Nutrient Removal/Criteria Development Panel Discussion

Wei Lin

North Dakota State University

North Dakota Water & Pollution Control Conference
83rd Annual Conference
October 11-13, 2011 Bismarck, ND

Nutrients: N and P

- Nitrogen (N)

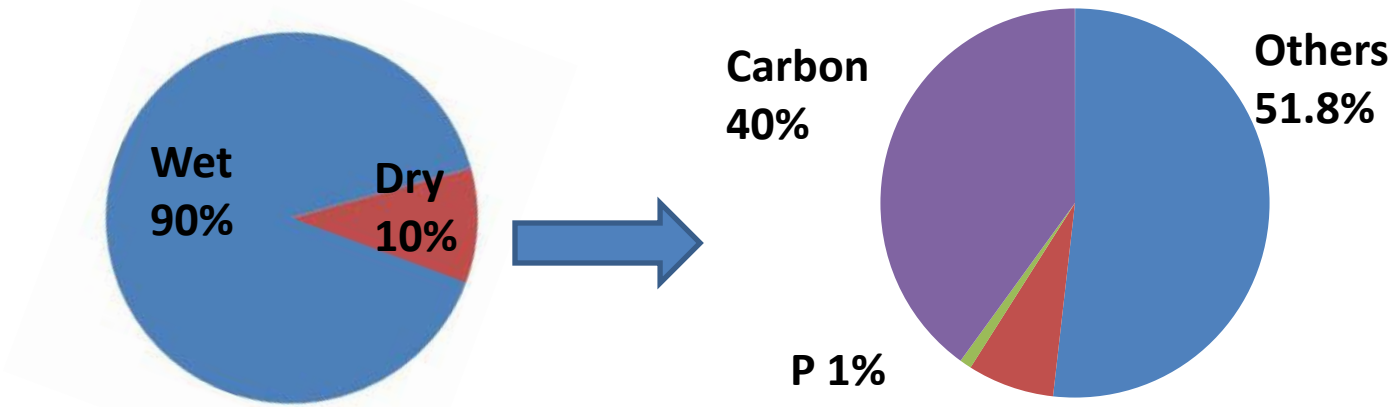
  Organic-N (NH_2), NH_3-N (NH_4^+-N), NO_2^--N, NO_3^-N

- Phosphorous (P)

  Organic-P, PO_4^{3-}-P, Poly phosphate

  Dissolve and particulate

- N and P are the major nutrients for algal growth in rivers and lakes



Percent of nutrients in phytoplankton biomass

Nitrogen species and their reactions

- Ammonia (NH_3) and Ammonium (NH_4^+)

$$NH_3 + H_2O \Leftrightarrow NH_4^+ + OH^-$$

NH_3 is toxic to fish and volatile

Higher percentage of NH_3 at high pH

- Nitrification – biological oxidation of NH_4^+

$$NH_4^+ + 1.5O_2 \xrightarrow{\text{Nitrosomonas}} NO_2^- + 2H^+ + H_2O$$

$$NO_2^- + 0.5O_2 \xrightarrow{\text{Nitrobacter}} NO_3^-$$

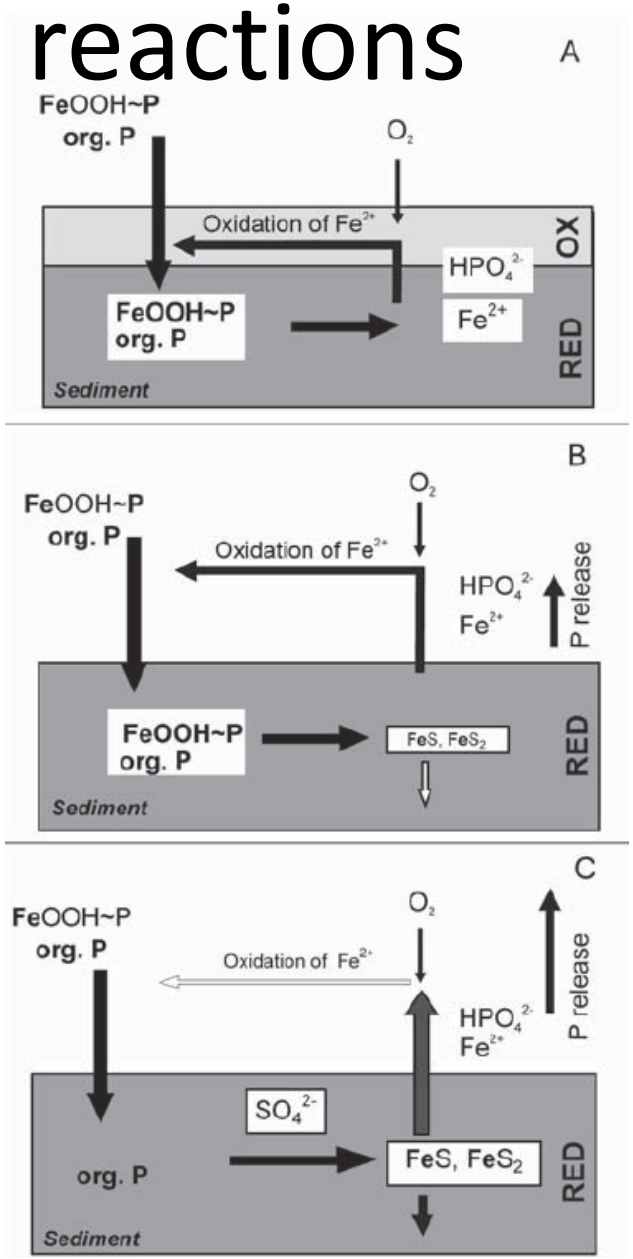
- Denitrification – an anaerobic biological process to reduce NO_3^- to nitrogen gas

