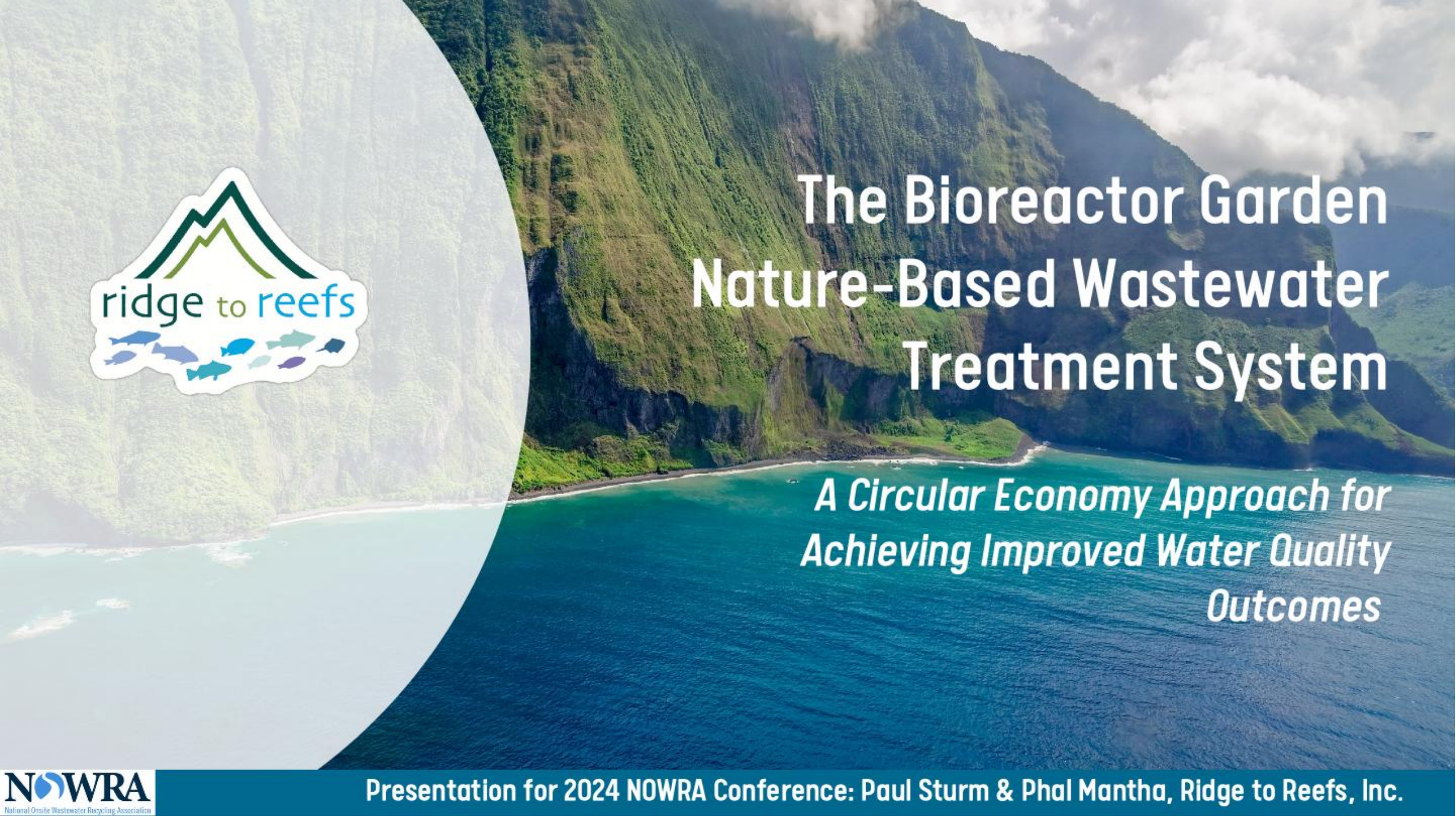

The Bioreactor Garden Nature-Based Wastewater Treatment System

A Circular Economy Approach for Achieving Improved Water Quality Outcomes

Presentation for 2024 NOWRA Conference: Paul Sturm & Phal Mantha, Ridge to Reefs, Inc.

