, which can be seen by the positive change in isotopic signature from snowmelt to groundwater. The flows from groundwater and soil water to the stream are dependent on hydrologic connectivity. My isotopic analysis shows that shallow groundwater in this system is always connected to the stream and provides baseflow during dry conditions. Baseflow sustains streamflow between periods of rainfall or snowmelt and does not respond quickly to excess precipitation (Brooks et al. 2003). Soil water is connected to the stream by quick flow during “wet-up” periods. Quick flow is the excess precipitation that infiltrated the soil and then arrived at the stream in a short period of time (Brooks et al. 2003).

Knowing that snowmelt plays the most significant role in groundwater recharge in New Hampshire, it becomes apparent that when salt is added to the snowpack, it too will enter groundwater. As the snowpack (contaminated with road salt) melts, the snowmelt and salt recharge the system. While some salt may remain in the soil, it is diluted and flushed out by precipitation recharge during rainfall events. Because the salt ends up in shallow groundwater it is highly expressed in streams during baseflow conditions. My research confirms that during “wet-up” periods when quick flow connects soil water to the stream, road salt expression decreases. This is because soil water is a dilution factor, not because road salt is no longer in the watershed.

It is important to determine source waters to a stream to understand hydrologic road salt expression. My research is important, especially to stakeholders such as the New Hampshire Department of Environmental Services, the NH Fish and Game Department, local water utilities, and volunteer river groups within the Pemigewasset River watershed, NH, as it provides a hydrologic foundation for further studies. Also, knowing the source of road salt contamination and when it is expressed in streams is vital to maintaining a healthy riparian habitat. Baseflow conditions are already stressed conditions for aquatic organisms, when another stressor, such as road salt, is added the strain escalates. Understanding the where’s and when’s of road salt contamination in streamwater is not only imperative to the health and well being of the environment, but to humans as well. New Hampshire gets 55% of its drinking water supply from groundwater (EPA). Because shallow groundwater in the Pemigewasset River watershed can be impacted by road salt application it is important to not only monitor this source for stream health, but also potential impacts to humans. Knowing what groundwater aquifer source is being pumped for drinking water is crucial.

It is important to determine source waters to a stream to understand hydrologic road salt expression. Using stable water isotopes I developed a conceptual model of hydrologic connectivity within the Pemigewasset River watershed, NH. With this model and the use of specific conductivity, I was able to understand road salt expression in the various streams sampled. In the future, this research can be used by various stakeholders in the watershed to better understand the hydrology and impacts of road salt and thus implement necessary management policies.

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