Potential Impacts of Anthropogenic Impervious Surfaces on Alkalinization in Urban Watersheds

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Abstract

Impervious surface coverage in the conterminous United States has been estimated at over 110,000 km^2, an area the size of Ohio (Elvidge et al., 2004). Anthropogenic impervious surfaces alter hydrologic flow paths and contribute to changing water chemistry. Acidic precipitation and road salt de-icers, common in the northeastern U.S., reach streams through runoff and deposition and interact with the impervious surface materials potentially accelerating their rates of chemical weathering.

A recent trend in alkalinization has been observed in streams of the Baltimore-Washington area despite minimal or no underlying carbonate lithology (Kaushal, 2013). My project investigated the potential for impervious surface materials to serve as sources of dissolved inorganic carbon (DIC), a by-product of chemical weathering, and alkalinization. I completed multiple experiments in which water of different acidity or salinity interacted with asphalt and concrete samples over various time scales. Data on changes to pH and DIC in the water chemistry were collected and analyzed.

Data indicate that salinization alone did not significantly change pH or DIC. However, acidification, and even water-surface interactions, alkalinized the water and increased DIC concentrations, especially in experiments with concrete. Stream biota and ecosystems are extremely sensitive to changes in DIC and alkalinity. The potential for weathered surface materials to alter stream chemistry should be considered in urban watershed management as degrading infrastructure is replaced or rehabilitated.

Hypotheses

- ***Increased salinization significantly increases the weathering of dissolved inorganic carbon from impervious surface materials and increases pH in urban surface waters.***
- ***Increased acidification significantly increases the weathering of dissolved inorganic carbon from impervious surface materials and increases pH in urban surface waters.***

Salinization and Acidification Experiments

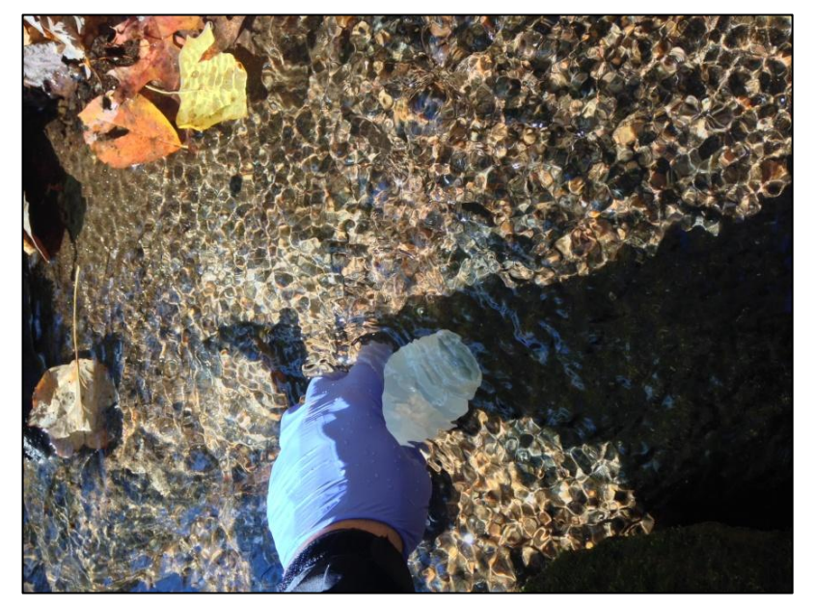
Stream water from the forested Pond Branch watershed was used as the experimental water for all treatments. Stream pH varied seasonally from 6.8-7.2.

