



Remediation of Domestic Wastewater Runoff Using Vermi-biofiltration

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Abstract Remediation of domestic wastewater by indigenous vegetation was carried out using wastewater runoff within Silpakorn University, Sanam Chandra Palace Campus, Thailand. The treatment system utilizes the biological filtration treatment unit working in conjunction with earthworm, the living organism in soil, and vegetation to form a joint wastewater treatment unit, vermi-biofiltration, to treat domestic wastewater. The joint system operates by means of the raw wastewater percolates vertically through layers of physical and biological filtration media in a container tank topped with a layer earthworm-filled soil and vegetation to further phytoremediate the wastewater. The wastewater runoffs were collected from 2 sources having two levels of COD, Low (with COD ranging from 40-100 mg/L) and Medium (with COD ranging from 500-800 mg/L). The subjected wastewater went through 7 cycles of treatment and had their water quality parameters measured to determine the treatment efficiency in comparison to the system with stand-alone filtration. Results showed that the vermi-biofiltration system, combining soil living organism and plant phytoremediation was effective in treating domestic wastewater runoff and yielded significantly better water quality parameters (in terms of COD, TSS, TDS and TS concentration) when compared to system that only undergone filtration.

Keywords: remediation, phytoremediation, vermi-biofiltration, water quality

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1. Introduction

Water demand generates wastewater, the characteristics of which depend on the end use of water. The discharge of the wastewater into the environment in addition to the natural causes contaminates the natural water systems making it unsuitable for use. Ideally the wastewater requires to be treated prior to discharge into receiving environment.

Wastewater generated in areas without access to centralized sewer systems rely solely on on-site wastewater systems. These typically comprise of septic tank or individual domestic wastewater treatment systems. An assessment of the pollution load is presented in terms of biochemical/chemical oxygen demand (BOD/COD) and suspended solids (SS) discharge. To reduce the pollution load, wastewater treatment has been made mandatory with set standards for discharges [1]. Various initiatives and incentives are being provided to the industrial sector for decrease in water use and adoption of cleaner technology, and reuse of water [2].

Water consumption without the proper or appropriate wastewater management is likely to cause the deterioration in water quality, affecting the surrounding environment and the related organisms that use these physical surroundings as their habitats. Severely polluted wastewater may cause death of aquatic plants and animals

in great number from contaminants and the lack of oxygen or oxygen depletion in the water and may as well affect the health and sanitation of human being [3].

Domestic wastewater if not properly treated can be one of significant contributors to the polluted waterway, especially from facilities in large institutions such as government buildings, commercial establishments, hospitals and universities [4]. Two domestic wastewater sources in this research were collected from drainage stream at the Faculty of Engineering and Industrial Technology, Silpakorn University building, which has been pretreated from the treatment system at the building basement and another from the nearby Petcharat cafeteria. Both wastewater sources were found to be relatively high in nutrients and had relatively few toxic components that need to be removed.

Wastewater treatment and remediation can be categorized base on the method involves to treat the water e.g. the physical treatment unit, for example sedimentation or clarifier tank which utilizes gravity force to treat suspended solid from wastewater stream. The biological unit, for example trickling filter which use microorganism attached to the filter media to help breakdown organic contaminants or the advance units using a combination of both mechanical and biological method. Biological wastewater treatment system especially phytoremediation has been broadly used since it utilizes clean technology by mean of using microorganism, plants or living animals to help treat or remediate the polluted water. It is by far more

environmental friendly and often cost less than other treatment methods.

The previous King of Thailand, King Bhumibol Adulyadej had foreseen the importance of this treatment method to remediate the wastewater generated in areas without access to centralized sewer systems and would therefore need to rely solely on on-site wastewater systems. Many royal projects proceed to help remediate and adjust the state of natural water resources and surrounding environment to their natural conditions. To honor the previous King Bhumibol Adulyadej's initiative this research on phytoremediation of domestic wastewater by indigenous vegetations was carried out. The treatment system utilizes the biological filtration treatment unit working in conjunction with earthworm, the living organism in soil, to form a joint wastewater treatment unit, vermi-biofiltration to treat domestic wastewater runoff.