$$6NO_3^- + 2CH_3OH \rightarrow 6NO_2^- + 2CO_2 + 4H_2O$$

$$6NO_2^- + 3CH_3OH \rightarrow 3N_2 + 3CO_2 + 6OH^-$$

Phosphorous and its reactions

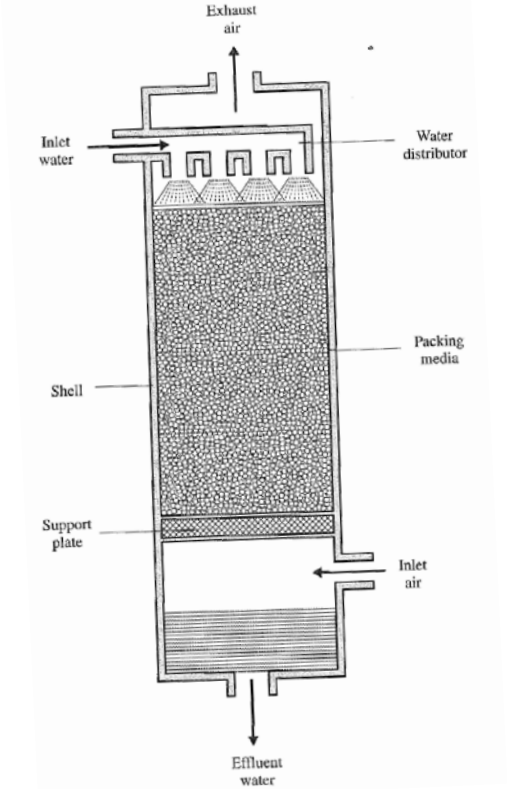
- P is not abundant, and it is not very soluble
- It does not exist in a gaseous form
- It tends to sorb strongly to sediments

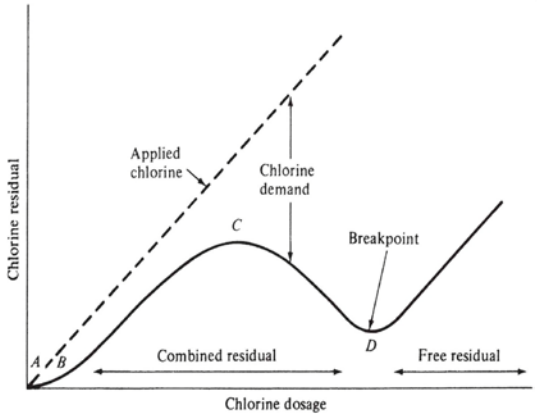


Nitrogen Removal – Chemical Processes

- Air stripping of ammonia
  - Increase pH to 11 with lime [$Ca(OH)_2$]
  - Strip NH_3 with enough air flow in packed media tower
- Breakpoint chlorination of ammonia
  - Sufficient amount of Cl_2 to oxidize ammonia nitrogen to nitrogen gas