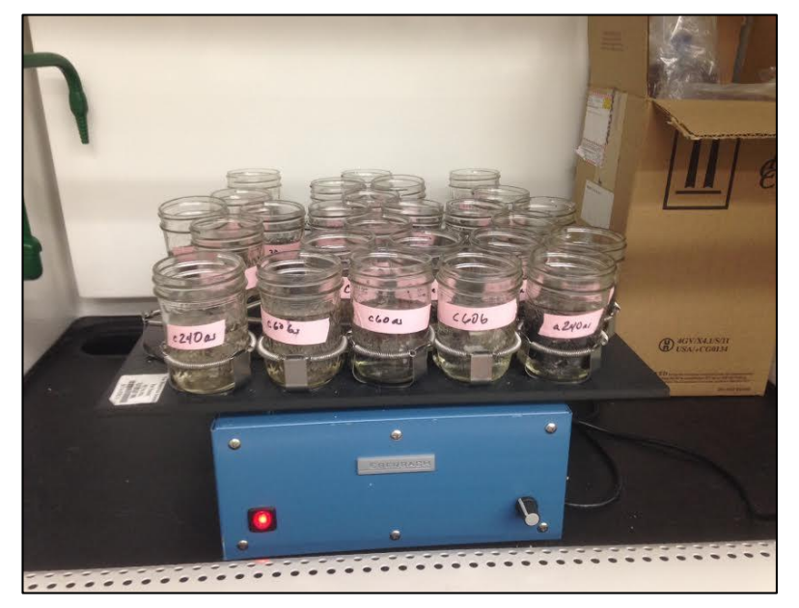
Salinization

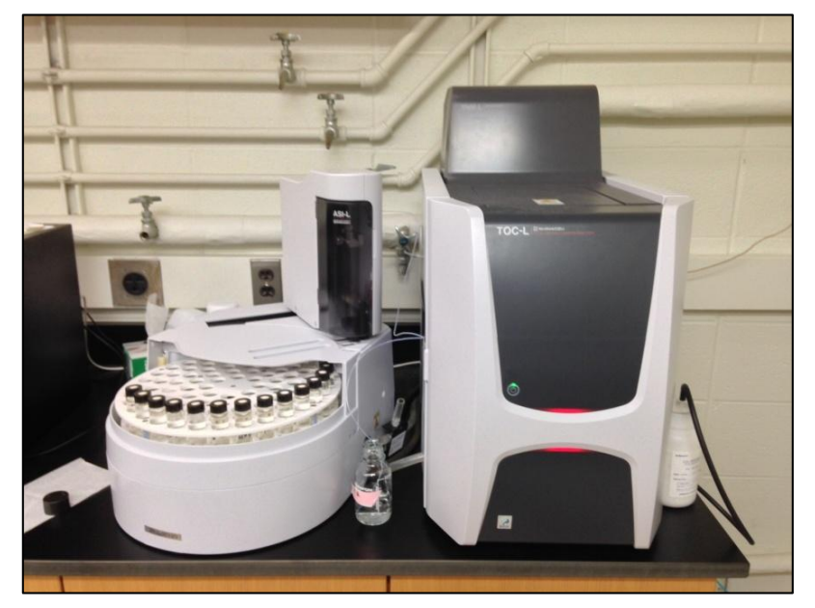
- Surface materials and water with no salt addition or 100 mg/L NaCl.
- Interaction periods at the hour scale, minute scale and sub-minute scale
- pH readings recorded, water filtered and analyzed for DIC concentration

Acidification

- Surface materials and water at starting pH 6.86 , pH 4.5, or pH 3
- Interactions at intervals of 30, 60 and 180 seconds.
- pH readings recorded, water filtered and analyzed for DIC concentration



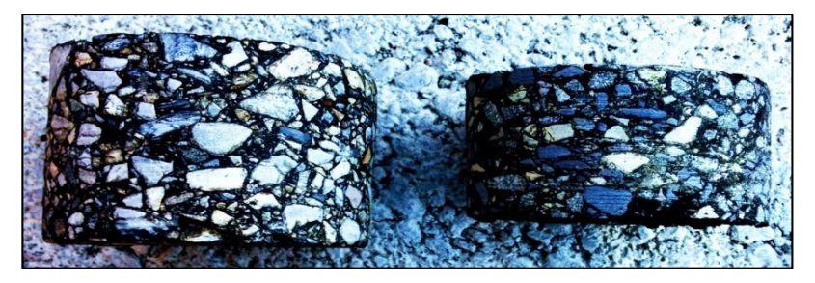




Anthropogenic Impervious Surface Materials

Concrete bridge deck core: cement ($CaCO_3$) filler surrounding mixed aggregate, commonly non-pyritic silicates resistant to polish.

