FLORIDA ENVIRONMENTAL HEALTH ASSOCIATION, INC.
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Passive Ways to Reduce Nitrogen in Onsite Wastewater Treatment Systems

by

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FLORIDA DEPARTMENT OF HEALTH

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Presentation overview

- Onsite Wastewater Nitrogen Reduction
- Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study
- Pilot Test Results
- Next Steps
- Questions and Answers

Onsite Wastewater Nitrogen Reduction

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Why is nitrogen a concern?

Human Health

- SDWA Limit of 10 mg/L NO_3 – N
- Harmful algal blooms (HABs) – N and P

Ecosystem Health

- N is the limiting nutrient for eutrophication of many coastal waters and some freshwater systems, P typically the limiting nutrient for freshwater systems
- Increased watershed nutrient loading can be linked to:
  - Algal blooms
  - Loss of seagrass and other habitat
  - Hypoxia

Nitrogen in wastewater

EPA (2002) estimates for residential wastewater:

- ~**11.2 grams** of nitrogen per person per day
  - 70 - 80% as toilet wastes
  - 10 - 15% is food preparation
  - Household products
- Total 69.3 gallons per capita per day (gpcd)

(Based on: American Water Works Association Research Foundation detailed study of 1,188 homes in 14 North American communities)

- Typical total nitrogen concentration 26 to 75 mg/L

Onsite Wastewater Treatment: Biological Nitrogen Removal

Primary Treatment

Mineralization of organic N to TKN
(mostly ammonia – NH_4)

Nitrification

TKN (Ammonia and organic N) oxidized to nitrate (NO_3) by nitrifying bacteria, requires oxygen

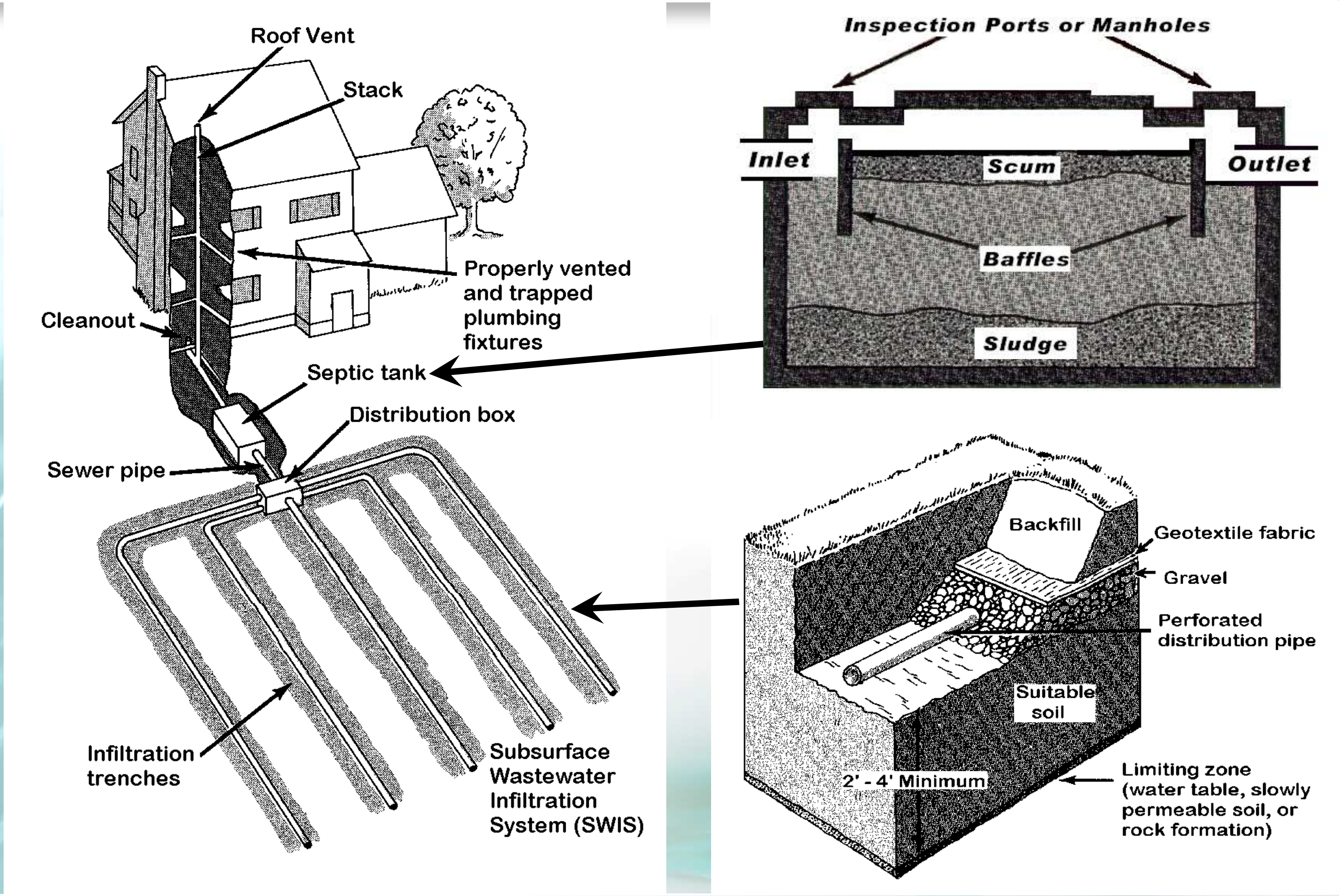
Denitrification

Nitrate converted to N_2 in anoxic environment; requires supply of electron donor

Dispersal

Effluent discharge to the soil or landscape

Conventional onsite sewage treatment and disposal systems (OSTDS)



Bio-N removal is a two-stage process

OSTDS effluent nitrogen removal typically occurs in two stages:

1. "nitrify" nitrogen compounds to NO_3 (nitrification)
2. "denitrify" NO_3 to nitrogen gas (denitrification)

$$\text{Organic N} \rightarrow NH_4^{+} \rightarrow NO_2^{-} \rightarrow NO_3^{-} \rightarrow N_2$$

Ammonification (Organic N → NH_4^{+})

Nitrification (Aerobic) (NH_4^{+} → NO_3^{-})

Denitrification (Anoxic) (NO_3^{-} → N_2)

Two types of denitrification reactions

Denitrification: reduction of nitrate to N_2 gas:

