# Advanced Denitrifying Bioreactor Project

## Prototype Design and Testing

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# Acknowledgements to the CSUMB Bioreactor Team

| **Students** | **Faculty** |
| --- | --- |
| Justin Vivar | Arlene Haffa, Ph.D.  (Microbiology mentor) |
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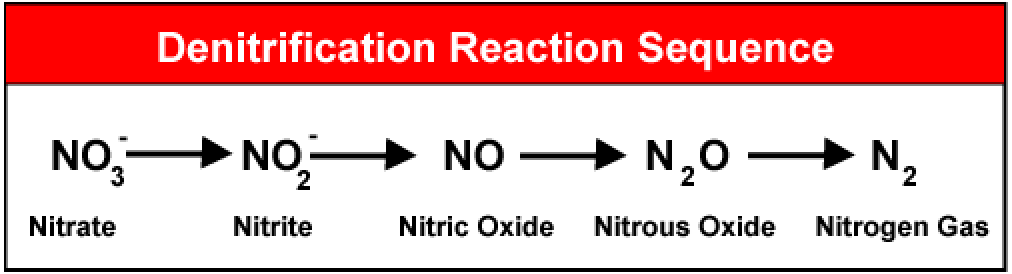
| Alixandra Rachman | |
| | |

# Basic Theory- Reduction of Nitrate to $N_2$

- In a compact bioreactor, we attempt to isolate facultative denitrifying bacteria from local sloughs and ponds, and grow large amounts of bacteria on a support matrix (plastic, ceramics, sand)
- Some very common denitrifiying bacteria, such as P. stutzeri, can complete the the entire process shown below **without release of substantial intermediate gases (GHGs)**




Source: http://wwwbrr.cr.usgs.gov/projects/EC_biogeochemistry/Cape.htm

# Nitrate In Agricultural Tailwater- A Global Problem

- Nutrient runoff is the largest unsolved water pollution problem globally
- Salinas river is one of the most impacted rivers in the US
- Currently,  farmers and growers have no cost effective solution
- Existing solutions are either too big and slow (woodchip bioreactors) or simply too expensive for farmers (ion exchange)
- But denitrification is a well established and cost effective process in other industries.
- So what’s the problem?

# Market Failure and Government Failure?

- If many industries can successfully denitrify wastewater, then the agriculture problem is not a technology problem but an innovation failure or “market failure”
- Fining the growers,  after we’ve all benefitted from California agriculture for decades,  is not the solution
- Rather, we need entrepreneurs to enter into this problem with support from the growers and “regulators”
- The CSUMB bioreactor team is developing a solution that can be transferred to the private sector

# Our Solution- Compact, Denitrifying Bioreactor

- *Denitrification rate (DNR) > 600 grams of $NO_3$-N per cubic-day, enables a very small footprint
- Small footprint allows farmers to place the reactor as close to the source of tail-water as possible
- Another benefit of close placement- higher denitrification rates at higher concentrations
- A 10 gallon-per-minute system (< 200 $ft^2$) can be placed almost anywhere on the map (right)

*Utility scale denitrification systems routinely achieve DNR > 2kg $NO_3$-N per cubic-day*

# Major Performance Goals for Prototype

- Denitrification rate > 600 g/$m^3$-d @ 25 mg/L of $NO_3$-N in wastewater
  - Affects the footprint, high DNR allows flexible placement, consistent with other small aquaculture systems
- Portable/Temporary
  - Ability to transport to grower site for weekly, monthly demonstrations
- Maintainance- daily reactor cleaing (air sparging), refill carbon supply periodically
- Grower cost: < $0.50 per 1000 gallons treated