Asphalt pavement: petroleum-based carbon filler surrounding similar mixed aggregate, sometimes sealed with a coal-tar based sealcoat.



Results

Salinization did not significantly increase alkalinization or concentrations of DIC.

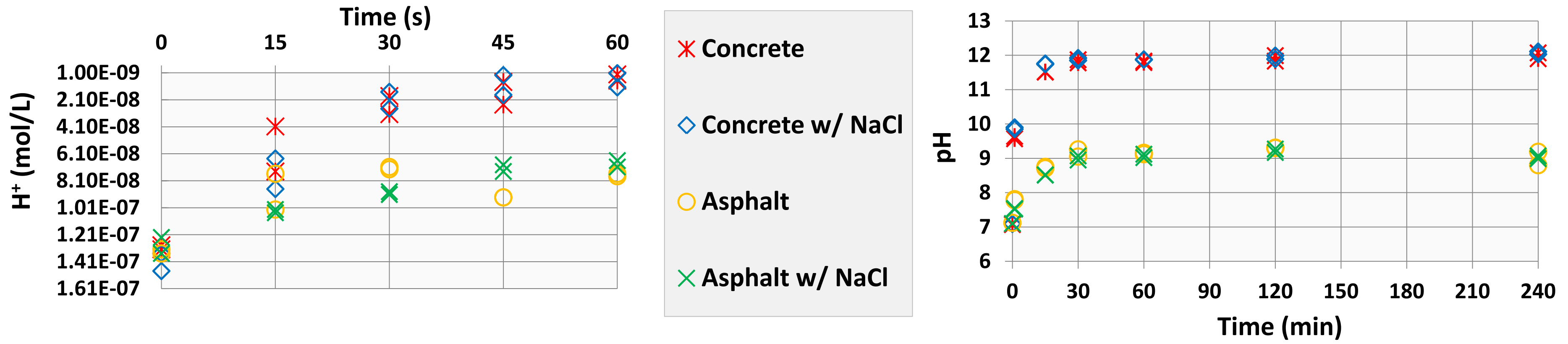


Figure 1: Alkalinization occurred in all water samples over sub-minute (left) and minute to hour (right) timescales. Variation in alkalinity was attributed to length of interaction time and/or surface material type rather than a salt addition.

