WATER CONSERVATION AND CONTAMINANT REMOVAL FROM GRAYWATER USING COLORADO NATIVE PLANTS IN A HYDROPONIC GREEN WALL

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Colorado River Basin

- Populations continue to increase as water supplies dwindle.
- Western Slope households use 12,000 gallons of water a year on average to wash laundry.
- The reuse of this source of graywater is a logical way to reduce overall household water demands.

Estrada et al. 2020, Outcalt, 2022, National park Service, 2021. image source: www.usgs.gov

What is Graywater?

Graywater is water discharged from bathroom and laundry room sinks, bathtubs, showers, laundry machines.

It does not include wastewater from toilets, urinals, kitchen sinks, dishwashers or non-laundry utility sink.

Can you utilize Graywater in Grand Junction?

- **Colorado Regulation 86:** Each local city, city and county, or county has the discretion to decide whether to adopt any of the graywater uses along with the associated minimum design criteria and control measures set forth in this regulation.

- **Grand Junction: Ordinance No. 5094 adds Chapter 13.40 to GJMC Graywater Control Program**

Randi Kim, Utility's Director City of Grand Junction, & EPA

Category C graywater (Single family, indoor toilet and urinal flushing)

- Must be a certified NSF/ANSI 350 Class R onsite residential water reuse treatment system.
- A disinfection system is required.
- System must be capable of providing a chlorine residual of 0.2 to 4.0 mg/L.
- Must visibly dye graywater with either blue or green food grade vegetable dye.

The Cost of a Graywater Treatment System

- Graywater treatment systems marketed for single-family homes can vary between \$6,000 and ~\$13,000.
- Yearly maintenance is usually required and can cost anywhere between \$200 to \$900 per year.

Yu et al, 2015, image: greyter.com

WHAT'S A GREEN WALL?

Green walls can be split into two major categories

1. **Green Facades**

2. **Living Walls**

Associate Professor Freddy Witarsa Ph.D., Colorado Mesa University, image: greenscreen, http://goddearthplants.com

Green Walls

- Traditional green walls are vertical structures that have plants attached to them.
- The vegetation is usually planted in growing media consisting of soil, stones, or water.
- Due to the presence of living plants, green walls generally consist of a built-in irrigation system.
- The consumption of water is an important consideration for a green wall in a drought laden, arid climate such as the Colorado River basin.

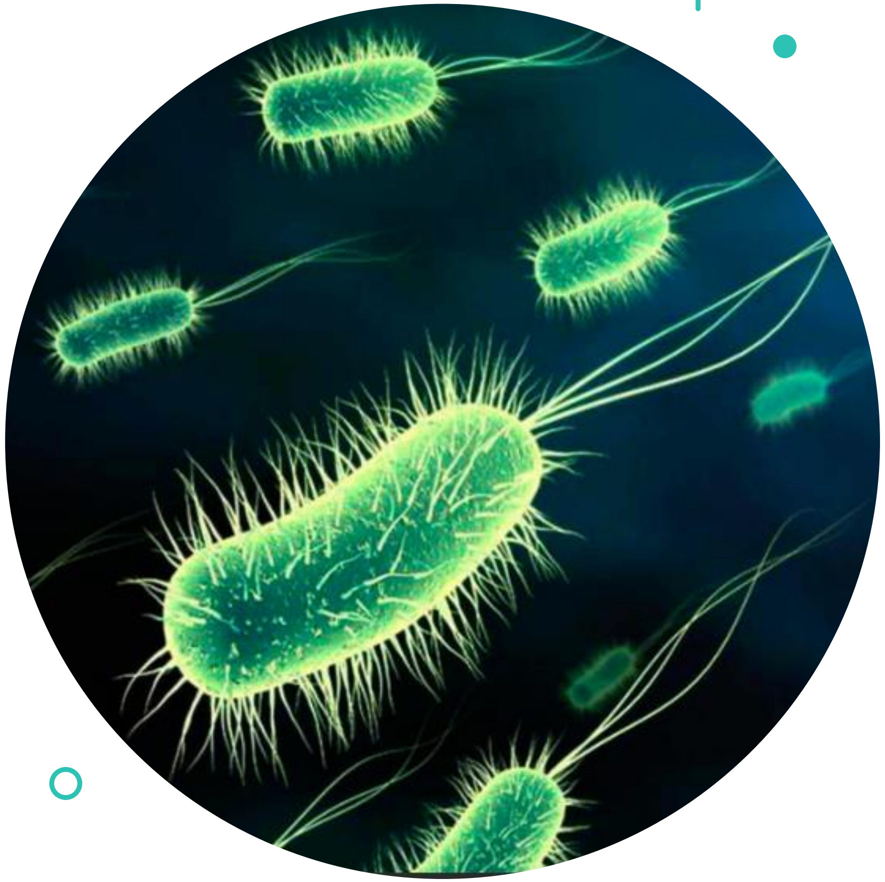
Our Study

- Inexpensive
- Beautiful
- Water Conservation
- Empowering
- Educating
- Eco-friendly
- Sustainable

Key Objectives

1. Removal of *E. coli*

- Previous research has demonstrated successful use of perlite growing media for the removal of *E. coli* and other common graywater contaminants.