    $2NH_3 + 3HOCl \rightarrow N_2 + 3H_2O + 3HCl$
- Iron exchange
- Reverse Osmoses



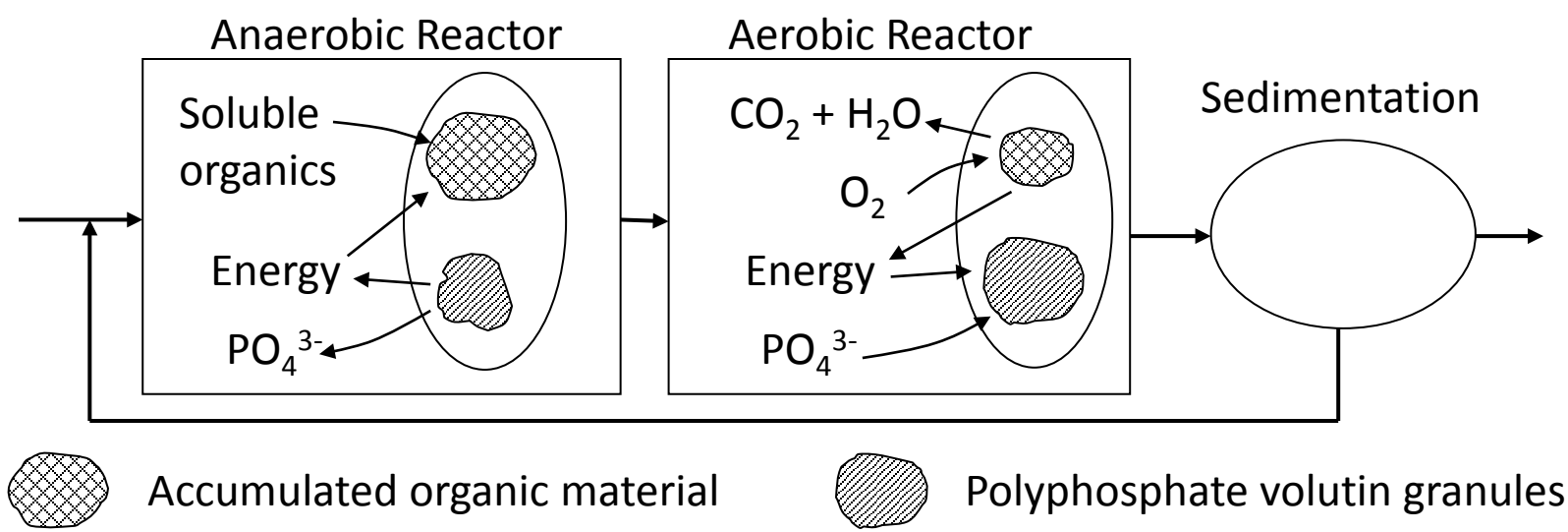


Nitrogen Removal-Biological

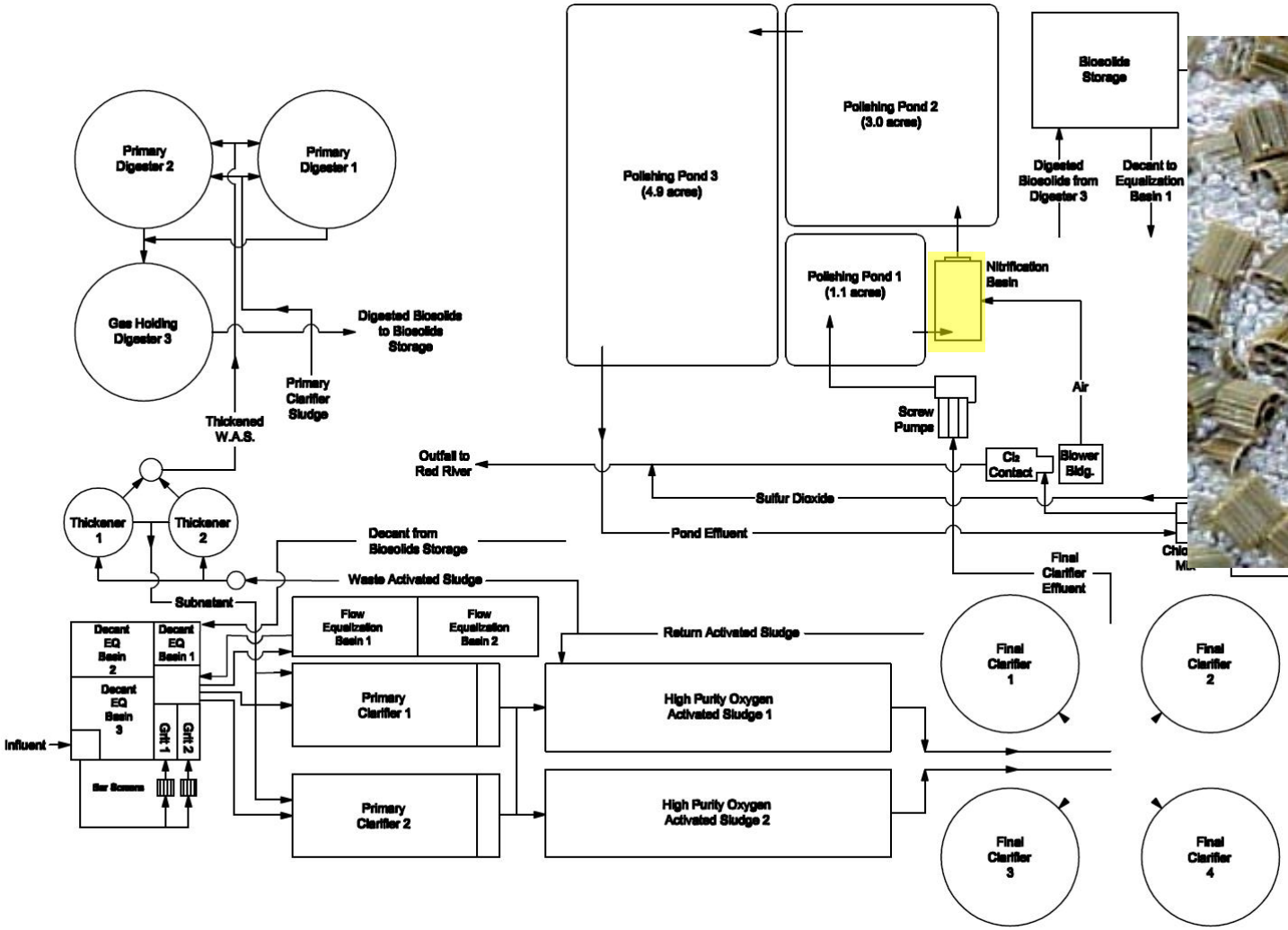
- Nitrification: converting NH_4^+-N to NO_3^--N
  - Combined BOD removal and nitrification
  - Separate-stage nitrification
  - Suspended processes
  - Attached growth processes
- Denitrification: converting NO_3^--N to N_2
  - Separate systems with external carbon sources
  - Combined carbon oxidation nitrification-denitrification.

