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Physico-chemical and Microbiological Performance Evaluation of Phytoremediation Plant

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Abstract

Wastewater treatment is a major environmental problem in the world particularly in Pakistan, and most conventional treatment approaches either have too much high cost or does not provide acceptable solution. The use of specially selected and engineered plants for environmental a clean-up is an emerging technology called phytoremediation. Phytoremediation is the eco-friendliest and cost effective technique for removal of contaminants without the need of excavating or disposing of them. The study was conducted at NUST to treat wastewater of capacity 0.1 MGD and use this treated wastewater for horticulture purposes, fish feed and poultry etc. Apart from this, sampling from 10 points i.e. inlet, sedimentation tank and 8 different ponds were done once a week and different tests like pH, Temperature, TDS, COD, Total Coliforms, Fecal Coliforms etc. were conducted and depending upon the wastewater characteristics, best suitable plants were selected for greater decontamination efficiency for pilot scale plant. Three systems were established, lab scale, pilot scale and parallel scale treatment system, Parallel scale treatment system was designed to check the individual uptake efficiency by plants and the results were the following, water lettuce showed the maximum removal of COD i.e. 90.36%, typha and duckweed almost showed the same value of removal i.e. 83% and pennywort showed the least removal efficiency of COD i.e. 78%.

Keywords: Phytoremediation, Contaminants, Water lettuce, Duckweed, Pennywort, Parallel scale treatment system

Introduction

Water pollution has resulted in many problems all over the world, which include drinking water supply, sanitation supply and survival of species. Pollutants in water are the main reason for global deaths and transferring of diseases between living creatures. Water in rivers, streams and seas etc. are being deteriorated because of direct discharge of sewage water without proper treatment. Nearly 95 percent of the industrial waste and approximately 90-95 percent of domestic sewage come from the urban areas into the fresh water reserves without any prior treatment [1].

Wastewater pollution is a major environmental and social concern. Discharging of wastewater without proper treatment into the environment has adverse health and ecological impacts. Environmental Protection Agency (EPA) has set it mandatory to treat wastewater before discharging it into the environment. Industries are major polluters of environment. The disposal of treated wastewater below discharge standards from households or other units can result in adverse soil pollution and surface water contamination [2]. The capacity of Water and Sanitation Agency (WASA) has a limited number of wastewater treatment plants and need specialized input to enhance their capacities.

Pakistan is water strained and will probably face water shortage in the upcoming period of time [3-4]. One possible solution is wastewater reclamation and reuses through treatment.

Traditional wastewater treatment plants involve higher capital and operational costs and for that reason, these systems are not a good solution for such areas which cannot afford such expensive wastewater treating methods. Constructive wetlands are getting importance because of their effective and low-cost alternative for wastewater treatment. As compared to conventional treatment systems, these systems are better as they are low-cost systems and have lower or zero energy requirements. They can be established right at the same place as where the wastewater is produced and can be maintained by relatively untrained personnel.

Wetlands are planned systems used to exploit the processes involved in natural wetlands related with plants, soil, microbes and wetland hydrology to treat wastewater. These systems can be used for the purification of domestic wastewater particularly restraining the concentration of COD and TDS to

NEQS permissible limit of 150 and 3500 respectively. Unlike natural wetland, treatment in constructed wetlands is accomplished under more controlled environment, resulting in excellent constancy and better treatment efficiency of the functions involved in wetland across entire system [5]. The purpose of our research was mainly to compare the performance efficiency of nutrient removal from wastewater between a pilot scale and lab scale system and also the uptake individual efficiency of Typha, Pennywort, Water Lettuce and Duck Weed. Meanwhile, Wetlands are terrestrial ecosystems characterized by high and fluctuating water tables. The problems which can be encountered are: The spatial and temporal differences in the degree to which wetland soils are waterlogged create a very dynamic soil environment with, on average, lower oxygen concentrations than unsaturated soils; Wetland soils are characterized by gradients in redox conditions from totally oxidized to extremely reduce; These conditions require special adaptations for the plant and microbial species in the wetland. Wetland plants, particularly in wetlands with strongly fluctuating water tables, need adaptations to the shortage of oxygen in the root zone, but also to extended periods of dry conditions during low-water phases.