2. Materials and Methods

Investigation on the efficiency of the domestic wastewater treatment using vermi-biofiltration was set up at the Department of Biotechnology Laboratory, Faculty of Engineering and Industrial Technology, Silpakorn University, Sanam Chandra Palace Campus. The scope was set to focus on domestic runoff from two sources differing in COD concentration levels (Low and Medium) nearby the Faculty.

The physical and biological filtration tank adopted the system set up by Tomar and S. Suthar in their investigation on urban wastewater treatment using vermi-biofiltration system [5] as seen in schematic diagram in Figure 1. The system consisted of layers of coarse aggregate (construction rock) with an average diameter of 20 mm at 12.5 cm thickness (designated Layer 1 in Figure 1), fine aggregate (sand) with an average diameter of 5 mm at 5

cm thickness (Layer 2). Above that was a layer of sawdust and dry plant leaves at a thickness of 5 cm respectively (Layer 3 and 4). A geotextile mesh was used to separate between each layer preventing mixing of materials between each layer, allowing only the wastewater to percolate through. Layer 5 was a mixture of soil + coarse and fine aggregate, home for the earthworm species African Night Crawler and the roots system of the phytoremediated vegetations from the above layer (Layer 6), Two indigenous vegetations with phytoremediated properties were selected, Umbrella plant (Scientific Name: *Cyperus alternifolius L.*) and Nut grass (Scientific Name: *Cyperus rotundus Linn.*). The treatment systems operated in cycle of 'load' (where the wastewater was pumped, kept saturated to the topmost layer and allowed to percolate through layers of filtered materials in the biofiltration tank) for 8 hours and 'unload' (where the wastewater was discharged off at the bottom and kept in a storage tank) for 16 hours. The total of number of 7 load and unload cycles was used for this investigation corresponding to the treatment period from 1 day to 7 days.

2.1. Standard Water Quality Parameters

2.1.1. pH and Wastewater Temperature

The pH and the temperature of the runoff (both raw and treated) were measured daily from 1 to 7 days treatment period using pH meter and thermometer.

2.1.2. Chemical Oxygen Demand (COD)

The COD levels (measured in mg per litre of wastewater runoff) for the initial untreated raw wastewater and the treated were measured daily from 1 to 7 days treatment period using APHA, 1998, Standard Methods for the Examination of Water and Wastewater (Methods: 5220 B. Opened Reflux Titrimetric Method).

