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Analysis of the Phytoremediation Box as an Experimental Design

COURSE
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Partnership for Action Learning in Sustainability



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Rod Barnes, Town Administrator

ABOUT PALS

The Partnership for Action Learning in Sustainability (PALS) is administered by the National Center for Smart Growth at the University of Maryland, College Park (UMD). It is a campus-wide initiative that harnesses the expertise of UMD faculty and the energy and ingenuity of UMD students to help Maryland communities become more environmentally, economically, and socially sustainable. PALS is designed to provide innovative, low-cost assistance to local governments while creating real-world problem-solving experiences for University of Maryland graduate and undergraduate students.

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EXECUTIVE SUMMARY

For the culmination of the Ecological Technology Design semester project, our group, SalGrow, designed a phytoremediation box to solve a problem using ecological principles.

The Town of Edmonston, in Prince George's County, Maryland, was the client for the project. Edmonston is part of the Green Street project and has installed several bioretention cells (rain gardens) to combat flooding. But it still experiences flooding and is near several parking lots that create polluted runoff—salt and nutrient pollutants—during large storms.

After a site visit, SalGrow developed the idea for a phytoremediation box. The portable box would help combat runoff from the parking lots during large storms.

This floating phytoremediation box would be filled with hydrophytic plants for nutrient and salinity reduction. The hydrophytic vegetation would clean the water by removing salt and nutrient pollutants, leading to a direct decrease in nitrate and ammonia; a measurable decrease in phosphate; a decrease in salinity; a decrease in oxidation-reduction potential (ORP); a decrease in standard plate count (SPC), a measure of bacteria; and a slight increase in pH.

The design goal is to provide a modular, cost-effective alternative or "add-on" for combating inputs to stormwater during rainfall events. The cost for the prototype came to about $100, which included materials—boxes, pumps, grow light, tubing, connectors, growth medium, and the hydrophytic vegetation.

The recommendation is to use this solution for an initial trial because, while it showed promise, the implementation faced challenges such as plant shock, unsuitable room temperature, and delayed grow-light setup. The phytoremediation box design would need to be fundamentally altered, and more research conducted to improve the results. However, after fixing the issues, the phytoremediation box could function properly and be scaled up.

INTRODUCTION

Edmonston, Maryland, is a small town in Prince George's County. It is along the Northeast Branch of the Anacostia River and faces environmental challenges connected to its geography and land uses.

Because it's near many auto repair facilities, junkyards, and high-traffic roadways, the town experiences high inputs of urban pollutants, including heavy metals and excess nutrients, which enter the local waterways. Most commonly, they enter through stormwater runoff, especially during intense rain events, which have become more frequent because of climate change (MDE, 2022; Najjar et al., 2009).

The area's high level of impervious surface limits infiltration and increases pollutant travel, resulting in decreased water quality and increased flood risk (Booth et al., 2016).

During winter months, the use of road salt contributes to elevated chloride concentrations in streams, which have been linked to freshwater salinization and damage to aquatic ecosystems across the northeastern US (Kaushal et al., 2005; Corsi et al., 2010). In addition, nutrient overloading from surface runoff promotes eutrophication and can reduce dissolved oxygen levels in streams.

To address these compounding issues, one proposed ecological solution is a Floating Phytoremediation Nutrient Box (FPNB). This buoyant structure is planted with hydrophytic and halophytic species designed to absorb and filter pollutants in the water. Floating treatment wetlands have been tested for their ability to reduce nitrogen, phosphorus, and metals in contaminated bodies of water (Tanner & Headley, 2011; White & Cousins, 2013).

Plants used in these systems are selected based on their tolerance to salinity, ability to uptake nutrients, and ability to survive in aquatic environments. Rather than relying on complex machinery or chemical treatments, this approach utilizes the natural filtering capacity of vegetation to improve water quality in a low-maintenance way (Tanner & Headley, 2011; Vymazal, 2011). Besides improving water quality, these systems also offer other benefits such as microhabitat creation and reduced urban heat island effect.