Prodanovic et al. 2017, image: creative-biolabs.com

Key Objectives

2. **Removal of contaminants commonly found in laundry graywater.**

- No prior studies have investigated the efficacy of Colorado native plants in removing contaminants from graywater.

Pradhan et al., 2017, Rabalais et al., 1996, image: pexels-rdne-stock-project

Key Objectives

3) **Provide evidence to inform and support the technological development and design of an interior mounting graywater green wall.**

- Demonstrate a low-cost water conservation method that recycles water and can easily be maintained in any household.

image: pexels-rdne-stock-project

Study Implications

- Reduce demand on water supply.
- Delay the need for infrastructure investment.
- Reduce the need for watering restrictions during drought.
- Support river resiliency.
- Less household water demand.
- Bolster sustainable water practices.
- Increase awareness and access to green walls.

Randi Kim, Utility Director, City of Grand Junction

Hypothesis

- The treatment green wall with Colorado native plants will facilitate contaminant removal, thereby reducing the green wall owner's water and wastewater treatment needs.

Image: pexels-austing-sullinvan

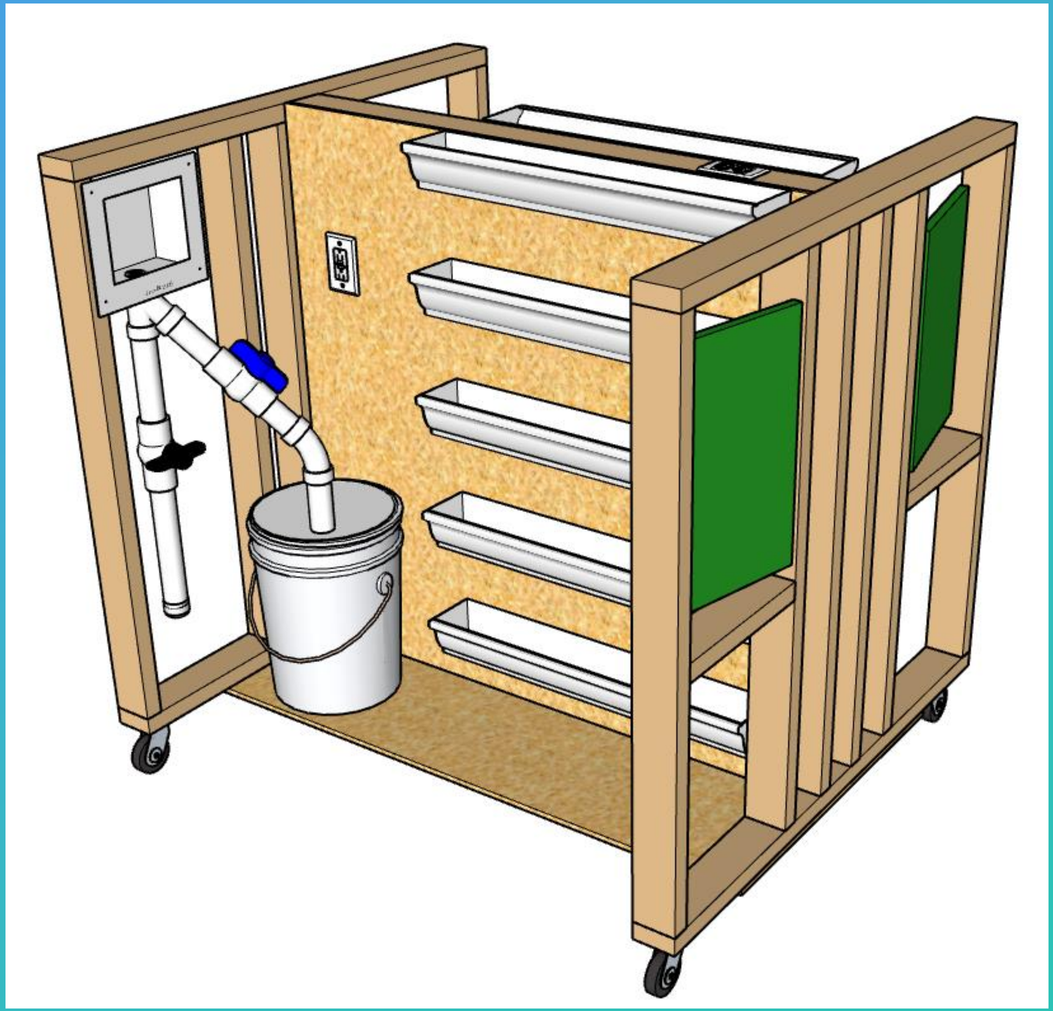
Methods

PLANT SELECTION

- Colorado Blue Columbine
- Yellow Prairie Coneflower
- Kannah Creek Buckwheat
- "Moonshine" Yarrow

GREEN WALL DESIGN

- Electrical system
- Plumbing system
- Hydroponic pump
- 24 W LED grow lights



Interdisciplinary Project

- Study wall was built at the Archuleta Engineering Center.
- The wall was moved to Wubben Science Center prior to starting the experimental phase.

Experimental Design

- **Lab-made synthetic graywater**
  - 14-gallons with commercial laundry detergent, soil, human and animal grade foods
  - 0.5 μL of lab-cultured *E. coli* strain B

- **Three experimental runs**
- **Collected more than 500 samples.**
- **Examined nine chemical parameters.**