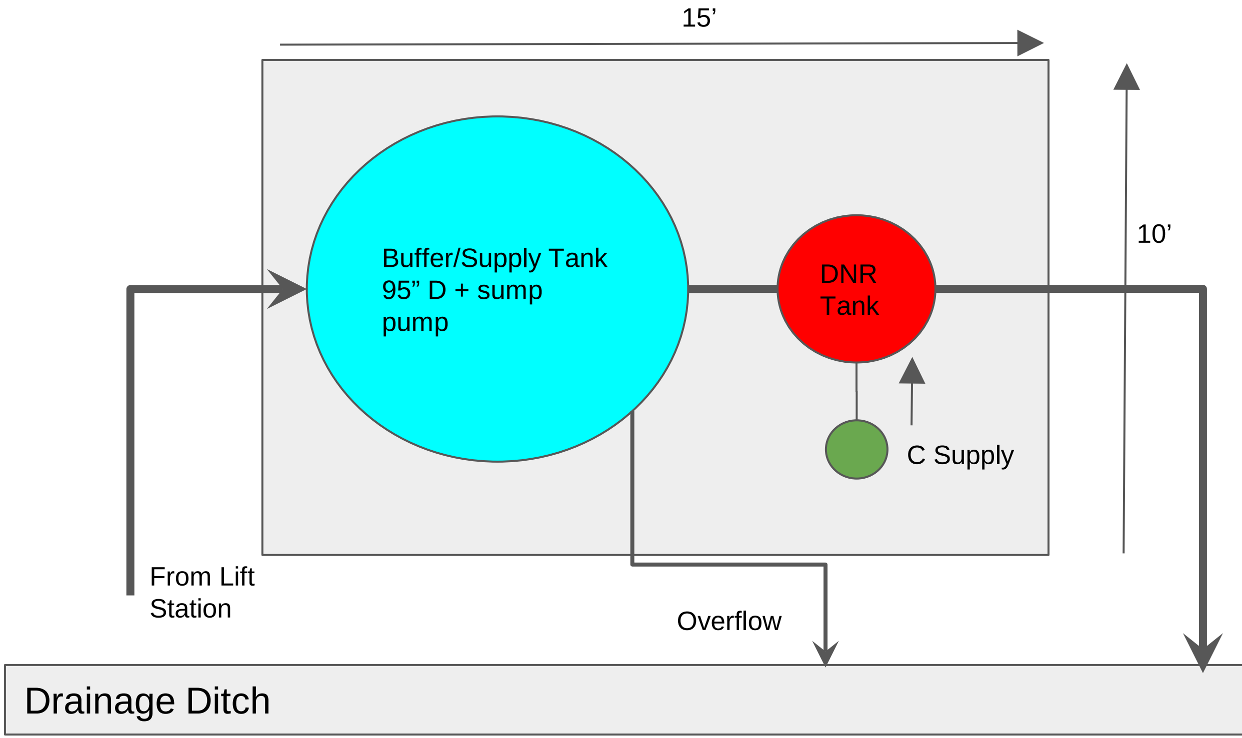
# Business Models
## (assumes a new private company has been formed)

- Smaller growers- grow pays monthly fee for denitrification service
- Larger growers- pay for design, install, and grower operates
- Public-Private- county/state and grower share cost.

# Project Design Features

- Bacteria- Facultative denitrifying anaerobes, isolated from local slough or holding ponds.
- Bacteria Support Matrix- plastic “bio-balls” with very high specific surface area (area/volume)
- External carbon injection system with industry standard control system
- Design- vertical up-flow, moving bed
- Wireless/Cellular communication

# Denitrifying Prototype Bioreactor




System:

- Flow 2-5 GPM Variable
- HRT:  Variable
- Power <500 Watts
- Supply tank (2.5-3.5 K gal)
- Denitrifying Tank (DNR) 200-600 gal)
- External carbon supply (tote) + metering pump
- Footprint < 200 ft$^{2}$’
- Foundation-packed dirt

# Denitrification Rate- A Key Performance Indicator

$$DNR = \Delta N x \frac{FR}{Vbed}$$

- Where:
- DNR- denitrification rate, in grams of $NO_3$-N removed/day-$m^3$ bed volume
- **Δ**N = change in concentration from inlet to outlet, in grams $NO_3$-N/$m^3$
- FR= Flow rate, in cubic meters per day
- Vbed= denitrification bed volume, in cubic meters

See Warneke (2011, p 4143)