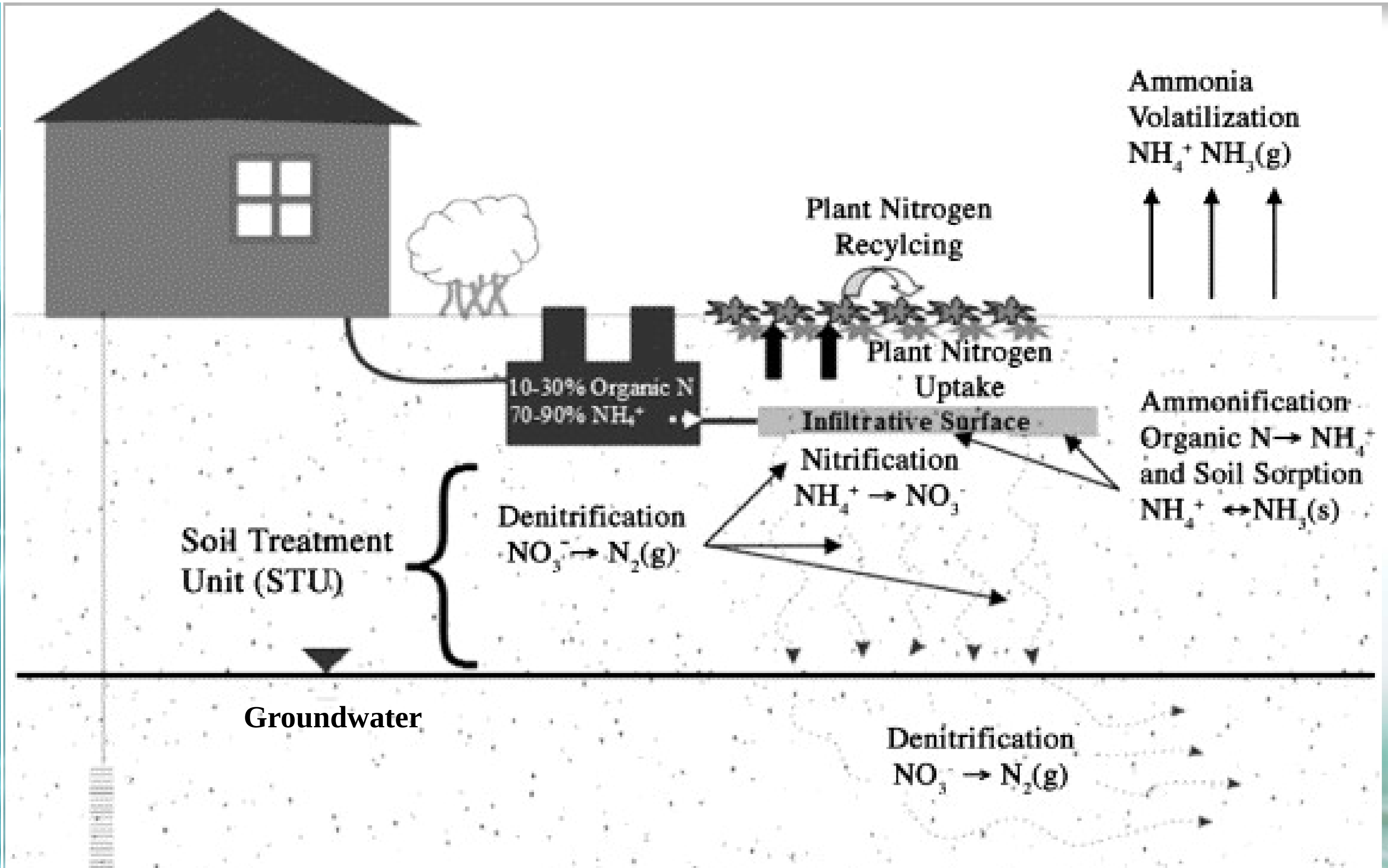
Heterotrophic

$$NO_3^- + 0.94\ CH_3OH + 0.94\ H^+ \Rightarrow 0.057\ C_5H_7O_2N + 0.44\ N_2 + 2.27\ H_20 + 0.71\ CO_2$$

Autotrophic

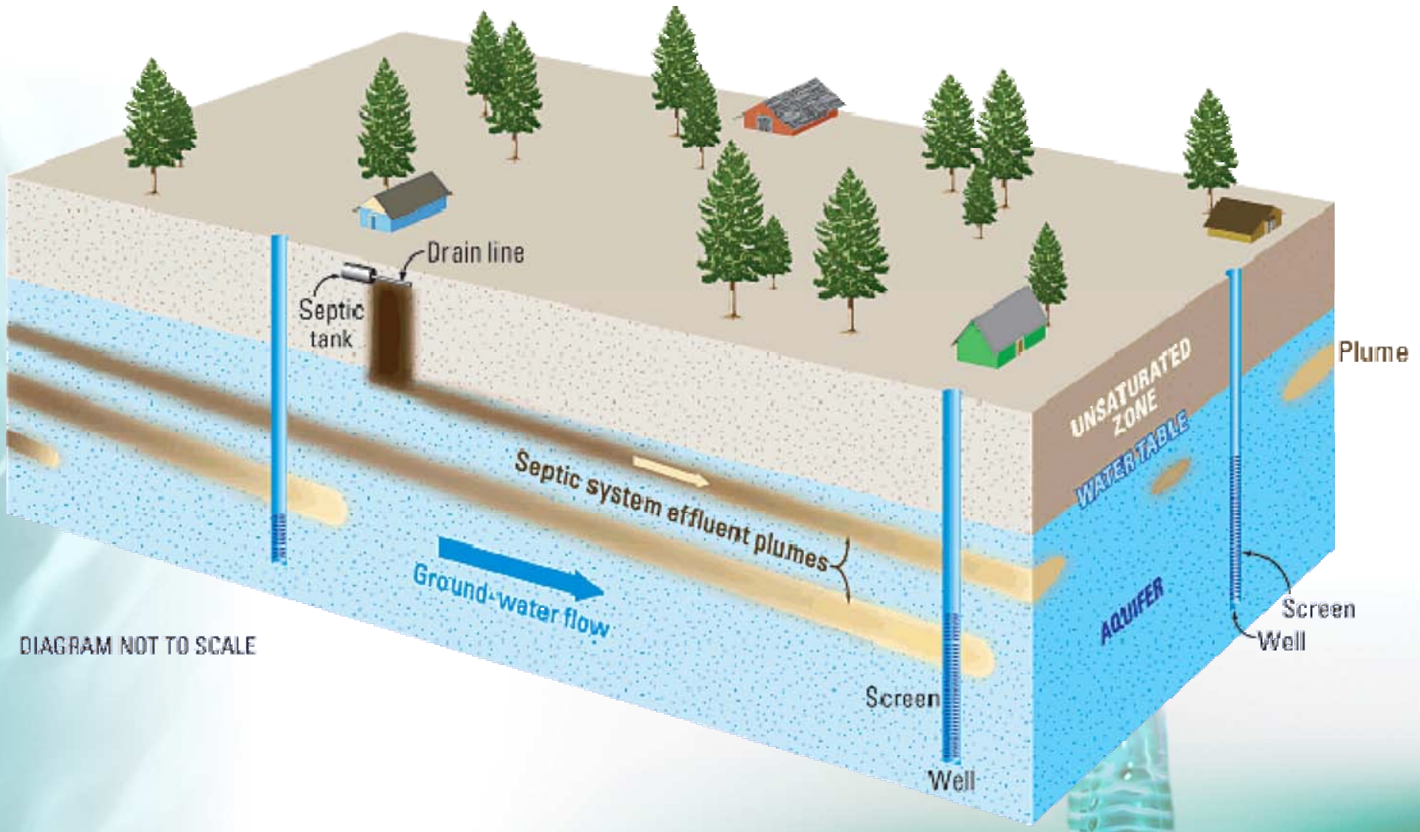
$$NO_3^- + S^o + 0.22\ CO_2 + 0.66\ H_2O \Rightarrow 0.044\ C_5H_7O_2N + SO_4^{-2} + 0.48\ N_2 + H^+$$

OSTDS Nitrogen Transformation



Source: Heatwole, 2006

Potential OSTDS Effluent Plume



http://pubs.usgs.gov/fs/2007/3103/

What are “passive” onsite nitrogen reduction systems?

- Current N-removing onsite systems are mechanical treatment units
- “Passive” nitrogen reducing OSTDS that are more similar to conventional onsite systems in their operation and maintenance
- A passive nitrogen removal system is an OSTDS that reduces effluent N using no mechanical aeration and only a single liquid pump for energy inputs, and uses reactive media for denitrification.

Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Study

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FOSNRS project initiated by Florida legislature

- Laws of Florida, 2008-152, FDOH study to further develop “passive” & cost-effective nitrogen reduction strategies for OSTDS
- Florida Onsite Sewage Nitrogen Reduction Strategies (FOSNRS) Project began in 2009
- This presentation focuses on preliminary project results from selected two-stage passive biofiltration systems.

Presentation today focuses on sulphur-based denitrification systems

Previous Studies of Sulphur-based Denitrification

Reference	Denitrification Media	Results
Kanter, Tyler and Converse (1998)	Sulphur/Dolomite Sulphur: <2.5 mm	TN Removal: 87.9% Nitrified Influent: 23.5 mg-N/L Effluent: 3.0 mg-N/L
Sengupta and Ergas (2006)	Sulphur/Oyster Shell (75/25% by volume) Sulphur: 4.7 mm	NO_3-N Removal: 80% Influent: 2-32 mg NO_3-N/L Effluent: 4.2 mg NO_3-N/L
Brighton (2007)	Sulphur/Oyster Shell (75/25% by volume) Sulphur: 2 - 5 mm	TN Removal: 81.7% Nitrified Influent: 23 mg-N/L Effluent: 4.2 mg-N/L
Smith et al. (2008)	Sulphur/Oyster Shell (75/25% by volume) Sulphur: 2 - 5 mm	TN Removal: 93.8% Nitrified Influent: 35.2 mg-N/L Effluent: 2.2 mg-N/L

Bench Scale Passive Nitrogen Removal Study

PNRS I Results (Smith, 2008)

- Showed feasibility of passive two stage biofiltration
- One pump, no aerators, reactive media
- Continuous 24/7 operation for 8 months
- Proof of passive 2-stage biofiltration concept provided

Treatment Media	Effluent TN (mg/L)	TN Reduction (%)
Zeolite & Sulphur Media	2.2	97
Expanded Clay & Sulphur	2.6	96.2

AET
Applied Environmental Technology

Pilot study to further the concepts developed by Smith, et. al (2008)

Objectives:

- Follow up to previous study with larger, pilot scale units and various media combinations
- Develop detailed performance data for passive biofiltration designs
- Produce scalable design criteria from pilot scale biofilters for subsequent full-scale testing

A unique pilot facility was constructed at UF research center

- University of Florida, Institute for Food & Agricultural Sciences (IFAS)
- 475 acres of land in SE Hillsborough County
- Facility conducts agricultural research & trials for vegetables, fruit and ornamental plants
- Experts in soil and water science onsite

Test facility includes numerous treatment trains

- All use two-stage biofilters:
  - Stage 1 Nitrification
  - Stage 2 Denitrification
- Stage 1 unsaturated filters
  - 2 media layers
  - evaluated 15” and 30” media depths
- Evaluated single pass vs recirculating stage 1 biofilters
- Evaluation of both lignocellulosic and sulphur denitrification biofilters
- Also testing reactive media in a more in-situ/in-ground system approach

Test facility construction

Setting up tanks

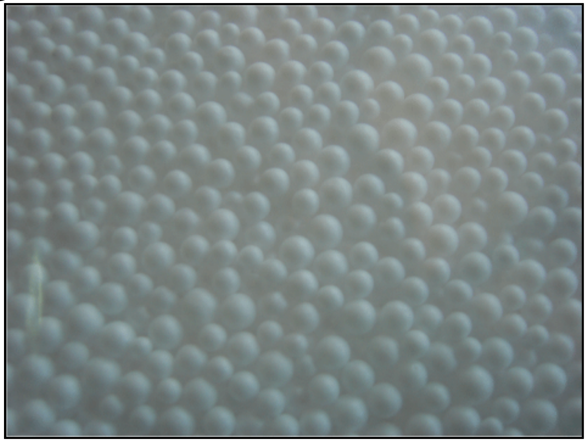
Mixing Media Batches

Gravel Underdrain

Various nitrification media are being studied

Examples of Stage 1 Media

Zeo-Pure clinoptilolite



Expanded polystyrene

Filter sand

Expanded clay

Various denitrification media are being studied

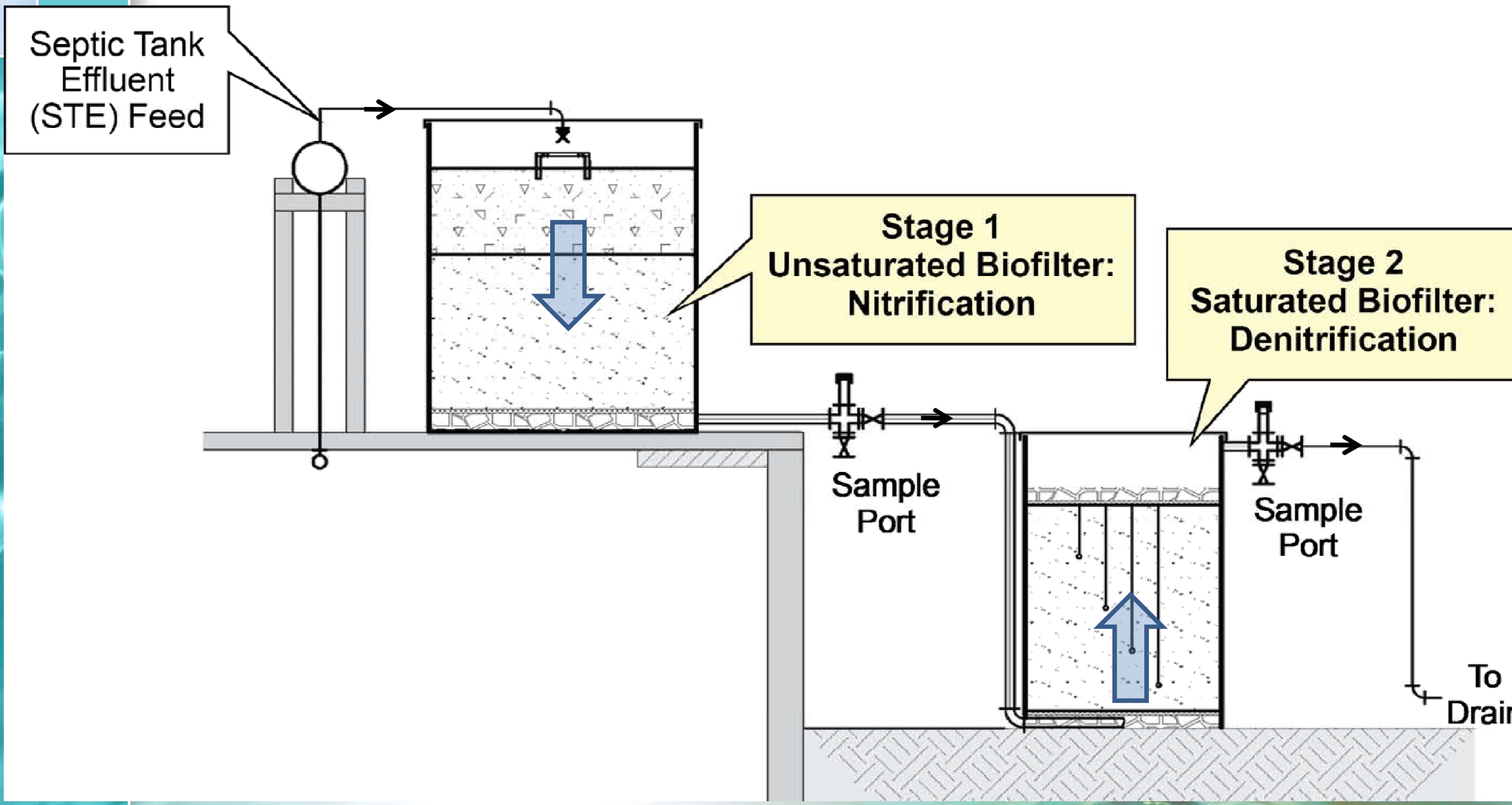
Examples of Stage 2 Media

Lignocellulosics

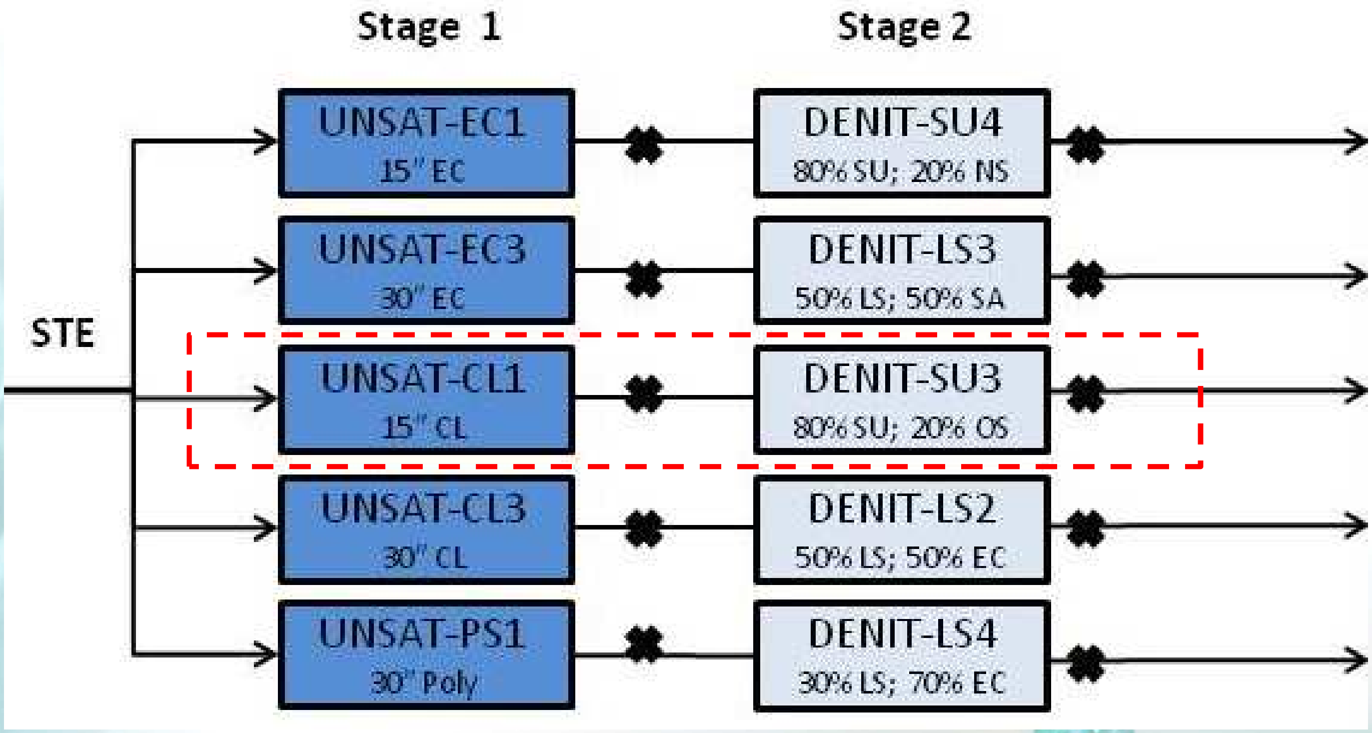
Elemental Sulphur

Expanded Clay

Two stage single pass biofilters

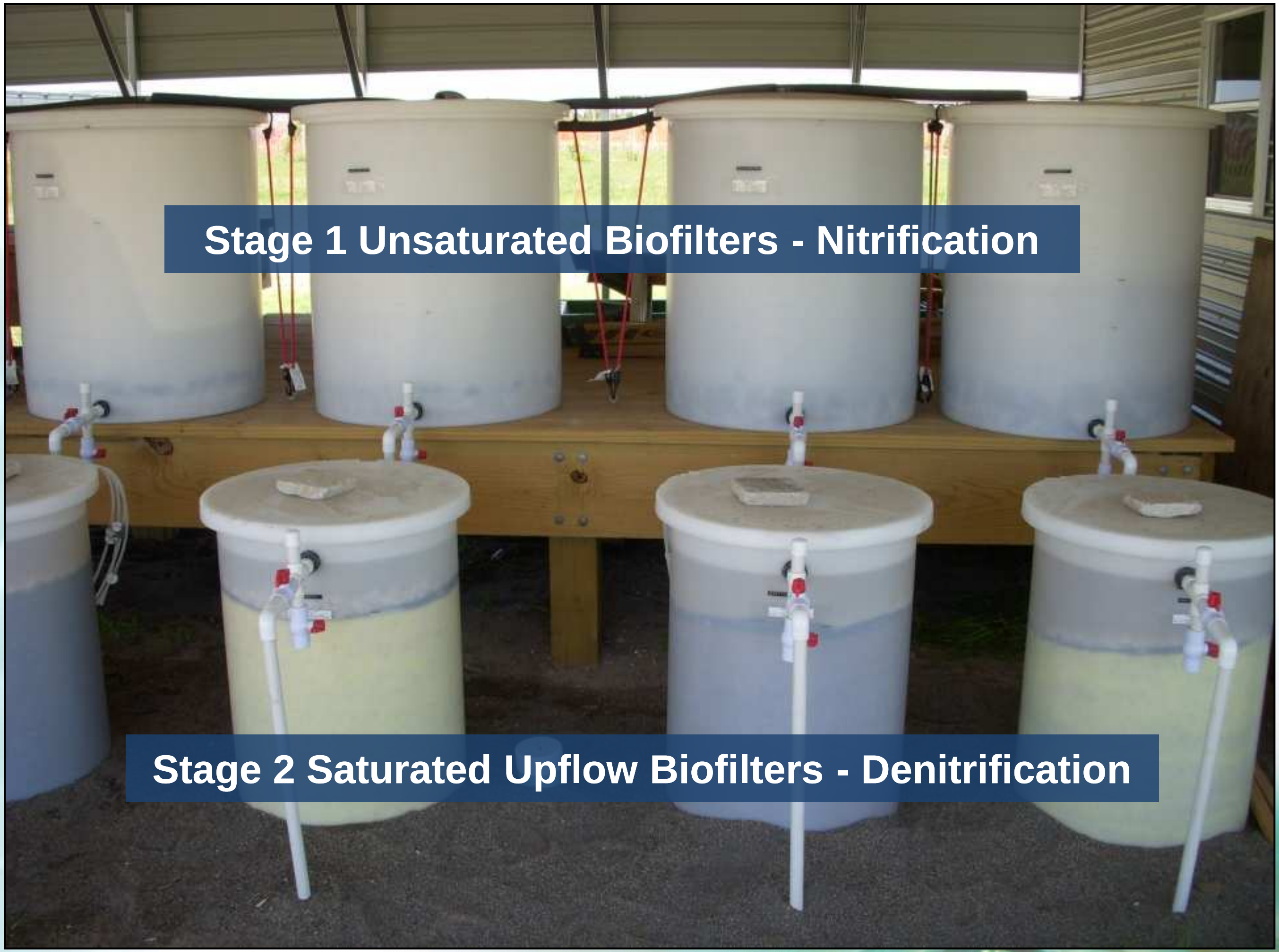


Two-Stage Single Pass Biofilters

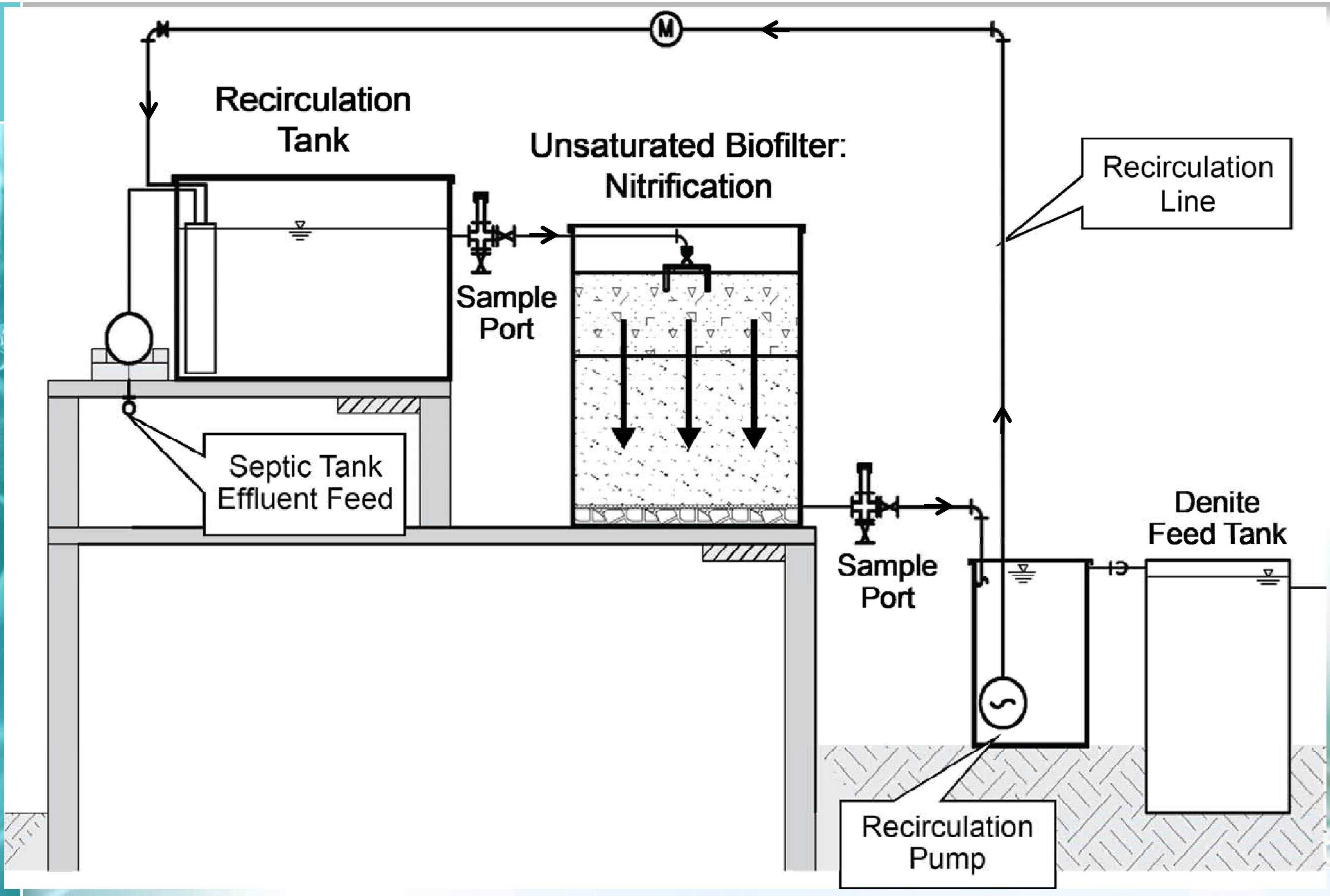


Stage 1 media: EC = expanded clay, CL = clinoptilolite, Poly = expanded polystyrene,
Stage 2 media: SU = sulphur, NS = sodium sesquicarbonate, LS = lignocellulosic, SA = sand,
OS = oyster shell, EC = expanded clay,