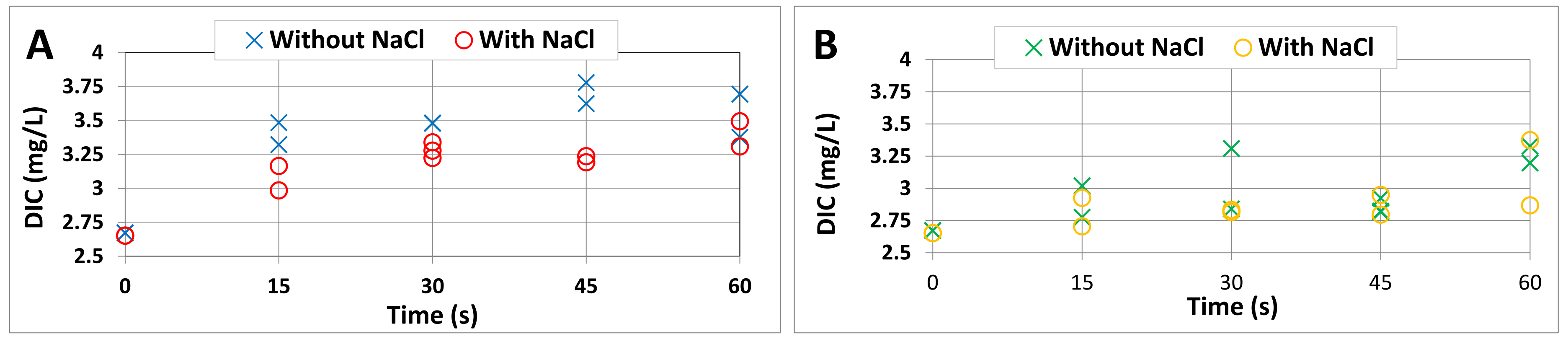


Figure 2: DIC concentrations increased significantly in concrete-water interactions (2A) relative to asphalt-water interactions (2B) but salinization did not have a noticeable effect.

Acidification, material type, and simple water-surface interactions are significant factors in alkalinization and increased DIC concentrations.

