Review Article

Synthetic Floating Plant Clusters for Urban Storm Water Depolluting System

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Abstract

Urban storm water runoff during its flow picks up pollutants from pervious and impervious surfaces of various urban infrastructures. Wide range of pollutants can occur in an urban runoff which can degrade the nearby water sources. Therefore, the urban storm water runoff needs to be treated to remove pollutants in order to reduce its effect on ponds, lakes, rivers, etc. Various filtering materials have been experimented for treatment of the same, but found not practicable due to high frequency of clogging. Studies have been carried out using floating wetlands to remove nutrients from waste streams. Researchers have evidently proved that these systems can provide reasonable extent of treatment for the runoff waters as well. The root zone of the plants plays a very important role in removal of organic and inorganic, metal and nonmetal pollutant loads, which are picked up during the flow. In the present study, the polyurethane sheet (2 nos.) having surface area of 0.2×0.2 m^2 and thickness of 0.025 m and *Eichhornia crassipes,* are used for construction of floating plant clusters. A channel of volume of 0.25 m^3 is used as reactor for depolluting system in which a constant flow of synthetic storm water 0.00025, 0.0005 and 0.001 m/min is maintained. A synthetic urban runoff is prepared in the laboratory which constitutes nutrients and heavy metals. The treated water is taken for analyzing turbidity, nitrate, phosphorus, lead, zinc and cadmium. The system showed a promising result of >80% nutrient removal. Similarly, heavy metal removal by floating plant clusters is found to be >85%. Hence, urban storm water collection and conveyance system, if planned and managed properly, can be provided with synthetic floating plant clusters as mesocosm to remove nutrients and heavy metals from the stream.

Keywords: Depolluting, Storm water, Urban runoff, Floating wetlands, Plant clusters.

Introduction

Storm water is the water which originates from the event of precipitation. Naturally, the storm water infiltrates into soil, or held on surface or evaporates or forms runoff and reaches nearby water bodies (streams, rivers and ponds). Storm water runoff from urbanized areas is generated from residential, commercial and industrial areas, roads, highways, bridges and other impervious layers. Arnold and Gibbons [1] pictorially presented the effects of urbanization (pavements and concrete structure) on rate runoff and infiltration (Fig. 1).

Storm water is commonly pollutant free; however, during the course of precipitation, the rain droplets capture and dissolve the pollutants and reach the ground. Further, when the runoff occurs, it picks up wide range of pollutants such as solids, oxygen-demanding substances, nitrogen and phosphorous, pathogens, petroleum hydrocarbons, metals, synthetic organics, etc. The common pollutants found in the urban runoff are: eroded soil, lawn chemicals (fertilizers and pesticides), housing products (paints, thinners, solvents, cleaning agents, etc.), oil and grease, dust (atmospheric

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deposition and automobiles), and septic system discharges. These pollutants commonly originate from diffuse or nonpoint sources. The typical characteristics of storm water published by New Jersey Department of Environmental Protection (2004) are as furnished in Table 1. However, the characteristics vary depending upon the region, type of land use and land cover, vegetation, atmospheric inputs and sources of pollutants (point or nonpoint).

