# BIOLOGICAL NITROGEN REMOVAL FOR PASSIVE ONSITE WASTEWATER TREATMENT SYSTEMS USING SALTWATER TOILET FLUSHING

**National Onsite Wastewater Recycling Association 2022 Mega-Conference**

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UNIVERSITY of SOUTH FLORIDA


# Laughing Bird Caye National Park, Belize

- 11 miles from coast of Belize
- World Heritage Site
- Coral cover reduced to 6% after Hurricane Iris in 2001
- Active coral restoration since 2006
- Coral cover > 60% in 2022

Image by:

FRAGMENTS of HOPE

# Nutrient Pollution

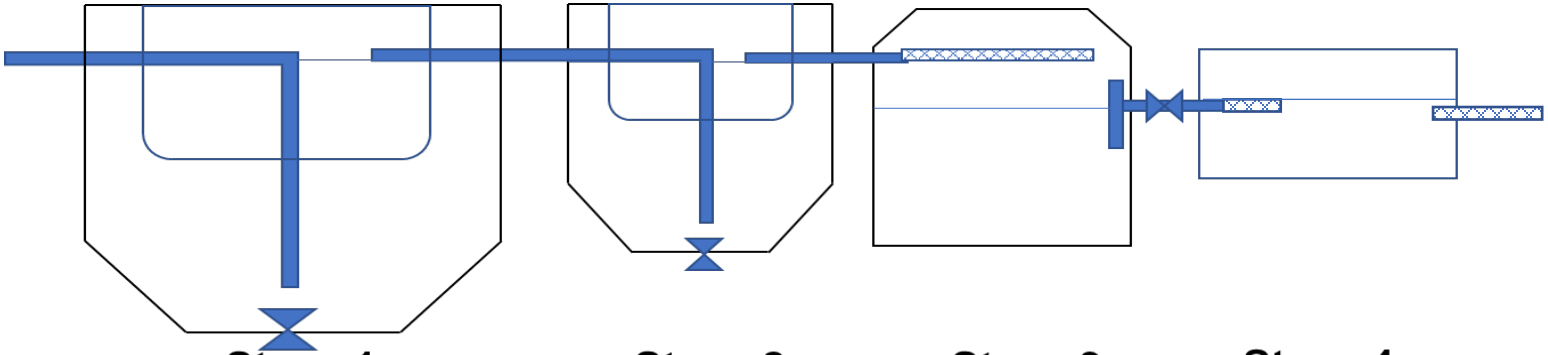
**Sources:**

- Fossil fuel and biomass combustion
- Agricultural runoff
- Urban runoff
- Industrial waste
- Incomplete wastewater treatment

**Impacts:**

- Eutrophication
- Groundwater contamination
- Negatively impacts human health and local economies