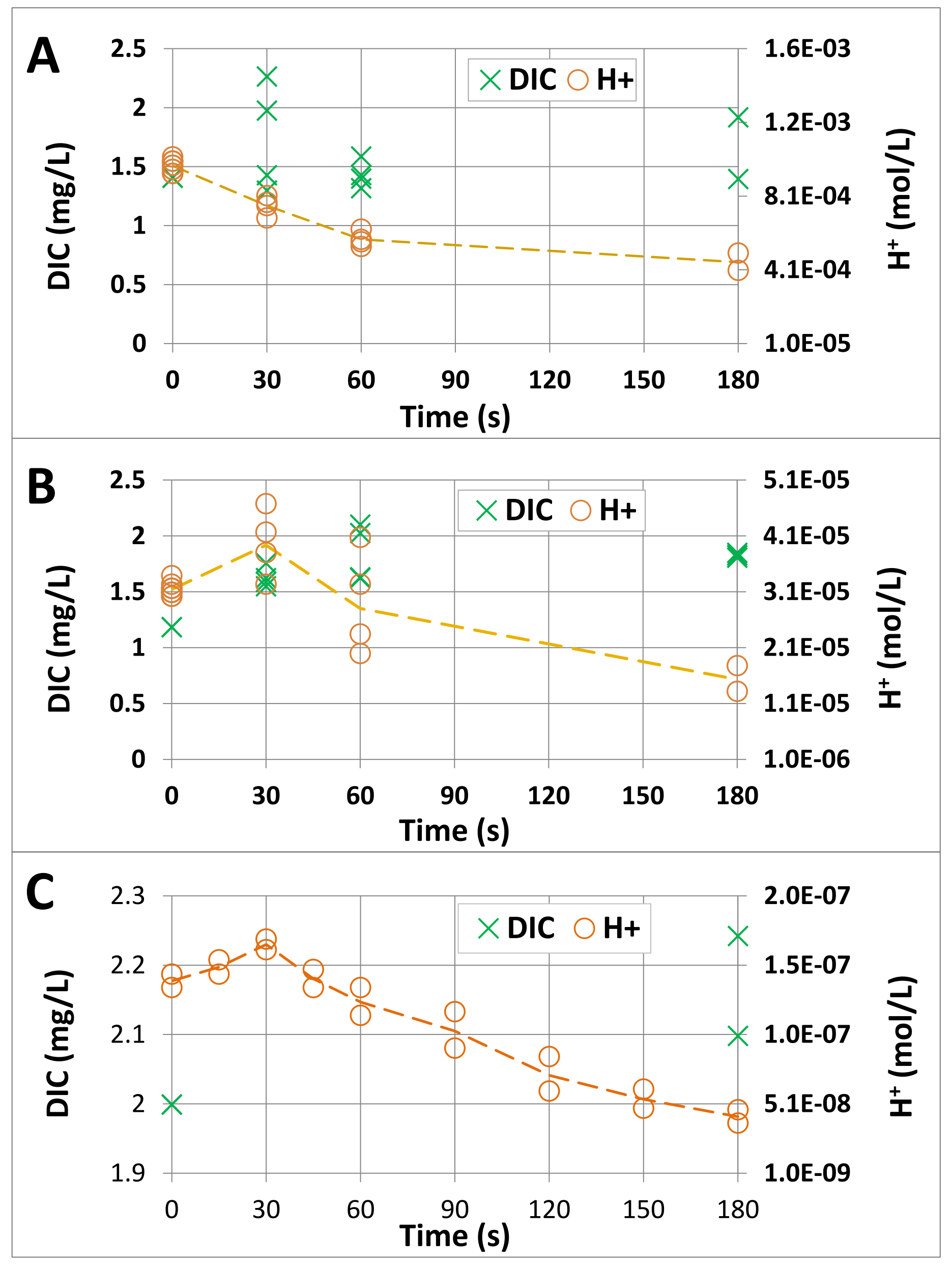


Figure 3: Asphalt-water interaction at (A) pH3, (B) pH 4.5, (C) pH 6.86. Dotted orange lines are drawn through mean H$^+$ concentrations at each time interval and do not represent trend lines.