Complications and Modifications

- Leaking
- Clogging
- Plant Mortality
- Data Inconsistencies

Results and Discussion

Chemical Oxygen Demand

Tray three

- Control: mean COD = 426 ± 19 mg/L
- Treatment: mean COD = 386 ± 21 mg/L

Tray five

- Control: mean COD = 361 ± 46 mg/L
- Treatment: mean COD = 253 ± 84 mg/L

- ➢ Treatment wall overall removal: 66%
- ➢ Control wall overall removal: 51%

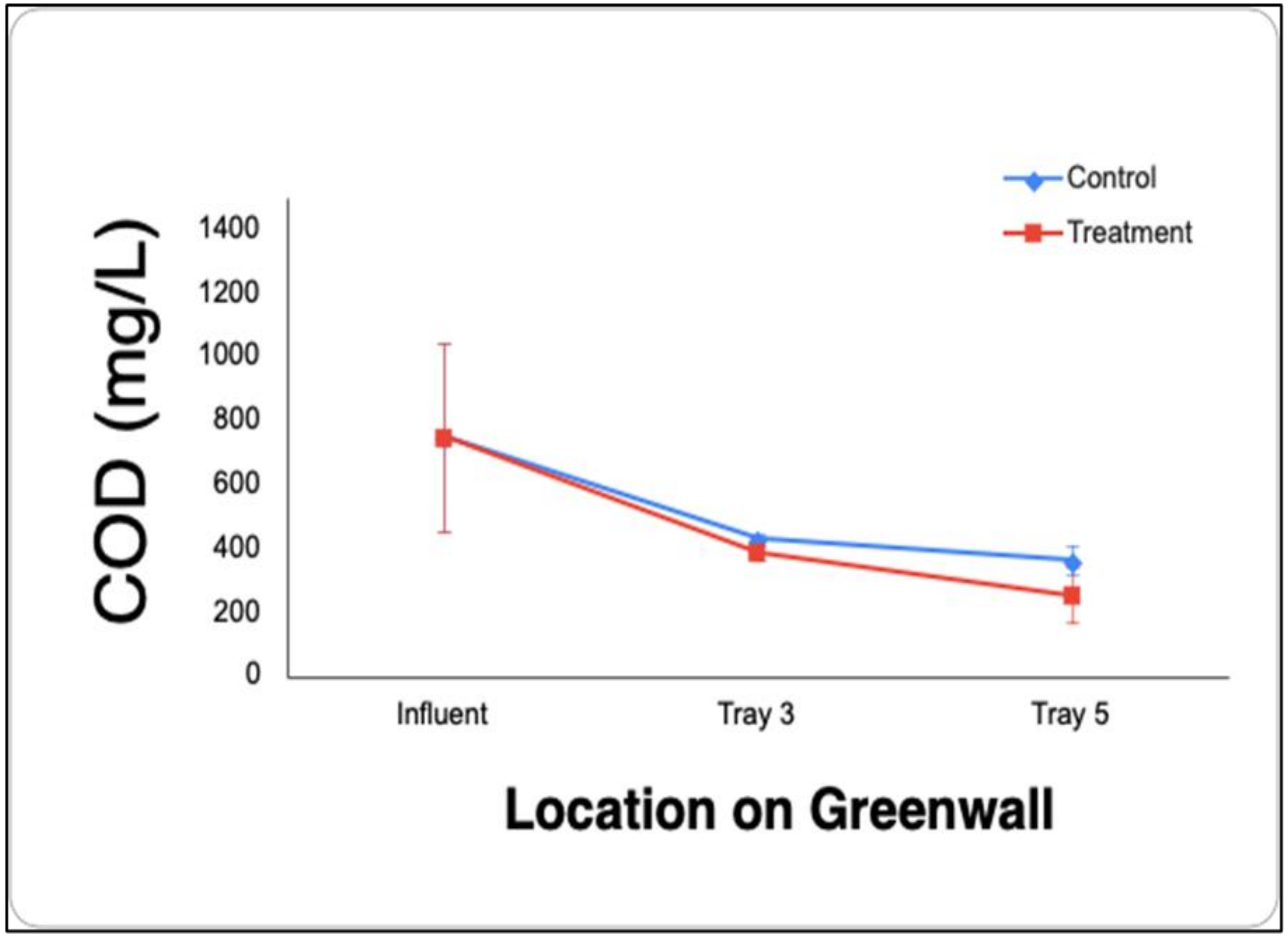


Figure 2. Average COD results for all experimental runs for treatment and control walls.

Total Suspended Solids

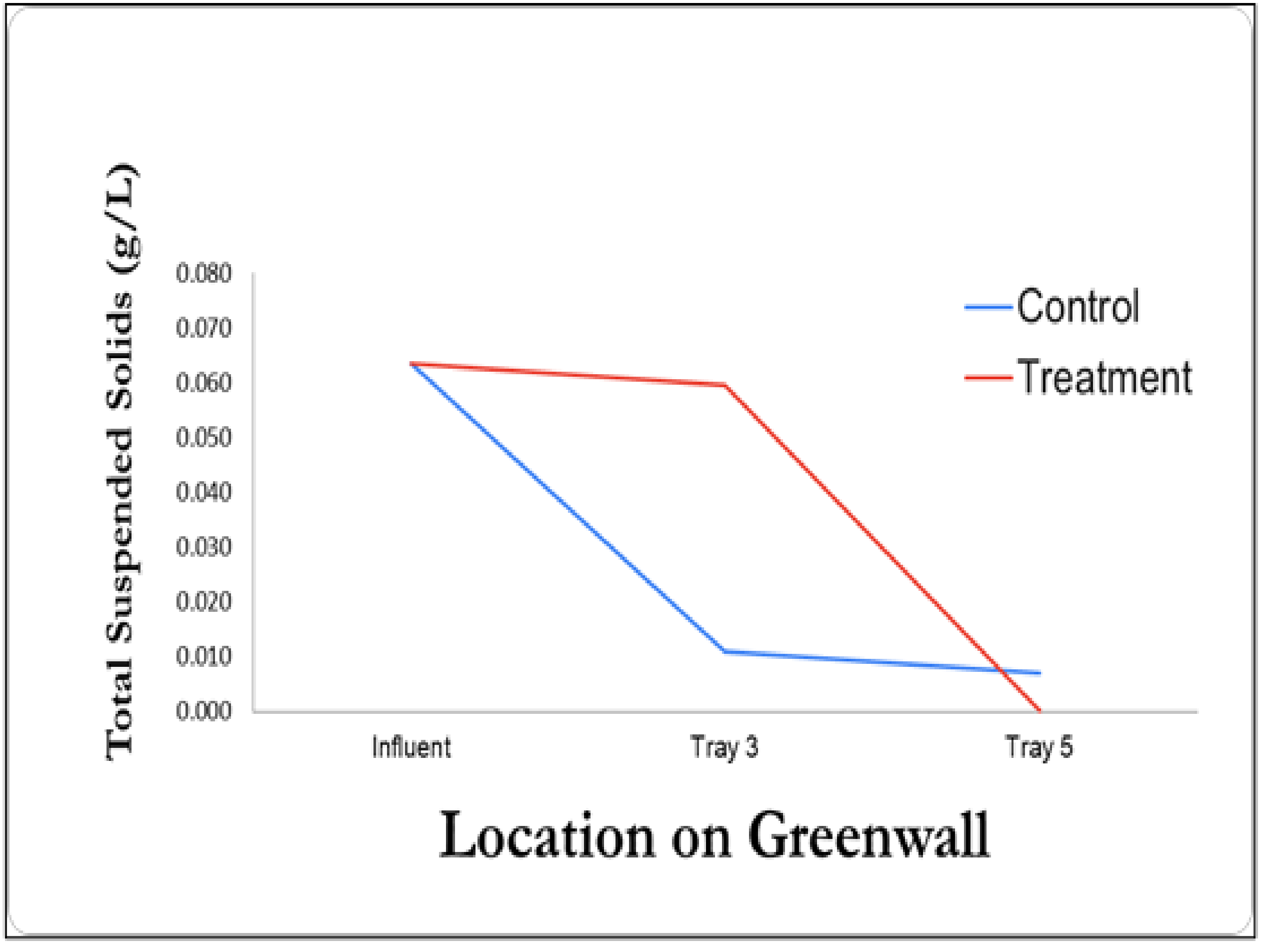
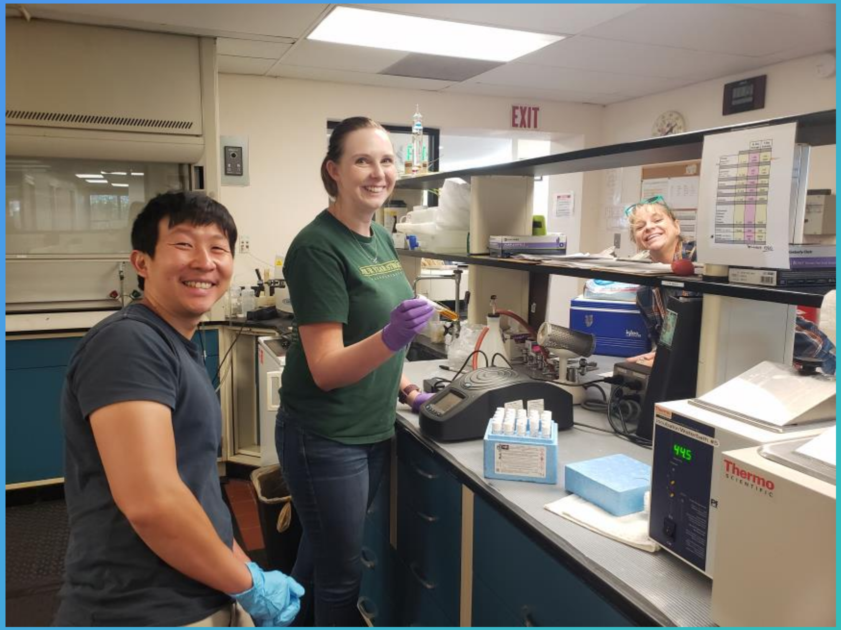