While not a complete solution on their own, floating phytoremediation platforms serve as a scalable and affordable supplement to best management practices, especially in compact and urbanized settings like Edmonston.

OBJECTIVES

This study aimed to discover if the phytoremediation box was a feasible alternative to other, more costly endeavors. This study also aimed to discover the strengths and weaknesses of this solution.

The Green New Deal addresses several environmental factors, and the phytoremediation box solution addresses "restoring ecosystems through land preservation, afforestation, and science-based projects" (D'Souza, 2024). The phytoremediation box is meant to help combat Freshwater Salinization Syndrome and reduce nutrient runoff into stormwater. This would help restore communities and ecosystems, especially those like Edmonston, which suffer from high amounts of waste runoff.

METHODS

The ecological system in this project, a Floating Phytoremediation Nutrient Box, is a small and inexpensive treatment unit to help manage water flow in urban areas by using vegetation to filter the water. The design is based on the idea of biomimicry, copying how wetlands naturally remove pollutants, but in a small and mobile form.

This FPNB tested for this project was built using a plastic container that held 4,250 mL of water, with 32.04 grams of Miracle-Gro fertilizer and 2.56 grams of iodized salt added to mimic salt and nutrient pollution. A small pump kept the water moving, and a floating platform held seven different plant species (see Table 1). The Miracle-Gro is composed of:

- nitrogen (N): 24% (including 3.5% ammoniacal nitrogen and 20.5% ureanitrogen)
- phosphate (P2O5): 8%
- potash (K2O): 16%
- micronutrients:
    - boron (B): 0.02%
    - copper (Cu): 0.07% (0.07% water soluble copper)
    - iron (Fe): 0.15% (0.15% chelated iron)
    - manganese (Mn): 0.05% (0.05% chelated manganese)
    - molybdenum (Mo): 0.0005%
    - zinc (Zn): 0.06% (0.06% water soluble zinc).

Table 1. FPNB plants and their nutrient uptake potential

Plants	Nutrient Uptake Potential
Hornwort	Nitrate, Salt
Microsword	Nitrate
Anchoris	Nitrate
Dwarf Hair Grass	Nitrate
Amazon Sword	Nitrate, Salt
Brazilian Pennywort	Nitrate
Spring Onions	Nitrate

To grow the plants indoors, a programmable grow light was set to run for nine hours each day. The plants were in a lightweight growing medium, such as those used in hydroponics to mimic wetland soil, but still work well in a container. The total cost to build the system was about $100, making the system affordable and easy to recreate.

The FPNB was tested at a bench scale, small enough to monitor indoors while large enough to showcase how the plants interact with simulated runoff. This scale was chosen for practicality and affordability and offers a starting point for future scaling.

Plant selection and design choices were informed by peer-reviewed studies and technical reports. Sources were found in databases like Google Scholar, ScienceDirect, and Web of Science, using search terms including “phytoremediation,” “aquatic plants,” and “stormwater treatment.” Priority was given to research on nutrient and salt removal by freshwater species in urban runoff scenarios.

RESULTS

The design and test were chosen to evaluate their capacity to combat salinity and nutrient pollution in bodies of water. The system contained 4250 mL of water with 32.04g Miracle Nutrient Grow and 2.56g iodized salt to model enrichment by nutrients and salt through runoff.

Seven hydrophytic species were planted in the box, selected according to their nitrate and salinity absorbability capacity: Hornwort, Microsword, Anchoris, Dwarf Hair Grass, Amazon Sword, Brazilian Pennywort, and Spring Onions. After five days of operation, water samples were analyzed using test kits. The observed changes in chemical concentrations can be seen in Tables 2 and 3.

