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A Review on Removal of Phosphate and Nitrate from Kitchen Wastewater by Constructed Wetlands

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Abstract— Constructed wetlands are in use since the early 1950s and prove to be effective in the treatment of wastewater. There are several other terrestrial plant species which are equally effective as that of wetland plants. Also, vertical flow wetlands have had a history of significantly reducing the organic matter contents as well as microbial species by providing more oxygenated environment, from wastewater. For Vertical subsurface flow constructed wetland, removal efficiency and mass removal rate of pollutants were considerably high. A model house with 3 x 3 x 2.5 m of length, width and height was established with constructed wetland. The sewage produced was passed through the constructed wetland and its efficiency was analyzed at the same time monitoring the differential temperatures between inside and outside of the model house. The artificial wetland consists of breakstone and gravel etc as well as plants. New-type multi-layer artificial wetland is proposed for the treatment of domestic sewage and COD, BOD, NH_3-N, TN, TP removal, when the hydraulic loading reaches approximately 0.44 $m^3/(m^2\ d)$ and hydraulic retention time (HRT) reaches 3 days the removal efficiencies are 90.6%, 87.9%, 66.7%, 63.4% and 92.6%.

Keywords— Wastewater; Nitrogen; Phosphorus; COD; BOD; Canna indica; Constructed wetland; Multi-layer artificial wetland; Removal efficiency;

I. INTRODUCTION

Land availability in India is a chief constraint to adopt constructed wetlands. In comparison with the surface flow, subsurface flow is 100 times smaller and has 3 times smaller HRTs. Thus, vertical flow constructed wetlands are feasible for Indian scenario. Plants offer larger surface area for the growth of microbes and thereby promotes the development of bio-film and increases oxygen transport. *Canna indica* is a plant species used for phytoremediation since 1950s. The roots grow rapidly with a larger surface area and higher root number. They participate significantly in the nutrient removal and has great pollutant tolerance. The suitability of *Canna indica* over *phragmitis* is studied.

The traditional effluent treatment methodologies happen to be expensive and entails skilled labour. Here, constructed wetlands are cost effective along with being extremely functional in pollution control. Although the subsurface flow wetlands are effectual in organic C and particulate matter removal, they have been less successful with regard to the removal of P and N. In spite of the fact that subsurface flow constructed wetlands are among the new technologies, the operational conditions are poorly defined. Studies have shown that the plants enhance the surface area for microbial growth and provides oxygenated conditions. However, only minor variations in the removal of chemical oxygen demand (COD), total suspended solids (TSS), N and P from wastewater were witnessed by a Zhu et al. [1] in their study. In addition to it, Coleman et al. [2] revealed that gravel is effective in wastewater treatment.

By choosing the suitable growth media, particle size, surface nature, bulk porosity and pore spaces of the growth media, high purification efficiency can be obtained. Gravel is the most commonly used growth media in constructed wetlands. It was found that sand was more efficient than gravel and a mixture containing soil and sand contributed for the highest pollutant removal efficiencies. Feeding can be in batch or continuous mode and, it affects the aeration conditions. Performance evaluation of a wetland is carried out based on the pollutant removal efficiency and in this study, considering the vegetation condition, type of growth media, and feeding mode.

There are wastewater treatment systems that use plant as phytoremediation in overland flow, plant filtration and constructed wetland. The constructed wetland is a natural wastewater treatment method and cost effective. It is suitable for domestic wastewater treatment for household size also offering beautiful landscape.