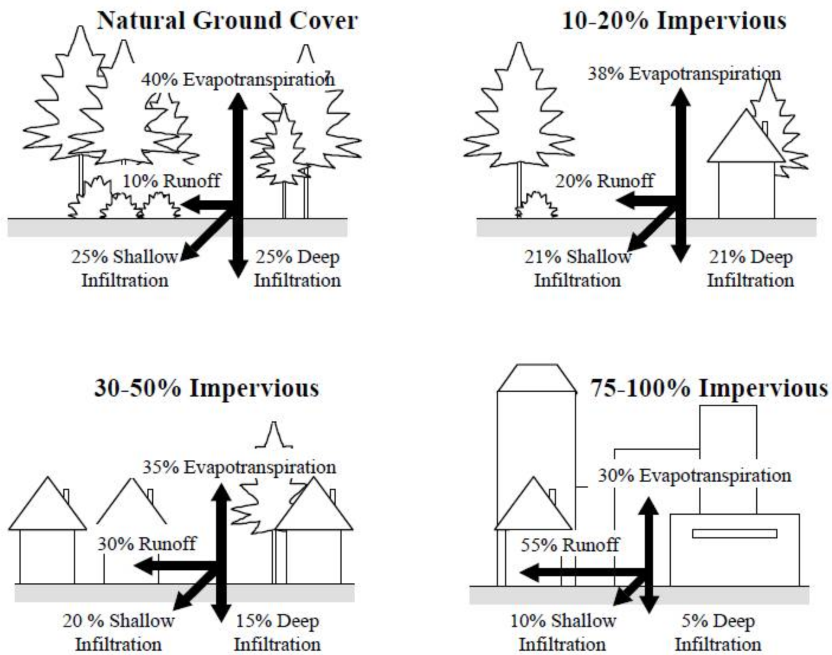

Figure 1.Effects of Urbanization on Runoff and Infiltration [1]

Parameter	Concentration	Parameter	Concentration
Total suspended solids	80 mg/L	Petroleum hydrocarbons	3.5 mg/L
Total phosphorous	0.3 mg/L	Cadmium	2 µg/L
Total nitrogen	2 mg/L	Copper	10 µg/L
Total organic carbon	12.7 mg/L	Lead	30 µg/L
Fecal coliform	10000 cfu/100 mL	Zinc	140 µg/L
E-coli	1450 MPN/100 mL	Insecticides	0.1-2 µg/L
Oil and grease	3 mg/L	Herbicides	up to 5 µg/L

Table 1.Typical Characteristics of Storm Water

The adverse impacts of these pollutants on the receiving water body can be classified as: (i) Short term changes in water quality during and after storm events along with variation of pollutant concentration and bacteria levels; (ii) Long-term water quality impacts caused by the cumulative effects of repeated storm water discharges from various sources, and (iii) Physical impacts due to soil erosion and deposition associated with increased frequency and volume of runoff that alters aquatic habitat. Storm water is a useful resource for meeting urban water demand and sustainable development of an urban area. Hence, the treatment of storm water plays a very important role to utilize it as useful resource for various purposes, like domestic and industrial, gardening, recharging groundwater, lakes and ponds. While managing the urban runoff, the storm water collection and drains play a vital function by removing the inert grit particles and floating matters and oil and grease. The significant parameters which have to be addressed in depolluting the urban storm water runoff are turbidity, oxygen-demanding substances, nutrients (nitrate and phosphorous) and heavy metals (lead, zinc and cadmium) which have detrimental effect on the aquatic ecosystem (eutrophication of lakes). The effects on public health due to inadequately managed storm water runoff include increase in water-borne diseases, reduced quality of drinking water, and increase in load to treatment plants [2]. There are various conventional methods such as media-based filtration [3, 4], grassed swales [5], detention pond [6, 7] and constructed wetland [8], which are experimented and employed to remove pollutants from storm water runoff. An innovative approach known as floating wetlands has been studied for treatment of ponds or lakes worldwide for reducing various pollutants [9, 10]. Commonly employed aquatic plants and various advantages of using treatment wetlands over other storm water management systems are well documented by Southwest Florida Water Management District [11]. Keeping all the above facts in view, present study is focused on using synthetic floating plant clusters to treat the urban storm water. The specific objectives is to select the aquatic plant species and build floating plant clusters and employ the same for treating the synthetic storm water (constituting nitrate, phosphorus, lead, zinc and cadmium) in a fabricated channel and carryout the performance of evaluation of the urban storm water depolluting system.

Materials and Methods

Three transparent rectangular glass rector channels having dimensions 1 m×0.5 m×0.5 m is fabricated with top open to atmosphere as shown in Fig. 2a. The polyurethane foam sheet is used for keeping the plant in floating condition and the isometric view of the foam is as shown in Fig. 2b. The plant is placed in the holes provided in the foam in such a way that root system is in contact with water, and shoots system is in contact with atmosphere. Two foams (placed in series) of the surface dimension 0.2 m×0.2 m each having thickness 0.025 m are used to keep the plants in place. The foam is tied to cleats (4 no.) provided in the channel to maintain its center position. *Eichhornia crassipes* obtained from local water body is initially washed with clear water to remove the adhered dirt both on root and shoot system of the plant.

