# NUTRIENT AND HEAVY METAL ACCUMULATION IN A LAB-SCALE VERTICAL SUBSURFACE FLOW CONSTRUCTED WETLAND PLANTED WITH SELECTED PLANTS SPECIES

**Remedios T. Tamang and Francis Jhun T. Macalam**

*Department of Environmental Science and Technology, College of Science and Mathematics, University of Science and Technology of Southern Philippines, Cagayan de Oro Campus, Philippines*

Main Author: Tel.: +63 917 134 6754 Email: remedios.tamang@ustp.edu.ph

***ABSTRACT****. Local plants that are not widely studied in the Philippines like gabi (Colocasia esculenta), kangkong (Ipomoea aquatica), citronella grass (Cymbopogon nardus), and fortune plant (Dracaena sanderiana) were studied to evaluate their effectiveness in the uptake and accumulation of nutrients and heavy metals specifically nitrogen, phosphorous, lead (Pb) and mercury (Hg). The study shows that the removal of total nitrogen and total phosphorus by plant uptake in a vertical subsurface flow-constructed wetland among the four selected plant species depicts a small part in nutrient removal. The same could be said to plant uptake of heavy metals whereby Pb and Hg uptake couldn't be detected accurately due to its trace presence in the plants. Uptake of N has no significant difference ($p > 0.05$) between the four plants for both the 4 days and 8 days retention time but N accumulation was significantly ($p \leq 0.05$) more in the 8 days retention for each plant. Uptake of P has no significant difference ($p > 0.05$) between the four plants for both the 4 days and 8 days retention time. While P accumulation was the same with the 8 days retention for each plant. Pb accumulation for all the selected plants was < 1.25 mg/L. Since the measured values for 4 days & 8 days retention time is < 1.25 mg/L, values between 1.25 to 0.00 is varied, so percent removal cannot be determined. Mercury uptake for all selected plants was 0.01 mg/L, measured values were uniform for both 4 days and 8 days retention time and any significant difference in accumulation rate could also not be determined.*

**Keywords:** Phytoremediation, leachate, nitrification, denitrification, macrophytes

## 1. INTRODUCTION

The rising demand for freshwater resources coupled with the growing global population has put this valuable resource under relentless threat of pollution. Contamination of water by toxic pollutants through the discharge of municipal and domestic wastes, industrial wastewater, landfilling sites, etc., has become a worldwide problem, due to its harmful effects on human health and to the fauna and flora of receiving water [1] Herath & Vithanage. Although there are natural causes, much of the eutrophication seen currently is a result of inadequately treated wastewater and agricultural run-off that end up in receiving water bodies According to [2] Otieno sufficient treatment of wastewater for reuse will therefore be a worthwhile alternative in bettering the challenge of water scarcity and environmental degradation. In most developing countries, there are few wastewater treatment facilities mainly because current treatment procedures are expensive, and they require high energy costs and highly-trained personnel for operation and maintenance. There is also a lack of effective environmental pollution control laws or law enforcement. A wide range of centralized sewage treatment methods are used instead in developing countries, including stabilization pond systems, septic tanks, activated sludges, trickling filters, anaerobic systems, and land application systems Another study was conducted by Kinyua [2]. Adoption of low-cost and effective technologies such as constructed wetlands will therefore be a suitable option for many industries and households involved in wastewater treatment.

Constructed wetlands are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and their associated microbial assemblages to assist in treating wastewater Vymazal, [4] The treatment of landfill leachate by natural systems has proven to be a more environmentally sustainable and very effective method for the treatment of a variety of wastewaters. The environmental benefit of treatment of landfill leachate in a constructed wetland includes; decreased energy consumption by using natural processes rather than conventional; efficiently removed of many pollutants from wastewater and also enhance environment by providing a habitat for vegetation, fish, and other wildlife According to [5], Kamarudzaman *et al.*, several studies have demonstrated that phytoremediation capabilities of plants in constructed wetland systems were very effective to remove and immobilize metals as well as nutrients (nitrogen and phosphorus. Phytoremediation as a green technology is one of the main environmentally friendly technologies that are gaining wider use for wastewater treatment [6]Mojiri et al., Plant roots exude a wide variety of organic compounds which support the microbial community and can facilitate absorption of some heavy metals that are hazardous to both human and livestock Otieno [7].