Figure 1. AutoCAD mockup of the original design (top-view)

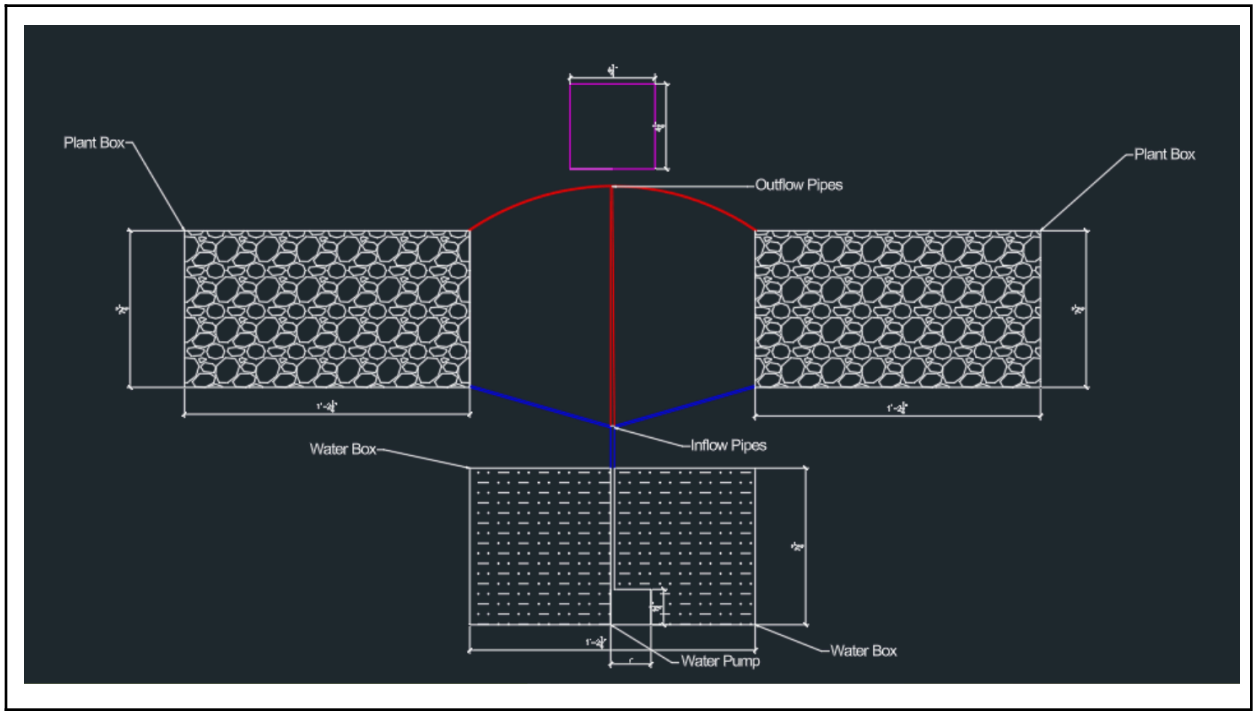


Figure 2. AutoCAD mockup of the original design (side views)

