Temporal Variation in Silica and Alkalinity in Groundwater and Stream Water from White River Field Station near IUPUI, Indianapolis Indiana

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Introduction

In this project temporal trends in silica and alkalinity were evaluated for river water and groundwater in the floodplain along an urban reach of the White River in the City of Indianapolis, Indiana, USA (Figure 1). The goal of the project was to conduct a comparative analysis of the temporal trends in silica and alkalinity between river water and from groundwater collected from select locations in the floodplain. Figure 2 illustrates how the floodplain is divided into eight sections with most sections having two monitoring wells within them. An "A" well represents the well closest to the river's edge, while the "B" well represents the well farthest from the river's edge.

Sampling and Analytical Methods

Groundwater was collected from monitoring wells constructed of 5.2 cm PVC riser fitted with 152 cm PVC screens (20 slots per 2.54 cm). The monitoring wells were installed in hand-augured holes and screened across the water table. With the exception of MW1C, which has a depth of 16.67m, the remaining monitoring wells range in depth from 1.26 to 2.41 meters. The groundwater sampling locations are shown in Figure 2. Sampling was conducted on a weekly basis for a 15 month period. Groundwater from the monitoring wells was pumped to the surface through a flow cell using a peristaltic pump. Prior to collecting water, the temperature, pH, and specific conductance was monitored in the flow cell using a HydroLab™ minisonde. When these parameters stabilized, water was collected in 250 ml HDPE bottles for subsequent analyses.

River water was collected at an upstream location near the 10th Street bridge and at a downstream location near the New York Street bridge (Figure 1). River water was collected using the grab method. Water was collected about 10 cm below the stream surface and about 3 meters from the east bank using a plastic bottle attached to a telescoping rod. The water from the plastic bottle was used to fill 250 ml HDPE bottles for subsequent analyses.

Ground and river water samples were transported to the laboratory within two hours and refrigerated at 4°C until analyses. The samples were filtered through a 0.45 μm filter prior to silica and alkalinity analyses. Alkalinity as bicarbonate was measured by potentiometric titration using 1.5 N H_2SO_4 to an acid equivalent point of 4.5 (Hach, 1992). Silica was measured using a Hach DR/890 colorimeter (Hach, 2000).

In addition to collecting water for chemical analyses, river discharge data was obtained from the United States Geological Survey gauging station, White River at Indianapolis (03353000) (http://in.waterdata.usgs.gov, 2002). This gauging station is approximately 2 km downgradient of the study site.

Results and Discussions

The results of river discharge and chemical analyses for silica and alkalinity are summarized in figures 3, 4, and 5. Temporal trends in river discharge show distinct seasonal variations (Figure 3). River discharge increased from late fall through the spring and decreased through the summer and early fall. Superimposed on the seasonal trends were several increases in river discharge and flooding of the study site during high precipitation events.

Temporal Trends in Silica

Silica in river water ranged from approximately 3 to 9 mg/L with ranges and the average for individual wells displayed in Table 1. Silica in groundwater was generally higher compared to river water. Silica values in groundwater sampled from MW-1A, MW-1B, MW-2A and MW-2B in the northern portion of the study site ranged roughly from 7 to 19 mg/L, while groundwater from MW-3A, MW-4A, MW-5A, and MW-5B in the middle portion of the site and MW-6A, MW-6B, MW-7A, MW-7B, MW-8A and MW-8B in the southern portion of the site ranged from 5 to 17 mg/L.

Temporal trends in silica of river water showed a strong seasonal dependence similar to other studies (Hem, 1985). Silica decreased from late fall through spring and increased through late summer. Temporal trends in groundwater silica for most locations sampled in the floodplain mimicked the river water trend. Exceptions include groundwater from MW-1C and MW-3A (Figure 4). MW-1C is a deep well (~ 16 m) that most likely derives its groundwater from a deeper aquifer compared to the shallow monitoring wells. MW-3A is located at the edge of a riparian wetland complex and may be influenced by wetland water in this region.

The primary source of dissolved silica in natural waters is the chemical breakdown of silicate minerals in rock and sediments by chemical weathering processes (Hem, 1985). The silica is transported to rivers via groundwater. In both groundwater and rivers, the concentration of silica is controlled by the solubility and seasonal recharge. Silica solubility increases with increased water temperatures. Silica concentration may also decrease in river and groundwater systems with seasonal recharge and in river water during increased runoff from precipitation. Thus, the silica concentrations are influenced by the amount of precipitation received within a drainage basin and the residence time of groundwater within an aquifer.

