Removing nitrate and phosphate from agricultural runoff or drainage

Collaboration:
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• Cooperating growers

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Surface water monitoring shows high NO\textsubscript{3}-N is common...
Irrigation and fertilization practices can be improved …

... but some wastewater remediation will likely be needed to consistently meet environmental targets
What remediation practices can remove soluble nutrients?

- Conservation practices that remove sediment are generally ineffective in removing *soluble* nutrients.

- Biological denitrification has potential.
Biological denitrification:

\[
\begin{align*}
\text{NO}_3^- & \rightarrow \text{NO}_2^- & \rightarrow \text{NO} & \rightarrow \text{N}_2\text{O} & \rightarrow \text{N}_2 \\
\text{Nitrate} & \quad \text{Nitrite} & \quad \text{Nitric oxide} & \quad \text{Nitrous oxide} & \quad \text{Atmospheric nitrogen}
\end{align*}
\]

Requirements for denitrification:
- Anaerobic conditions
- Bacteria capable of reducing NO$_3$-N
- Labile (microbially-available) carbon to support the reaction
Denitrification occurs in wetlands, but …

- denitrification rate is usually limited by carbon availability, meaning that nitrate removal per unit land area is low
- wildlife attraction can raise microbial food safety concerns
Denitrification bioreactors (DBR):

Organic waste material to provide labile carbon
Building a DBR
Salinas Valley, 2011:

chipped construction wood from Monterey Regional Waste Management District
DBR 1
34 cubic yards

treat tile drain water

May 2011

DBR 2

17 cubic yards

treat tile drain water

June 2011

DBR 3

16 cubic yards

treat surface runoff

June 2012
Continuous pumping into DBRs from tile drain sump or tailwater pond

DBR outlet drains into surface ditch after approximately 2 days of residence time
• Surface water pretreated with polyacrylamide (PAM) to keep sediment out of the bioreactor
Moderate temperature allows denitrification all year:

Site 1

Site 2

Site 3

Surface water

Tile effluent

Date
DBR performance on tile drain effluent:

- **Site 1**
  - Summer average: \( \approx 8 \text{ PPM NO}_3\text{-N / day} \)
  - Winter average: \( \approx 5 \text{ PPM NO}_3\text{-N / day} \)

- **Site 2**
  - Denitrification rates achieved

  - Summer average: \( \approx 8 \text{ PPM NO}_3\text{-N / day} \)
  - Winter average: \( \approx 5 \text{ PPM NO}_3\text{-N / day} \)
DBR performance on surface runoff:

Irrigation season average:
\approx 11-13 \text{ PPM NO}_3\text{-N} / \text{day}
DBR performance on surface runoff:

What about PO$_4$-P?

- Aluminum sulfate (alum) was injected during portions of 2012 (shaded area)

- Both alum and bioreactor treatment appear to remove PO$_4$-P
Are there environmental issues with DBRs?

- nitrous oxide (N₂O) release
  - high per unit land area, small as a % of N denitrified
- dissolved organic carbon (DOC) and tannins in DBR effluent
  - effluent may need to be recycled on-farm in the initial weeks of operation
Are there microbial food safety implications?
- No exposed water = no wildlife attraction
Is a commercial scale DBR feasible?

Based on a year-around operation:

- at an average of 6 PPM NO₃-N removal per day of residence time, a DBR has the theoretical capacity to remove about 3 lb N / yd³ of volume annually; operational capacity probably less

- under commercial conditions, a DBR 50 x 100 x 5 ft could probably remove at least 2,000 lb N annually

- costs are probably between $1 - 4 per lb of NO₃-N denitrified

- management practice changes would still be needed to come close to meeting environmental goals, particularly with tile drain effluent