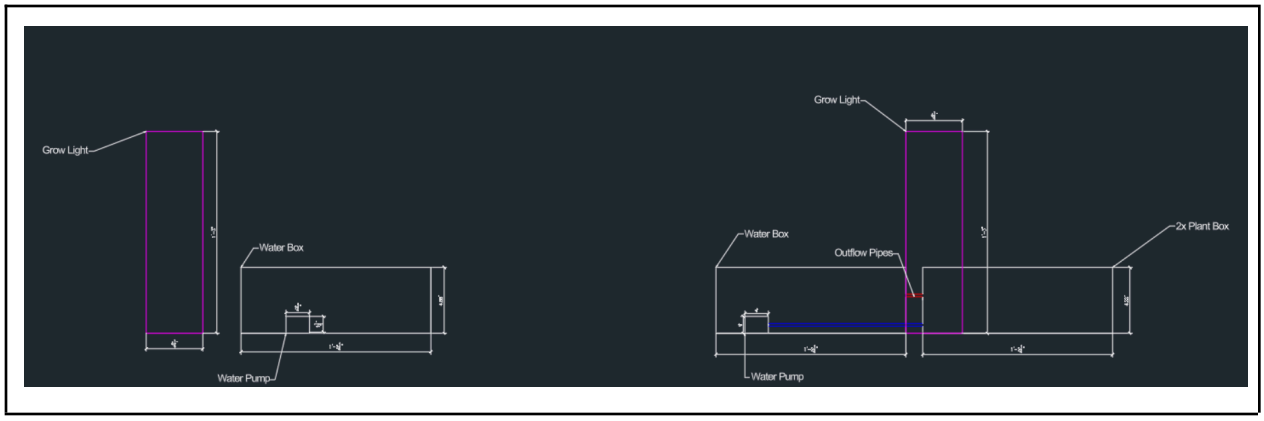


Table 2. Data collected on three days using a YSI meter

Day	Temperature (°C)	pH	ORP (mV)	NH4+-N mg/L	SPC -uS/cm (not calibrated)	mmHg
04/22/2025	22.2	6.22	13.1	116.05	8063	759.9
04/24/2025	22.0	8.35	-23.2	116.25	8844	766.2
04/29/2025	20.5	8.52	-38.6	104.20	12060	764.7

Table 3. Data collected using water samples before and after adding nutrient pollutants and salt (Values were obtained running an ammonia, orthophosphate, and TnT nitrate analysis.)

	Before		After	
	Sample 1	Sample 2	Sample 1	Sample 2
Ammonia (mg/L)	0.275	0.031	0.217	0.081
Nitrate (mg/L)	1.01	0.922	2.06	1.60
Reactive Phosphate (mg/L)	ABS > 3.5	ABS > 3.5	ABS > 3.5	ABS > 3.5

These results indicate that the system did not demonstrate effective nutrient or salt reduction during the limited test period. The conditions included a two-day delivery delay, inhibiting early photosynthesis in plants; low room temperatures unsuitable for some of these plant species; transplant shock due to shipping and installation stress; and a test period too short to witness lasting pollutant breakdown. For that short test period, neither system registered valuable nitrate, phosphate, or salinity data, especially since a decrease had been anticipated rather than an increase.

These shortcomings aren't evidence against the phytoremediation process, but against these specific logistical and environmental deficiencies encountered in practical application. Despite the constraints, the design is encouraging. Studies have indicated that similar floating treatment wetlands can reduce nitrogen. (Tanner & Headley, 2011; White & Cousins, 2013).

Such a full-scale system could be deployed in urban streambanks and stormwater holding basins and be integrated into existing bioretention infrastructure like Edmonston's. Greenhouse gas abatement associated with the system, indirectly quantified in this study, is likely due to reduced eutrophication and reduced energy consumption for water treatment processes.

The trial didn't produce the anticipated water quality outcomes, yet the principle involved is sound and should be further tested with modified experimental conditions, extended test period duration, and more selectivity in plant choice.

DISCUSSION

The expected outcome of this experimental design was that the variety of plants would take up nutrient pollution and salt from the contaminated water (Hygger, 2022). These plants use different phytoremediation mechanisms to cope with and even take advantage of excess metals, ions, nitrogen, phosphorus, or salt in the soil and water (Kafle et. al., 2022).

The effectiveness of remediation is dictated by a variety of factors, including the contaminant, plant biomass, metabolism, soil and water pH, electric conductivity, organic matter content, microbial processes, and added amendments (Kafle et. al., 2022).

Because Salgrow's experimental design is based on nutrient pollution and salt removal, the plants chosen use phytodesalination and phytovolatilization, biological mechanisms that are ideal for nutrient pollution and salt removal (Kafle et. al., 2022). Based on this information, the expected outcome was that the plants would be able to remove nutrient pollution and salt from the contaminated water.