# Laughing Bird Caye National Park Wastewater Treatment System

**Stage 1**

Media: Plastic Carriers

**Stage 2**

Media: Plastic Carriers

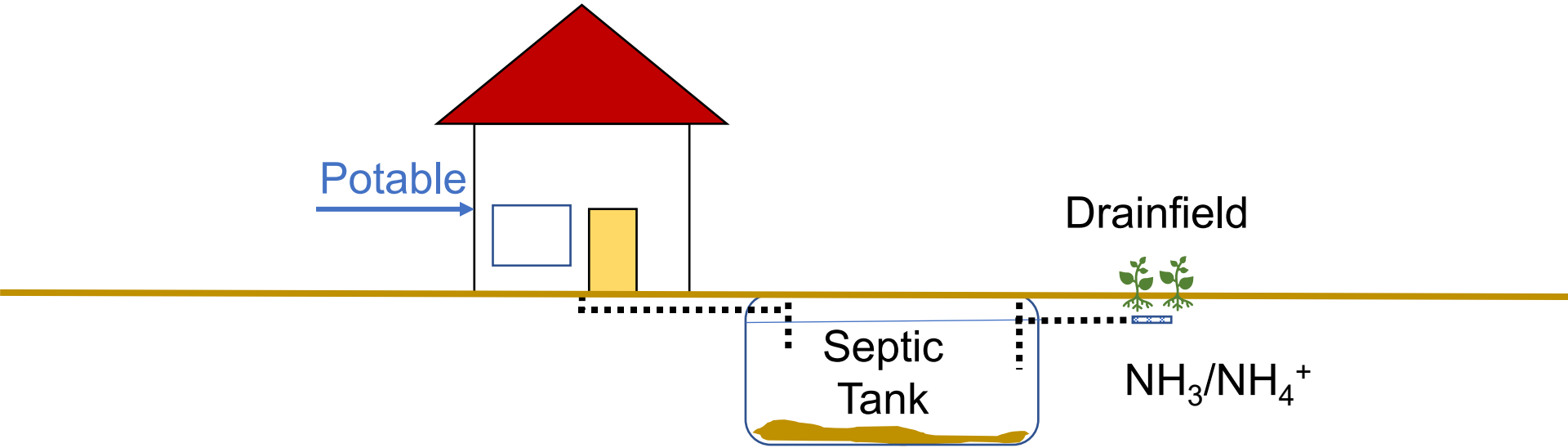
**Stage 3**

Media: Rocks

**Stage 4**

Media: Rocks

# Conventional Septic System



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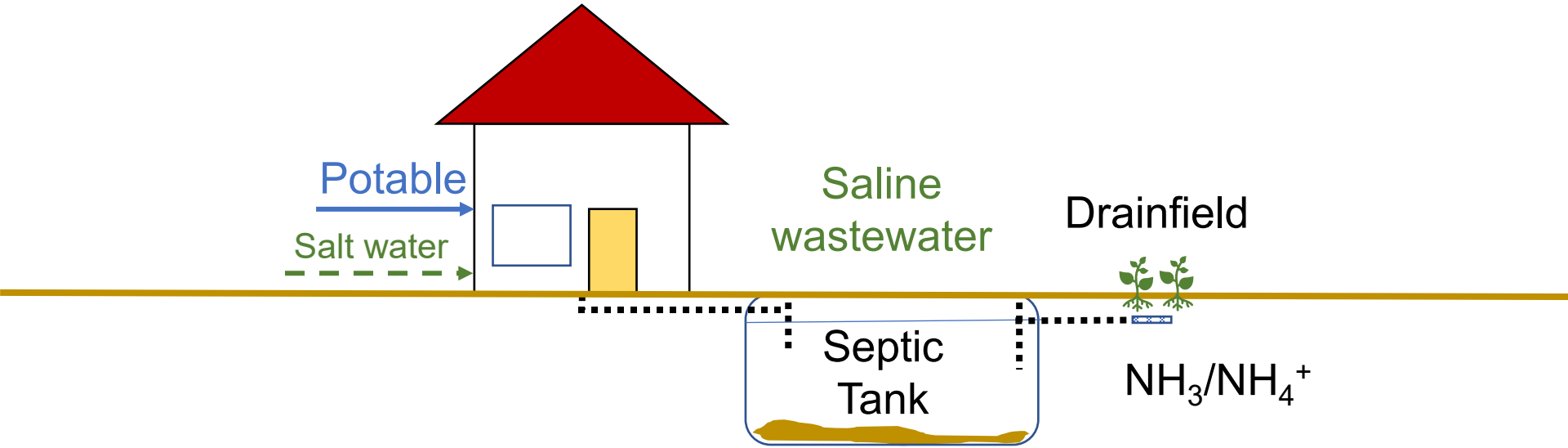
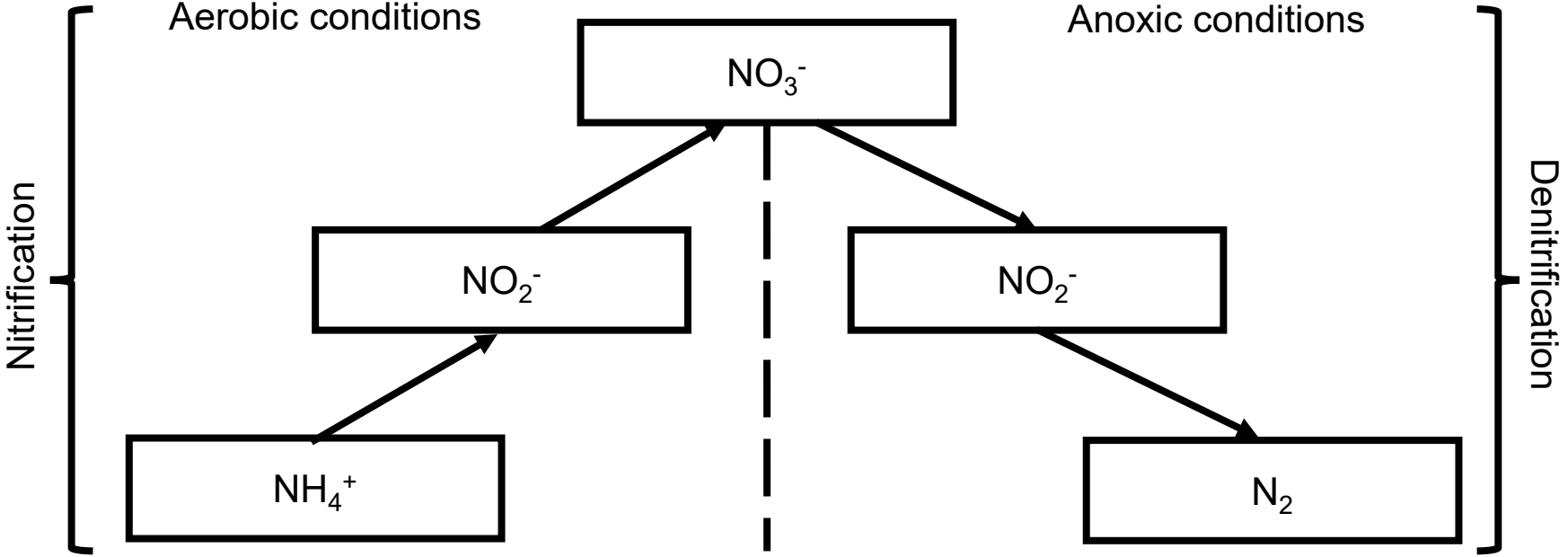


# Nitrification Denitrificaiton



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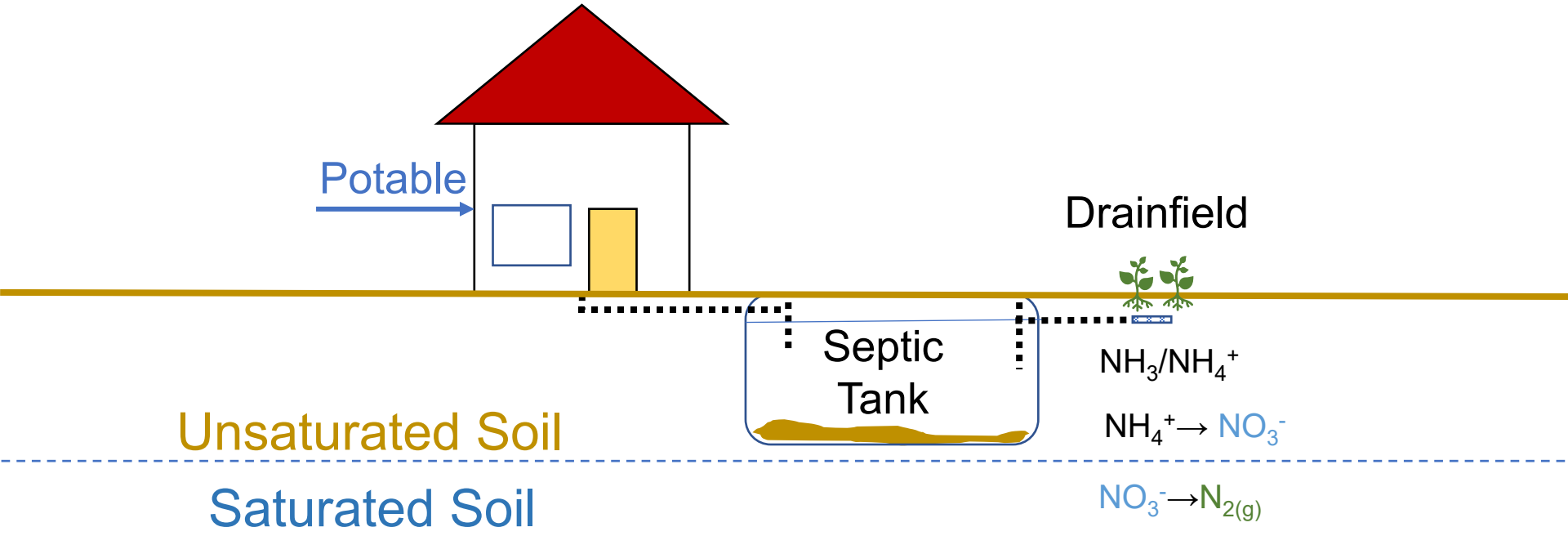
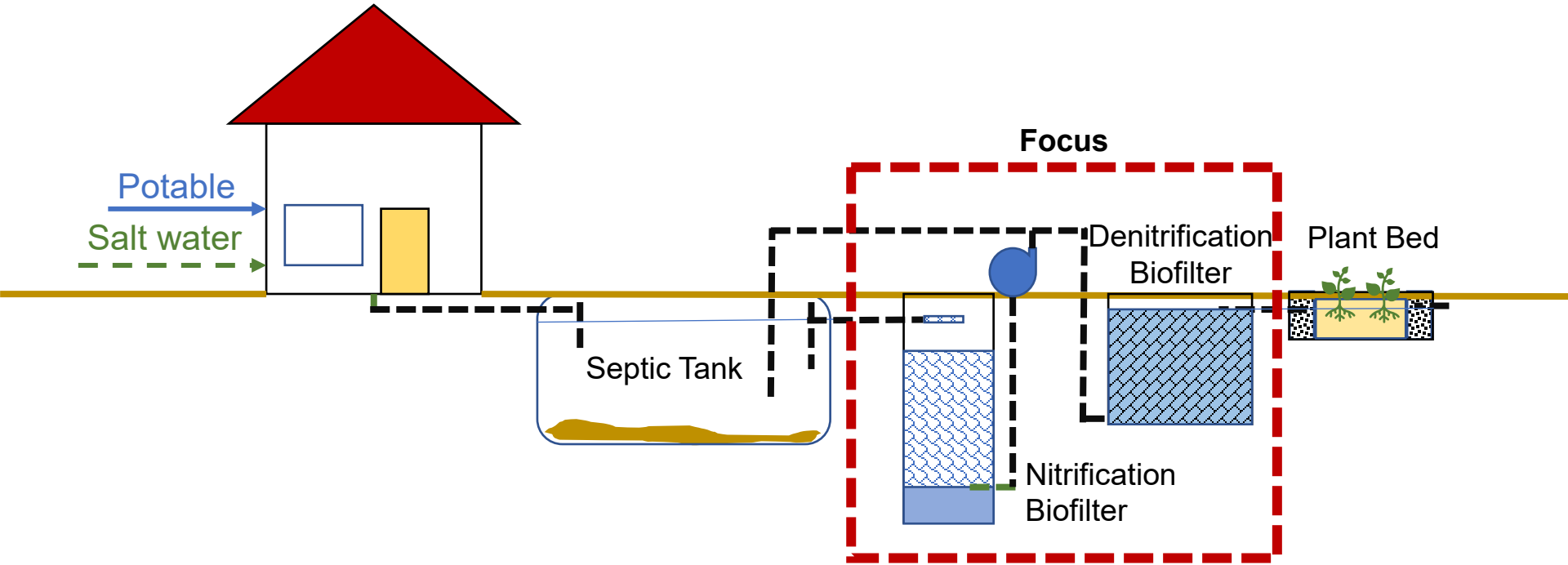


