Fate of Heavy Metals and Nutrients at the CATchment

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Introduction:

Rain gardens are an element of green infrastructure, promoting human health and well-being. They have also emerged as an effective strategy to treat stormwater runoff in urban areas by encouraging infiltration and the capture of pollutants such as heavy metals and nutrients[1]. The establishment of a rain garden on UK's campus (named the CATchment) is an initiative to educate the UK community about stormwater control measures as part of its Municipal Separate Storm Sewer Systems Permit. In this study, water quality was followed by measuring heavy metal and anion concentrations since 2015 from separate sections of the CATchment (inlet and pool) coupled with data loggers which were installed to record daily redox potential in the bank and pool.

Aerial view of the CATchment showing the locations of study

Materials and Methods:

- Anions (nitrate, phosphate, chloride, sulfate) concentrations were determined using ion chromatography.
- Dissolved metal concentrations (copper and zinc) were quantified using graphite furnace atomic absorption spectroscopy.
- Redox potentials (E_h) were recorded daily in the pool and bank using data loggers. pH and EC were measured weekly as well.
- Iron(II) concentration was measured colorimetrically using the ferrozine method and a UV-VIS spectrophotometer at a wavelength of 562 nm.

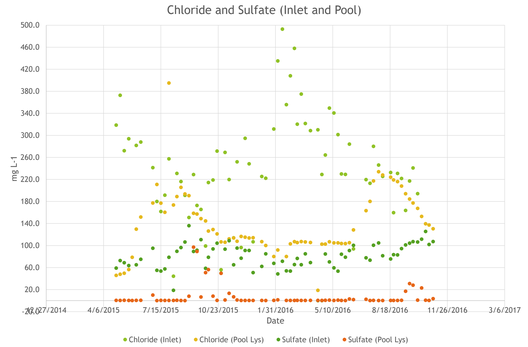
Taking a water sample from the lysimeter

Preparing ferrozine-standard recipe in the glovebox in order to complex Fe^{2+} in the field

Results:

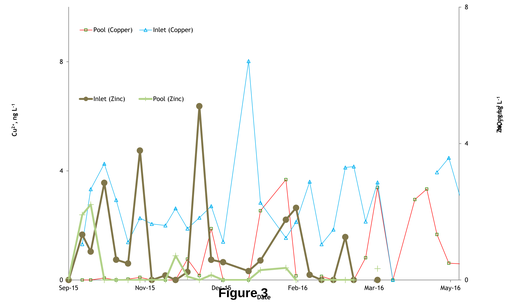
- Dissolved chloride was the most abundant anion in runoff at the inlet followed by sulfate (Fig 1).
- Sulfate levels decreased in porewater at the pool lysimeter when compared to the inlet (Fig. 1, Table 1)

Figure 1



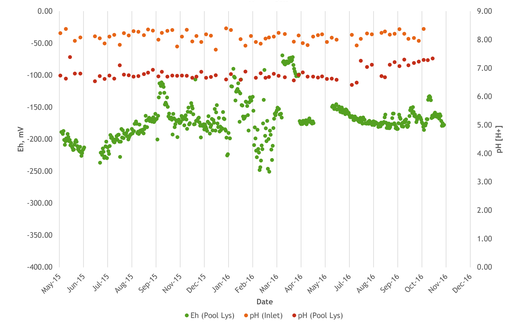
- Dissolved copper and zinc were present in urban runoff at the inlet at ppb levels (Fig. 2) , agreeing with other urban runoff studies[2].

Figure 2



- As stormwater enters the pool, it becomes reduced as shown by the negative redox potentials (Fig. 3)

Figure 3



- There was a concurrent decrease in dissolved copper and zinc at the pool when compared with the inlet (Fig. 2 and Table 1)
- Appearance of high levels of dissolved iron(II) in the pool compared to the inlet confirms reducing conditions (Fig. 4)

Figure 4

Table 1: Mean values from April 28, 2015 to November 1, 2016

Locations	pH	EC	Fe^{2+}	Chloride	SO_4^{2-}	Cu	Zn
		mS cm^{-1}	μM	mg L^{-1}	mg L^{-1}	ng L^{-1}	ng L-1
Inlet	8.1	1.23	5.0	250.6	81.22	4.52	1.29
Pool	6.7	1.63	897.4	139.03	7.42	1.19	0.46

- As heavy metals (Cu and Zn) flow from the inlet into the pool their solubility is reduced.
- One possible fate of the metals, consistent with trends in decreased sulfate, pH, and E_h, is the precipitation of metal-sulfide minerals[3].

Figure 5.

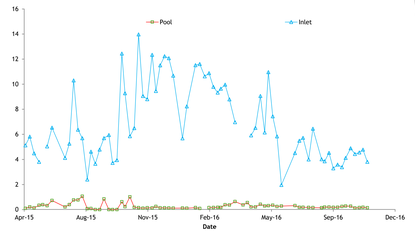


Figure 6.

- Nitrate concentrations were greatest at the inlet, in some cases exceeding 10 mg/L (Fig. 5).
- Nitrate levels decreased in the pool lysimeter (Fig. 5), possibly due to reduction by denitrification in light of the strongly reducing conditions[1] (i.e. low E_h and elevated Fe^{2+}).
- Orthophosphate was consistently low in both the inlet and pool lysimeter (Fig. 6).

Implications and Future Directions:

- Future work will involve measuring sulfide concentrations in porewater along with speciation calculations to predict whether conditions are oversaturated with respect to metal-sulfide precipitation.
- The data from this study complements efforts by Extension faculty in teaching workshops about stormwater best management practices where there is a lack of data in Kentucky on how rain gardens affect water quality.

References:

1. Li, L., Davis, A.P. 2014. Urban stormwater runoff nitrogen composition and fate in bioretention systems. Environmental Science & Technology, 48, 3403-3410.
2. Grout, H., Wiesner, M.R., Bottero, J. 1999. Analysis of colloidal phases in urban stormwater runoff. Environmental Science & Technology, 33, 831-839.
3. Hamilton-Taylor, J., Davison, W., Morfett, K. 1996. The biogeochemical cycling of Zn, Cu, Fe, Mn, and dissolved organic carbon in a seasonally anoxic lake. Limnology and Oceanography 41, 408-418.

Acknowledgements:

This project was funded by a grant from the University of Kentucky Student Sustainability Council. The TFISE and LFUCG provided funding for the construction of the CATchment. We thank Suzette Walling for coordinating efforts at the CATchment.