However, this didn't occur. If the experiment were rerun, to be successful, several factors should change before scaling-up the box(es) to make an impact in streams and rain gardens. As well as a larger box, further research into plant-growth medium,

sustainable construction materials, alternate plants, and different variations of the box to suit different environments would be useful.

For instance, introducing amendments can enhance the plants' ability to conduct phytoremediation. Natural amendments (paper waste, biochar, compost, etc.) can increase microbial production and plant growth, increase plant biomass, and improve phytoextraction, all of which are critical for this system to work (Kafle et. al., 2022). Other amendments can include chemical, microbial, or genetic engineering. However, these are less ideal for this project. Therefore, to create a scaled-up and successful design, it's important to understand optimal plant conditions (i.e., what they uptake best, growth conditions, amendments), growth medium, and structural design and materials (floating box, stationary box, modular box, etc.).

As it stands, phytoremediation research has largely been directed toward "grounded" techniques (rain gardens, constructed wetlands, etc.). However, there are limitations in the field, which include site-specificity, climate-specificity, and component-specificity, that can limit their use (Kafle et. al., 2022). More research is required in all three of these areas to determine potential widespread scaling. Because phytoremediation is a relatively recent idea, most communities haven't invested in "modular" phytoremediation beyond rain gardens or constructed wetlands to handle wastewater effluent, which achieve a similar effect. Phytoremediation boxes would need to be implemented on a widespread scale to achieve the same effect as a rain garden, which isn't economically feasible. Instead, the boxes should be used as additions to pre-existing phytoremediation or in low-flow streams and ponds to treat low levels of pollution.

Regardless, "phytoremediation is considered to be an economically viable and environmentally sound technique for remediating the pollutants originating from different sources in the environment" (Kafle et. al., 2022). Research has shown that the cost of using phytoremediation is less than other conventional treatment methods (Kafle et. al., 2022). In some cases, the cost of treatment was found to be about five to 13 times less than chemical treatment (Raskin & Ensley, 2000; Mulbry et al., 2008).

Also, for a polluted area of 2,500 hectares, phytoremediation's effectiveness is 87.5% to 95.8% stronger than standard microbial treatment (Kafle et. al., 2022), making phytoremediation more economically viable than microbial treatment. Subsidies of about $2,500 per hectare would be a good starting base to treat water systems using phytoremediation. However, this value will vary with different and refined designs and different water systems.

RECOMMENDATIONS

Based on this trial, we don't recommend that Edmonston use this design in its current form. While the phytoremediation box showed conceptual promise as a

low-cost, ecologically friendly solution for reducing nutrient and salt pollution, several implementation issues limited its effectiveness.

Challenges such as plant shock during transfer, unsuitable indoor temperature, delayed installation of the grow light, and a short testing period compromised the system's performance and made it difficult to draw reliable conclusions.

It is theoretically well designed, and its modular, scalable design is well matched to urban waterways like Campus Creek and to application in other urban catchments with stormwater nutrient and salinity issues. With continued development, in its environmental control, in-field deployment, and trial length, it can be an excellent option. To be an effective solution, it needs the support of a cooperative government, routine maintenance schedules, and grants or community programs. Further trials in the field can be used to further solidify the process and observe the boxes' real potential.

TEAM CONTRIBUTION

Muqarib Tahir Anwar: I worked on the Discussion section, all the tables, editing the report, and generating the title page. For the presentation, I worked on project design, solution, expected results, actual results, and shortcomings. For the overall project, I did plant research, selected the plants through Amazon, conducted materials research, and I was heavily involved in building and collecting data for the prototype, and presenting it.

Jishan Chowdhury: I worked on the Results and Recommendations sections of the report. I researched and visited the site to get the suitable prototype plants. I also helped build the prototype and worked on making parts of the slide presentation.

Cai Diggs: I worked on finding the prototype materials on Amazon and on data collection. For the PowerPoint, I did the potential solutions, why the solution was chosen, and the S.W.O.T. analysis. For the final report, I did the Introduction.