Two-stage single pass biofilters



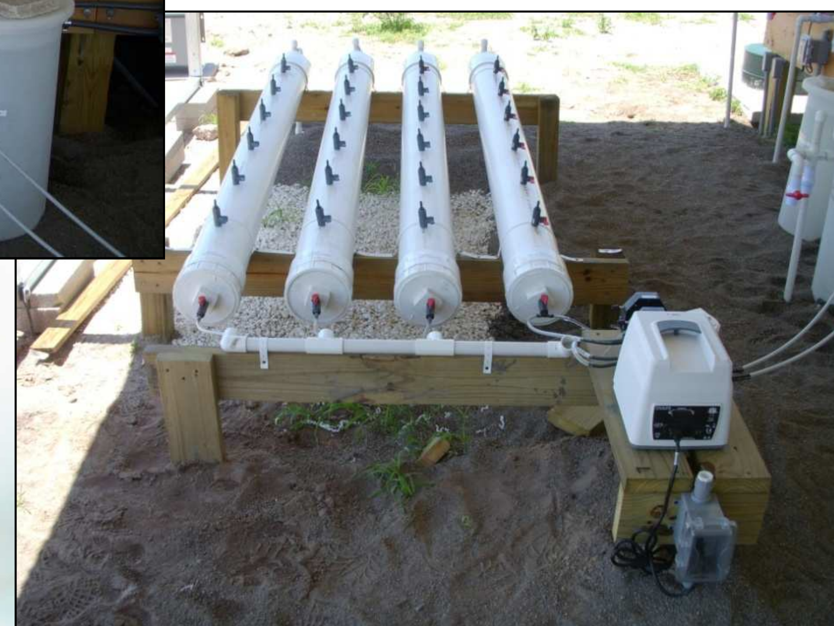
We are also evaluating Stage 1 recirculating biofilters



Stage 1 recirculating biofilters & Stage 2 horizontal saturated biofilters

Stage 1
Recirculating Biofilters

Stage 2
Saturated Biofilters



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Pilot Test Results

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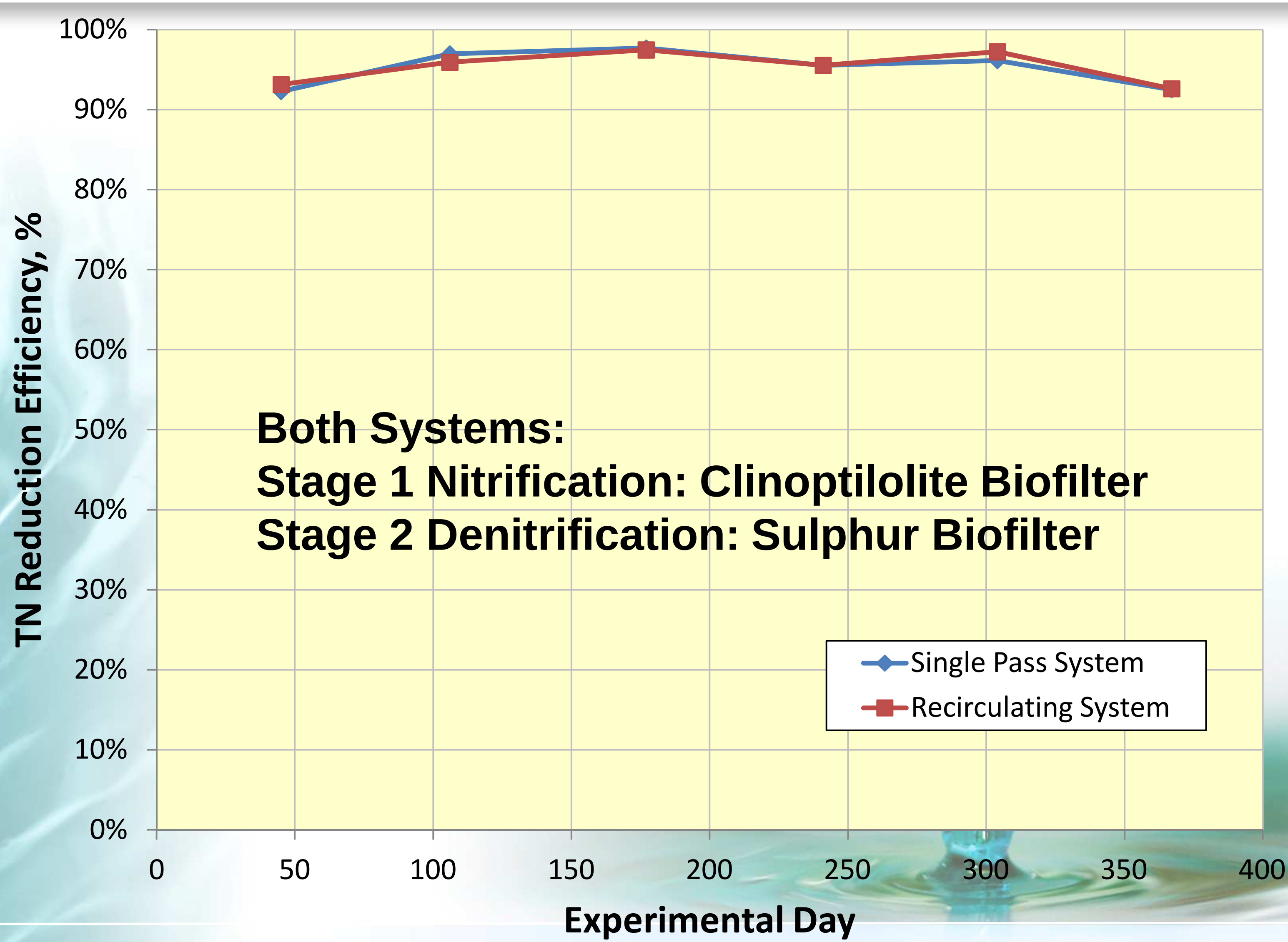
Results show consistent treatment at very low N levels

	Stage 1 Treatment Media	Stage 2 Treatment Media	Effluent TN[1] (mg N/L)		TN Reduction (%)
STE			MEAN	61.04	
			STD DEV	19.12	
			MIN	35.02	
			MAX	80.01	
Single Pass	Clinoptilolite	Sulphur	MEAN	2.60	95.2
			STD DEV	0.52	
			MIN	1.85	
			MAX	3.02	
Recirculation	Clinoptilolite	Sulphur	MEAN	2.54	95.3
			STD DEV	0.40	
			MIN	2.04	
			MAX	2.96	