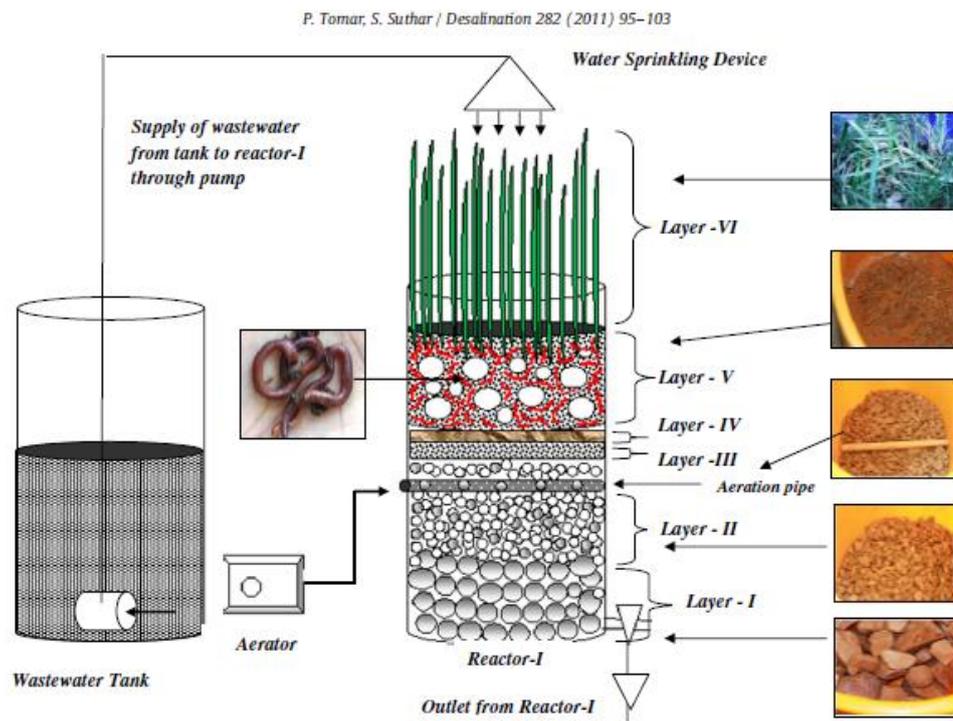


Figure 1. Schematic diagram of the vermi-biofiltration (phytoremediated plant + earthworm) used

2.1.3. Total Suspended Solid (TSS) and Total Dissolved Solid (TDS)

TSS and TDS for the initial untreated raw wastewater and the treated were measured daily from 1 to 7 days treatment period using Standard Methods for the Examination of Water and Wastewater by American Public Health Association, APHA 2540 SOLIDS.

2.1.4. System Operation

The test to compare the efficiency for wastewater treatment system operated in 3 levels. The 1st Level was conducted to find the best suited phytoremediated vegetation from the selection of Nut grass and Umbrella plant, while keeping other parameters (e.g. addition of earthworm and source of wastewater runoff) the same. The 2nd Level carried on with the best suited vegetation and tested with different sources of wastewater (with different levels of COD concentration). Lastly the 3rd Level compared the contaminants removed from different systems between biofiltration only, phytoremediation (filtration+the selected phytoremediated vegetation) and vermi-biofiltration.

3. Results and Discussion

3.1. Standard Water Quality Parameters

3.1.1. pH and Wastewater Temperature

The pH and temperature of the wastewater runoff both before and after treatment were averaging around 6.8 to 7.5 for all systems tested at different Levels. The runoff temperature recorded during the 7 days treatment period averaging around 30 degree Celsius. Both the pH values and the temperature of the wastewater runoff were well within the range of the acceptable Thailand water quality standard [6].

3.1.2. Chemical Oxygen Demand (COD)

The measurement of COD is important in the wastewater treatment because it provides an index to assess the effect discharged wastewater will have on the receiving water body [7]. Higher COD levels mean a greater amount of

oxidizable organic material in the sample, which will reduce dissolved oxygen (DO) levels. A reduction in DO can lead to anaerobic conditions, which is deleterious to higher aquatic life forms [8].

Figure 2 shows the level of COD contaminant measured in milligram per liter of wastewater runoff sourced from the cafeteria near the Faculty of Engineering and Industrial Technology, Silpakorn University. Initial measurement of runoff COD before treated was 102 mg/L which was slightly below the allowable effluent COD in accordance with Thailand water quality standard (120 mg/L). In this 1st Level the only different in the two treatment tanks was the phytoremediated vegetations, one was Nut grass while the other was Umbrella plant, both undergone 7 treatment cycle of load and unload, both with a soil layer filled with African night crawler earthworm. It can be seen from the result that the vermi-biofiltration of the two selected vegetations differed little in term remediation property and removed little to nominal COD from a Low level of contamination (40-100 mg/L). At the end of 7 days treatment period the COD of the treated wastewater effluent were 98 mg/L and 95 mg/L for Nut grass and Umbrella plant respectively. Umbrella plant was selected as the preferred phytoremediated vegetation to continue to the 2nd Level as its introduction helped better removed COD from the wastewater runoff.