Disclaimer. . .

The materials being presented represent our own opinions, and do NOT reflect the opinions of NOWRA.

Our Team

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Our Mission

Nature inspired solutions for a more resilient planet.

How We Achieve It

We catalyze local capacity & develop nature-based solutions to create communities where connected human and natural systems thrive.

Our Vision

We envision a world where:

- *Everyone has access to locally-sourced, healthy food.*
- *Clean water supports communities and healthy oceans.*
- *Energy is derived from renewable sources.*
- *People support sustainable entrepreneurship and circular economies.*

We envision a world where connected human and natural systems thrive.

In This Presentation

1. Introduction
2. System Testing/Performance
3. Fostering Circular Economies
4. Pharmaceutical Reduction
5. “Zero Discharge” Systems
6. Reuse of Treated Effluent
7. System Scalability
8. Next Steps

Q&A Session

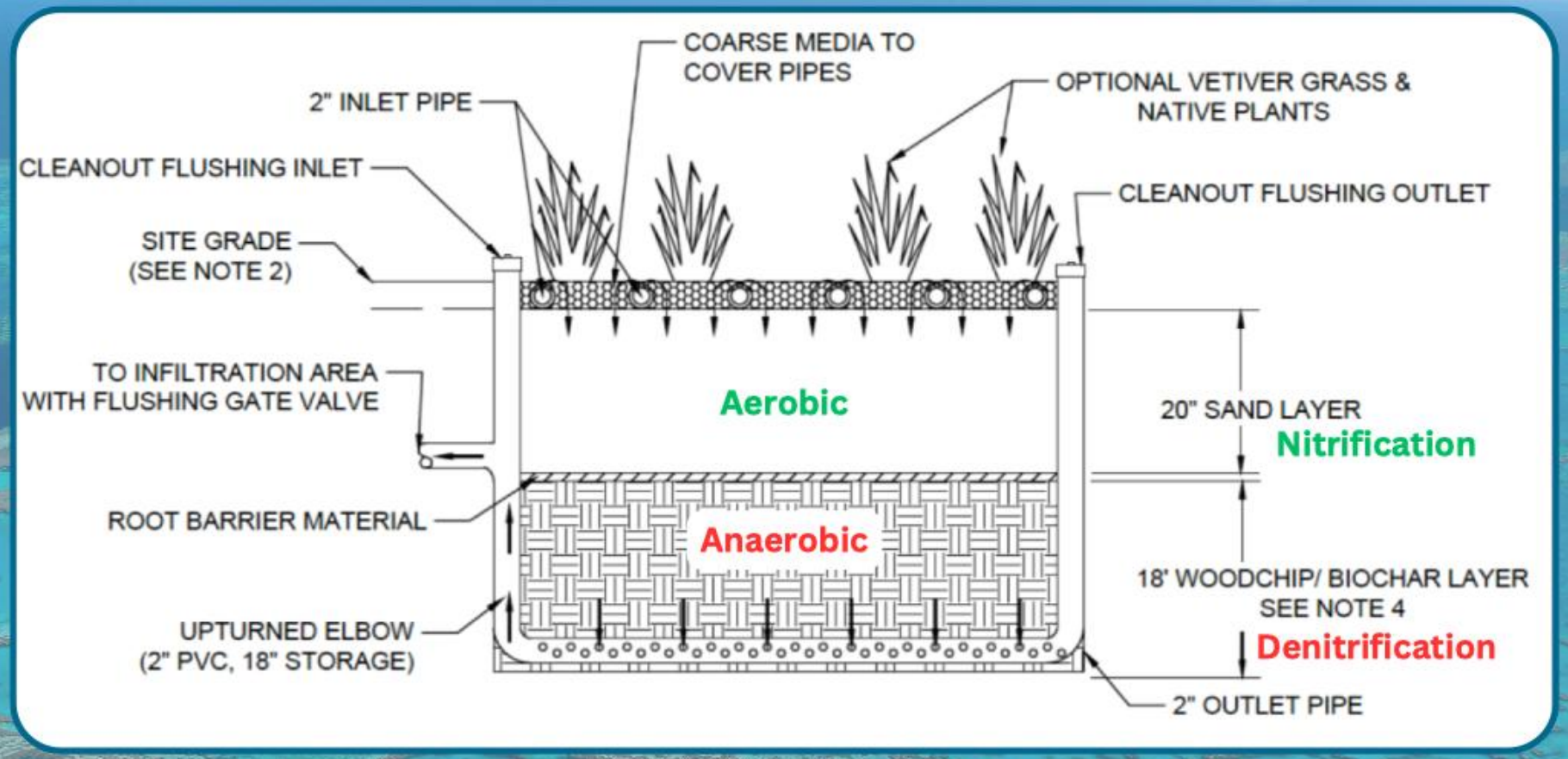
Introduction: The Bioreactor Garden

