The Evaluation of Subsurface Constructed Wetlands for the Treatment of Domestic Wastewater in Jamaica

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March 1, 2021

Abstract

Accelerated population growth and resource consumption have incurred strains on existing centralized waste treatment technologies in developing states. Due to their cost-effectiveness and minimal environmental impacts, increased attention has been given to artificial or constructed wetlands as a means of treating domestic wastewater. Constructed wetlands (CWs) exist as surface level, sub surface or hybrid configurations and are known to treat wastewater through wetland vegetation, soils, and microorganisms or periphyton. Sub-surface systems are preferred due to minimal human exposure, higher removal efficiencies and odour and pest minimization. This treatment strategy is employed as a bio-filter for TSS, BOD_5, COD, TN, TP, and HMs of domestic waste origins. Sufficient, conclusive data regarding the performance of CWs in a tropical context is lacking despite increases in their usage. Further assessments of the impact of pre-treatment, location in the process, degree of maintenance and presence and/or distribution of vegetation on organic loading, microbial health, and mass component removal in CWs are required. Three (3) wetlands will be assessed to determine their mass removal efficiencies for the named wastewater constituents and these values will be compared to those obtained from peer-reviewed design equations for constructed wetlands. Deviations and trends will be analyzed using statistical software such as Minitab and procedures for the correction of underperforming CWs will be generated for the benefit of general stakeholders and regulatory bodies in the country of study.

Key Terms: bio-filter, constructed wetland, domestic wastewater, effluent, organic loading.

Background

The United Nations (2020) estimates that the world's population will increase by 2 billion persons by 2050. This consistent accelerated population growth, urbanization and economic development have incurred strains on existing waste management technologies and as such, optimization of existing and new designs is increasingly becoming necessary (Baird, 2019). Whilst conventional treatment plants dominate the market, since the 1950's increased attention has been given to more sustainable technologies, particularly artificial or constructed wetlands (Seidel, 1976). Constructed wetlands (CWs) are the cost-effective, environmentally-sound alternatives for the biological treatment of domestic, municipal, agricultural, and industrial wastewater (Odinga et al., 2013). They involve the use of wetland vegetation, soils, and a plethora of microorganisms or periphyton to rehabilitate wastewater. These wetlands may be developed using surface level, sub surface or hybrid configurations; sub-surface systems are preferred due to minimal human exposure, higher removal efficiencies and odour and pest minimization (Maiga, von Sperling, Mihelcic, 2017; Halverson, 2004). This sanitation biotechnology is a useful bio-filter for suspended solids (SS), biochemical oxygen demand (BOD_5) and other typical contaminants in point and non-point sources of domestic, agricultural and refinery origins (Davis, 1995).

Whilst deemed applicable for secondary and tertiary treatment of wastewater, there is a paucity of information with respect to the factors that are most impactful in optimizing CW operation at different process stages, particularly in Jamaica. Variations in wastewater strength, vegetation density and distribution, presence of invasive species due to poor maintenance and pre-treatment of influent to CWs all have the potential to significantly affect organic loading levels, microbial health, and subsequent buffering capacity of the system (Davis, 1995). Domestic wastewater usually contains solids, microorganisms, nitrates, phosphates, heavy metals like lead and to a lesser extent toxic benzene-toluene-xylene (BTX) constituent that originate in laundry detergents, processed food, toiletries, cosmetics, fragrances, and other common household chemicals (Drozdova et al, 2018). Given varying degrees of success with CWs in meeting NRCA effluent standards in Jamaica and increased population growth, a comparative approach is required to analyze the efficacy of this treatment method against design parameters. From these results, it will be possible to identify the best practices that may be employed for effective operation of CWs for the treatment of domestic wastewater.

Problem Statement

There exists a dearth of understanding of the optimal performance of constructed wetlands within the Caribbean context. The need arises for extended analysis of the soundness of constructed wetlands as a means of treating wastewater, especially amidst shifts in population growth and consumption. Thus, this paper posits further investigation of the effects of variables such as influent pre-treatment, location in the process, degree of maintenance and distribution of vascular and non-vascular plant species on organic loading and microbial health and hence the effectiveness in remediating domestic wastewater by way of subsurface constructed wetlands in Jamaica.

Sub-Problems

1. To classify by volumetric loading, pre-treatment type and development size, the wastewater being fed to CWs used as tertiary treatment, and CWs used as secondary treatment.