The 2nd Level result can be seen in Figure 3, in this test two wastewater sources differing in levels of COD contaminations, Low (102 mg/L) and Medium (604 mg/L), were tested to see the influence of the contamination level has on the removal efficiency. It can clearly be seen that the higher contamination level of COD measured in Faculty building runoff was greatly removed in the vermi-biofiltration system, yielding effluent COD of 102 mg/L at the end of 7 days treatment period, or 83% removal efficiency compared to 7% in the case of low COD level in runoff from Cafeteria source. The graph in Figure 3 further shows a high COD removal rated during the first three load/unload cycles whereby the organic load was still in abundance as compare to the latter term of treatment period. Higher level of COD concentration from Faculty building runoff was selected as it provided more food which was necessary for the biological decomposition by living organism present in the vermi-biofiltration system.

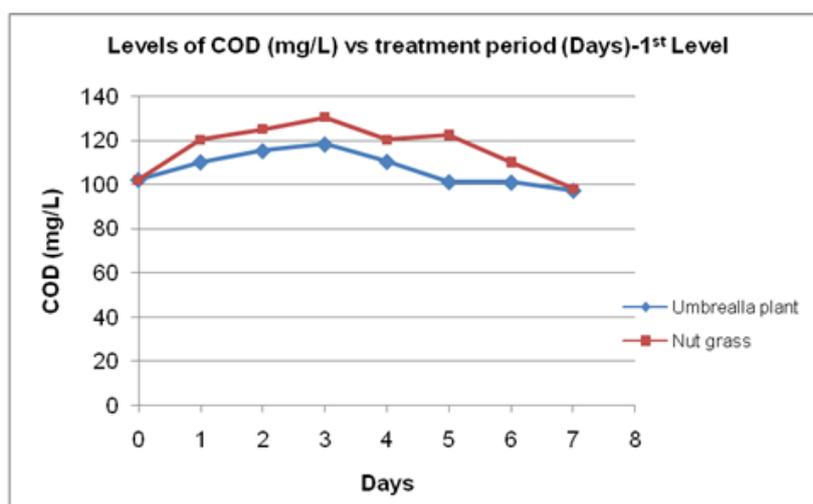


Figure 2. First Level COD removal

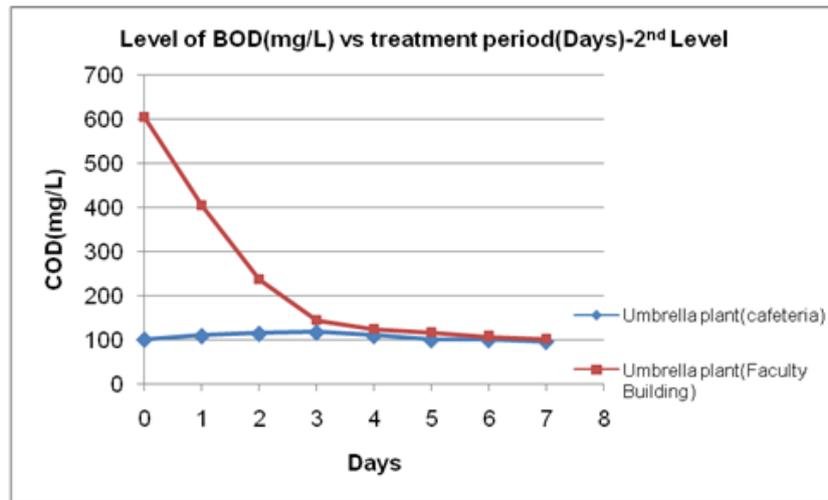


Figure 3. Second Level COD removal

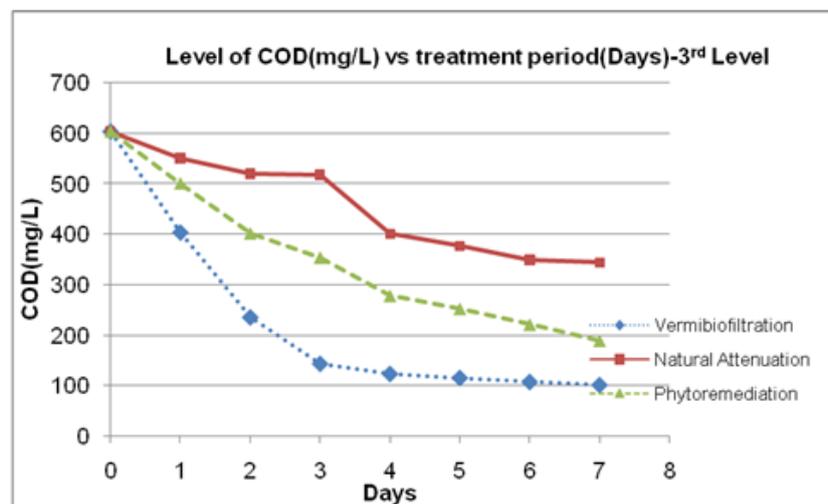


Figure 4. Third Level COD removal

Figure 4 shows the result of the 3rd Level comparison; here the vermi-biofiltration (vegetation and animal) optimized from the 2nd Level was compared to 1) the filtration system whereby the wastewater runoff was fed to the stand-alone filtration tank with no presence of phytoremediated vegetation or earthworm and 2) the system with phytoremediated vegetation only. After the 7 days treatment period the filtration system with both vegetation and animal working together, or the vermi-biofiltration, yielded the highest COD removal efficiency with 83% (effluent COD of 102 mg/L). This was followed by the system with just the Umbrella plant which removed 69% of its initial COD (final effluent of 189 mg/L). The stand-alone filtration system was lasted in COD removal efficiency having the final effluent COD after the 7 days treatment period of 345 mg/L, a removal efficiency of 43%.

3.1.3. Total Suspended Solid (TSS) and Total Dissolved Solid (TDS)

The term "total solids" refers to matter suspended or dissolved in water or wastewater. Total Solids includes both total suspended solids, the portion of total solids retained by a filter and total dissolved solids, the portion that passes through a filter (American Public Health Association, 1998).

