Mobilization of Phosphorus from River Sediments in the Chesapeake Bay Watershed

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Introduction

Chesapeake Bay is the largest estuary in the United States. The cause and extent of eutrophication in the Chesapeake Bay has been the focus of much research (Boesch et al. 2001; Kemp et al. 2005). Because of the low stoichiometric need of Phosphorus (P) among other major nutrients (106C: 16N: 1P; Redfield et al. 1958), small amounts of P addition could cause severe impacts on water quality in the receiving catchments or groundwater aquifers and could promote eutrophication.

Figure 1: Phytoplankton growth and fish kills due to eutrophication

In river waters, P exists in dissolved, colloidal and particulate phases and both in inorganic and organic forms. When river water reaches estuaries, much of the sediment P may be released due to fluctuation in physico-chemical parameters such as redox potential, pH, temperature (Kim et al., 2003), salinity (Jordan et al., 2008) and biological activity (Hupfer et al., 1995). A detailed understanding of different P phases in the water column and in sediments, different mechanisms that promote the release of P from sediments, and the environmental factors that change the bioavailability of P are required to fully understand the extent to which P can be mobilized and transported to the Chesapeake Bay.

Study Area

Paul Creek, Patuxent, and Nanticoke Rivers in the Chesapeake Bay Watershed

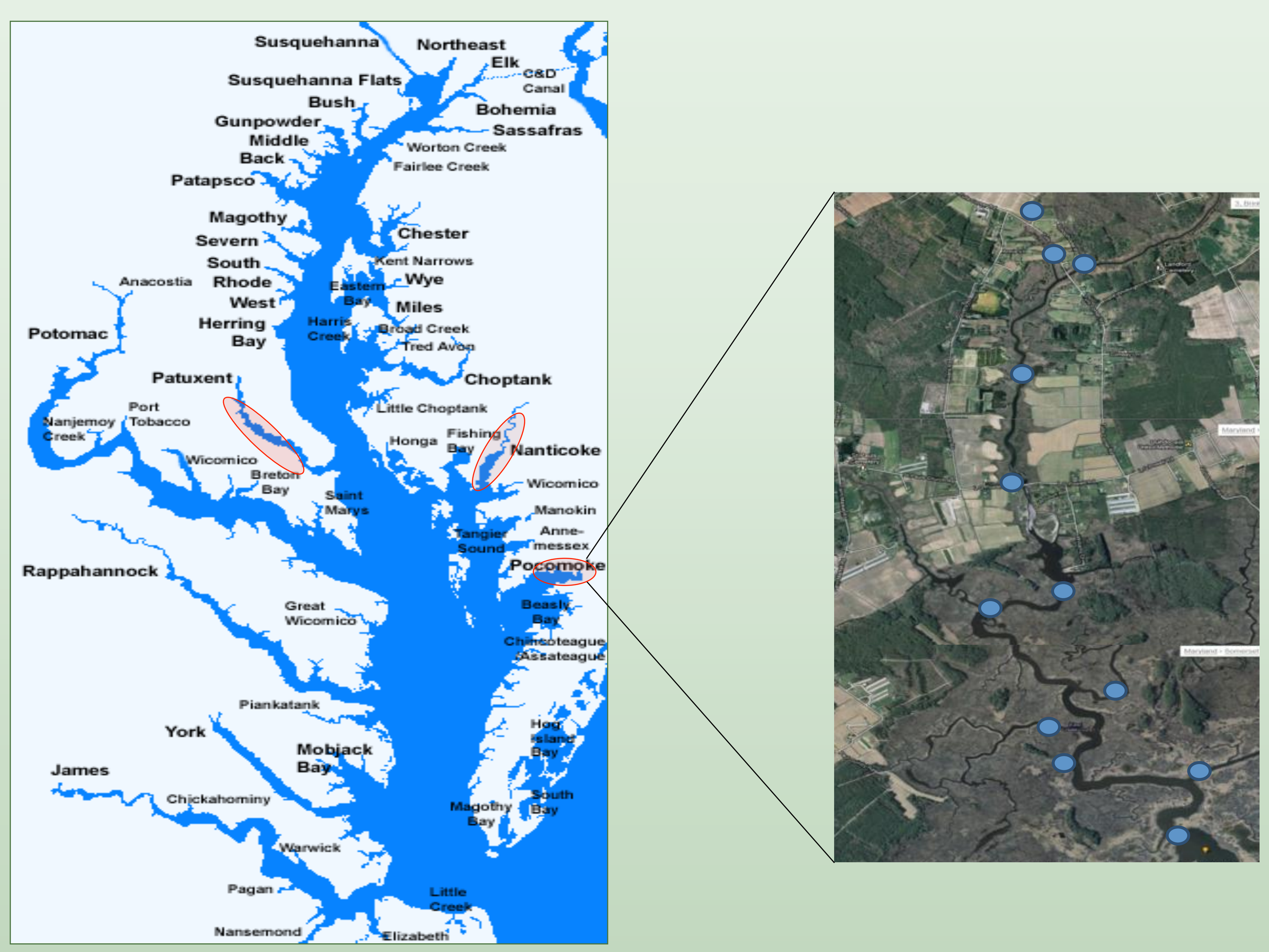

Figure 2: a) Study area showing three rivers, highlighted in the Chesapeake Bay watershed, b) A major section of Paul Creek showing water and sediment sampling sites.

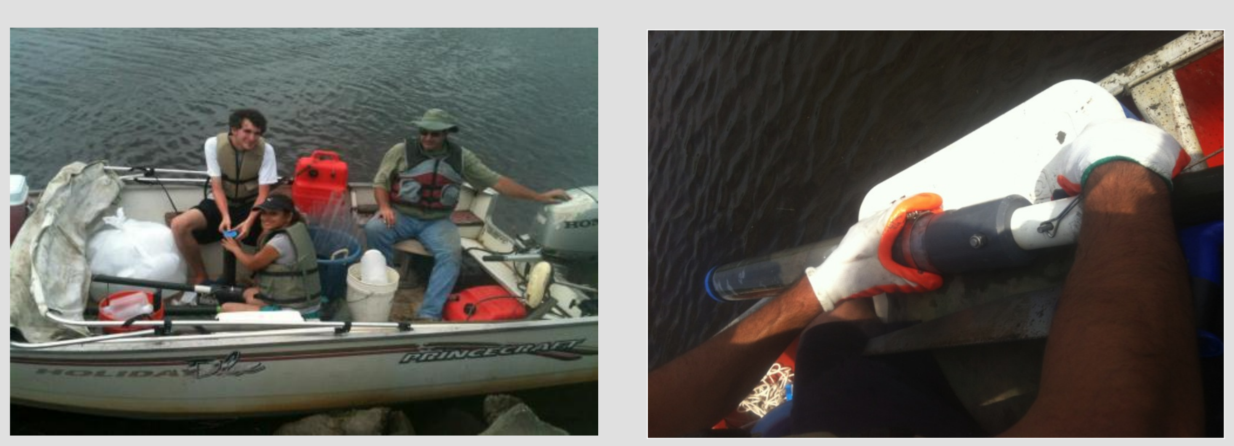

Figure 3: Sample collection in Paul Creek, Chesapeake Bay

Result and Discussion

Particulate phosphorus in water column

Different size fractions of suspended sediment in the water column (0.02, 0.05, 0.1, and 0.4 µm) were separated using Stoke's law of settling. The concentration of inorganic P was measured by colorimetric method and total P was measured by ICP.

Phosphorus concentration in a site closer to the agricultural field was highest. This is most likely due to fertilizer and poultry manure input. However, the concentration decreased at the lower reaches of the creek (Fig. 4) due to the retention of P in river sediments.