Phosphorous Removal

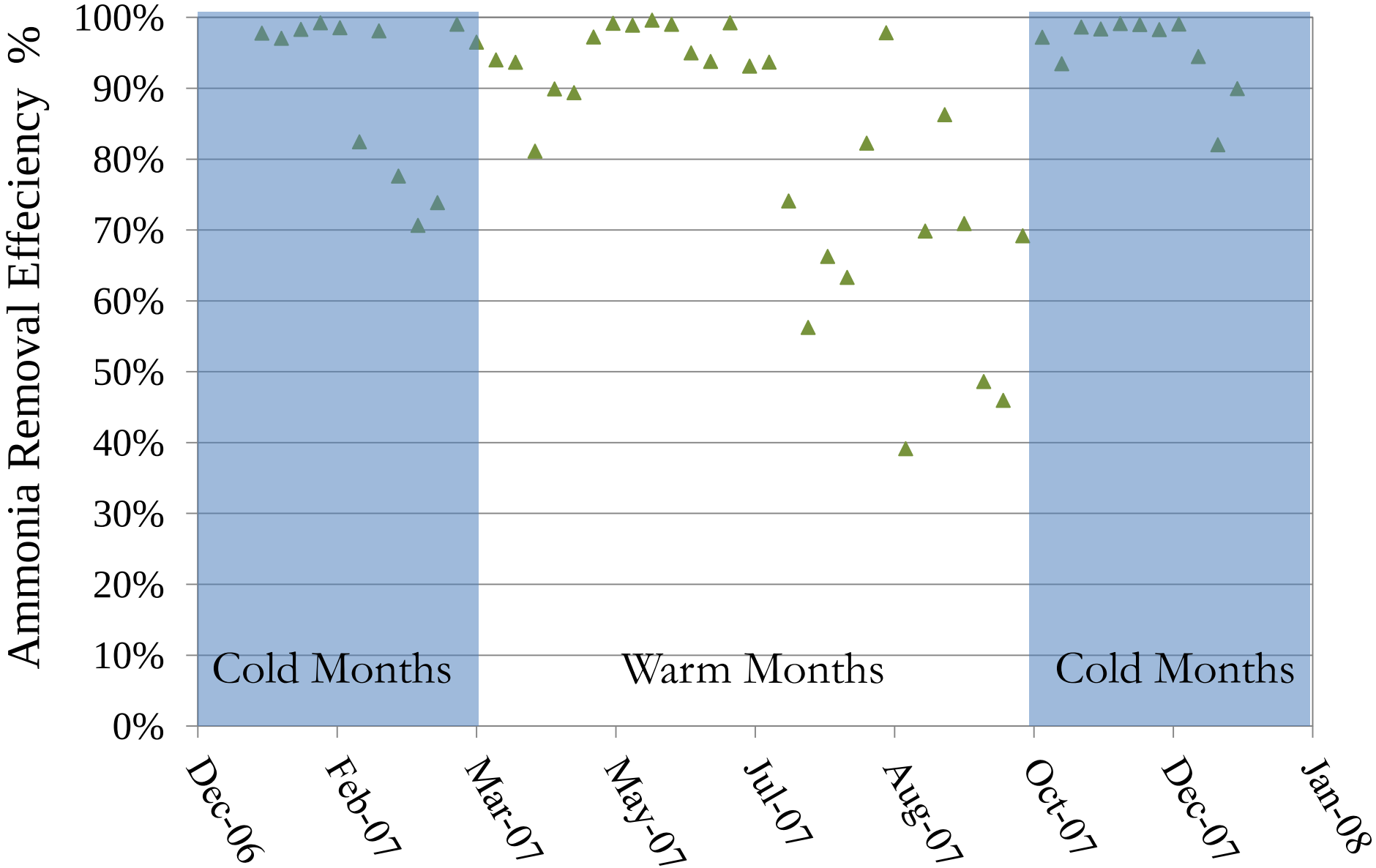
- Chemical precipitation
  - Reaction of phosphate with metal ions to form precipitates
  - Commonly used: lime, ferric salts, or aluminum salts
  - The process is temperature and pH dependent
- Biological
  - Removal by phosphate accumulating organisms