[1]Continuous operation for 367 days

Results of sulphur based denite systems are excellent



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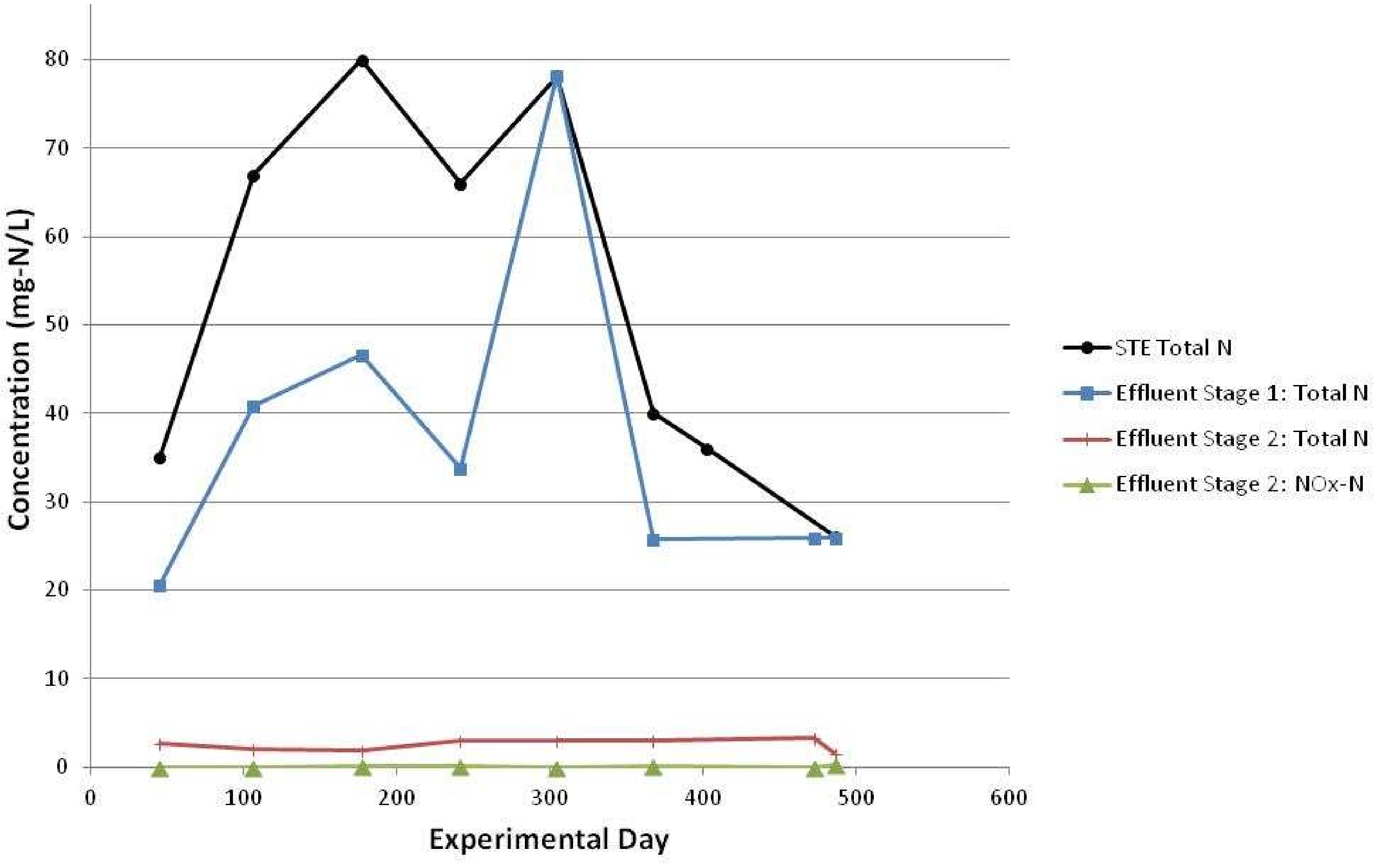
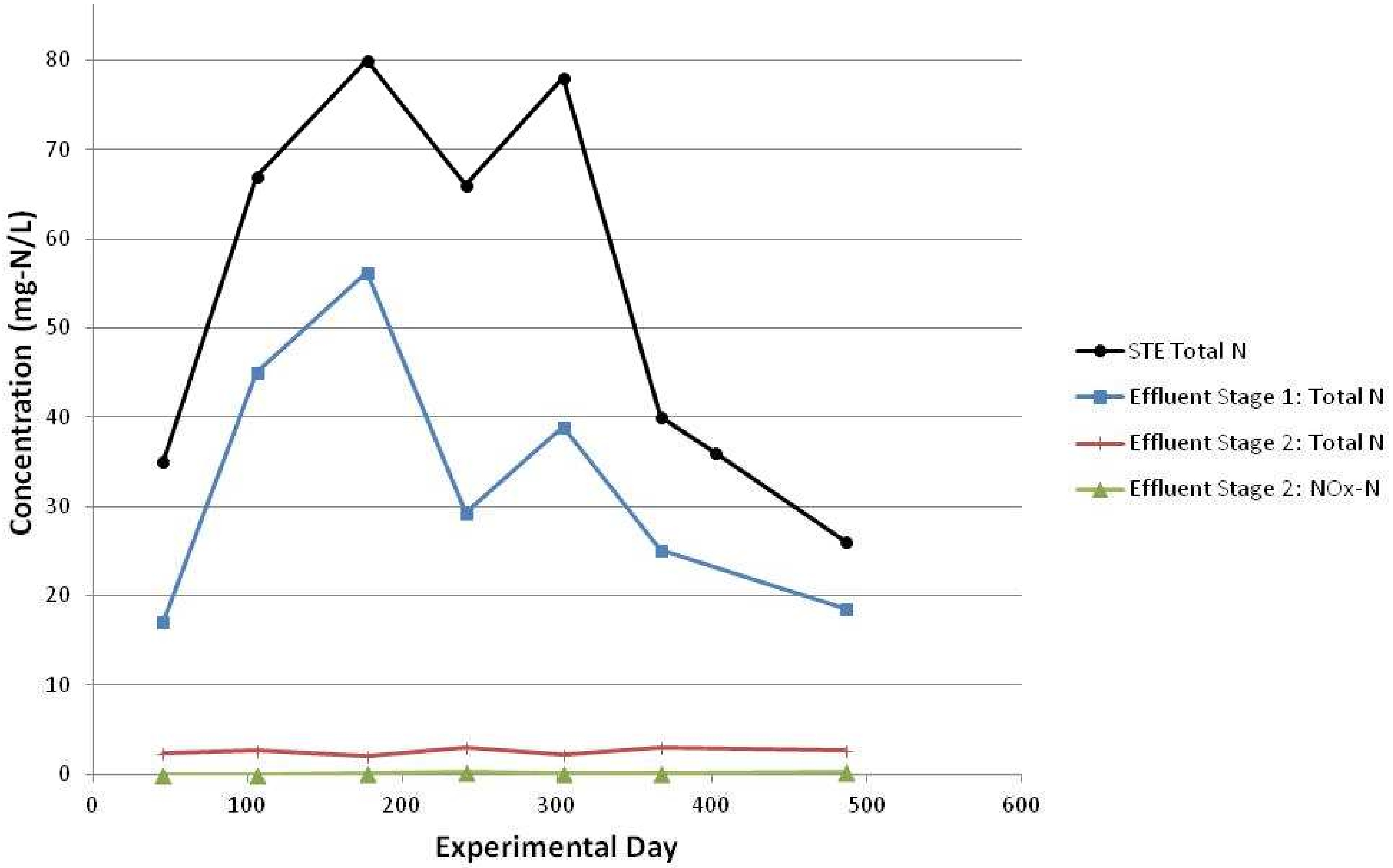
Single Pass System

Stage 1 Nitrification: Clinoptilolite Biofilter
Stage 2 Denitrification: Sulphur Biofilter



Recirculating System

Stage 1 Nitrification: Clinoptilolite Biofilter
Stage 2 Denitrification: Sulphur Biofilter