Materials and Methods

This study focused on the performance efficiency of a pilot-scale and lab-scale phytoremediation plant which has been installed at NUST. It receives a supply of 0.2 MGD from two sewerage lines. Samples were collected from each pond on a weekly basis from both plants. These wastewater samples were collected to perform Microbiological analysis (Total Coliforms and Faecal Coliforms) as well as for physic-chemical examination (pH, DO, Conductivity, Turbidity, TSS, TDS, COD). The 250 ml sterilized (autoclaved) plastic sample bottles were used whereas 500 ml plastic bottles were used to collect wastewater samples from each differently constructed wetland and sedimentation tank from both the lab scale and pilot scale units. Moreover, these were preserved at 4°C throughout the whole research.

Detailed analysis of various physicochemical and bacteriological parameters namely, pH, Conductivity, Turbidity, TSS, TDS were collected through Potentiometric Method of Analysis where as COD was through The Closed Reflux, Colorimetric Method and DO by using DO Meter, besides Total Coliforms and Faecal Coliforms were carried out for all the wastewater samples collected as per Membrane Filtration Technique (MF).

Both plants consisted of a sediment tank and eight wetlands as shown in Figure 1. The water was treated with the help of different plants each having different uptake capacity and characteristics. In first wetland Typha was grown, the bed contained gravels mixed with soil so that the roots of typha could get a suitable bed for growth. Second and third wetland had Duckweed and it was floating as they don't need any bed for the growth. Fourth and fifth wetland had Pennywort and it was also floating. Sixth and seventh wetlands had Water lettuce and the eighth tub contained water hyacinth.

Typha, maximum capacity is about 3-4 months after this new plants are placed for germination; water lettuce, grows in high temperature i.e. in summer so its lifespan is about six months from March to September; duckweed grows in winter so age limit of duckweed is 3-4 months; pennywort, the temperature range required for its growth is wide that's why this plant grows throughout the year.

Phase 1: Lab Scale Unit

A lab-scale unit was established at Institute of Environmental Sciences and Engineering (IESE), NUST. The purpose of establishing a lab-scale unit was to analyze different aspects and different working conditions in order to achieve better