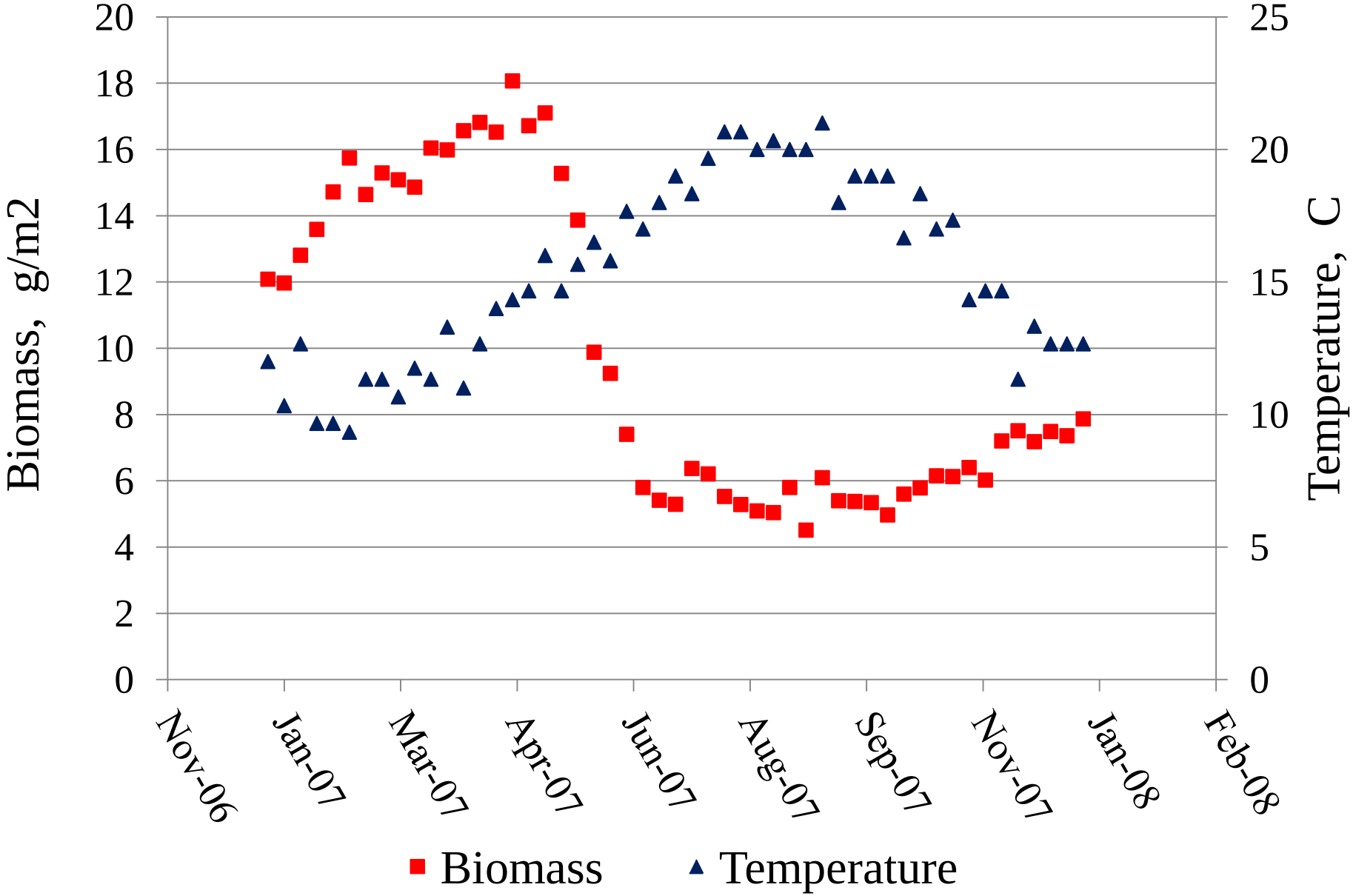
Impact of Temperature on Nitrification in Moorhead MBBR Reactor