The rector channels 1, 2 and 3 are charged with synthetic storm water at a flow rate of 0.03125, 0.0625, and 0.125 L/min, i.e., approximately equal to 0.00025, 0.0005 and 0.001 m/min respectively. The required flow rates were regulated using peristaltic pumps. The treated water is analyzed for the considered parameters to determine the efficiency of the floating plant clusters storm water depolluting system. In order to maintain the uniformity (to certain extent) with respect to the *E. crassipes*, plants having same weight are used in each channel. The weight of each aquatic plant chosen is 0.25+/−0.05 kg. Each plant is weighed after washing with clear water and draining out water completely. The plants root zone is submerged in tap water for 24 h before it is employed in the reactor.

The stock solutions of lead, zinc, cadmium, nitrate, and phosphate are prepared by dissolving $PbCl_2$, $ZnSO_4$, $7H_2O$, $3CdSO_4$, $8H_2O$, KNO_3, and KH_2PO_4 in deionized, respectively. The stock solutions are used to prepare synthetic storm water. Based on the literature [4], and drinking water quality and effluent discharge (surface water) IS standard, the concentrations of the synthetic storm water constituents were fixed and are presented in Table 2. The used oil procured from local mechanical shop is used in the synthetic runoff water.

The heavy metals were analyzed using inductively coupled plasma mass spectroscopy, nitrate (phenol di-sulfonic acid method), and phosphorous (stannous chloride method). Oil and grease is measured as per standard methods [12]. The effect of flow rate on removal of pollutants is determined by varying flow rates and drawing samples from the reactor to analyze the concentration remaining in the treated water. The samples are drawn at time intervals of 0.25 h up to 6 h.

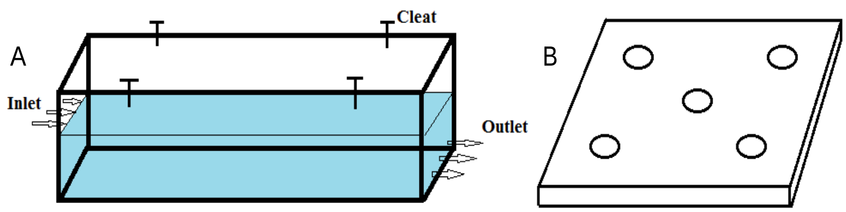

Figure 2.(a) Glass Channel and (b) Polyurethane Foam

Parameter	Concentration	Parameter	Concentration
Nitrate	45 mg/L	Zinc	6 mg/L
Phosphorous	10 mg/L	Cadmium	2.5 mg/L
Lead	2.4 mg/L	Oil and grease	12 mg/L

Table 2.The Characteristics of Synthetic Urban Storm Water Runoff

Results and Discussion

The samples obtained at regular time intervals of 0.25 h (up to 6 h) were analyzed for considered parameters (Table 2). The removal efficiency of the pollutant by the rector channel is determined with respect to each parameter.

From Fig. 2, it is evident that the nitrate ions are effectively absorbed by the roots of *E. crassipes*. The average removal of nitrate from the depolluting system is 78, 81 and 86% in channels 1, 2 and 3 respectively. The nitrate is an essential constituent for plants for growth and production of seeds. It is easily absorbed by root zone and converted to NH_4. The ammonia is further converted to amino acids and proteins. The nitrate absorbed by root may diffuse directly to shoot system or may be converted to ammonia initially and then transferred to shoot system.

Phosphorus (P) is a pivotal nutrient for all the living things on earth. The phosphorous in case of organic type needs to be hydrolyzed for uptaking by the plant roots. The hydrolysis is taken care by roots or microorganisms (rhizomes). In the present case, phosphate source is derived from monopotassium phosphate in which potassium is also an essential element for the cellular processes in plants, including turgor regulation, charge balance, movement, and protein synthesis. Hence, the rate of uptake of phosphorus and potassium is high compared to nitrate. The total average phosphorous removal was observed to be greater than 80, 84 and 90% by channels 1, 2 and 3 respectively (referring to Fig. 3).