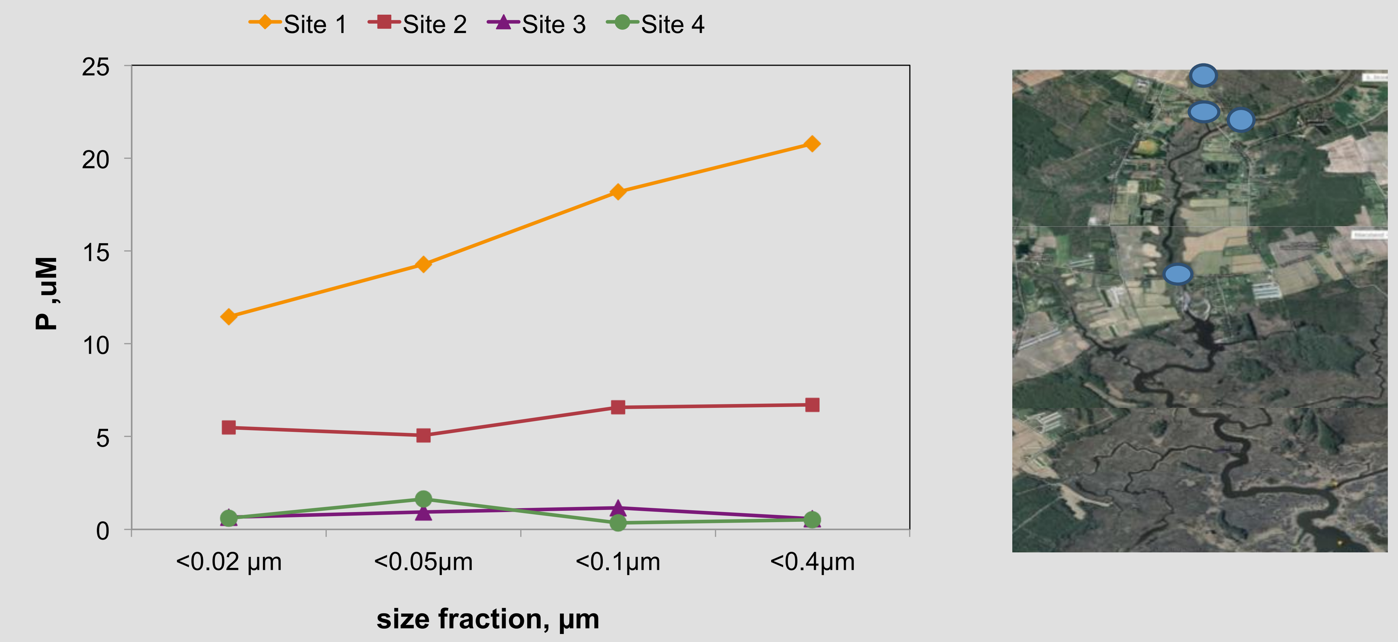

Figure 4: P concentration in different size fractions of suspended sediments in Paul Creek water .

Effect of physico-chemical and biological processes on P release from river sediments

The study analyzed the effect of site relevant fluctuations in physico-chemical parameters (pH, salinity, temperature, and Eh.) and biological activities (sediment incubation with and without spiked *Shewanella putrefaciens* CN32, a facultative anaerobe) on P mobilization.

P released from Paul Creek and Nanticoke River sediments showed a steady increase in P with the increase in salinity, pH and enhanced bacterial activities. Increase in pH can cause increase in net negative charge to PO_4 and sediments thus promotes P release from sediments.

Consumption of dissolved oxygen by CN32 led to more reducing conditions that resulted in the reductive dissolution of Fe(III) oxides and thus release of iron oxide bound P. However, Fe(II) concentration did not change significantly in the Nanticoke River sediments, but it released high P. Therefore, it is likely that the increase in P might also be due to the bacterial uptake and release of sediment bound P.