The lower concentration of silica in river and groundwater from the floodplain may be explained by variation in the source of river flow and groundwater recharge over seasonal scales. During seasons with increased precipitation (fall – spring), runoff and recharge to the groundwater system has less time to interact with rocks and sediments resulting in lower silica in both ground and surface water during this period of higher precipitation. In rivers, runoff from overland flow dilutes the dissolved silica causing the observed lower values. Higher silica in groundwater compared to river water results from longer interaction with the rocks and sediments in the groundwater aquifer.

The mechanism of production, transport and dilution of silica within a watershed can be used to explain why silica levels in the river are lower during the months of high precipitation and higher during the drier months. It can be inferred that during the drier months the major source of inflow into the river is from the groundwater. During months of higher precipitation the silica becomes diluted and decreases in the river. In fact lower silica values during the different seasons are related to increased precipitation and increase volume of river flow.

Groundwater from the floodplain can be explained in a similar manner. When precipitation is low, it can be assumed that water present in the water table resides there for a longer duration. When precipitation is high, more water is introduced into the aquifer and residence time is decreased. Again, the lower residence time, the lower the silica content will be.

Temporal Trends in Alkalinity

Alkalinity levels in the river range from 140-280 mg/L (see Table 2). Alkalinity in the groundwater is generally higher than the river concentrations. Alkalinity concentrations in samples collected in the northern portion of the research site from MW-1A, MW-1B, MW-

2A, and MW2B, range from 212-622 mg/L (see Table 2). Groundwater collected from MW-3A, MW-4A, MW-5A, MW-5B, the middle portion of the study site and MW-6A, MW-6B, MW-7A, MW-7B, MW8A, and MW-8B in the southern portion of the site range from 108-470 mg/L (Figure 5).

Temporal trends are not as distinguished for alkalinity as they are for silica concentrations. The river shows a very slight trend that suggests a small increase in alkalinity from summer to late winter, shifting to a slight decrease from late winter to early summer (Figure 5). MW-1B and MW- 3A follow this same trend, although more pronounced than that observed for the river samples. The other sampling locations show the opposite trend, suggesting a decrease from the summer to winter months, and an increase from winter to summer (Figure 5). Plot 2 which contains MW-2A and MW-2B however, are not indicative of either of these trends. In fact, this is the only site that seems to show such drastic differences between the A and B wells.

Alkalinity is a measure of the water's capacity to resist a lowering in pH when acids are added (Soulsby, 2001). The primary components that form alkalinity reflect the history of the water, as an imprint left by previous encounters with varying rocks, primarily those enriched in carbonate (Hem, 1985). However, nearly all natural bodies of water contain significant amounts of dissolved carbon dioxide which results from atmospheric interactions (Soulsby, 2001). The trend observed in the majority of the wells, which suggests higher levels of alkalinity in the summer as compared to the winter months coincides with results found by Soulsby and others (2001). According to Soulsby and others (2001) the drier, summer months are when aquifers are dominated by groundwater, making them enriched in groundwater solutes, which results in increased alkalinity levels. In the winter months the aquifer is better influenced by the river particularly during times of snowmelt. Their study does not explain the trend exhibited by the river and MW-1B and MW-3A.

Conclusions

The objective was to assess the extent of temporal variations for these two proxies. Temporal trends in silica of river water showed a strong seasonal dependence similar to other studies. Silica in the groundwater is generally higher than that measured in the river. The silica concentrations are influenced by the amount of precipitation received within a drainage basin and the residence time of groundwater within an aquifer. Silica concentrations are lower during months with increased precipitation; due to decreased residence time within the aquifer in addition dilution in surface waters.

Alkalinity temporal trends are not as distinguished as they are for silica concentrations and there are two opposing trends observed. The river and two monitoring wells show higher alkalinity levels from summer to late winter, whereas most of the other wells show higher alkalinity levels during the summer months. This latter trend coincides with previous studies, which suggest that the aquifers are dominated by groundwater during drier periods and therefore are more enriched in groundwater solutes. Further work needs to be conducted to better understand the trend exhibited by the river and the corresponding wells.

References

Hach, 1992. Digital Titrator Model 16900-01 Manual. HACH Company.

Hach, 2000. Colorimeter Procedures Manual. HACH Company.

Hem, J. D., 1985. Study and interpretation of the chemical characteristics of natural water. 3rd ed. U.S. Geological Survey Water-Supply Paper 2254. 263p.

Soulsby, C., Malcolm, R., Gibbins, C, and Dilks, C., 2001, Seasonality, water quality and biological responses in four streams in the Cairngorm Mountains, Scotland; Hydrology and Earth System Science, vol. 5(3), p. 433-450