Figure 1. TSS data for experimental run one.

- Treatment: **99.5% decrease** in TSS between influent (0.064 g/L) and treatment Tray five (0.0003 g/L).
- Control: **89.2% decrease** of TSS between influent (0.064 g/L) and Tray five (0.007 g/L).

➢ Both walls were effective at removal of TSS with treatment wall ~ 10% more effective.



- High TSS and COD removal observed.
- Trapped organic matter likely held in the system by plants and growing media.
- Plant root systems could enable physical removal of materials.

Prodanovic et al., 2019 & 2020, Pradhan et al., 2019

***Escherichia coli* Loading**

- <u>Treatment:</u> mean MPN 13.9/100 mL
- <u>Control:</u> mean MPN 413/100mL

➢ *E. coli* **increased by 321%** between influent (7 ± 3.28/100 mL) and **treatment** tray five (29.5 ± 23.5/100 mL).

➢ *E. coli* **increased by 8,214%** between influent (7 ± 3.28/100 mL) and **control** tray five (582 ± 518/100 mL).

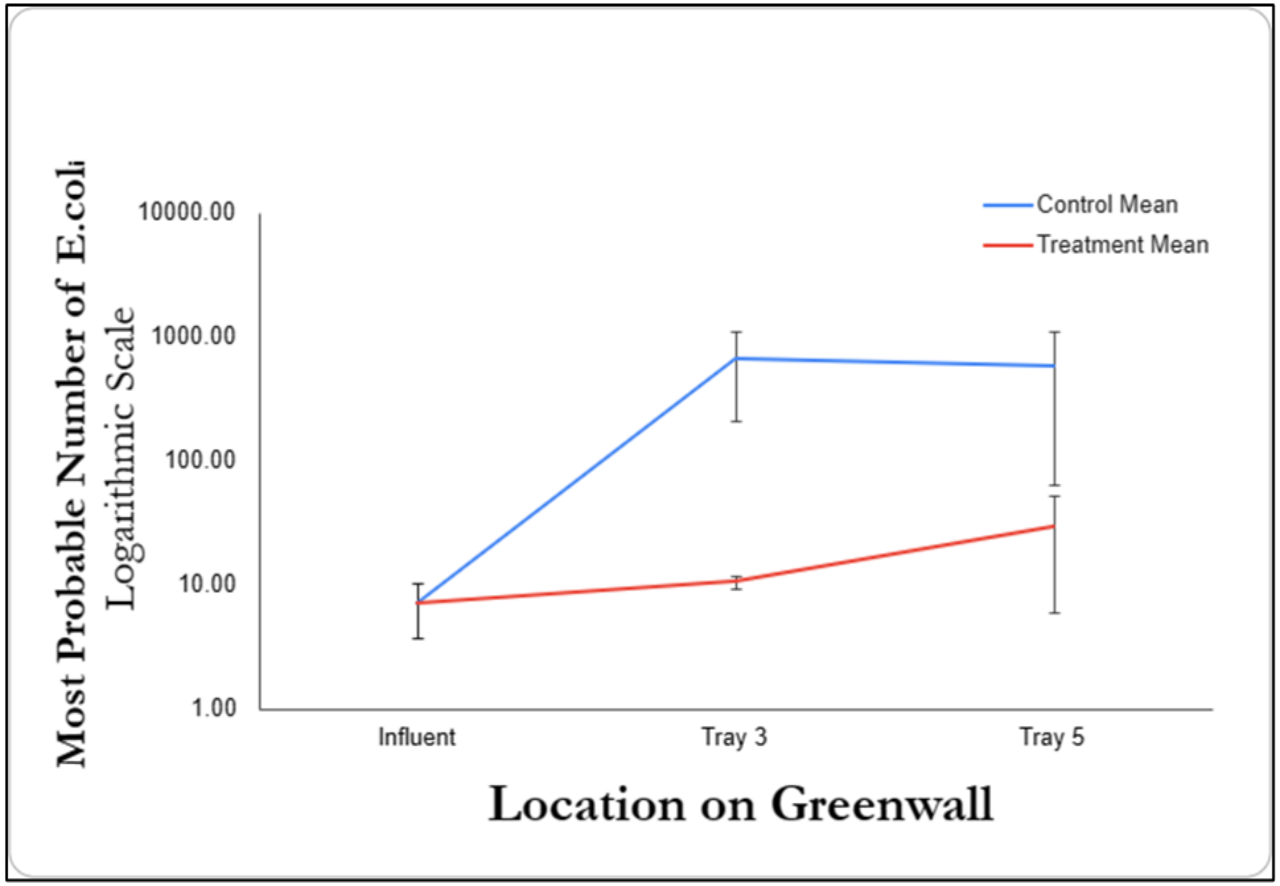


Figure 3. Average MPN of *E. coli* per 100 mL of sample for experimental runs 2 & 3.

- *E. coli* could have adsorbed to perlite media.
- Plant roots and associated biofilms could act as antimicrobial compound source.
- Control wall may be a more hospitable growing environment for *E. coli*.
- Plant replacement may have also removed *E. coli*.

Stevik et al. 2004, Shirdashzadeh et al. 2017.

Total Nitrogen

- Treatment: mean TN **decreased by 30%** between influent (18.38 mg/L) and Tray five (12.8 mg/L).

- Control: mean TN **decreased by ~ 68%** between the influent (18.38 mg/L) and control Tray five (5.8 mg/L).

