The Biogeochemistry of Wetland Soils Derived From Fine-Grained Estuarine Sediments

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Initial Questions Regarding Wetland Establishment

- Would low pH from pyrite oxidation present a challenge to fertility?
- Would nutrient amendments be necessary to promote a viable wetland ecosystem?
- What other biogeochemical impediments to wetland success might occur?
- How long before “normal” wetland microbiological processes (i.e. denitrification) would occur?
Channel Characteristics

- Most are fine-grained, rich in iron oxides and iron sulfides
- Sediments are mostly derived from the Susquehanna River and from shoreline erosion
- Because of rapid burial rates, pore water ammonium accumulates rather than diffusing into overlying water
- High pore water iron coincided with moderate phosphate concentrations, with higher pore water sulfide concentrations in more southerly deposits
Material Placement

- Dredging utilizes clamshell dredges.
- After transport by barge, the material is slurried and pumped into confined material cells.
- As the material settles, it consolidates, the overlying water is pumped “overboard” and the material dries.
Why Would pH Be A Problem?

Iron sulfides, including pyrite, form in Chesapeake Bay sediments when sulfide produced by sulfate-reducing bacteria interacts with iron oxide minerals which are abundant in the bay.

Upon exposure to oxygen during drying and “crust management”, low pH arises because of pyrite oxidation:

$$4\text{FeS}_2 + 15\text{O}_2 + 8\text{H}_2\text{O} \rightarrow 2\text{Fe}_2\text{O}_3 + 8\text{H}_2\text{SO}_4$$
During crust management, sulfuric acid is produced as iron sulfide minerals are oxidized.
Methods and Measurements

• Sediment chemical parameters were measured at the outset of wetland cell development and at (many) intervals thereafter.
• Pore water chemistry, using equilibrators, consisted of pH, ammonium, soluble reactive phosphorus, iron, silica, chloride and sulfate.
• Solid phase chemistry included grain size, water content, percent organic matter, organic carbon, nitrogen, total and inorganic phosphorus, iron, and chromium reducible sulfur.
• Intact cores were used for sediment-water exchange rates of ammonium, nitrate, soluble reactive phosphorus, oxygen and N₂.
Some initial pH’s were low, but generally above 5.5.

pH’s increased over time, presumably because of the longer period of inundation, exchange with tidal waters, and production of alkalinity with sulfate reduction.
Over a decade, significant increases in CRS, a measure of pyrite sulfur, and both carbon and nitrogen were observed.
Pore Water N and P

These represent the initial conditions at the time of planting and the time is the age of the soil after the last inflow.
The concentration of ammonium decreased over time due to plant uptake, exchange with overlying water.

Soluble reactive phosphate in pore water tended to increase due to loss of iron oxide adsorbing capacity as oxides were converted to sulfides.
Denitrification – N$_2$/Ar Time Course

- Denitrification rates in intact cores were similar in cell of different ages and was not lower the first year of cell development.
- Rates were generally higher than in other Chesapeake mid-bay sediments.
Microalgal Photosynthesis

- Benthic photosynthesis by microalgae was observed as soon as cells were flooded.
- Rates were generally high and suggested that such production could be 10% of *Spartina alterniflora* production.
Conclusions

- The initial concerns at the outset of the project - low fertility because of low pH and low nutrient concentrations – were shown to not be important.
- With time, both organic matter and pyrite sulfur build into the wetland sediments, more closely resembling tidal marshes in the region.
- Fine grained sediments from upper Chesapeake Bay navigation channels to not appear to have characteristics that hinder plant establishment.