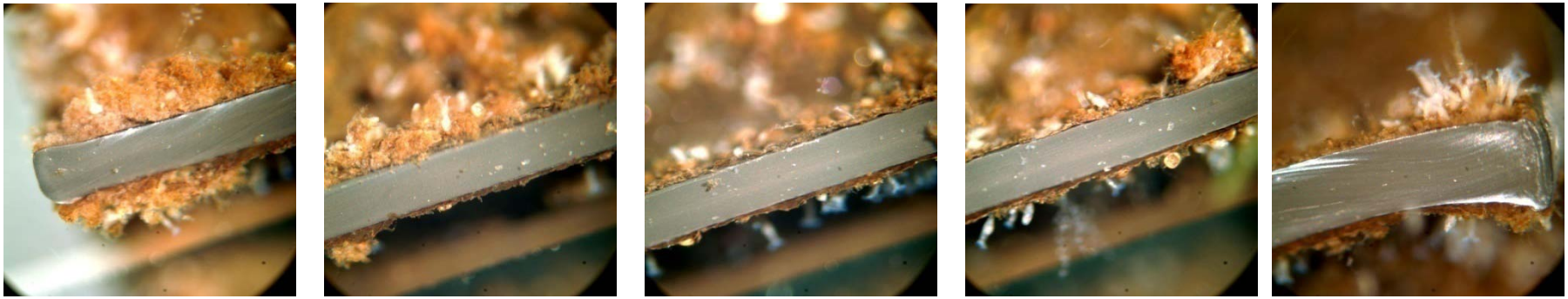
MBBR Removal Efficiency 2007

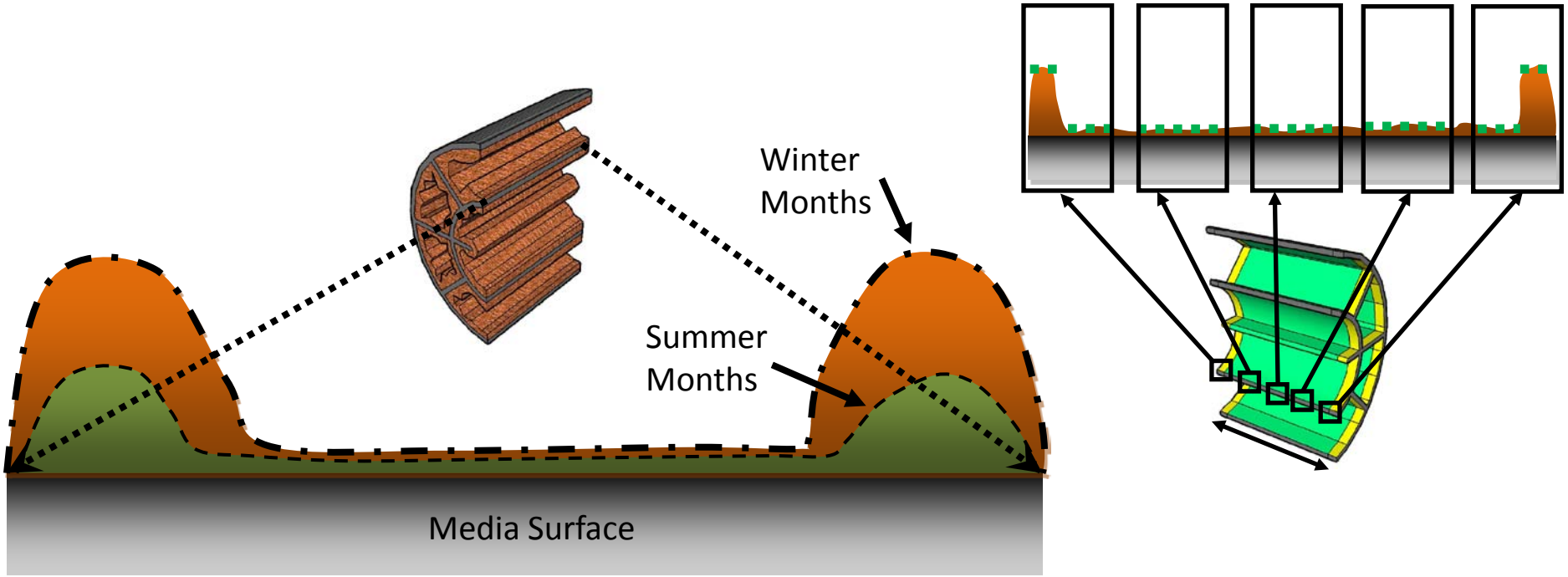


Biomass and Temperature in 2007



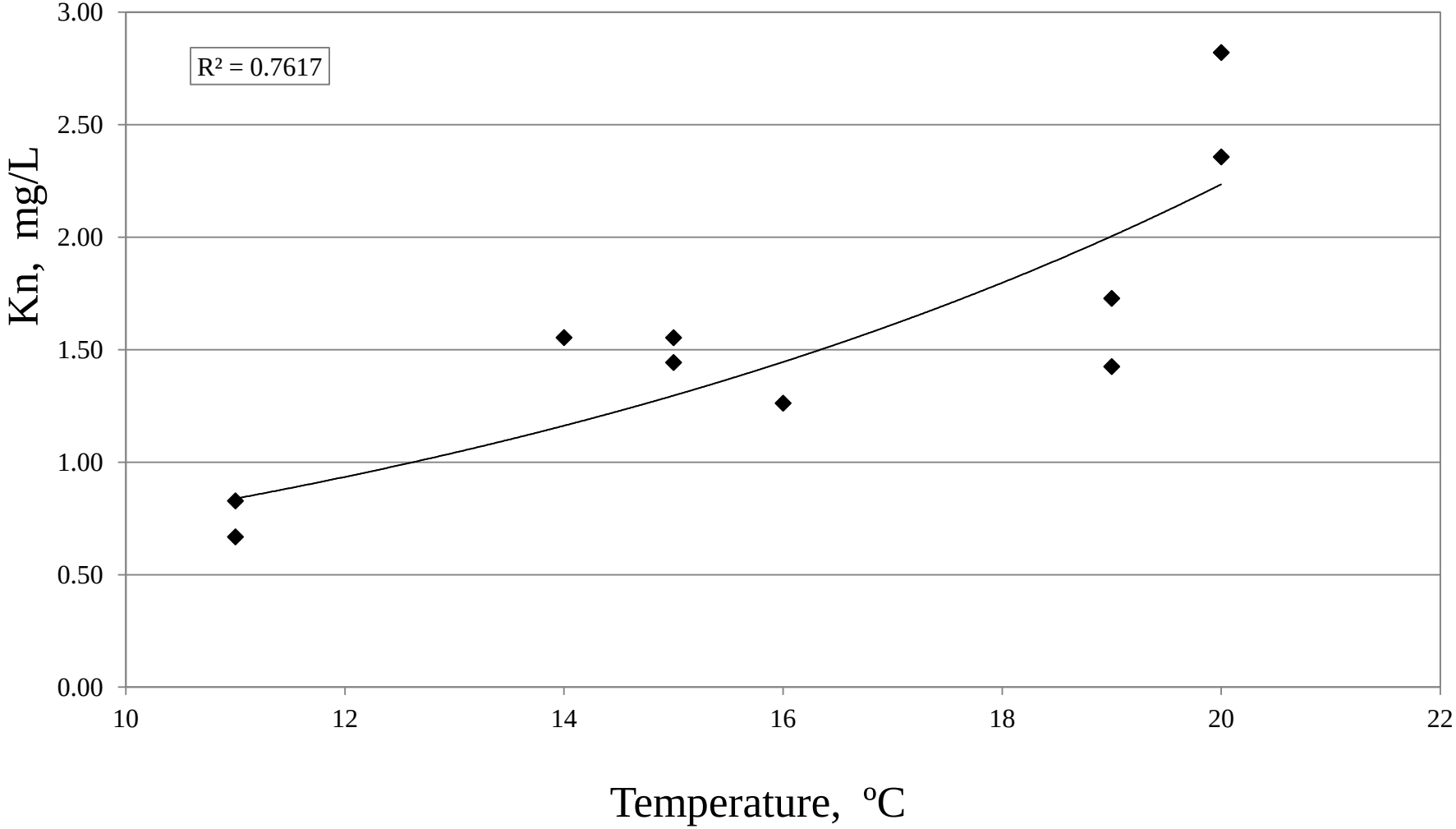
Biofilm Distribution