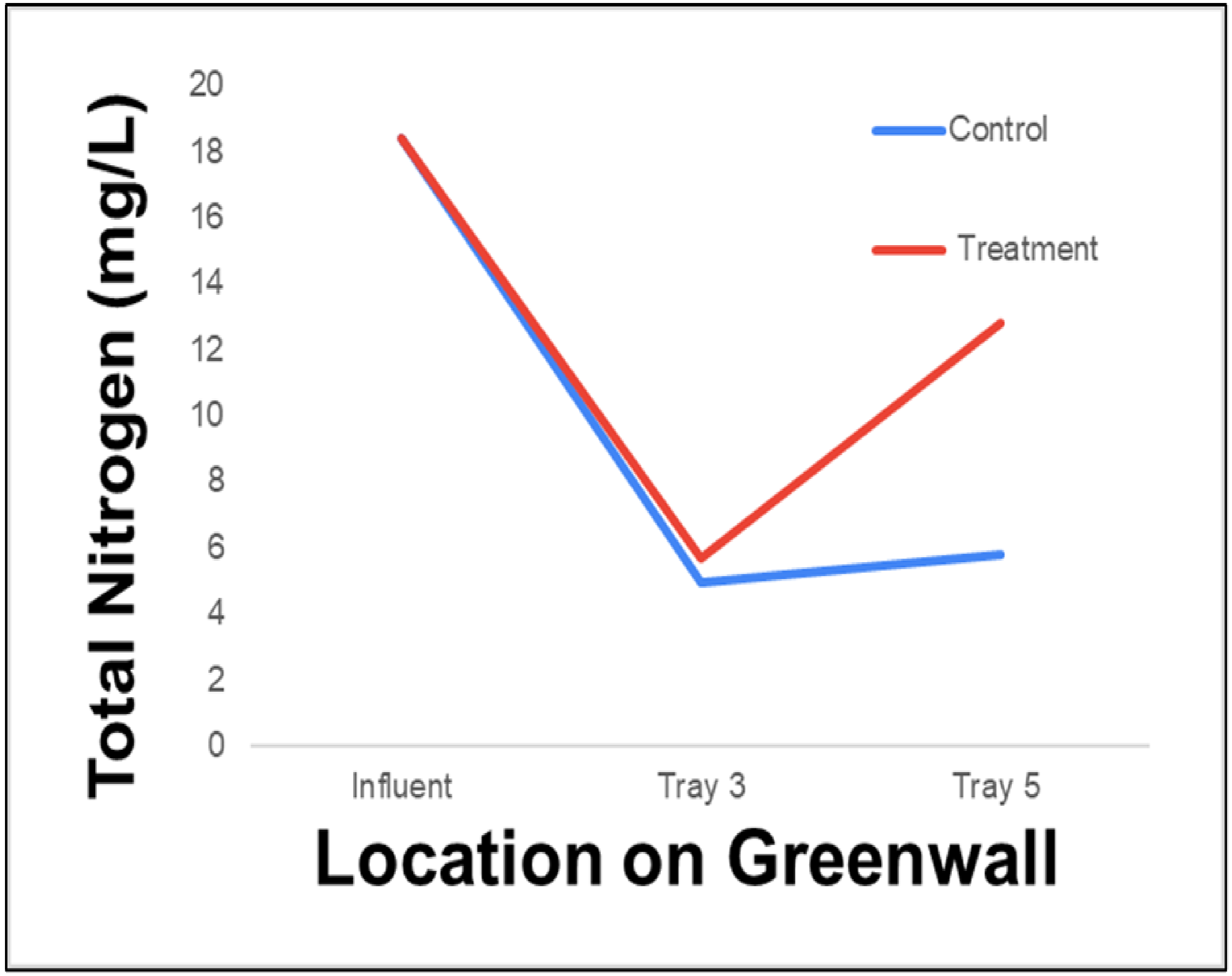


Figure 4. TN results for experimental run three. Results are the sum of TKN and nitrate/nitrites-N concentrations.