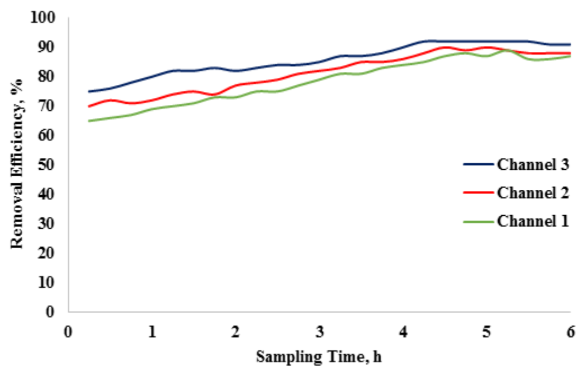

Figure 3.Nitrate Removal by Depolluting System

The zinc and cadmium removal is observed to vary from 86 to 97% and 88 to 98% respectively, in the present study from the start to end of the experiments. This is because zinc is an essential micronutrient for activating the plant enzymes. And also the sulfate ion is an essential secondary nutrient required for the plant growth which is added as zinc sulfate and cadmium sulfate to the synthetic water. Sulfate ions are used for synthesis of amino acids which are utilized for protein synthesis. Sulfate is also required for production of chlorophyll and utilization of phosphorus and other essential nutrients. Sulfate is commonly considered to equal the rank of nitrogen for optimizing crop yield and quality. Hence, the uptake of zinc and cadmium from synthetic water is high with *E. crassipes*. Even the lead uptake is found to be effective and average removal ranged from 90 to 95%.

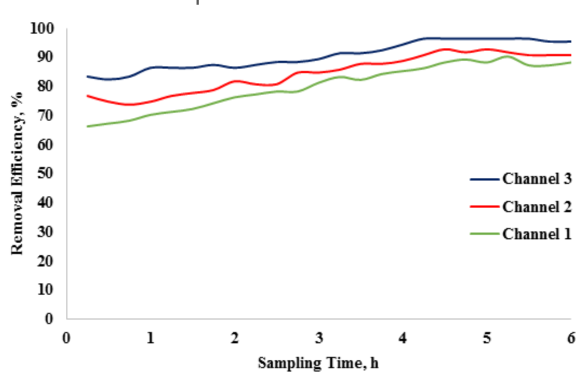

Figure 4.Phosphorus Removal by Depolluting System

By inspection, about 90% of the oil and grease added were trapped on the surface of the water at the outlet end and remaining was found on the channel and polyurethane foam surfaces. Hence, the oil and grease trap and skimming becomes as vital component while addressing to storm water treatment. From the present study, it is evident that in continuous flow phytoremediation, the efficiency is affected by flow rate. From Figs. 2 and 3 as the flow rate decreased the removal efficiency of nitrate and phosphorous from depolluting system increased. Similar trend is observed with respect to all the other storm water parameters. The interaction between ions and roots will be maximum at low flow rate hence removal efficiency is high. The root zone of floating plant clusters, in the reactor channel (depolluting system) is found to be sufficient enough to remove the pollutants from the synthetic urban storm water runoff.

Conclusion

From the present study, it can be concluded that the root zone provided in the reactor is sufficient enough to remove >80% of both nitrate and phosphorous even at maximum flow rate considered in the present study. In continuous flow phytoremediation, the efficiency of the system is affected by flow rate, i.e., as the flow rate increases efficiency decreases. The heavy metal uptake is effective in the present simple depolluting system. The average removal of heavy metals (zinc, cadmium and lead) is found to be >85%, which is a significant value in phytoremediation. The designed reactor channel performance is found to be promising for depolluting the urban storm water runoff. Hence, the storm water channels can be provided with the floating plant clusters to depollute the runoff water before it reaches the water body. The treatment may be provided in the channel or a detention pond depending upon the convenience. Further study is recommended to understand the effect of shock load on the performance of the rector.

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