Widely use plants in constructed wetlands include vetiver grass (*Chrysopogon nemoralis*), common cattails (Typha latifolia) and common reed (*Phragmites australis)*. However, this study utilized local plants that are not widely studied namely; gabi (*Colocasia esculenta*), kangkong (*Ipomoea aquatica*), citronella grass (*Cymbopogon nardus*) and fortune plant (*Dracaena sanderiana*).

This study aims to compare and evaluate the accumulation of nitrogen, phosphorous and lead (Pb), and mercury (Hg) in the selected plant species before and after subjecting the landfill leachate to the lab-scale vertical subsurface flow constructed wetland.

## 2. METHODOLOGY

The landfill leachate sample was taken from sanitary landfill of Cagayan de Oro City and the lab-scale vertical subsurface flow constructed set-up and analysis of the sample was done at the University of Science and Technology of Southern Philippines Cagayan de Oro Campus.

There were five trays of dimensions 45 X 40 X 35 cm was taken and perforated pipes of diameter 1.75 cm extending inside the tray were attached to both sides of the tray as the inlet and outlet as shown in Figure 1. Four trays were planted while one was not to serve as the control. The inlet was above the outlet with respect to the distance from the bottom of the tray. Similarly, the outlet was placed at the bottom. The plants chosen are aquatic plants and depend on their adaptability to the climate. The plants used for the lab scale model was gabi (*Colocasia esculenta*), kangkong *(Ipomoea aquatica*), citronella grass (*Cymbopogon nardus*), and fortune plant (*Dracaena sanderiana*) which are locally available. There were three layers of purification, namely gravel, sand (sieved with 1.18mm sieve), and garden soil in the tray setup so as to explicitly recreate a soil stratum. Local soil growing a variety of plants was taken, preferably loamy, containing silt and clay. Each of these layers had specific roles to play in the purification process of a constructed wetland.

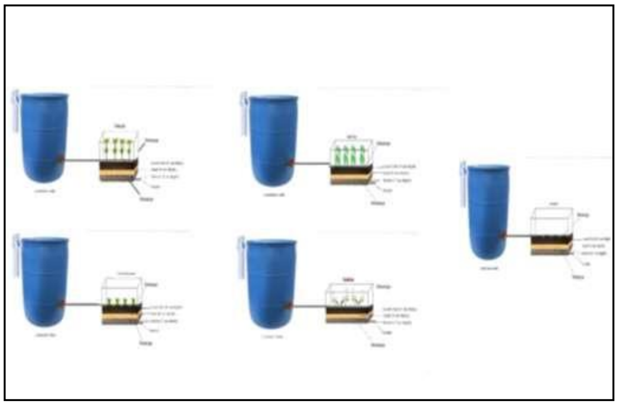

**Figure 1. Schematic diagram of the Vertical Subsurface Flow system of the study. Adapted from Herath & Vithanage (2015)**

For a period of one month since planting, selected plants were watered with fresh water. Subsequently, on the actual experimentation day, the constructed wetland was fed continuously at a fixed retention time with diluted leachate from the landfill. The gabi *(Colocasia esculenta*), kangkong *(Ipomoea aquatica*), citronella grass (*Cymbopogon nardus*) and fortune plant (*Dracaena sanderiana*) continuously receive wastewater into the vertical subsurface flow system at retention times 4 days and 8 days.

**Plant Harvesting and Sample Analysis**

Analysis of the plant tissues were conducted initially before the treatment procedures begin and after the termination of the experiment. This analysis was conducted to determine the uptake of total nitrogen (TN), total phosphorus and heavy metals (lead (Pb) and mercury (Hg)) by the plant tissues. Composite sample of gabi (*Colocasia esculenta*), kangkong *(Ipomoea aquatica*), citronella grass (*Cymbopogon nardus*) and fortune plant (*Dracaena sanderiana*) was randomly harvested from each of the vertical subsurface flow constructed wetland after each retention times. The shoots and roots from each wetland unit was composited, air dried, weighed and analyzed for total N, total P and heavy metal (Pb & Hg) concentration using atomic absorption spectroscopy. This was done in 3 trials for each retention time. The data obtained were subjected to a two-way ANOVA at a 5% level of significance. Means were separated using an LSD test to determine if there were significant differences between treatment pairs.