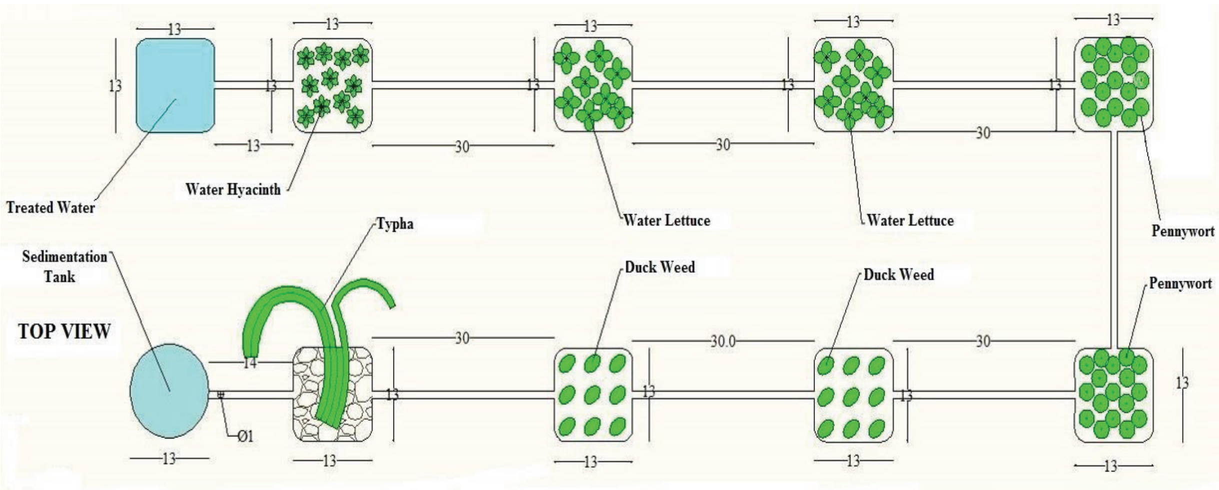

Fig-1: Layout of Lab Scale and Pilot Scale Treatment System

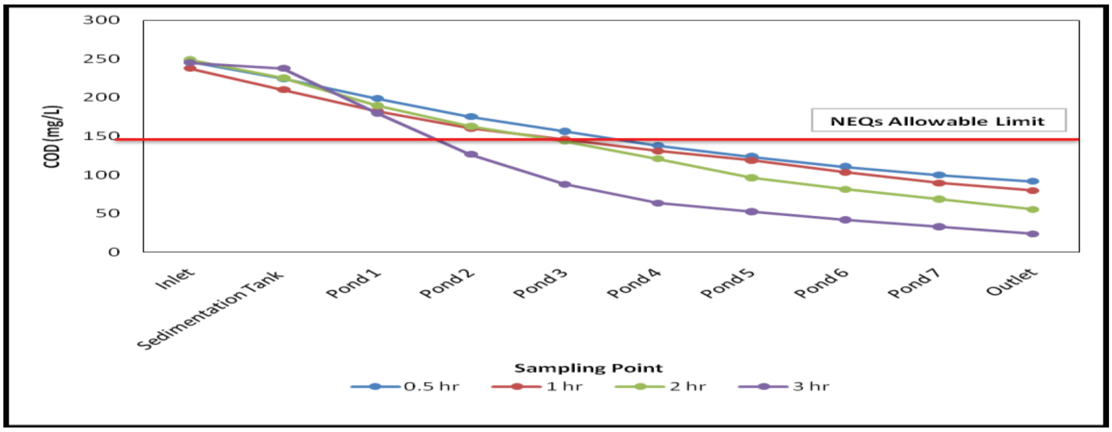

Fig-2: COD removal of Lab Scale Unit

results. The unit was run at different hydraulic retention times to check treatment efficiency and to determine the optimum HRT.

For further study regarding our project, we fabricated a lab-scale design of our pilot scale plant. The specification of our lab scale is following: A lab-scale unit was established to treat NUST wastewater which we bring from our pilot scale plant and placed in sedimentation tank which we placed in our lab-scale unit. It consisted of a sediment tank and eight wetlands. They were connected with polyvinylchloride (PVC) pipes and check valves are used to control the flow. The water was treated with the help of different plants each having different uptake capacity and characteristics. The unit was run at different hydraulic retention times (HRT) to check treatment efficiency and to determine the optimum HRT. Importantly, before operating the plant, the ponds having soil, sand, and gravel will be kept soaked with fresh water for 3 to 4 weeks in order to acquire saturated growth of grass and associated microbial community in the rhizosphere, in the respective ponds. This will help in the establishment of a compact bed suitable for wastewater treatment.

Phase 2: Pilot Scale Unit

Pilot scale plant is established at National University of Sciences & Technology (NUST), at the back of Isra apartments, where the NUST sewerage lines pass. Those sewerage lines can be considered as the outlet of NUST complete sewer system. The wastewater generated from offices, student hostels and staff residential colony led towards a sedimentation tank and then to constructed wetlands. Pilot scale phytoremediation plant has the ability to treat supply of one sewerage line i.e. 0.1 MGD. The total area of pilot scale plant is 120 ft. * 100 ft. The dimension of sedimentation tank is 35 ft. * 12 ft. * 6 ft. and dimension of each wetland is

22 ft. *50 ft.*7 ft. The wetlands were covered with Low-density polyethylene (LDPE) to prevent the infiltration.

Phase 3: Parallel Scale Unit

Parallel scale unit was designed to check individual uptake efficiency of Typha, Water Lettuce, Duckweed and Pennywort. This system was established in IESE. 4 tubs of same size and dimension were connected to a single sedimentation tank. 4 different plants were placed in individual 4 tubs. 100 grams of each plant species was placed in 4 liters of wastewater. Same HRT was applied in all 4 tubs.

Results and Discussion

COD is an important parameter to characterize wastewater. No specific criterion has been described by WHO for COD. The COD of the influent ranged from 244-241mg/l. These high values are due to the contamination of wastewater with organic compounds. After treatment, the concentration of COD decreased in the effluent for both the units planted with different species.

For lab scale system, different hydraulic retentions were given and results were recorded. 62.88%, 66.48%, 77.75%, 90.36% COD removal was achieved at HRT of 0.5 hrs, 1.0 hrs, 2.0 hrs and 3.0 hrs respectively as depicted in Figure 2.