The Bioreactor Garden is a green infrastructure, nature-based wastewater treatment system that purifies effluent discharged from traditional septic systems.

- Uses passive, naturally-driven processes.
- Mimics the actions of wetland filtration.
- Nitrification is performed through aerobic treatment media, and denitrification is performed by bacteria which grow on the wood chips and biochar. This process safely converts Nitrate into harmless N2 gas.

Cross Sectional Schematic

The Bioreactor Garden is a green infrastructure, nature-based wastewater treatment system that purifies effluent discharged from traditional septic systems.



Multi Redundant Treatment

Mechanisms:

Phytoremediation, filtration through sand and biochar, treatment provided by nitrification & denitrifying bacteria

Relevant Treatment Processes

6 Different Mechanisms of Phytoremediation

1. Nitrification (NH_4 > NO_2- > NO_3-)

2. Denitrification (NO_3- > N_2)

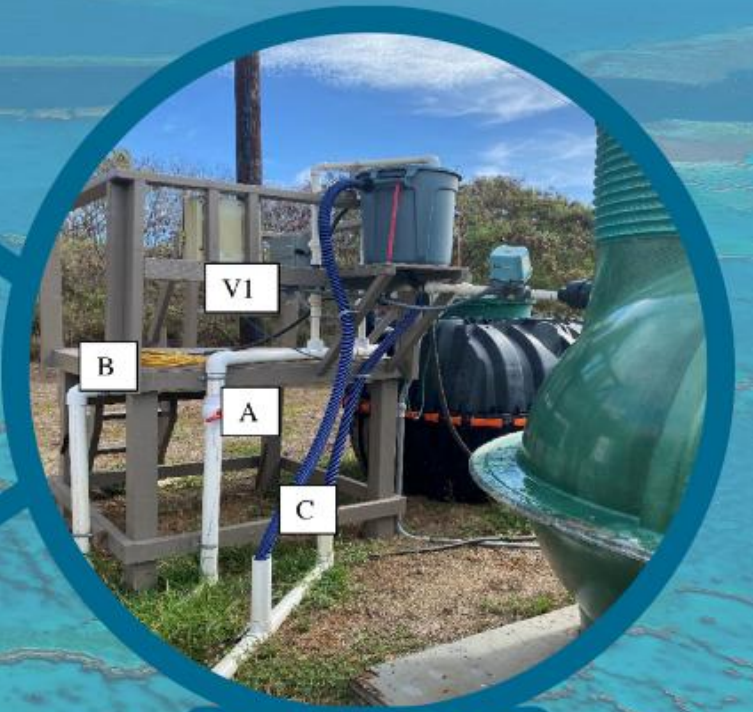
Phytoremediation provides additional treatment by reducing suspended sediments, nutrients, and bacteria.