## 3. RESULTS & DISCUSSIONS

**Initial Parameters of Diluted Leachate**

Table 1 shows the result of the initial parameters of the diluted leachate

Planting and establishment of gabi (*Colocasia esculenta*), kangkong (*Ipomoea aquatica*), citronella grass (*Cymbopogon nardus*) and fortune plant (*Dracaena sanderiana*

**Table 1 shows the result of the initial parameters of the diluted leachate**

| Water quality parameters | Units | Initial Parameters of Leachate (Diluted) |
|---|---|---|
| Total Nitrates (TN) | mg/L | 19.21 |
| Total Phosphates (TP) | mg/L | 17.38 |
| Lead (Pb) | mg/L | 0.087 |
| Mercury (Hg) | mg/L | 0.01 |

**Nitrogen Accumulation of selected plants in the various treatments**

Table 2. Shows N accumulation in selected plants of the lab-scale vertical subsurface flow constructed wetland systems during the sampling period. Nitrogen accumulation in the lab-scale vertical subsurface flow constructed wetland planted with gabi was 2.69 mg/Kg at 4 days retention time while N accumulation during the 8 days retention time was 3.42 mg/Kg. N accumulation for the constructed wetland planted with kangkong was 1.68 mg/Kg and 3.48 mg/Kg for the 4 days and 8 days retention time respectively.

Fortune plant and citronella plant showed uptake of 1.72 mg/Kg and 1.18 Kg at 4 days of retention time while both showed 3.49 mg/Kg and 3.38 mg/Kg uptake at 8 days of retention time. During the 4 days retention time, gabi showed a slightly higher uptake at 27.51 % followed by fortune plant (17.44%) while citronella (0%) and kangkong (-58.93%) showed no uptake. However, during the 8 days retention time citronella showed the higher uptake at 68.11 % followed by fortune (63.87%), gabi (40.73%), and kangkong (24.36%).

Removal of nitrogen compounds in CWs is governed mainly by microbial nitrification and denitrification, while other mechanisms such as plant assimilation, matrix adsorption and ammonia volatilization are generally of less importance [8] A study by Richardson et al. The potential rate of nutrient uptake (assimilation) by plant is limited by its net productivity (growth rate) and the concentration of nutrients in the plant tissue and macrophyte growth is not the only potential biological assimilation process: microorganisms and algae also utilize nitrogen. According to the author for lower loaded systems the potential uptake is significantly higher, e.g. 46% of the nitrogen load for treatment of greywater. There is no any significant removal attained among the evaluated macrophytes, as the overall average efficiency of all three macrophytes was approximately equal.

**Table 2. Accumulation of Total Nitrogen**

| | | Retention Time | | | |
|---|---|---|---|---|---|
| | | 4 days | | 8 days | |
| Treatments | Initial TN | TN Reading (mg/Kg) | % Uptake TN | TN Reading (mg/Kg) | % Uptake TN |
| VSSF+ Gabi | 1.95 | 2.69 | 27.51 | 3.42 | 40.73 |
| VSSF+ Kangkong | 2.67 | 1.68 | -58.93 | 3.48 | 24.36 |
| VSSF+ Fortune Plant | 1.42 | 1.72 | 17.44 | 3.49 | 63.87 |
| VSSF+ Citronella Plant | 1.18 | 1.18 | 0 | 3.38 | 68.11 |

The maximum total nitrogen removal was seen at the retention time of 8 days for citronella grass (*Cymbopogon nardus*). It was reduced significantly from 19.21 mg/l to 3.38 mg/l providing a removal efficiency of 82.4 percent followed by gabi *(Colocasia esculenta*), kangkong (*Ipomoea aquatic*), fortune plant *(Dracaena sanderiana*) and control with 3.42 (82.2%), 3.48 (81.9%), 3.49 (81.8%) and 3.91 (79.6%) mg/L respectively as seen in figure. Nitrogen removal requires a longer HRT as compared with the removal of organics Kumar & Choudhary [9].