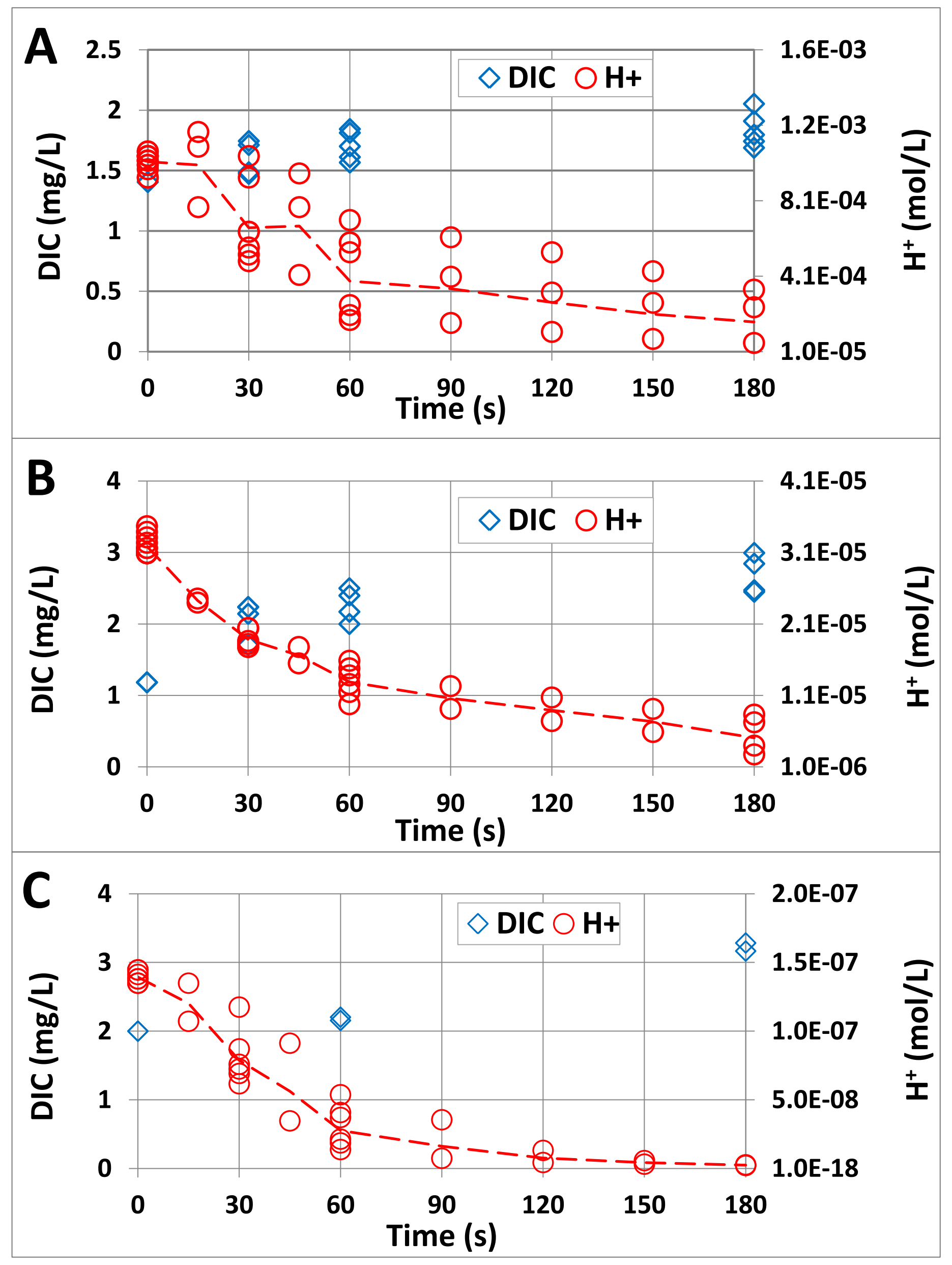


Figure 4: Concrete-water interaction at (A) pH3, (B) pH 4.5, (C) pH 6.86 . Dotted red lines are drawn through mean H$^+$ concentrations at each time interval and do not represent trend lines.

Discussion

Although salinization did not impact pH and DIC concentrations in these experiments, it can play a role in mechanically weathering infrastructure through efflorescence (recrystallization) as it infiltrates cracks and pore spaces in surface material.
Filler materials in impervious surfaces are subject to weathering, as are the aggregate minerals that interact with water, contributing to total alkalinity.

$CaCO_{3(s)} + H_2CO_3 \longrightarrow Ca^{2+} + 2HCO_3^-$ *(Most susceptible to weathering)*
calcite

$Na_0 \cdot 5Ca_0 \cdot 5Al_1 \cdot 5Si_2 \cdot 5O_8 + 9H^+ + 7H_20 \longrightarrow 3AlOH^{2+} + 5H_4SiO_4 + Na^+ + Ca^{2+}$
plagioclase feldspar

$Si0_{2(s)} + 2H_20 \longrightarrow H_4Si0_4$ *(Least susceptible to weathering)*
quartz

Figure 5: Adapted from Schnoor and Stumm (1986), lithological weathering reactions and potential for generation of alkalinity.

Concrete surfaces were much more susceptible to chemical weathering from acidic water, as anticipated due to cement filler material that is partially comprised of calcium carbonate. Over increasing time periods, pH levels and concentrations of DIC continued to rise as the buffering capacity of the solution is impacted (Figure 6). This offers a potential explanation for alkalinization in urban watersheds that do not have a natural carbonate lithology. To a lesser extent, the asphalt surfaces also contributed to alkalinization and increased DIC, but the chemical composition of asphalt filler material would not experience the same interaction. Either reactions with the aggregate or some depositional material on the samples may account for changes to DIC in asphalt-water interactions.