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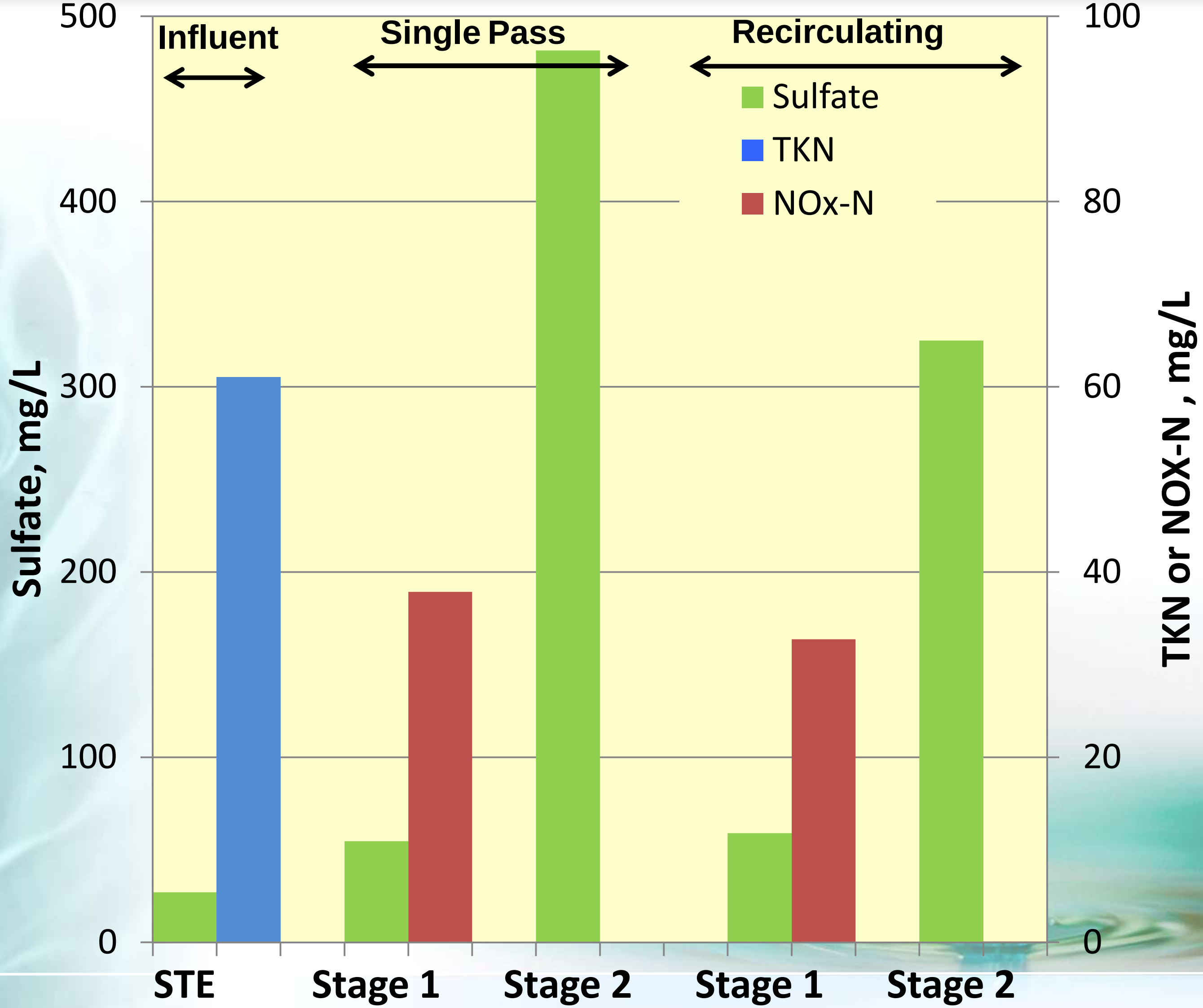
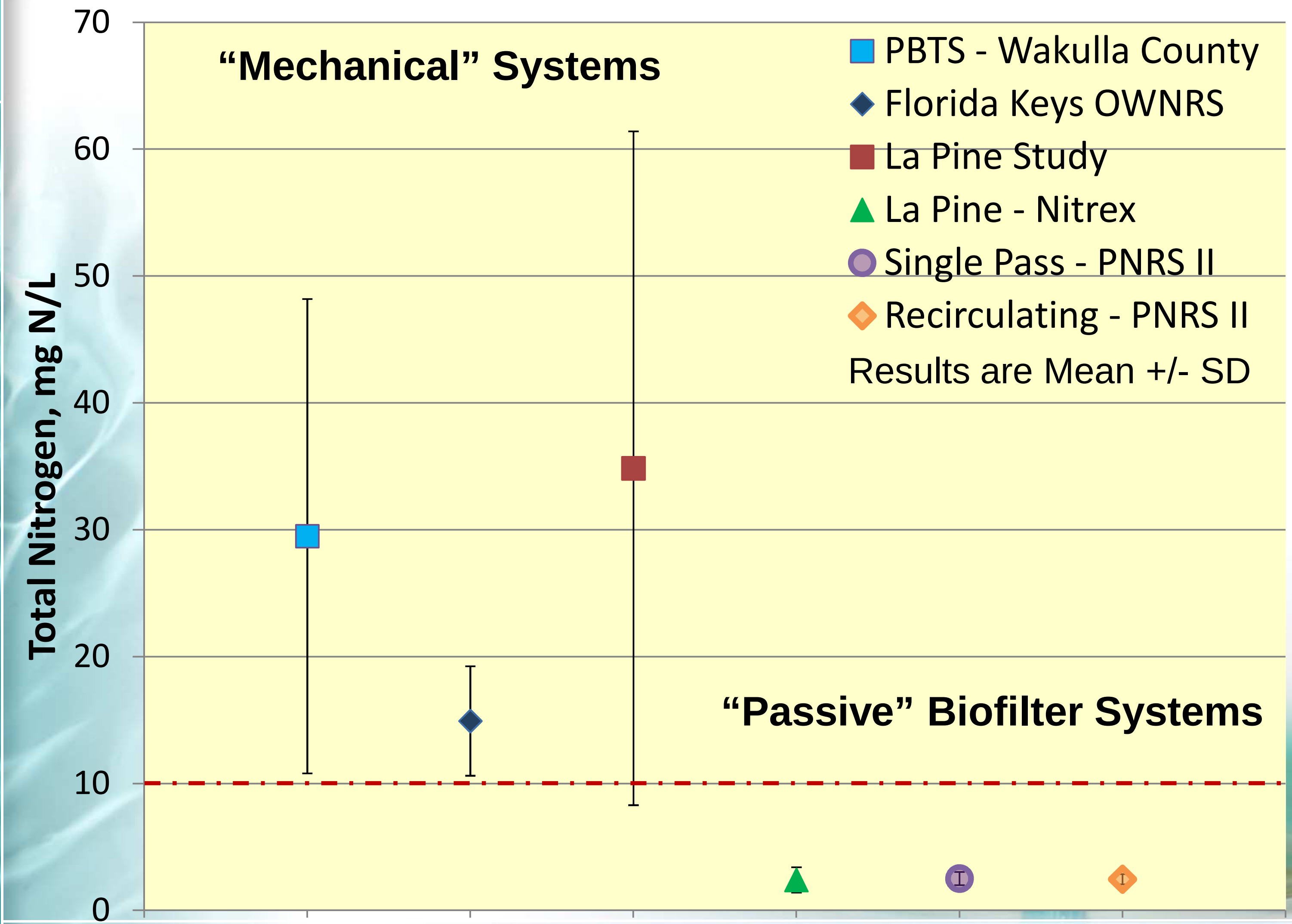
Single pass vs recirculating biofilters: sulfate