Sample	March, 2014		April, 2014		May, 2014	
	COD (mg/L)	TDS (mg/L)	COD (mg/L)	TDS (mg/L)	COD (mg/L)	TDS (mg/L)
Inlet	244 (230 - 259)	645 (641 - 651)	240 (230 - 255)	720 (709 - 728)	241 (233 - 251)	725 (718 - 732)
S.T	216 (211 - 226)	611 (605 - 618)	206 (197 - 217)	671 (664 - 684)	208 (201 - 221)	697 (686 - 709)
Pond 1	168 (158 - 172)	559 (546 - 569)	169 (157 - 178)	647 (639 - 657)	173 (165 - 179)	666 (657 - 675)
Pond 2	132 (129 - 136)	531 (526 - 542)	149 (142 - 156)	615 (604 - 623)	151 (142 - 158)	624 (618 - 631)
Pond 3	119 (100 - 129)	503 (496 - 513)	128 (119 - 138)	583 (574 - 591)	130 (121 - 139)	589 (581 - 596)
Pond 4	100 (93 - 106)	476 462 - 485)	112 (106 - 119)	541 (530 - 554)	112 (106 - 118)	563 (559 - 567)
Pond 5	86. (81 - 92)	437 (426 - 451)	95 (91 - 102)	498 (492 - 509)	99 (92 - 105)	521 (514 - 529)
Pond 6	72 (65 - 78)	395 (384 - 406)	79 (73 - 85)	464 (457 - 470)	87 (82 - 93)	486 (480 - 495)
Pond 7	57 (53 - 61)	367 (356 - 375)	67 (62 - 73)	431 (421 - 447)	73 (70 - 76)	450 (439 -461)
Outlet	43 (40 - 47)	341 (334 - 352)	54 (47 - 59)	403 (387 - 412)	62 (55 - 68)	415 (404 - 423)

For pilot scale system, no visible change was observed in pH and temperature. COD removal and TDS removal for March 2014 are 82.37% and 47.13% respectively.

COD removal and TDS removal for April 2014 are 77.50% and 44.02% respectively. COD removal and TDS removal for May 2014 are 74.27% and 42.76% respectively. The Table below shows the COD and TDS values of March, April and May. Upper values show the mean values and lower values show the minimum – maximum values

In parallel scale system, COD removal achieved for Typha, Duckweed, Pennywort and Water Lettuce were 84.12 %, 83.60 %, 79.75 %, and 86.60 % respectively by applying HRT of 1 day. Water Lettuce showed the maximum COD removal percentage while Pennywort showed the least COD removal percentage. Typha and Duckweed almost showed the same COD removal percentage. The graph shows the pictorial change in the values of COD. Figure 4 depicts that as the HRT is increasing, removal efficiencies of COD are also increasing.

Microbial profile of Pilot Scale System

The domestic wastewater was contaminated with both pathogenic microorganisms and faecal coliforms. In order to analyze the extent of contamination, the wastewater was subjected to bacteriological analysis before and after treatment by determining the MF and plate count method (CFU). For determining total bacterial count, CFU was used and for determining the number of faecal coliforms, MF was done. These methods showed the percentage reduction in bacteria.

When the untreated wastewater was analyzed, the results showed that it contained a large amount of contaminants (up to 1.2 × 107 CFU/ml). The sources of these pathogens were mainly the infected persons and animals or who are carriers of these pathogens. Pilot scale system and lab scale system have the ability to remove a great quantity of pathogens (total and faecal coliforms).

Lower removal efficiencies of total coliforms and fecal coliforms were observed in the month of April as compared to March and May as shown in Figure3. The reason for lower removal efficiencies of total coliforms and fecal coliforms in the month of April is due to excessive raining in the month of April.

Conclusions

Lab scale and pilot scale systems have proved to be an effective natural treatment strategy for wastewater treatment. Improvement in the microbiological, physical and chemical parameters was observed and the treated water was safe enough to be used for irrigation purposes.

In addition to, five different plants were used in this study i.e. Pistia stratiotes (water lettuce); Hydrocotyle umbellate (pennywort); Typha

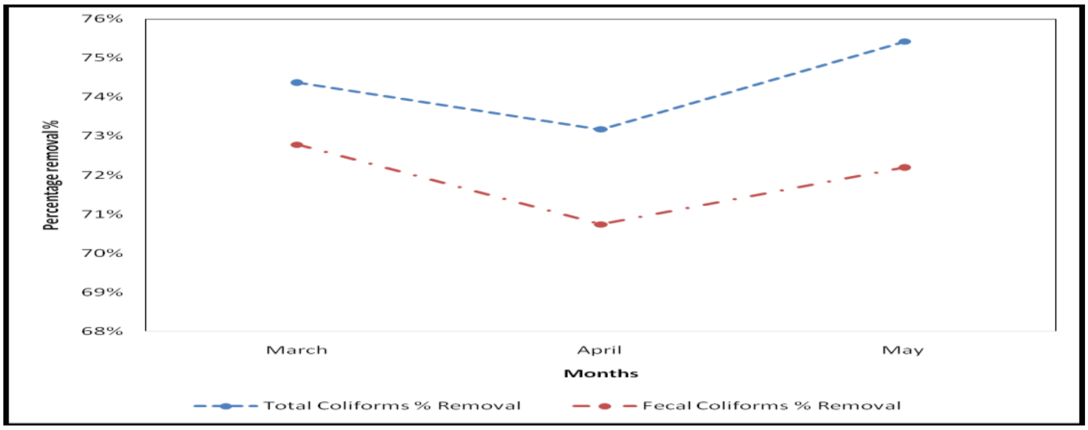

Fig-3: Removal efficiencies of total coliforms and fecal coliforms for the month of March, April, May