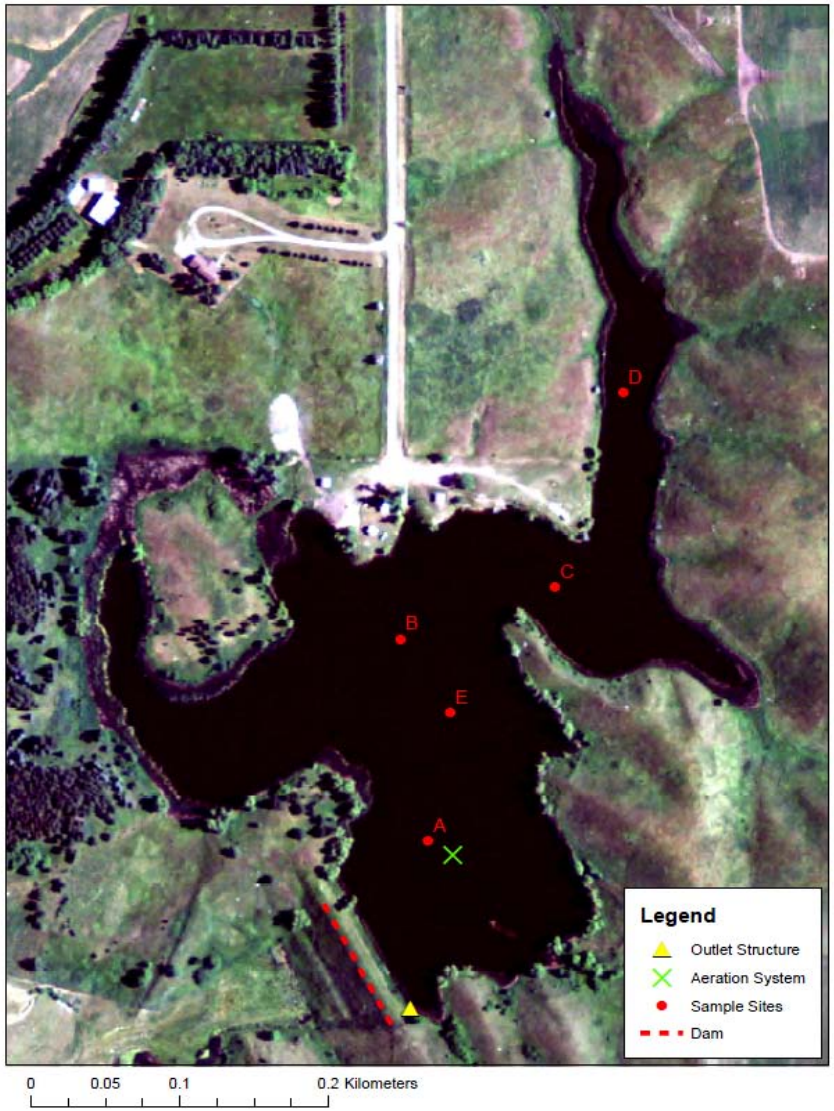


Impact of temperature on reaction rate

$$k_{N,2}=k_{N,1}\theta^{(T2-T1)} \qquad \theta=1.12$$

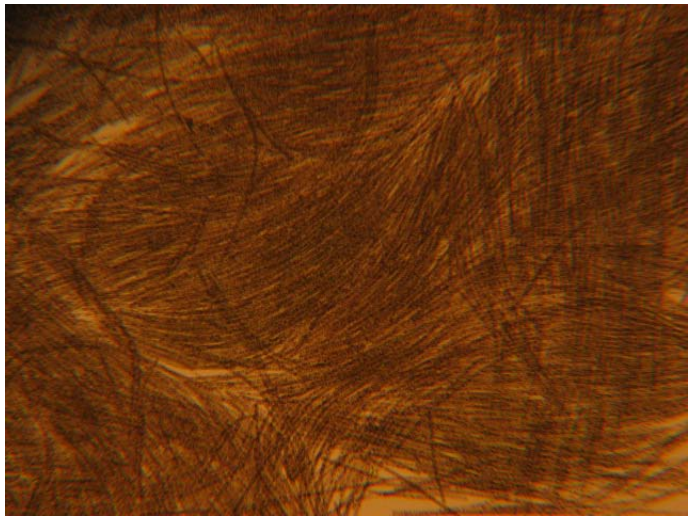


Impact of P and N on Lake Water Quality Heinrich-Martin Dam, LaMoure County



- The impoundment is highly eutrophic
- Excessive algal growth in summer
- Dead algae biomass contributes to high organic contents in the sediment
- An anoxic zone is formed near the bottom

July 13, 2011



July 27, 2011

The

End