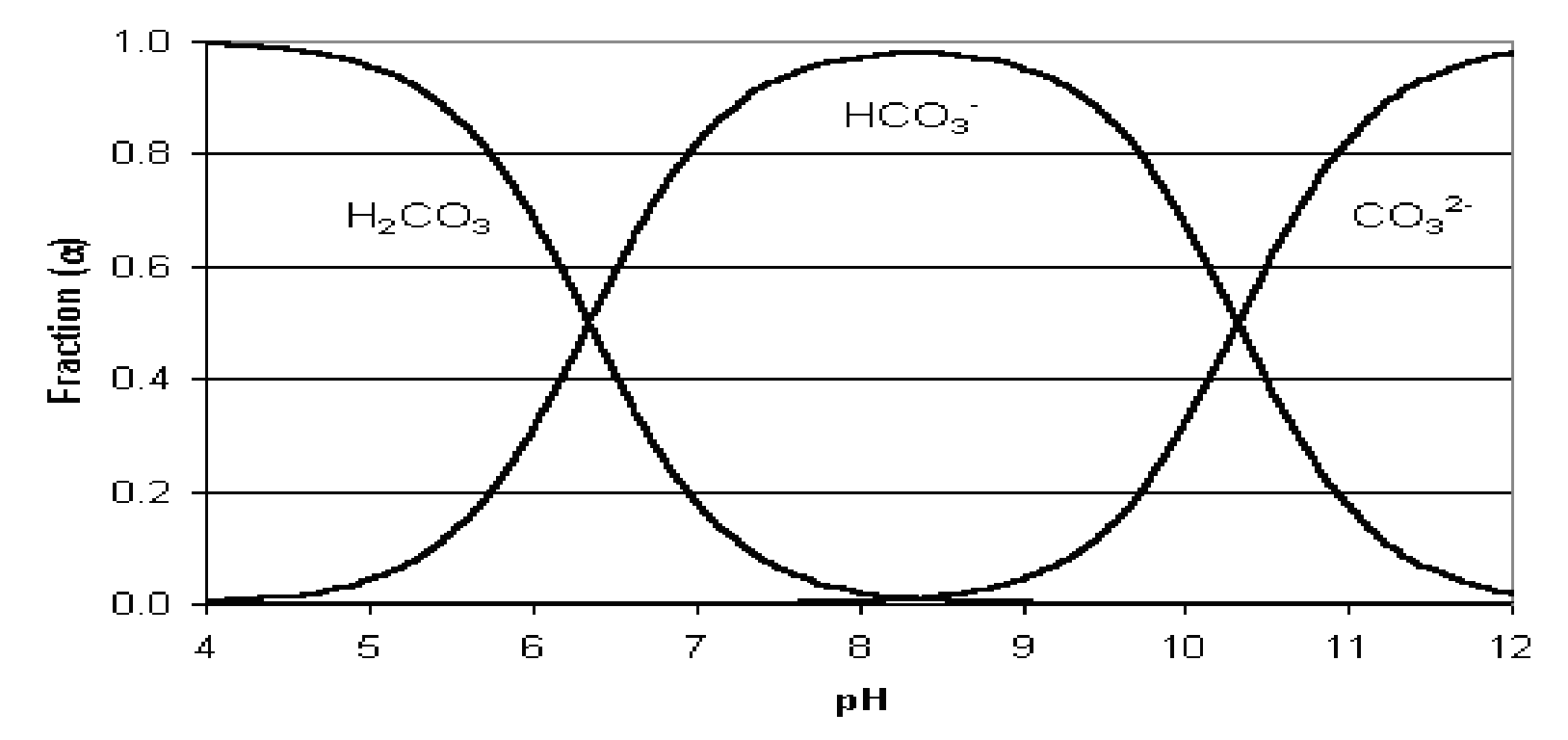


Figure 6: Bicarbonate buffering system

Conclusions and Broader Implications

- Anthropogenic impervious surface materials are potential sources of alkalinization in urban watersheds and should be considered a factor influencing urban water quality.
- Salinization did not contribute to changes in pH and DIC, but application of de-icers should be managed due to its role in elevated chloride levels in urban watersheds.
- Quantifying contributions of anthropogenic impervious surface materials to stream and river alkalinization, based on surface type and area, may be useful in modeling fluxes of inorganic carbon at the watershed scale.

References

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Kaushal, SS *et al.*, 2013. Increased river alkalinization in the eastern US. *Env. Sci. and Tech.* 47(18): 10302-10311.
Schnoor, JL and Stumm, W, 1986. The role of chemical weathering in the neutralization of acidic deposition. *Schweiz. Z. Hydrol.* 48(2): 171-195.
All photos taken by Tom Doody.

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