(a) (b) (c)

Figure 5: Experimental set up a) pH experiment, b) redox experiment inside glove box, and c) a sediment core from Paul Creek.

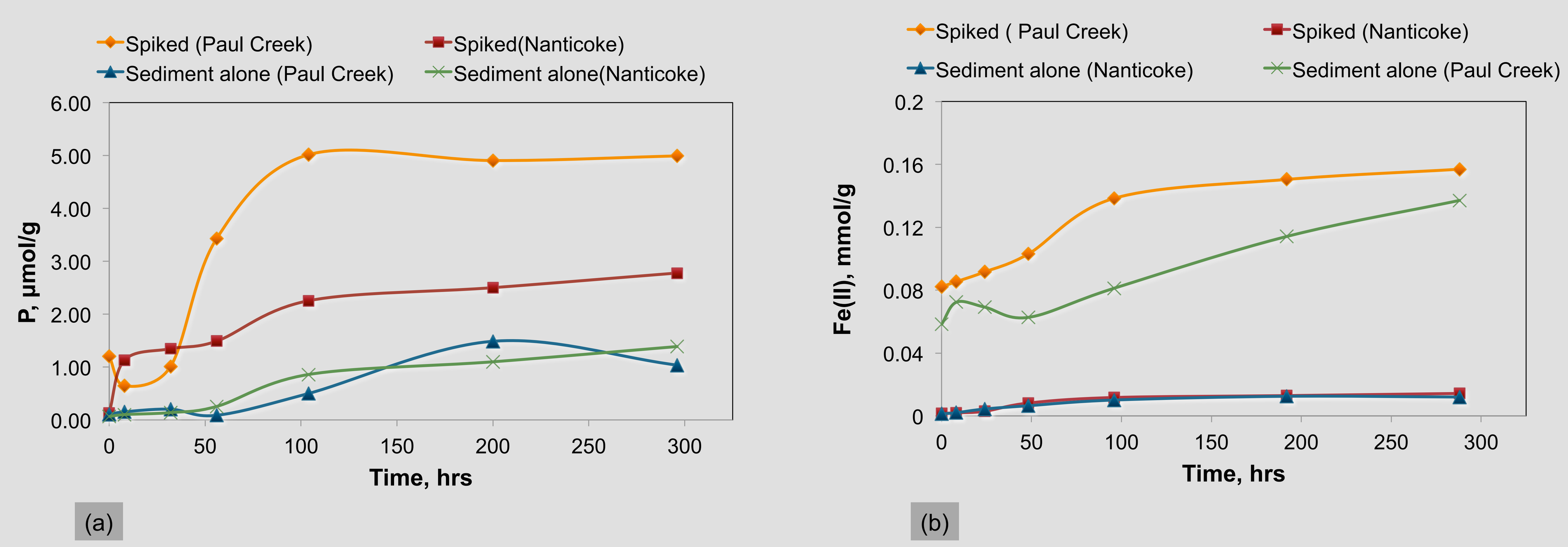

Figure 6: a) P release, and b) Fe(II) concentration due to sediment incubation with and without spiked bacteria (Shewanella putrefaciens CN32) in Paul Creek and Nanticoke River sediments.