Total dissolved solids (TDS) can comprise of inorganic salts (such as calcium, sodium and magnesium) and some small amounts of organic matter that are dissolved in water. The total dissolved solids test provides a qualitative measure of the amount of dissolved ions is used as an indicator test to determine the general quality of the water. Water with high level of TDS may have aesthetic problems or cause nuisance problems such as staining, taste, or precipitation.

The values of TSS, TDS and TS of domestic wastewater runoff from the Faculty building, that has undergone treatment by the vermi-biofiltration of umbrella plant and earthworm, in general, slightly decreased during the treatment duration of 7 days. The slight reduction in the values was due to the high concentration of waste solids derived from the Faculty building runoff, also the presence of Umbrella plant either in the form of roots, debris or rotting leaves and stems in water. The final removal efficiency were 69%, 10% and 17% for TSS, TDS and TS respectively.

4. Conclusion

Phytoremediation of domestic wastewater by indigenous vegetations was carried out using wastewater runoff within

Silpakorn University, Sanam Chandra Palace Campus, Thailand. The treatment system utilizes the biological filtration treatment unit working in conjunction with earthworm, the living organism in soil, to form a joint wastewater treatment unit, vermi-biofiltration to treat domestic wastewater runoff. The subjected wastewater went through 7 cycles of treatment and was found that the vermi-biofiltration was more suited to treat domestic wastewater with medium level of COD contaminant concentration. Results showed that the vermi-biofiltration system, combining soil and plant phytoremediation was effective in treating domestic runoff and yielded the highest COD removal efficiency of 83% compared to the others treatment systems tested. TSS, TDS and the overall TS parameters of the treated domestic wastewater runoff also were more favorable when treated with the joint vermi-biofiltration, having lowered the contaminants concentration when treated with the joint system with TSS having the highest percentage removal efficiency of 69%.

Acknowledgements

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