2. To determine the strength- pH, TSS, COD, BOD_5, heavy metals, nitrates, phosphates, BTX- of influent and effluent to and from CWs [Guide- NRCA 2013 Effluent Standards].
3. To examine the effect of degree of maintenance on CW performance.
4. To investigate the impacts of plant species on nutrient removal by assessing depth of plant roots and biomass yields and the effluent concentrations of planted and unplanted CWs.
5. To assess the final characteristics of treated samples of domestic wastewater hence the removal efficiency of the CW system after variable manipulation.

Delimitations

The investigation will exclude wastewater from municipal, industrial, and agricultural sources. The location of the wastewater sample- urban or rural- must be specified for the CWs being analyzed. If completed, the types of secondary treatment that the influent is subjected to- natural-type ponds or mechanical aeration but be specified. These factors impact wastewater composition and subsequent contaminant removal.

Purpose and Significance

The purpose of this study is to investigate the efficiency of subsurface constructed wetlands in decreasing the concentration of wastewater contaminants. This body of work follows on the need to corroborate the viability of CWs amidst its increased popularity amongst developers who seek to utilize this less capital and labour intensive option. Within regional and local contexts, conclusive, empirical data surrounding the optimal use of this ecological waste management technology remains deficient. Consequently, the time is opportune to analyze the correlation between a multiplicity of physical, biochemical, and chemical variables and the effluent produced by this treatment process.

Undertaking research of this nature can be of tremendous significance in any setting where CWs are used. Stakeholders and beneficiaries include but are not excluded to private developers, regulatory bodies at the national and regional levels, such as at the National Water Commission and National Environmental and Planning Agency and the communities they serve. In this research, a partial audit of several CWs in Jamaica domestic wastewater will be crafted and conducted. The subsequent results, trends and deviations will allow for the articulation of best practices and corrective measures for underperforming CWs for both the NWC and private contractors. Thus, given the afore-mentioned benefits of CWs, further exploration of this natural technology is worthwhile and crucial to the sustainable development of our changing nation. Thus, the findings of this research will help in optimizing this system in a methodical and reliable way.

References

Baird, A. (2019, August 26). Securing wastewater treatment for the future. *WaterWorld.* Retrieved from: https://www.waterworld.com/international/wastewater/article/14038852/securing-wastewater-treatment-fit-for-the-future

Davis, L. (1995). A handbook of constructed wetlands: a guide to creating wetlands for agricultural wastewater, domestic wastewater, coal mine drainage and stormwater in the mid-Atlantic region (Vol. 1: general considerations). *Washington, D.C: US Natural Resources Conservation Service, US Environmental Protection Agency-Region III and the Pennsylvania Department of Environmental Resources*. Retrieved from: https://www.epa.gov/sites/production/files/2015-10/documents/constructed-wetlands-handbook.pdf

Drozdova, J., Raclavska, H. Raclavsky, K., Skrobankova, H. (2018). Heavy metals in domestic wastewater with respect to urban population in Ostrava, Czech Republic. *Water and Environment Journal. https://doi.org/10.1111/wej.12371*

Halverson, Nancy. (2004). Review of Constructed Subsurface Flow vs. Surface Flow Wetlands. *ResearchGate*. 10.2172/835229.

Maiga, Y., von Sperling, M., Mihelcic, J.R. (2017). Constructed Wetlands. In: J.B. Rose and B. Jiménez-Cisneros, (eds) *Global Water Pathogen Project*.

Odinga, C. A., Swalaha, F.M., Otieno, F.A.O., Ranjith, K. R. & Bux, F. (2013) Investigating the efficiency of constructed wetlands in the removal of heavy metals and enteric pathogens from wastewater. *Environmental Technology Reviews*, 2:1, 1-16, DOI: 10.1080/21622515.2013.865086

Our Growing Population. (2020). *United Nations*. Retrieved from: https://www.un.org/en/sections/issues-depth/population/.

Seidel, K. (1976). Macrophytes and water purification: "In biological control of water pollution" J. Tourbier and R.W.Pierson.Jr.(Eds). P*hiladelphia,PA:University of Pennsylvania Press*

State of the Tropics Data. (2020). *United Nations 2012*. Retrieved from: https://www.jcu.edu.au/state-of-the-tropics/data/population-growth-2010-2050