Temporal Variation in Groundwater and VOC Flux through a Sandy Streambed, North Carolina

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1. Introduction

Volatile organic compounds (VOCs) are common soil and water contaminants due to their widespread use over the last century and poor historical waste disposal practices[1]. VOC discharge from groundwater into surface water is an important but under-studied aspect of VOC transport and fate in the environment. In this study, we combined measurement of groundwater VOC concentrations in a streambed with measurements and modeling of streambed temperature, to quantify the coupled groundwater and VOC flux into a stream from a contaminated aquifer.

2. Study Area

The study area was a section of Hominy Swamp Creek that runs through an urbanized portion of Wilson, NC. This section of the creek receives inputs of groundwater contaminated with benzene, perchloroethylene (PCE) and its degradation products, and other VOCs[2].

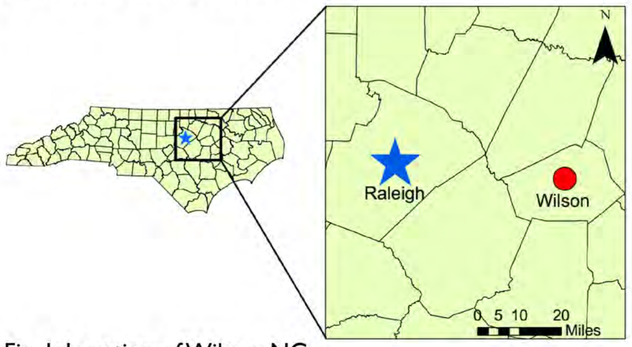


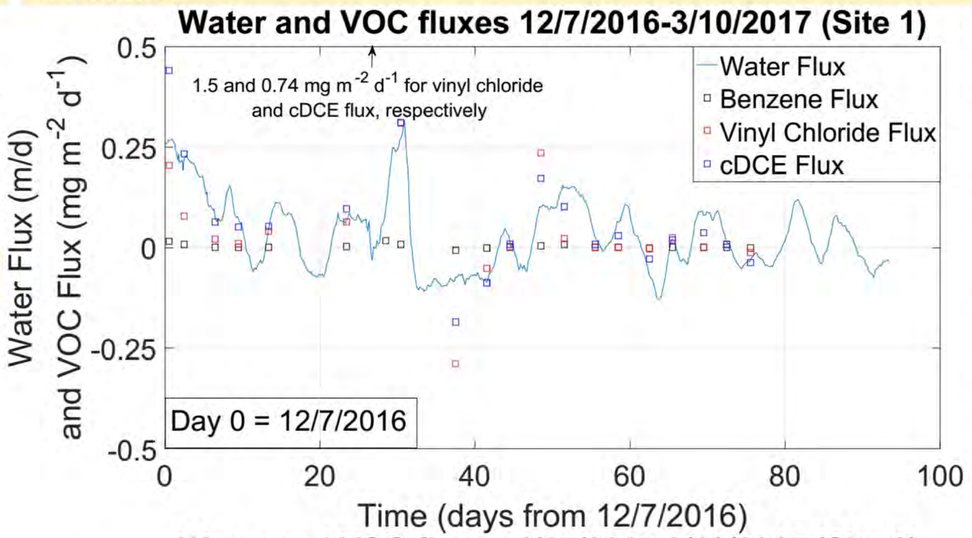
Fig. 1: Location of Wilson, NC

3. Methods

- Vertical arrays of temperature loggers (thermal profilers) collected temperature time series at multiple streambed depths (Fig. 2); data were filtered using dynamic harmonic regression to isolate the 24-hour component of temperature variation.
- Filtered temperature time series were processed using the heat transport code VFLUX 2[3,4] to yield hourly-scale estimates of water flux (v_f).
- Groundwater samples were collected using piezomanometers beneath the streambed every 3-4 days (fig. 2) and analyzed using gas chromatography – mass spectrometry to produce VOC concentrations, [VOC].
- VOC flux (f_{VOC}) through the streambed was quantified as $f_{VOC} = [VOC]v_f$ during December 2016 to February 2017 at two spots about 13 m apart in the streambed of Hominy Swamp Creek. Sites 1 and 2 are 78 and 91 m downstream of the Goldsboro Street South bridge, respectively.

Fig. 2: Thermal profilers were used to collect temperature data (left) while groundwater samples were collected using a piezomanometer (right).