**Phosphorus Accumulation of selected plants in the various treatments.**

Table 3 shows P accumulation in selected plants of the lab-scale vertical subsurface flow constructed wetland systems during the sampling period. Phosphorus accumulation in the lab-scale vertical subsurface flow constructed wetland planted with gabi was 0.254 mg/Kg for both 4 days and 8 days retention time. P accumulation for the constructed wetland planted with kangkong was 0.218 mg/Kg for the 4 days and 8 days retention time respectively. Fortune plant and citronella plant showed uptake of .0951 mg/Kg and 0.122mg/Kg at 4 days and 8 days of retention time.

**Table 3. Accumulation of Total Phosphorus**

| | | Retention Time | | | |
|---|---|---|---|---|---|
| | | 4 days | | 8 days | |
| Treatments | Initial TP | TP Reading (mg/Kg) | % Uptake TP | TP Reading (mg/Kg) | % Uptake TP |
| VSSF+ Gabi | 0.25 | 0.254 | 3.54% | 0.254 | 3.54% |
| VSSF+ Kangkong | 0.24 | 0.218 | -8.26% | 0.218 | -8.26% |
| VSSF+ Fortune Plant | 0.0609 | 0.0951 | 35.96% | 0.0951 | 35.96% |
| VSSF+ Citronella Plant | 0.0972 | 0.122 | 20.33% | 0.122 | 20.33% |

showed that HFWs seem to be more effective in

The removal efficiency for phosphorus of all treatment cells is slightly lower. [10] A study by Lüderitz et.al. P elimination than VFWs because of the longer flowing distance and treatment time and removal of plants from the soil filter leads to a significant decrease of 50% in the P elimination rate.

**Heavy metal (Pb & Hg) uptake of selected plants in the various treatments**

Table 4 shows the heavy metal accumulation in selected plants of the lab scale vertical subsurface flow constructed wetland systems during the sampling period. Pb accumulation for all the selected plants was < 1.25 mg/L. Since the measured values for 4 days & 8 days retention time is < 1.25 mg/L, values between 1.25 to 0.00 is varied, so percent removal cannot be determined. Mercury uptake for all selected plants was 0.01 mg/L, measured values were uniform for both 4 days and 8 days retention time and any significant difference in accumulation rate cannot be determined.

**Table 4 Accumulation Lead and Mercury**

| | Retention Time | | | |
|---|---|---|---|---|
| Treatments | 4 days (Pb) Reading | 8 days (Pb) Reading | 4 days (Hg) Reading | 8 days (Hg) Reading |
| VSSF+ Gabi | <1.25 | <1.25 | 0.01 | 0.01 |
| VSSF+ Kang kong | <1.25 | <1.25 | 0.01 | 0.01 |
| VSSF+ Fortune Plant | <1.25 | <1.25 | 0.01 | 0.01 |
| VSSF+ Citronella Plant | <1.2 | <1.25 | 0.01 | 0.01 |

Initial test for the leachate introduces to the constructed wetland systems in this study showed that Pb and Hg concentration were in trace amounts. This could be the main reason why there is a slow amount of uptake observed in the four selected plants. Plants generally do not accumulate trace elements beyond nearterm metabolic needs and these requirements are small ranging from 10 to 15 ppm of most trace elements suffice for most needs Tangahu *et al*., [11]

## 4. CONCLUSIONS AND RECOMMENDATIONS

Plant uptakes of total nitrogen in the studied types of plants with the labscale vertical subsurface flow constructed wetlands were varied. During the 4 days retention time, gabi showed a slightly higher uptake at 27.51 % followed by fortune plant (17.44%) while citronella (0%) and kangkong (-58.93%) showed no uptake. However during the 8 days retention time citronella showed the higher uptake at 68.11 % followed by fortune (63.87%), gabi (40.73%) and kangkong (24.36%). However during the 8 days retention time citronella showed the higher uptake at 68.11 % followed by fortune (63.87%), gabi (40.73%) and kangkong (24.36%). Uptake of N has no significant difference ($p > 0.05$) between the four plants for both the 4 days and 8 days retention time but N accumulation was significantly ($p \leq 0.05$) more in the 8 days retention for each plant.