Comparison with other N-reduction studies



Next Steps

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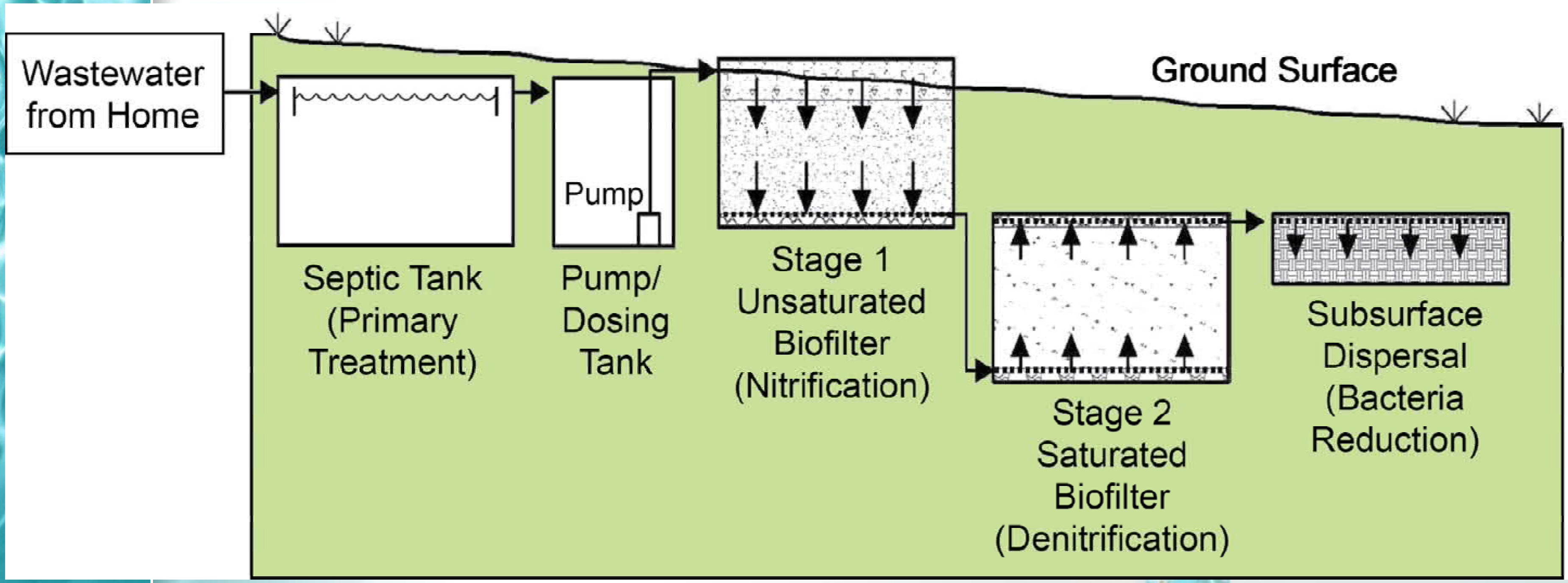
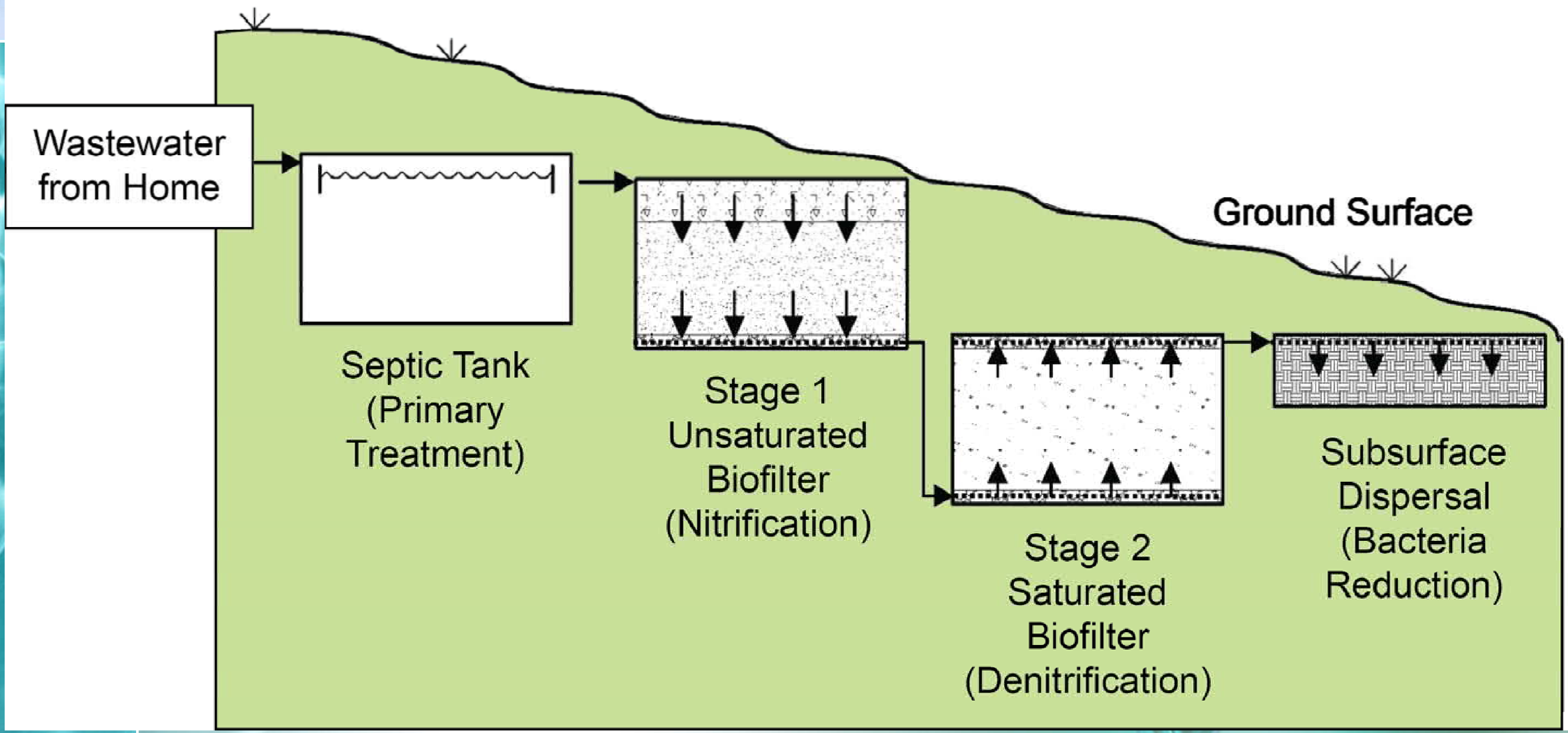
Install full-scale systems at actual home sites

Passive Nitrogen Systems Pumped Flow



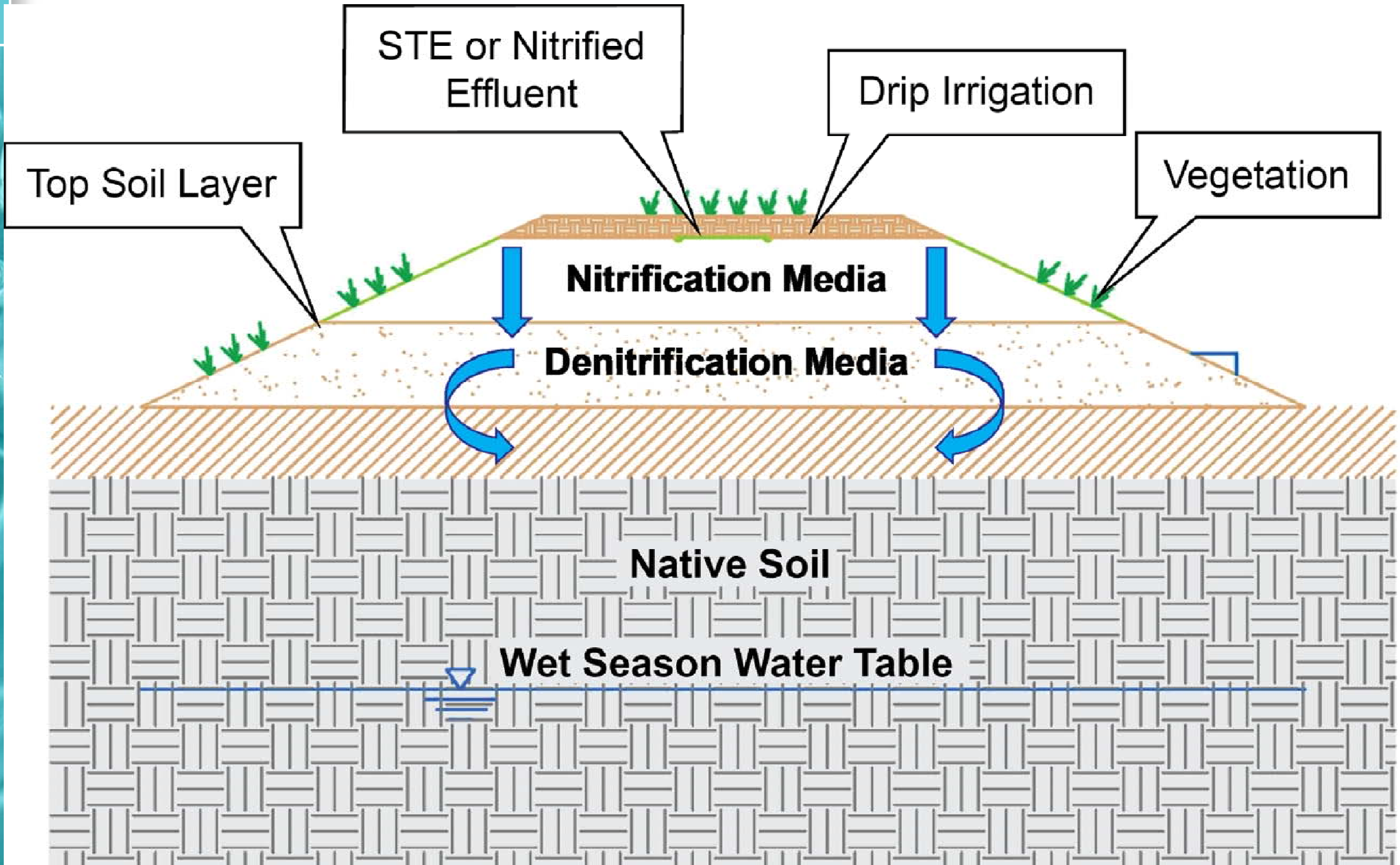
If topography allows, we will try gravity systems

Passive Nitrogen Systems Gravity Flow



Also will be investigating in-situ or mounded biofilters

Vertically Stacked In-situ Biofilter Concept



Successful results from FOSNRS Study would provide:

- OSTDS designs that achieve nutrient removal similar to wastewater treatment plants
- “Passive” systems that are effective and user-friendly for property owners
- Nitrogen reduction from OSTDS in sensitive watersheds where municipal sewers are not feasible

Project Status

- **Project began early 2009**
- **Task status to date**
  - Task A, C and D literature review reports (available at www.doh.state.fl.us/environment/ostds/research/)
  - Task A
    - PNRS II Test Facility Design & Construction
    - Passive system testing
  - Task B
    - Second system in design
  - Task C: Nitrogen fate and transport monitoring
    - Groundwater monitoring has begun at test facility
  - Task D: Soil & Groundwater Modeling
    - Soil modeling has begun

Questions?

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