University of Hawai'i NSF Equivalency Testing

Bioreactor Garden +
1,000 Gallon Septic Tank
(Infiltrator IM 1060)

Influent Sampler: ISCO 5800
(Refrigerated)

Effluent Sampler: ISCO 3700



Feed System Piping

NSF Testing Procedure

Testing Requirements:

- 600 Gallons per Day
- 16 Week Standard Performance Test Period
- Series of Four Stress-Loading Tests Over 7.5 Weeks
- Final 2.5 Weeks of Design Loading

Minimum performance for a NSF40 Class I effluent requires the 30-consecutive-day mean effluent concentration of CBOD5 and TSS be no greater than 25 mg/L and 30 mg/L, respectively.

The system was designed to provide a total flow of 600 gal/day to the Bioreactor Garden in a manner prescribed by the National Sanitation Foundation Standard 40 (NSF40) and 245 (NSF245) test protocols.

The NSF245 standard requires that the average of all samples during the 16-week design loading period provide at least 50% removal of total nitrogen (TN).

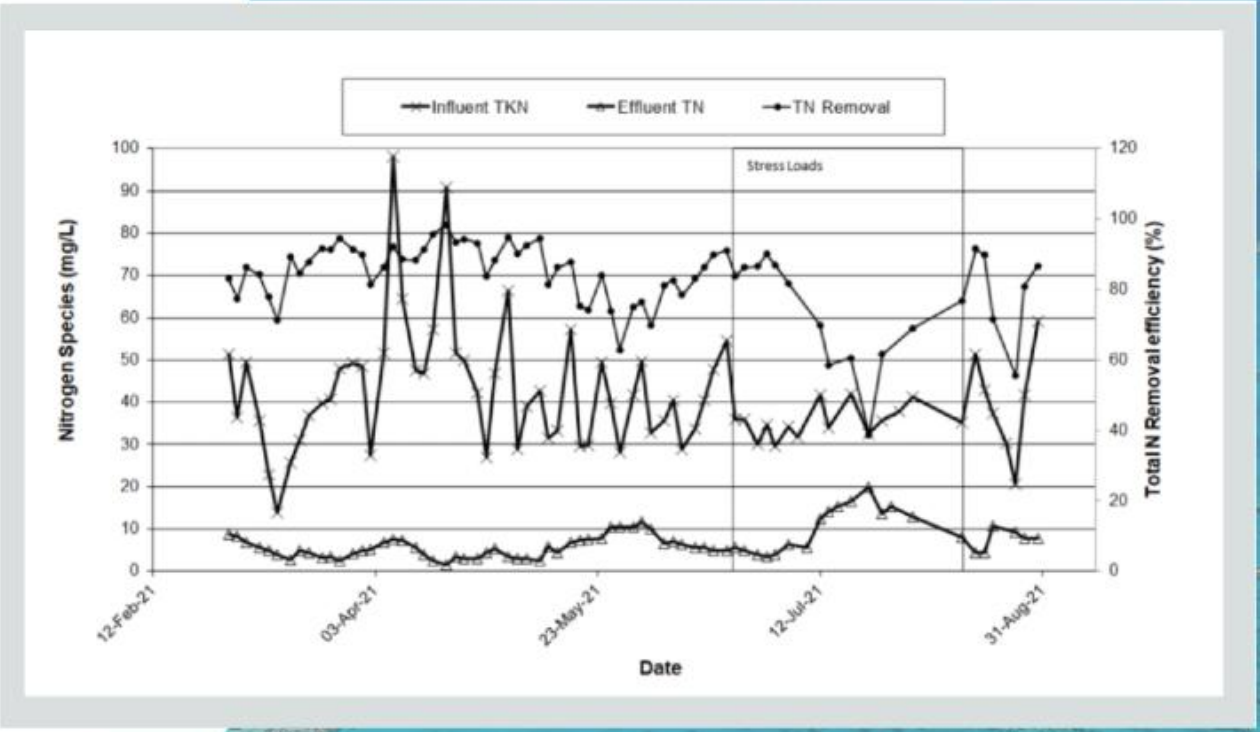
The NSF40/245 protocols call for 35% of the daily flow to enter between 6 am and 9 am, 25% to enter between 11 am and 2 pm, and 40% to enter between 5 pm and 8 pm.