Phosphorus accumulation in the lab-scale vertical subsurface flow constructed wetland during the 4 days and 8 days retention time were varied between the plants but not for each retention time. Fortune plant showed a slightly higher uptake at 35.96 % followed by citronella plant (17.44%) and gabi (3.54%) while kangkong showed a negative uptake of total phosphorus.

Pb accumulation for all the selected plants was < 1.25 mg/L. Since the measured values for 4 days & 8 days retention time is < 1.25 mg/L, values between 1.25 to 0.00 is varied, so percent removal cannot be determined. Mercury uptake for all selected plants was 0.01 mg/L, measured values were uniform for both 4 days and 8 days retention time and any significant difference in accumulation rate could also not be determined.

The study shows that the removal of total nitrogen and total phosphorus by plant uptake in a vertical subsurface flow-constructed wetland among the four selected plant species depicts a small part in nutrient removal. The same could be said to plant uptake of heavy metals whereby Pb and Hg uptake couldn't be detected accurately due to their trace presence in the plants.

## REFERENCES

[1] Herath, Indika & Vithanage, Meththika. (2015). Phytoremediation in Constructed Wetlands. 10.1007/978-3-319-10969-5_21.

[2] Otieno, Austine., Karuku, George., Raude, James & KOECH, Oscar (20170. Effectiveness of the Horizontal, Vertical and Hybrid Subsurface Flow Constructed Wetland Systems in Polishing Municipal Wastewater. Environmental Management and Sustainable Development. 6. 158. 10.5296/emsd.v6i2.11486.

[3] Kinyua, Gitau James (2014). Effectiveness Of Natural Wetland In Waste Water Treatment: A Case Study Of Tibia Wetland, Limurun Municipality, Kenya.

[4] Vymazal, Jan (2007). Removal of Nutrients in Various Types of Constructed Wetlands. The Science of the total environment. 380. 48-65. 10.1016/j.scitotenv.2006.09.014

[5] Kamarudzaman, Ainnihla & Abd, Mohd & Zakaria, Hafiz & Aziz, Roslaili & Faizal, Mohd & Jalil, Ab. (2020). Study the Accumulation of Nutrients and Heavy Metals in the Plant Tissues of Limnocharis flava Planted in Both Vertical and Horizontal Subsurface Flow Constructed Wetland.

[6] Mojiri, Amin., Ahmad, Zakiah., Tajuddin, Ramlah., Arshad, Mohd & Gholami, Ali (2017). Ammonia, phosphate, phenol, and copper(II) removal from aqueous solution by subsurface and surface flow constructed wetland. Environmental Monitoring and Assessment. 189. 10.1007/s10661-017-6052-x.

[7] Otieno, Austine., Karuku, George., Raude, James & KOECH, Oscar (20170. Effectiveness of the Horizontal, Vertical and Hybrid Subsurface Flow Constructed Wetland Systems in Polishing Municipal Wastewater. Environmental Management and Sustainable Development. 6. 158. 10.5296/emsd.v6i2.11486.

[8] Richardson,V.P.S., Meetiyagoda,T.A.O.K., Jinadasa, K.B.S.N. & Gamage.P.D. n.d. Total Nitrogen Removal of Municipal Solid Waste Leachate Using Hybrid Constructed Wetlands.

[9] Kumar Parveen, Choudhary, Ashutosh Kumar (2018). Constructed Wetlands – A Sustainable Solution for Landfill Leachate Treatment. International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS), Volume VII, Issue VI, ISSN 2278-2540

[10] Luderitz, Volker & Gerlach, F. (2002). Phosphorus Removal in Different Constructed Wetlands. Acta Biotechnologica - ACTA BIOTECHNOL. 22. 91-99. 10.1002/1521-3846(200205)22:1/23.0.CO;2-5.

[11] Tangahu, Bieby & Abdullah, Siti & Basri, Hassan & Idris, Mushrifah & Anuar, Nurina & Mukhlisin, Muhammad (2011). A Review on Heavy Metals (As, Pb, and Hg) Uptake by Plants Through Phytoremediation. International Journal of Chemical Engineering. 2011. 10.1155/2011/939161.