Total Phosphorus

Tray three

Treatment: 0.13 mg/L

Control: 0.30 mg/L

Tray five

Treatment: 0.18 mg/L

Control: 0.39 mg/L

- Treatment overall decreased: 89%
- Control overall decreased: 76%

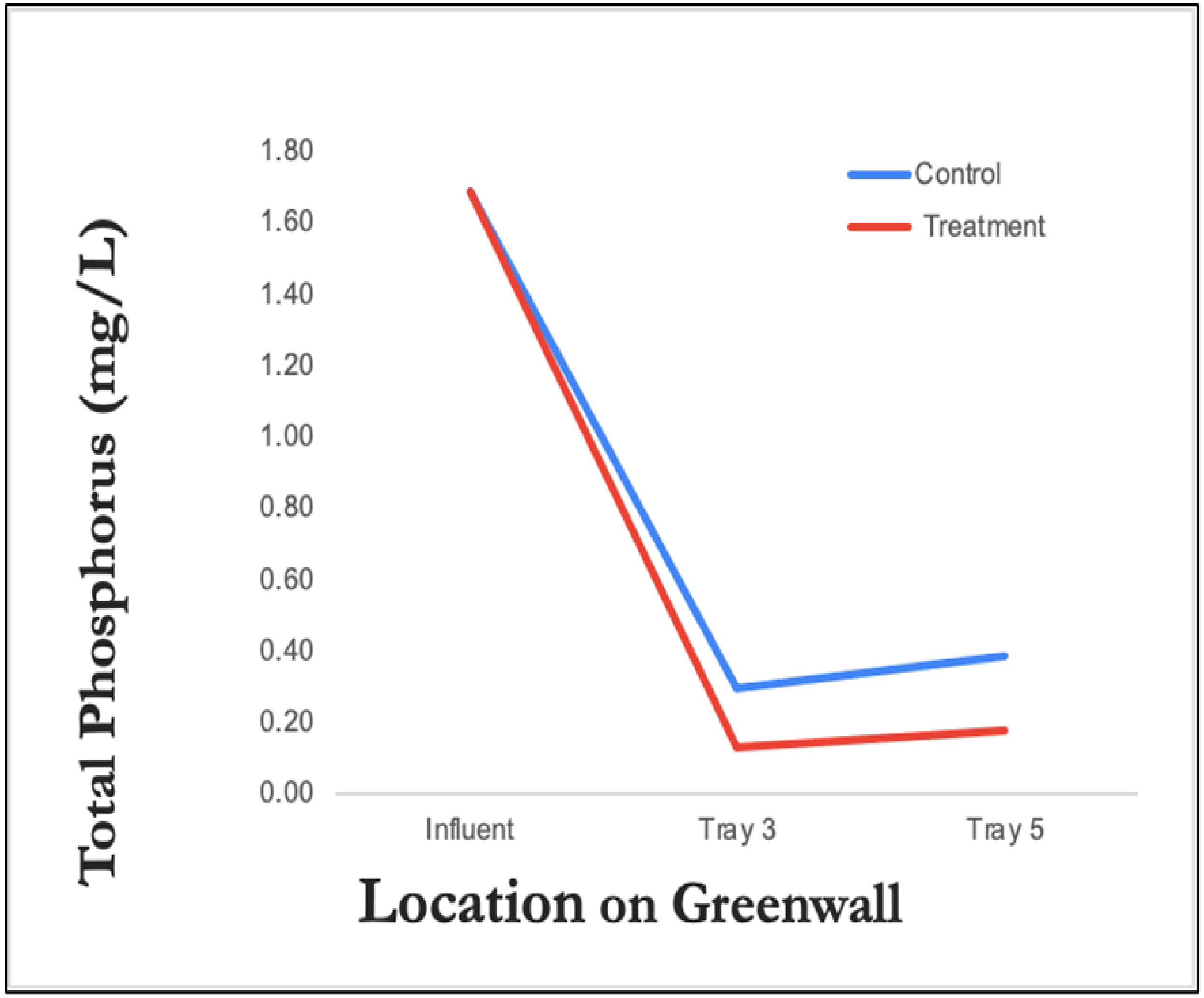


Figure 5. Total Phosphorus results for experimental run three.

Dissolved Oxygen

Treatment Wall: decreased by 4%
Control wall: decreased by 19%

Location	Control Wall DO (mg/L)	Treatment Wall DO (mg/L)
Influent	6.3 ± 1.9	6.3 ± 1.9
Tray three	6.0 ± 1.1	5.2 ± 1.8
Tray five	5.1 ± 0.65	6.1 ± 0.95

- Control: higher *E.coli*, lower DO, lower effluent TN, and higher effluent TP.
- *E. coli* (and other microbes) may have used nitrogen for growth.
- Microbial activity + decreased DO = denitrification
- Control tray's DO level may have facilitated phosphates to become solubilized and desorbed causing a higher TP effluent value.

Prodanovic et al., 2019 & 2020, Pradhan et al., 2019

Conclusions

Conclusions:

E. coli

- *E. coli* grew in the control wall more than the treatment wall.
- Plant roots, microbes, and/or plant replacement may have removed *E. coli* in the treatment wall.
- Perlite could promote the growth of *E. coli*.

Conclusions:

Contaminant Removal

- Both walls were successful in removing TP, TN, TSS, and COD.
- The treatment wall had higher removal efficiencies for most contaminants.

Recommendations for Future Green Walls & Studies

- **Flushing system with non-contaminated water could decrease residual *E. coli*.**

- **Installation of screens between trays for the hydroponic tubing.**
  - Reduce perlite movement and decrease clogging.

Recommendations for Plant Success

- Use perlite and soil for growing media.
- More consistent watering schedule during early root establishment.

Recommendations for Graywater Retention Time

- Higher retention times could affect the contaminant removal efficiency.
- Further research is needed to determine appropriate length for maximum removal.

Prodanovic et al., 2019 & 2020; Shirdashtzadeh et al., 2017; Biswal & Balasubramanian, 2022.

Image source: istockphoto.com

Broader Impacts

- Potential to:
  - purify air
  - increase humidity
  - stabilize ambient temperatures
  - reduce noise
  - decrease household energy costs
- Empower and educate individuals.
- Encourage individuals to be involved in other practices that reduce the impacts of drought.
- Visually appealing and calming to those in the presence of the wall.
- Increase home value.

Prodanovic et al., 2017

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