# Initial Prototype

- Flow rate- 1-2  GPM
- Reactor Design- 4 x 55 Gallon drums, connected in series
- Bacteria Source- isolated locally (see Van Niel and Allen)
- Unpressurized
- Simulated ag runoff- by adding potassium nitrate to tap water
- Carbon Source- denatured alcohol (ETOH + MEOH)
- Hydraulic Residence Time- < 2 Hours
- Carbon: Nitrogen ratio by mass- 1:1  to 2:1
- Expected NO3 removal-  90%

# Support Matrix for V1 Reactor

Plastic Bioballs$^{TM}$

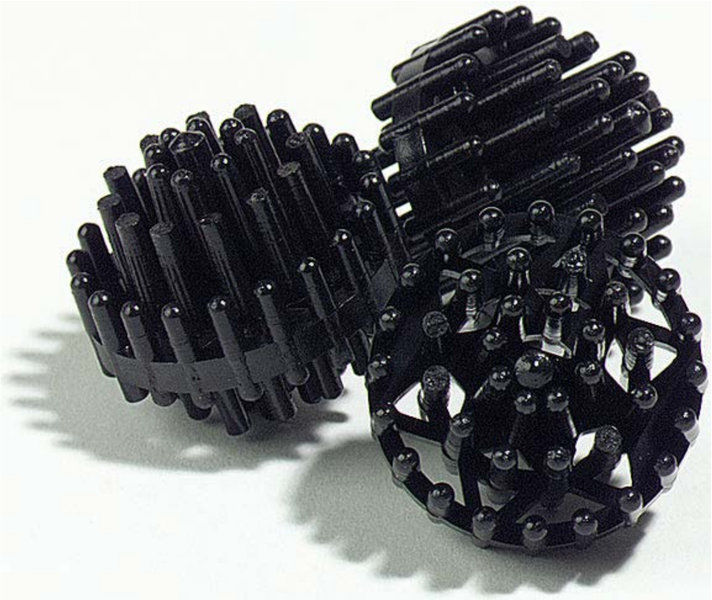


Image Source: Drs Foster and Smith Website

# Initial Prototype Results

- Uneven biofilm coverage of bio-balls
- Aspect ratio (H/W) too low to enable good mixing
- Good denitrification
- Dissolved O2 consistently under 1ppm
- pH steady at 7.5 entire period

# V2 Improvements (in process)

## Single Denitrification Tank Reactor

Simplifies connections, better flow/mixing via diffuser,  higher aspect ratio (H/W)

## Chemical metering pump for external carbon supply

Rola-Chem

## Support Matrix- Kaldnes K1

Neutrally buoyant,  Non locking, Greater surface, more movement

## PWM speed control for pump

Can evaluate different residence times

# Kaldnes K1 Media (Support Matrix)

- Much higher specific surface area (area/volume)- more bacteria per unit volume
- **Neutrally buoyant**
- Ideal for moving bed style bioreactors (does not “lock”
    - *“Rolling action” enable higher contact time between waste water and the support matrix*

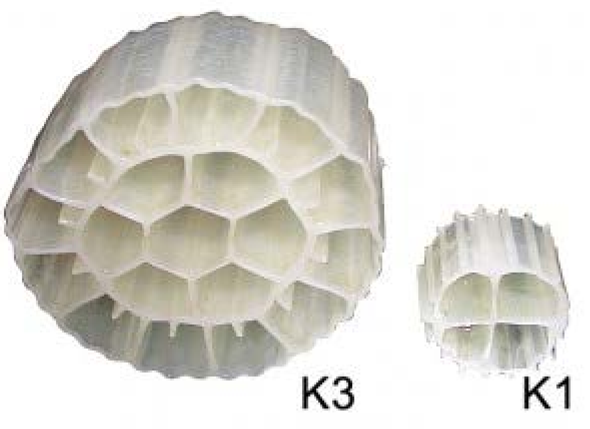



Image source: http://www.inmotionaquatics.com/Kaldnes-K1-and-K3-Media-Evolution-Aqua-sc-11.html

# V3 Prototype (June July)

- Add flow measurement
- Start/stop
- Datalog all parameters (Arduino, LabVIEW or Raspbeery Pi)
- Cellular or WIFI operation of reactor from office

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- US EPA Team
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- Grower Shipper Association
- Farm Board

# Thank You

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