# Passive Nitrogen Reducing System with Seawater used for Toilet Flushing





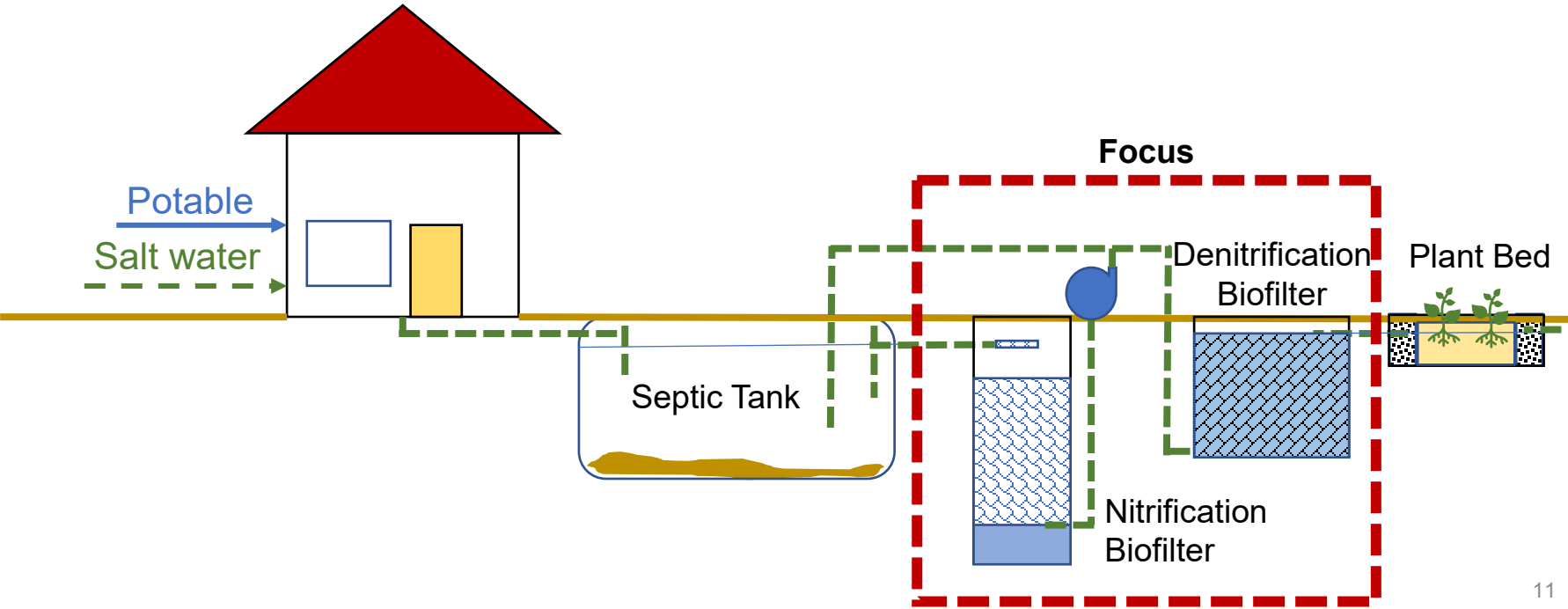
# Research Aims

Goal: Examine nutrient removal options in onsite wastewater treatment systems for water-stressed coastal environments

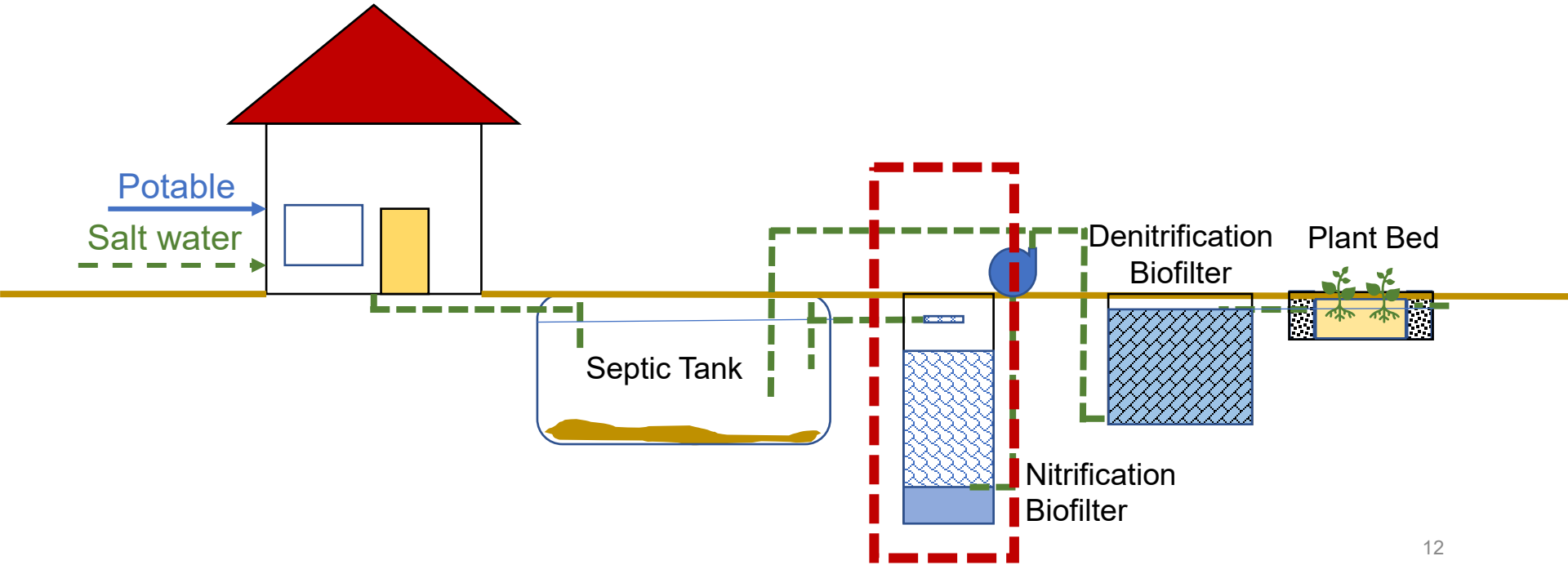
1. A trickling filter can provide enough aeration in a saline environment to convert a majority of the $NH_4^+$ to $NO_3^-$.