Louisa Ellison: I worked on securing the materials needed and researching the plants. I worked on scheduling Zoom meetings to ensure all deliverables and deadlines were met. I also worked on the Executive Summary and the Objective sections for this report and worked on the team presentation as well.

REFERENCES

Arjun Kafle, Anil Timilsina, Asmita Gautam, Kaushik Adhikari, Anukul Bhattarai, Niroj Aryal,Phytoremediation: Mechanisms, plant selection and enhancement by natural and synthetic agents, Environmental Advances, Volume 8, 2022, 100203, ISSN 2666-7657, https://doi.org/10.1016/j.envadv.2022.100203.

Aquarium Hygger. (2022, May 27). Best plants to remove nitrates. Petnanny Store. https://www.petnannystore.com/blogs/aquarium-maintenance/plants-to-remove-nitrates

Booth, D. B., Roy, A. H., Smith, B., & Capps, K. A. (2016). Global perspectives on the urban stream syndrome. *Freshwater Science*, 35(1), 412–420. https://doi.org/10.1086/684940

Corsi, S. R., Graczyk, D. J., Geis, S. W., Booth, N. L., & Richards, K. D. (2010). A fresh look at road salt: Aquatic toxicity and water-quality impacts on local, regional, and national scales. *Environmental Science & Technology*, 44(19), 7376–7382. https://doi.org/10.1021/es101333u

D'Souza, D. (2024, February 12). *What is the green new deal?*. Investopedia. https://www.investopedia.com/the-green-new-deal-explained-4588463 Edmonston. (n.d.). *Green Street Project*. Town of Edmonston. https://edmonstonmd.gov/green-street-project/

Kaushal, S. S., Groffman, P. M., Likens, G. E., Belt, K. T., Stack, W. P., Kelly, V. R., ... & Fisher, G. T. (2005). Increased salinization of fresh water in the northeastern United States. *Proceedings of the National Academy of Sciences*, 102(38), 13517–13520. https://doi.org/10.1073/pnas.0506414102

Maryland Department of the Environment (MDE). (2022). *2022 Integrated Report of Surface Water Quality*. https://mde.maryland.gov/programs/water/tmdl/integrated303dreports/pages/index x.as

Najjar, R. G., Walker, H. A., Anderson, P. J., Barron, E. J., Bord, R. J., Gibson, J. R., ... & Swanson, R. S. (2009). Potential climate-change impacts on the Chesapeake Bay. *Estuarine, Coastal and Shelf Science*, 86(1), 1–20. https://doi.org/10.1016/j.ecss.2009.09.026

Raskin, I. and Ensley, B. D., 20001906715, English, Book, USA, 9780471192541, New York, Phytoremediation of toxic metals., (x + 304 pp.), John Wiley and Sons, Phytoremediation of toxic metals., (2000)

Tanner, C. C., & Headley, T. R. (2011). Components of floating emergent macrophyte treatment wetlands influencing removal of stormwater pollutants. *Ecological Engineering*, 37(3), 474–486. https://doi.org/10.1016/j.ecoleng.2010.12.012

Vymazal, J. (2011). Constructed wetlands for wastewater treatment: five decades of experience. *Environmental Science & Technology*, 45(1), 61–69.

https://doi.org/10.1021/es101403q
Walter Mulbry, Shannon Kondrad, Carolina Pizarro, Elizabeth Kebede-Westhead, Treatment of dairy manure effluent using freshwater algae: Algal productivity and recovery of manure nutrients using pilot-scale algal turf scrubbers, Bioresource Technology, Volume 99, Issue 17, 2008, Pages 8137-8142, ISSN 0960-8524, https://doi.org/10.1016/j.biortech.2008.03.073.
White, S. A., & Cousins, M. M. (2013). Floating treatment wetland aided remediation of nitrogen and phosphorus from simulated stormwater runoff. *Ecological Engineering*, 61, 207–215. https://doi.org/10.1016/j.ecoleng.2013.09.020


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