In the constructed wetland wastewater treatment is achieved by triple synergistic effects of physical, chemical and biological interactions in the natural ecosystems. By filling certain media like gravel, plants are cultivated and characterized by favorable treatment performance, high survival rate, strong water resistance behavior, long growing period, beautiful appearance, high economic value. Domestic wastewater when flowing through the filled bed undergoes filtration, absorption, deposition, ion-exchange, assimilation by plants and decomposition by microbes,to achieve high efficient sewage purification. Constructed wetland treatment system is classified into Surface Flow Wetland (SFW), Vertical Flow Wetland, Tidal Flow Wetland. Of which SFW is most widely used. This treatment system have various advantages, such as low energy consumption, convenient operation and maintenance, low requirements on infrastructure, lost operating costs, high adaptability on inflow loading and favorable effluent quality

II. METHODOLOGY

Gargi Sharma et al., conducted an experiment wherein, secondary treated wastewater from Activated Sludge Process of an STP was fed to four up-flow constructed wetlands. The wastewater was stored in a feeding tank and water was passed through ports, periplastic pumps and valves to each wetland unit. Water flows in upward direction from the treatment bed and reaches the surface. The treatment effluent is collected in an effluent collector from the top most port. The water flow is controlled by using periplastic pump in each bed. It is collected in the inlet chamber and is uniformly distributed throughout the bed in all the units. 8-12mm gravel at the top and 16-20mm gravel at the bottom were laid in all the units. Vegetation and media characteristics for each treatment unit are as follows:

Table 1. Different Constructed wetland units with didderent plantation as well as media type (*Gragi Sharma et al*., 2014)

UFCW	Vegetation	Medium
Unit1	phragmitis	gravels
Unit2	canna	gravels
Unit3	none	gravels
Unit4	canna	gravels with sand

Twenty water samples were collected based on inlet and outlet sampling. It was carried out on weekly basis for constructed wetland units with *canna* (with and without sand layer incorporation). Inlet samples were drawn out from the ports located at the base and outlet samples from the port at the distal end, of each unit. Samples were collected in 100 ml autoclaved beakers and were sealed with aluminum foil and were subjected to physiochemical analysis.

Sara G. Abdelhakeem et al., experimented on vertical subsurface flow constructed wetland units which were fabricated using plastic with 0.3 x 0.3 x 0.3 m for length, width and depth, respectively for an effective volume of 0.0225 m^3. The sewage level below the surface media was kept 5 cm and the depth of growth media, 0.25 m. Raw sewage was fed from the top and drawn out from the bottom of the unit. The performance of the wetland was tested over a span of eight months maintaining a hydraulic retention time of 0.5 day and hydraulic loading rate of 0.15 m d^{-1}. The process was conducted under the presence and absence of plants, two types of growth media (gravel

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and vermiculate), continuous and batch feeding modes. The diameter of gravel was 5-10 mm, and porosity of the media was 30%. The vermiculate diameter was 5 mm and porosity of the media was 35%.

Wetland performance was evaluated based on percent removal, mass removal rate, areal removal rate constant and volumetric removal rate constant.

Removal efficiency

Removal efficiency(%)= $(C_{in} – C_{out}) / C_{in}$ x 100

where,

C_{in} and C_{out} = inflow and outflow concentrations, respectively (mg L^{-1})

Mass removal rate

$r = q (C_{in} – C_{out})$

where,

r = mass removal rate (g m^{-2} d^{-1})

q = hydraulic loading rate (m d^{-1})

Removal rate constants

Degradation of BOD, COD, TSS, N and P followed first order reaction. The rate constants are based on area (k_A) or volume (k_V).

$\ln (C_{out}/C_{in}) = -k_A/q$

where,

q = hydraulic loading rate (m day^{-1}) = Q/A

Q = flow rate through the wetland (m^3 d^{-1})

A = area of the wetland (m^2), and

k_A = areal removal rate constant (m d^{-1})

$\ln (C_{out}/C_{in}) = -k_V\, t$

where,

k_v = volumetric removal rate constant (d^{-1})

t = hydraulic retention time in the wetland (d) = $V\mathcal{E}/Q$

V = volume of the wetland (m^3)

$\mathcal{E}$ = wetland porosity

Methods of analysis:

The samples were analyzed by paper filtration method for TSS, open reflux method for COD, Wrinkler method for BOD, nesslerization method for ammonium nitrogen ($N\text{-}NH^{+}_{4}$), ultraviolet spectrophotometric screening method for nitrate nitrogen ($N\text{-}NO^{-}_{3}$), vanadomolybdophosphoric acid colorimetric method for soluble phosphate ($P\text{-}PO^{-3}_{4}$).