4. Results



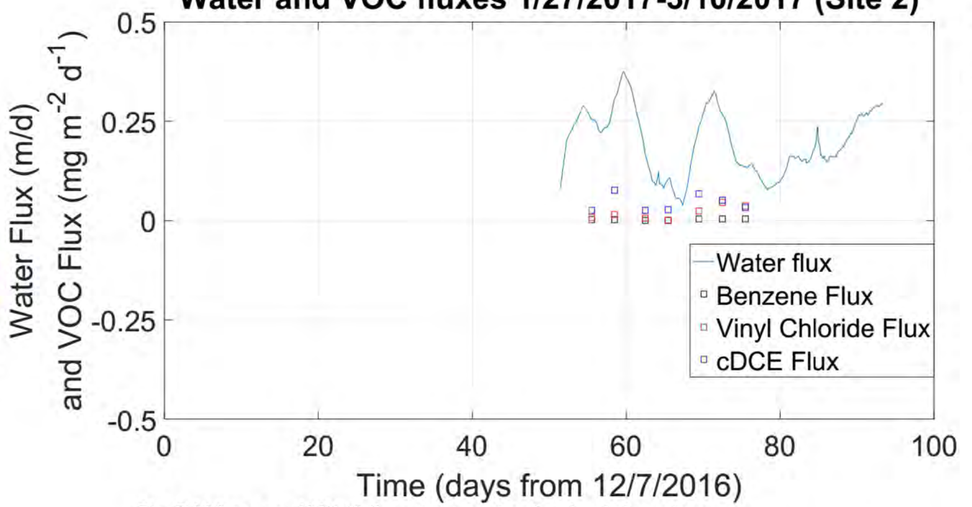


Fig. 3: Water and VOC flux time series for both locations.

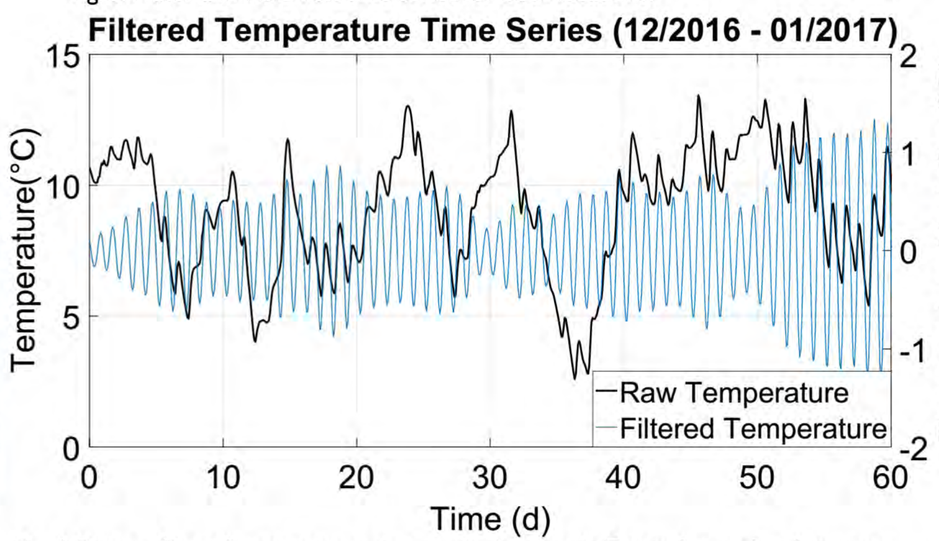


Fig. 4: Raw vs. filtered temperature time series from early December to late January at site 1, 8 cm beneath the streambed.

Groundwater Flux (v_f):

- Three continuous time series of water flux were produced.
- Groundwater fluxes ranged from -0.129 to 0.374 m/d (positive values denote upwelling) between all water flux time series.
- Groundwater flux time series occasionally demonstrate increased groundwater discharge in response to precipitation. However, this is not consistent throughout the results.

VOC Fluxes (f_{VOC}):

- VOC fluxes ranged from -0.28 to 1.5 mg m^{-2} d^{-1} between both locations (fig. 3).
- At site 1, the mean VOC fluxes for benzene, vinyl chloride and cis-DCE were 0.003 (s.d. = 0.006), 0.113 (s.d. = 0.358), and 0.107 (s.d. = 0.210) mg m^{-2} d^{-1}, respectively.
- At site 2, the mean VOC fluxes for benzene, vinyl chloride and cis-DCE were 0.003 (s.d. = 0.002), 0.017 (s.d. = 0.015), and 0.038 (s.d. = 0.020) mg m^{-2} d^{-1}, respectively.
- VOC flux was strongly correlated with water flux, except for benzene and vinyl chloride at site 2.

Temperature Data:

- Despite variable weather conditions, DHR was capable of isolating the 24-hour component of each temperature time series (fig. 4).

5. Conclusions

- Recently developed thermal modeling techniques in conjunction with repeated VOC sampling were used to document the magnitude and temporal variation of water and VOC flux from a contaminated aquifer to a stream without the need for wells or estimates of hydraulic conductivity.
- The method has the potential to scale up over larger areas of streambed or lakebed
- At both sites, cis-DCE shows the least variation in flux while vinyl chloride has the most variation.
- Site 2 has lower variation in VOC flux for all three VOCs compared to site 1.

References

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