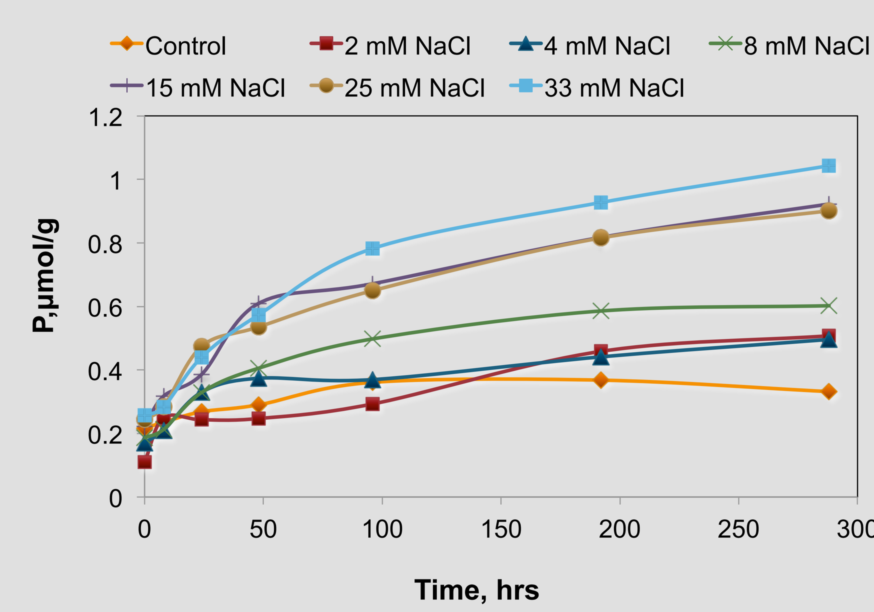

Figure 7: Effect of salinity on P release from Nanticoke River sediments.

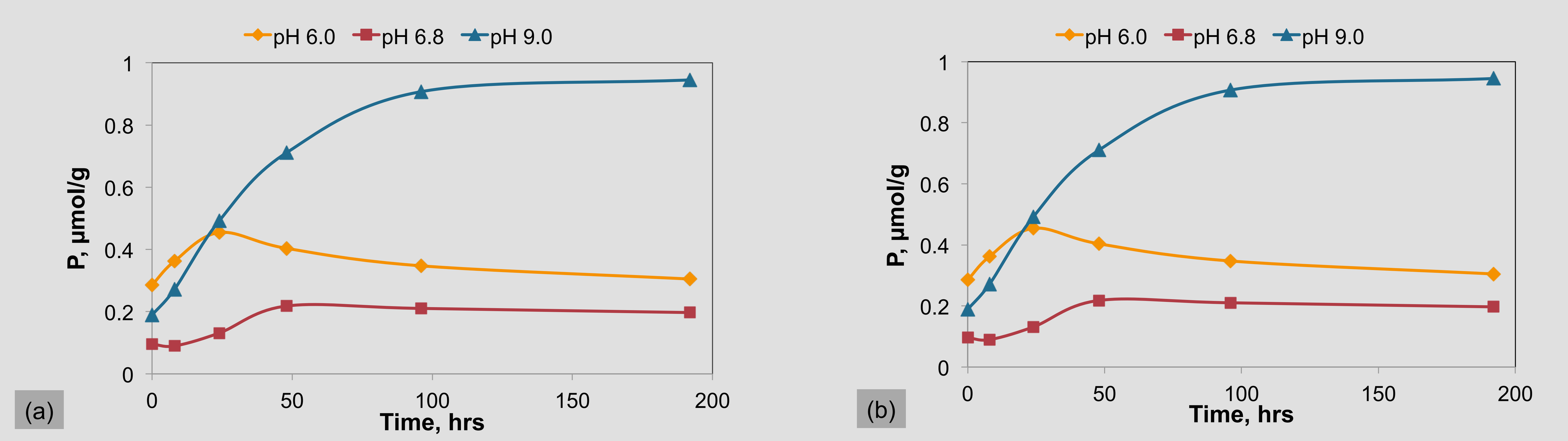

Figure 8: P release and retention due to changes in pH in a) Nanticoke, and b) Paul Creek sediments.

Conclusion and Implication

Our study shows that the P released from river sediments is positively correlated with the increase in salinity, pH, and enhanced biological activity. It suggests that the site relevant fluctuations of these parameters may promote remobilization of P from sediments and transported to the Chesapeake Bay.

These findings are expected to help quantify P mobilization potential in river sediments. It also provides an opportunity to manipulate natural environments to limit P mobilization or adjust appropriate strategies to limit P release to the bay.

References

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