2. Organic industrial wastes that are readily available in the local context can be used as slow-release electron donors for denitrification in OWTS applications where seawater is used for toilet flushing.

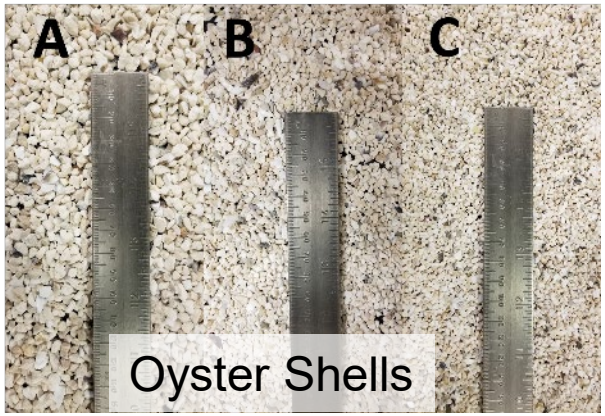
# Passive Nitrogen Reducing System with Seawater used for Toilet Flushing

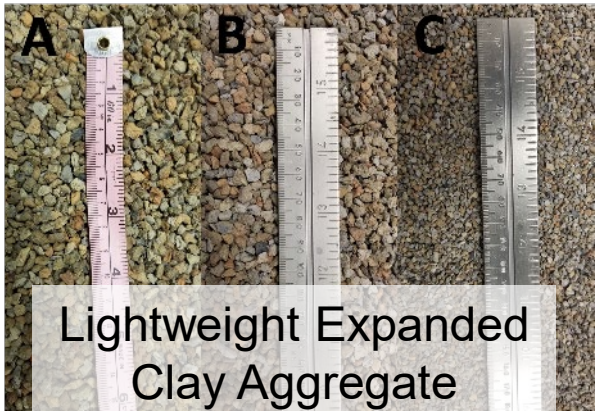


# Passive Nitrogen Reducing System with Seawater used for Toilet Flushing



# Media in Laboratory Scale System: Nitrification Column



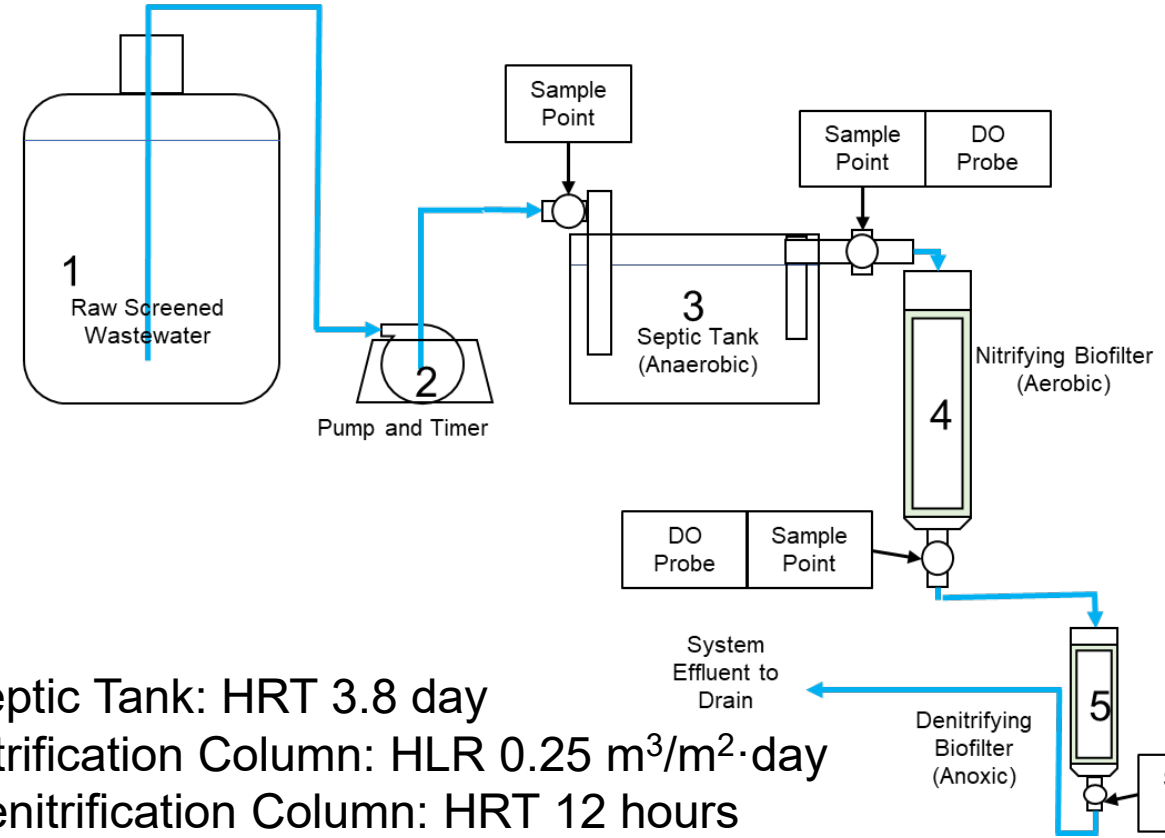



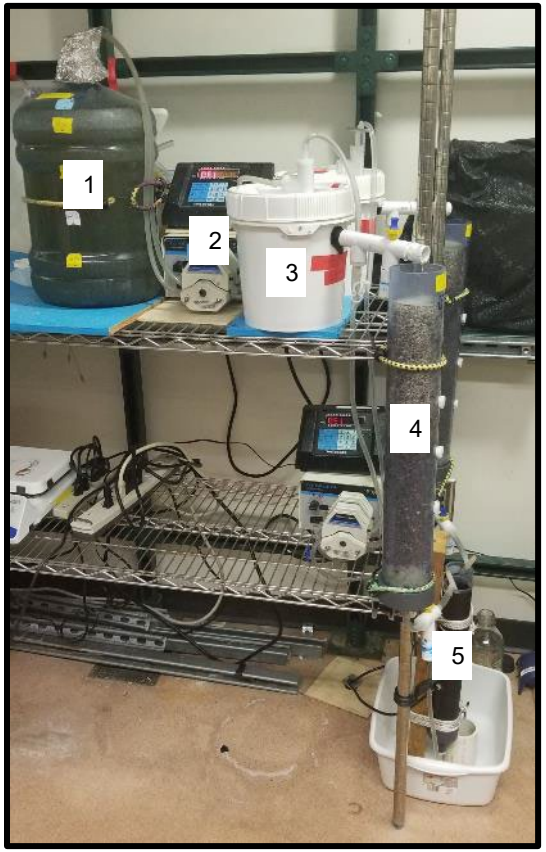

A) 60% <4.75-3.35mm

B) 30% <3.35-2.36mm

C) 10% <2.36-2mm

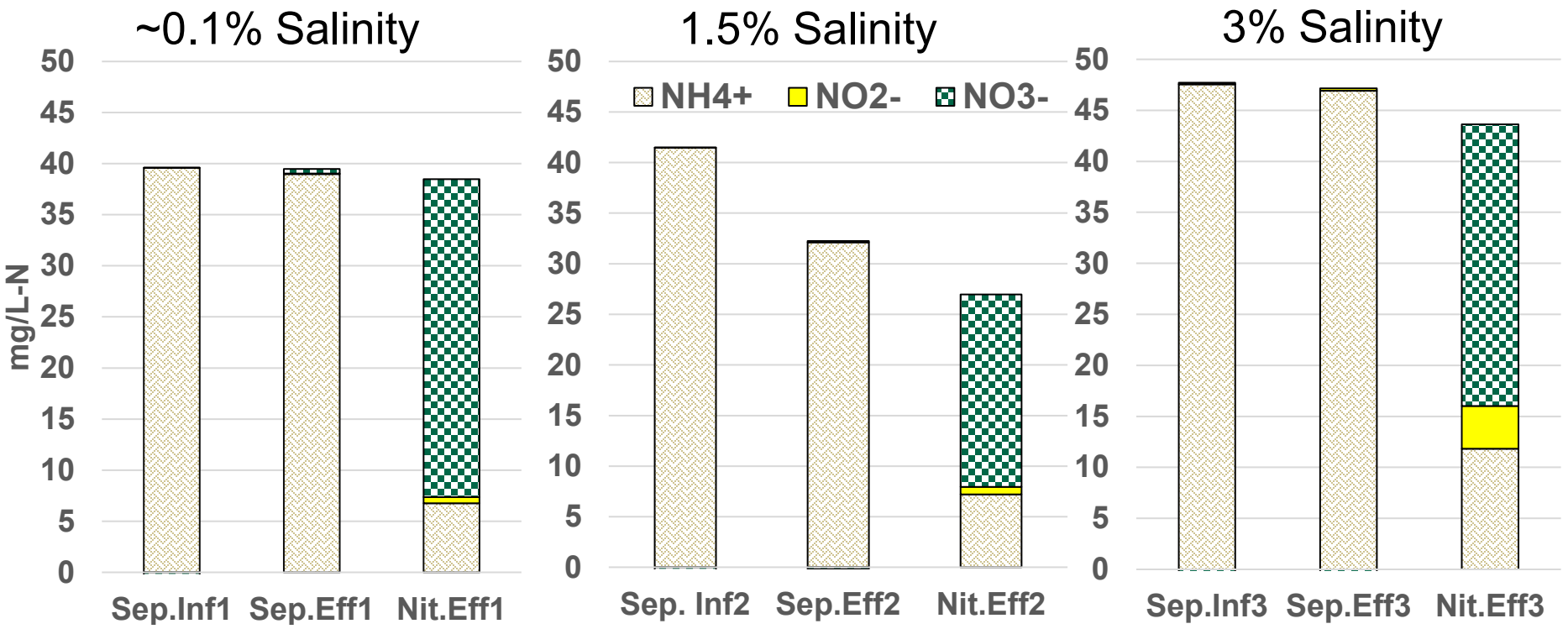
# Laboratory Scale System: Nitrification Column



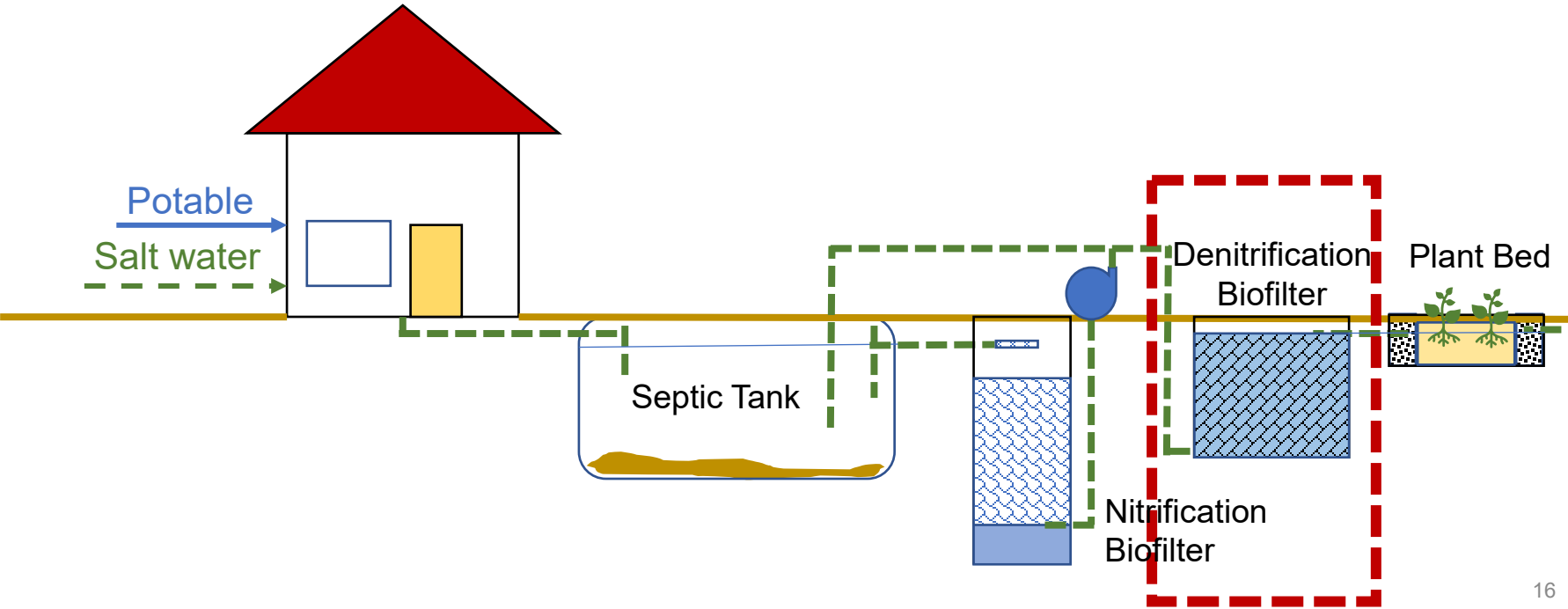

Septic Tank: HRT 3.8 day
Nitrification Column: HLR 0.25 $m^3/m^2 \cdot day$
Denitrification Column: HRT 12 hours

# Nitrogen Speciation for 3 different salinities




**% $NH_4^+$ removal** 82% for 0.1 78% for 1.5 and 3

# Passive Nitrogen Reducing System with Seawater used for Toilet Flushing



Banana Stem

Pine Wood Chips

Sulfur Pellets

Sugar Cane Bagasse

# Media:

1 cm L,W,H

Washed w/ potable water x3 and Deionized water x3

Dried for 48 hrs in 32$^{o}$C constant temperature room

# Denitrification Microcosm

~0.1% Salinity

Saltwater - 3% salinity


**Makeup water:**

Effluent from Northwest Regional Water Reclamation Facility (NRWRF) Hillsborough, FL

$NaNO_3^-$ to bring $NO_3^-$-N 60 mg/L

50 ml Inoculated with Return Activated Sludge from NRWRF

# Zero and First-order Kinetics

$$C_t = C_0 - K_0 t$$

$$C_t = C_0 e^{-Kt}$$

Where:

$C_0$ and $C_t$ = nitrate concentrations at time “0” and time “t” respectively

$K_0$ = zero-order rate constant (mg/L·day)

K = first-order rate constant (1/day)

# Denitrification: Electron Donor

| | Zero Order | | First Order | |
|---|---|---|---|---|
| | $R^2$ | $K_0$ (mg/L·day) | $R^2$ | $K_1$ (1/day) |
| **Low Salinity 50 g** | | | | |
| Endogenous Decay | 0.966 | 10.0 | 0.991 | 0.232 |
| Sugarcane Bagasse | NED | 46.2 | NED | 2.846 |
| Sulfur Pellets | 0.962 | 15.6 | 0.992 | 0.489 |
| Pine Wood Chips | NED | 34.2 | NED | 1.077 |
| Banana Stem | NED | 24.9 | NED | 1.028 |
| **Low Salinity 20 g** | | | | |
| Endogenous Decay | 0.966 | 7.2 | 0.997 | 0.144 |
| Sugarcane Bagasse | 0.833 | 1.7 | 0.871 | 0.067 |
| Sulfur Pellets | 0.767 | 12.6 | 0.901 | 0.395 |
| Pine Wood Chips | 0.986 | 21.5 | 0.995 | 0.638 |
| Banana Stem | 0.999 | 15.8 | 0.993 | 0.483 |
| **3% Salinity 50 g** | | | | |
| Endogenous Decay | 0.976 | 6.0 | 0.989 | 0.128 |
| Sugarcane Bagasse | 0.595 | 21.0 | 0.721 | 0.983 |
| Sulfur Pellets | 0.992 | 17.9 | 0.998 | 0.168 |
| Pine Wood Chips | 0.833 | 30.6 | 0.754 | 0.529 |
| Banana Stem | 0.785 | 34.0 | 0.784 | 0.579 |
| **3% Salinity 20g** | | | | |
| Endogenous Decay | 0.967 | 4.4 | 0.992 | 0.103 |
| Sugarcane Bagasse | 0.307 | 1.7 | 0.313 | 0.123 |
| Sulfur Pellets | 0.929 | 5.7 | 0.979 | 0.140 |
| Pine Wood Chips | 0.975 | 18.0 | 0.919 | 0.726 |
| Banana Stem | 0.999 | 9.2 | 0.941 | 0.309 |

# Denitrification: Electron Donor

Pine Wood Chips and Banana Stem ★★★

Sulfur Pellets ★★

Sugar Cane Bagasse ★ pH

# Conclusions

Goal: Examine nutrient removal options for passive onsite wastewater treatment in water-stressed coastal environments

1. Ammonia oxidation in nitrification column showed no significant difference with respect to salinity, 82-78% $NH_4^+$ removal

2. Woodchips, banana stem, sulfur pellets good electron donors at 3% salinity

# Next Steps

Longer denitrification microcosm study

Full system with best denitrification electron donor

Treatment train orientation

Microscopy

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# Questions?

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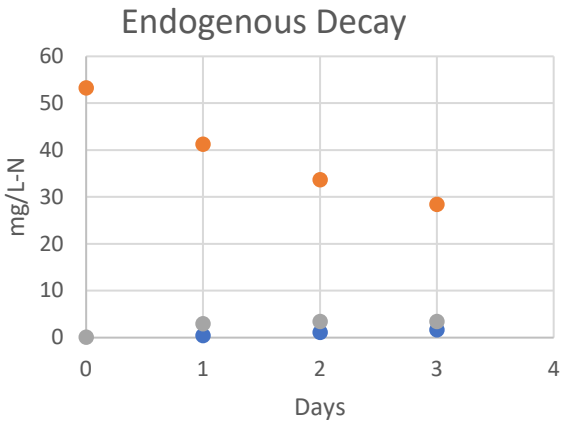
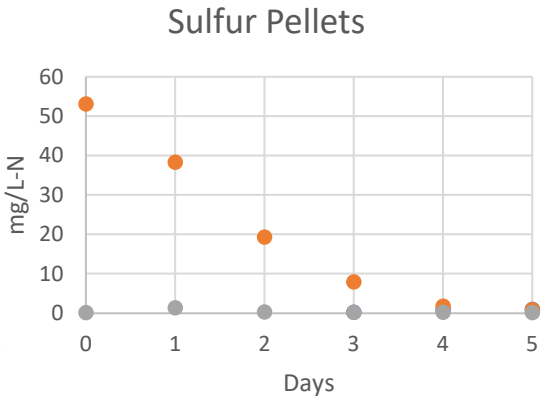
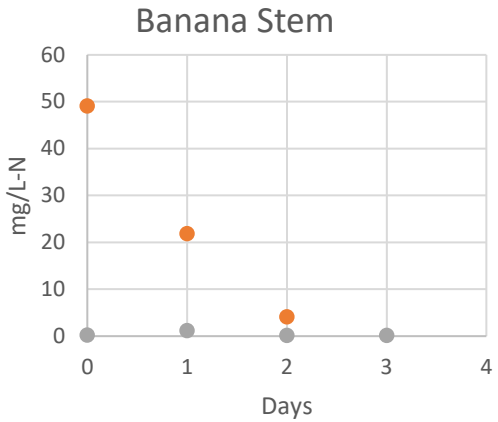
# Freshwater Microcosms 50g Donor