NSF Analytical Methods

The primary goal of testing the R2R-BG was to determine whether this system could produce effluent that satisfied the NSF40 Class I requirements and achieve at least 50% nitrogen removal.

Analyte	Method
$BOD_5/CBOD_5$	STM 5210 B
TSS	STM 2540 D
pH	STM 4500-H
Temperature	pH probe
TKN	STM 4500 N-org
TP	STM 8190
Cations/Anions	Dual Dionex ICS-1100 Ion Chromatographs, AS-DV Autosampler
Alkalinity	STM 4500 H+B
Color	STM 2120 B
Odor	Panel
Oily Film	Visual
Foam	Visual

Testing Resulted in Approval By Hawai'i Department of Health



During the 26-week evaluation period, effluent CBOD5 averaged **19 mg/L**, effluent TSS averaged **6 mg/L**, and pH averaged **7.6** (minimum 7.1, maximum 8.5). During the design loading period, TN removal averaged **87%**.

The data indicate that the R2R Bioreactor Garden met **all** of the requirements for NSF40 Class I effluent and all of the NSF245 criteria for TN removal.

Exceeds NSF40 & 245 Standards

- 87% Total Nitrogen Removal
- 83% Phosphorus Removal
- >15 - 20% Volume Reduction
- 95% TSS Removal

Pharmaceutical Reduction

Testing Performed by Texas A&M Marine & Environmental Geochemistry Lab

Exciting data from Kihei!

Recent lab tests show the bioreactor garden removes pharmaceuticals from wastewater!

Pharmaceutical Removal Rate	Caffeine	Antibiotics	SSRI	Seizure Medication
Bioreactor Garden (BG)	54.11%	98%	100%	37%
BG + sand/biochar filtration layer	48.21%	98%	100%	68%

Analytes included: Caffeine, Trimethoprim, Primidone, Sulfamethoxazole, Erythromycin, Carbamazepine, Fluoxetine

The Bioreactor Garden demonstrated nearly complete removal of antibiotics and SSRIs (Selective Serotonin Reuptake Inhibitors - a common pharmaceutical found in wastewater).

Fostering Local Circular Economies

Woodchips and Biochar from Invasive Species

Vegetated Leach Fields and Recycled Glass Pipe Bedding

Aerobic Filtration Sand from Recycled Glass

Native Species and Local Plants

Local Contractors

Vegetated Leach Fields & Zero-Discharge Systems

Hawai'i Department of Health (DOH) approved a 30% Reduction in Soil Absorption Trench Size, with a 15% reduction permitted for the Vetiver Grass present in the Leach Field and Bioreactor Garden respectively.

Excavation Costs are a significant portion of total cost for a wastewater upgrade. Therefore, these reductions can have a significant cost benefit for homeowners.

If evapotranspiration rates are greater than the amount of effluent discharged into the system, "Zero Discharge Systems" can be designed (effluent is transpired into the air by plants instead of being discharged into the ground).

Reuse of Treated Effluent

Septic Tank Sample

Leach Field Sample

Reuse of Treated Effluent for Agroforestry Establishment

Sampling performed by the Republic of Palau Environmental Quality Protection Board (EQPB).

Evaluating designs for integration of bamboo for production of renewable construction materials.

Evaluating other uses: vegetated fire buffers, "living fences", and agroforestry windbreaks for enhanced facilities benefits.

Nature Based Solutions are Scalable

Residential
200 - 1,000 GPD

Facilities/Commercial
1,000 - 10,000+ GPD

Municipal/WWTP/
Injection Wells
1,000 - 1 Million GPD

Ag/Landscape Scale
1,000 - 1 Million GPD

Next Steps. . .

Containerization

National NSF Certification

Build Partnerships with installers, engineering firms, and watershed groups

Utilize Nature Based Solutions for Wastewater Treatment Plants, Injection Wells, Landfills, and Confined Animal Feed Operations


Thank You
Questions/Answer Session

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