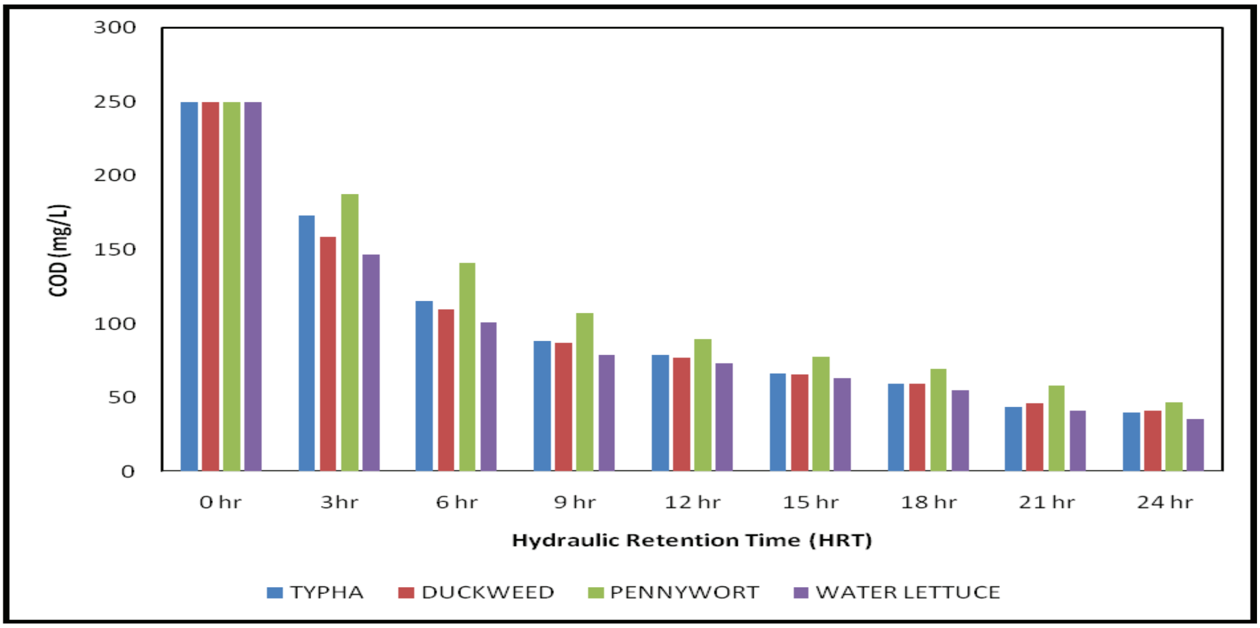

Fig-4: Change in the values of COD for individual plants with different HRTs

domingensis; Lemna minor (duckweed);Eichhornia crassipes (water hyacinth).These proved to be quite efficient wetland plants with minor differences in their performance competence. Hence it was proved in Figure 4 that the mutual interaction of roots and its associated microorganisms play a crucial role in the degradation of contaminants, more importantly with the difference of 3 hrs in hydraulic retention time, removal efficiency of different plants individually were changed gradually therefore, Water lettuce showed maximum removal of COD (90.36%) while typha year.

Recommendations

- The mechanism of the degradation of the contaminants is an important side to work on with special emphasis on biolytic process.

and duckweed almost showed the same removal value (83%) whereas pennyworts delivered the least removal efficiency of COD (78%).

Wetlands provide a consistent food supply, shelter and nursery grounds for both marine and freshwater species. The Economic value of constructed wetlands lies in the variety of commercial products they provide, such as food and energy sources. Rice can be grown in a wetland during part of the year, and the same area can serve as a wildlife habitat for the rest of the

- The overall behavior of any contaminant in relation with how they can be eliminated from the contaminated water or how they can be made less toxic or safe can be studied in future.
- For a better and efficient design, the microbial communities inhabiting the wetlands needs to be further investigated. Study of the genes encoding the enzymes

responsible for the degradation of contaminants and investigation of quantitative expression of these genes in the complex system is an important future topic.

- The most dominant species responsible for the purification of water in the system can be identified by analyzing the 16s RNA genes, subsequently understanding the microbial community in the system

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