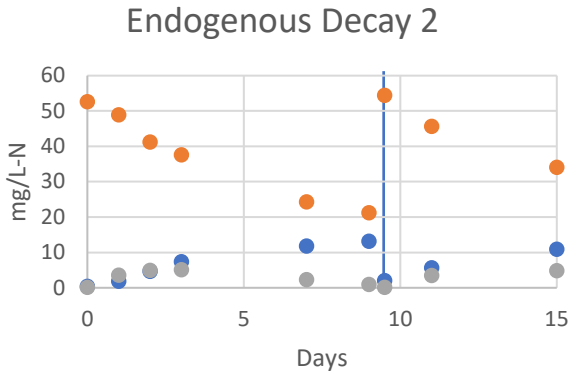


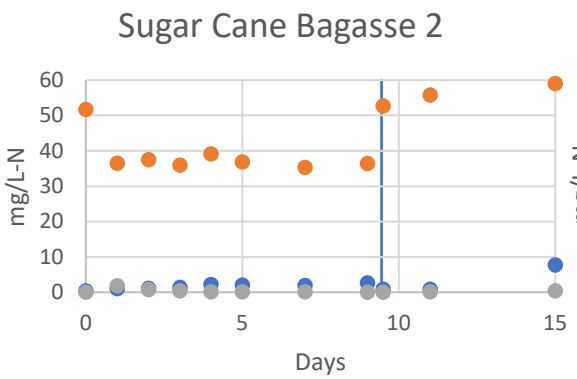


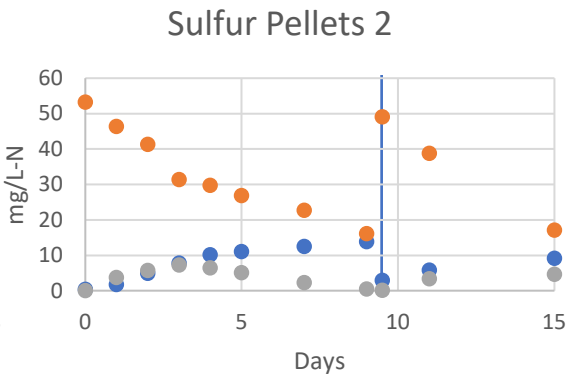


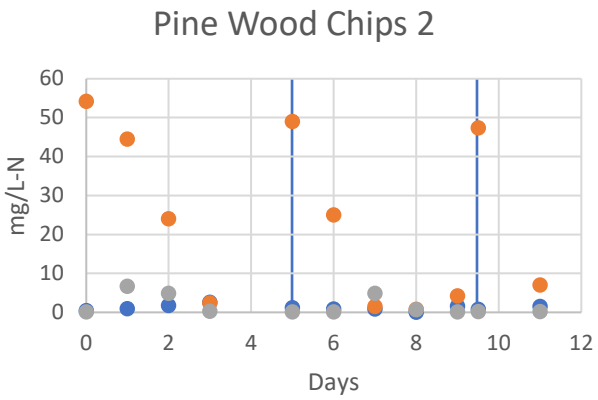


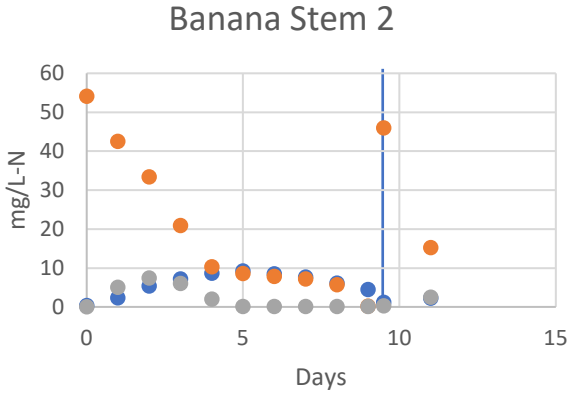

# 3% Salinity Microcosms 20g Electron Donor



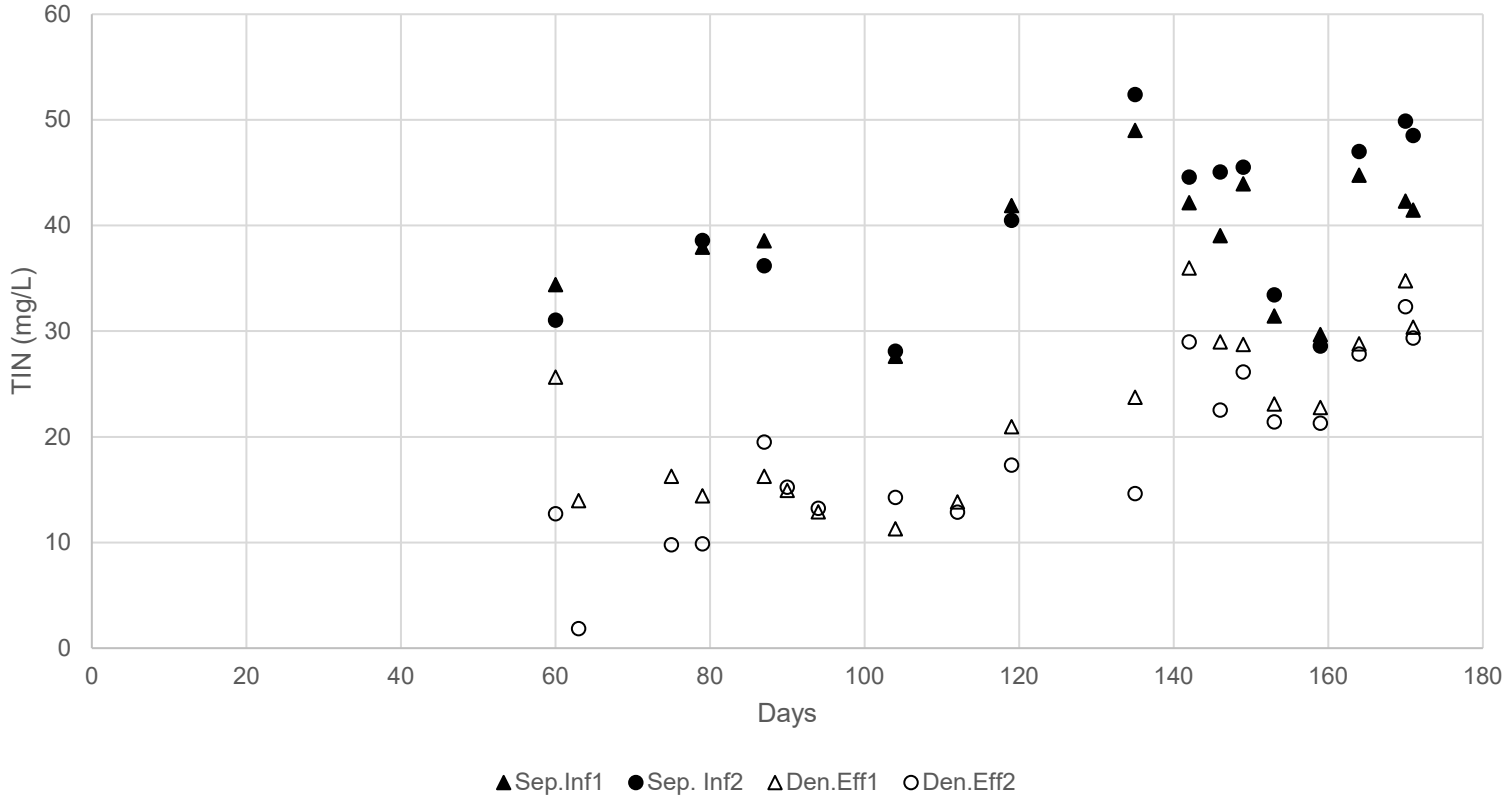



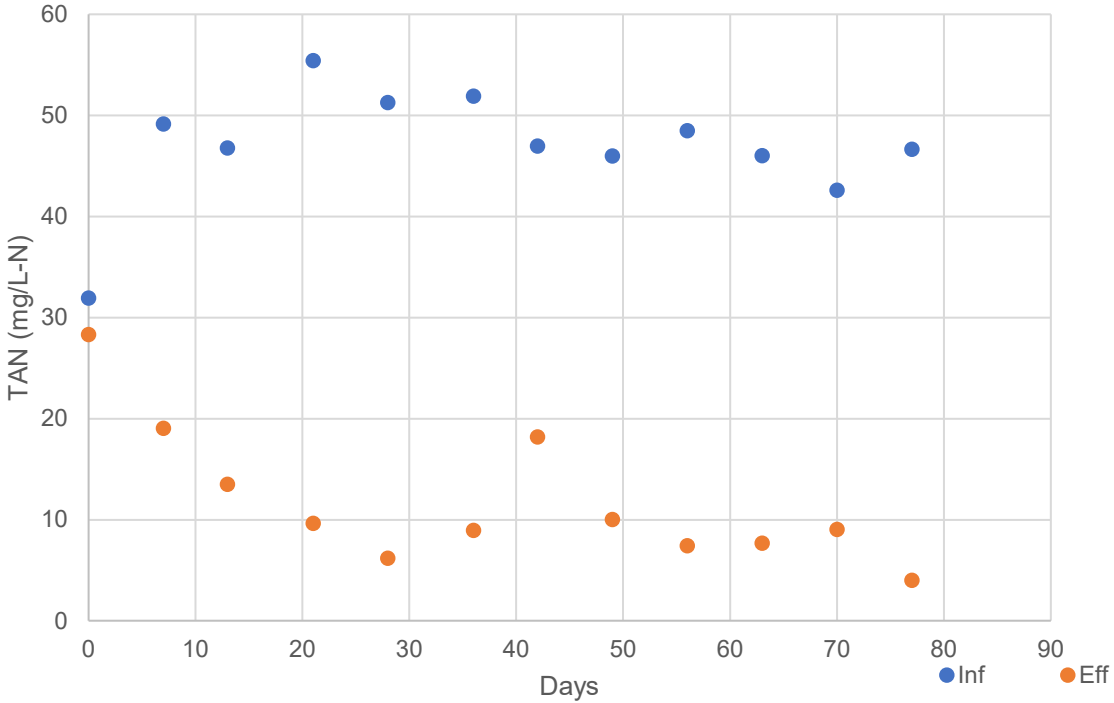

# Analytical Methods

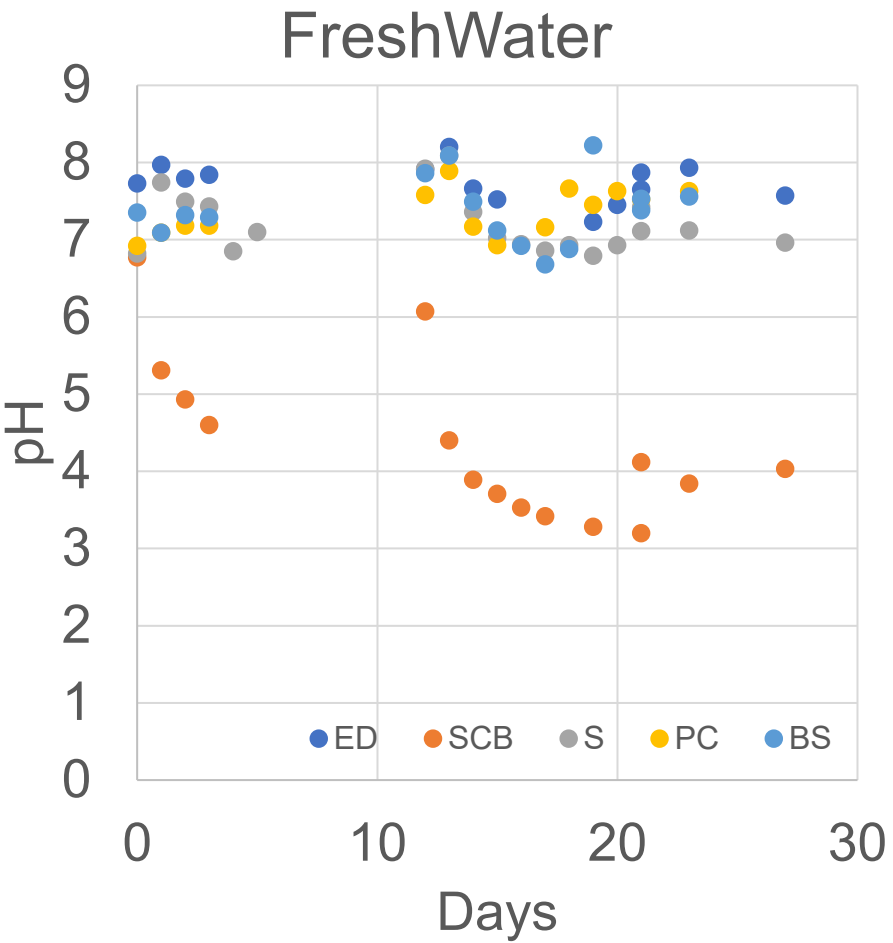
- TAN and NOx: Timberline Ammonia Analyzer