Akarat panrare et al., constructed wetland system was using square steel tubes as external structures with 2.0m length, 0.5m width and 0.7m height. A 100µ HDPE plastic sheet was used to cover the inner wall. Crushed rock of 40mm was laid to a height of 0.5m as wetland media. 20 *Canna indica* plants per square meter were planted.

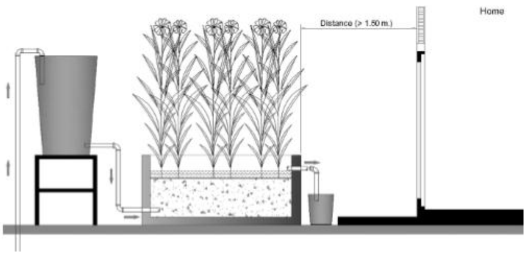

Fig. 1 Constructed wetlands (*Akarat Panrare* et al., 2015)

Shibao Lu et al., conducted experiment applied to subsurface flow artificial wetland with vertically upward flow and compound structure (Fig.2). A trapezoid concreted pond of 1.6m height, upper bottom with 3m length, lower bottom with 1.7m length, boulder layer with 20cm thickness, gravel stone layer with 30cm thickness, coal dust-furnace cinder mixed layer with 40cm thickness and soil layer with 30cm thickness, totaling 120cm thickness for filling materials. The process starts by leading domestic wastewater into sedimentation basin for settlement and then flows into influent water storage pond before overflowing and infiltration into multi-layer filling material zone through influent pipe. The over-flowing water then flows into effluent water storage pond.

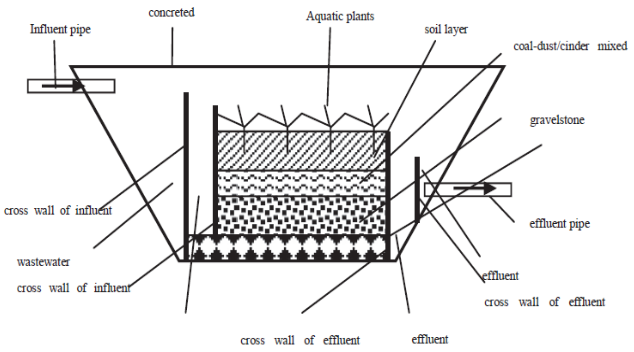

Fig. 2 Structure of multilayer (*Shibao Lu* et al., 2015)

Table 2 Experimental items, methods and water quality (*Shibao Lu* et al., 2015)

Item	Value	Analytic method
COD_{Cr} (mg L^{-1})	213~381	Dichromate process
BOD_5(mg L^{-1})	103~207	Dilution inoculation
NH_3–N(mg L^{-1})	48~112	Nessler's reagent
TN (mg L^{-1})	71~104	Ultraviolet spectrophotometry
TP (mg L^{-1})	4.8~12.1	Aluminic acid spectrophotometry
T/°C Temperature/°C	18~31	Thermometer
pH	5~9	Glass electrode method

III. CONCLUSION

The removal of the contaminants is dependent on the type of media particularly in planted beds. Mode of feeding in removal has no significant effect under all tested conditions. Among the three categories of pollutants such as organic matter, nutrients and microorganisms, it could be inferred that wetland performance was different for each parameter. The efficiency of wastewater treatment was directly proportional to the hydraulic retention time (HRT). Plantation showed significant impacts especially for the removal of nitrogenous compounds (*Gargi Sharma* et al.) and both nitrogen and phosphate removal (*Akarat Panrare* et al.). *Canna* planted wetland showed overall better performance in the order: unit4>unit2>unit1>=unit3. *Canna* plant is a good option for plantation in the development of wetlands since it has public acceptance because of its aesthetic appearance. Vertical up-flow constructed *Canna* wetland with gravel and sand media is suitable for post-treatment technology. Further research is in progress to determine the efficiency for removal of microbial contaminants from these wetlands.

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