- $NO_2^-$: Standard Methods and Strickland and Parsons
- COD: HACH method 8000 (3–150 mg/L)
- Dissolved Oxygen, pH, Temperature, Salinity: Thermo Scientific Orion 5 Star meter
- TSS, VSS, Alkalinity: Standard Methods

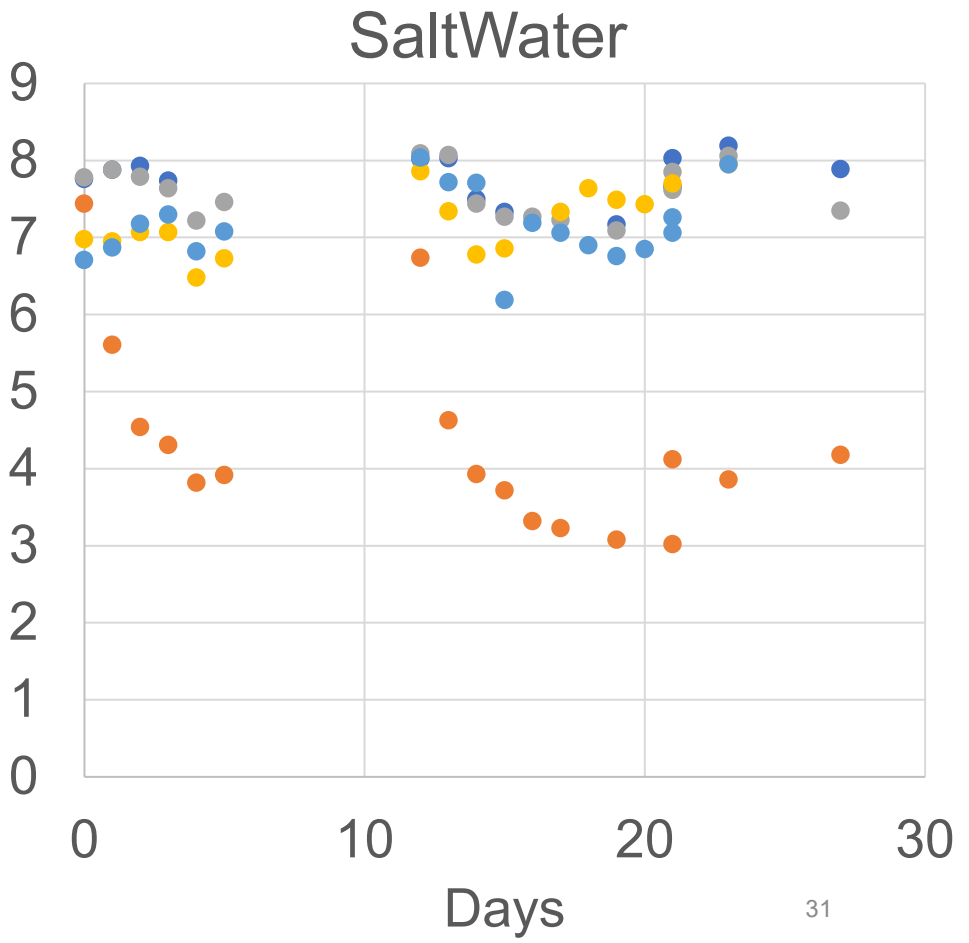
# 0.1 and 1.5% Salinity TIN removal w/ Denitrification



# 3% nitrification column




FreshWater
pH
9
8
7
6
5
4
3
2
1
0
0
10
20
30
Days
ED
SCB
S
PC
BS


SaltWater
9
8
7
6
5
4
3
2
1
0
0
10
20
30
Days