Performance Evaluation of Field Phytoremediation System

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2014

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Thesis Submitted in Partial Fulfilment

of the Requirement for the Degree of

BACHELOR

IN

ENVIRONMENTAL ENGINEERING

Institute of Environmental Sciences and Engineering (IESE)
School of Civil and Environmental Engineering (SCEE)
National University of Sciences and Technology (NUST)
Islamabad, Pakistan.
2014

APPROVAL SHEET

Certified that the contents and form of thesis entitled

Performance Evaluation of Field Phytoremediation System

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ACKNOWLEDGEMENTS

This dissertation would not have been possible without the guidance and the help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study.

First and foremost, my utmost gratitude to my supervisor, **Dr. Imran Hashmi** (Professor IESE, SCEE, NUST) whose technical assistance, sincerity and encouragement I will never forget. Many thanks also go to **Dr. Kamran Akhtar** (Associate Professor NICE, SCEE, NUST) **and Dr. Hamza Farooq Gabriel** (Associate Professor NICE, SCEE, NUST) who had kind concern and consideration regarding my research work.

I am also very thankful to **Mr.Owais** (DD Horticulture) for providing us the bowser for collection of wastewater. My special gratitude to **Engr. Muhammad Adnan** (Env.Engg Student) for providing us the plants from NARC which took us out of struggling many times.

I am grateful to **Ms.Sumaira Khan** (Quaid-e-Azam University), **Admin IESE** for their support and to the staff of **Environmental Microbiology lab** and **Environmental Wastewater Lab**. I would also like to pay special thanks to all of my friends who gave me support by all means in all my hardships. Finally, to MS Research Students **Ms. Arish Naseem** and **Ms. Amina Khalid** for accommodating to our queries and helping us during experimental work.

Haris Bin Khawar Cheema
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List of Abbreviations

APHA	American Public Health Association
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
GD	Gallons per Day
HRT	Hydraulic Retention Time
MGD	Million Gallons per Day
NTU	Nephelometric Turbidity Units
PVC	Polyvinylchloride
TS	Total Solids
TDS	Total Dissolved Solids
TP	Total Phosphorous
TSS	Total Suspended Solids
TVSS	Total Volatile Suspended Solids
UN	United Nations
WASA	Water and Sanitation Agency
WWF	World Wide Fund for Nature

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ABSTRACT

Wastewater treatment is a major environmental problem in world particularly in Pakistan, and most conventional treatment approaches either have too much high cost or do not provide acceptable solution. The use of specially selected and engineered plants for environmental clean-up is an emerging technology called phytoremediation.

Phytoremediation is the most eco-friendly and cost effective technique for removal of contaminants without the need of excavating or disposing them off. 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%.

INTRODUCTION

Without food, normal person in good physical condition can survive for 6 weeks but without water, survival potential is measured in days. 783 million people lack access to clean or safe water and 37 percent of the world's population doesn't have access to sanitation facilities (UN special report). Only 3% of the water resources is not salty, two third of water is locked up in glaciers and other ice caps, 0.08% of the remaining water is only used by human being in the ever increasing demand for sanitation, drinking, manufacturing, industries, washing and agriculture (World Bank, 2005). Human excess usage and fresh water pollution has resulted in so much water scarcity that it can be said that shortly this scarceness will lead to limitation of food production and urban supply. At the moment, water crisis in the whole world is due to population increase and excessive use of remaining water reserves.

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 a main reason of global deaths and transferring of diseases between living creatures. Water in rivers, streams and seas etc. is 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 (Hinrichsen *et al.*, 1997).

Wastewater pollution is a major environmental and social concern. Discharging of wastewater without proper treatment into the environment have adverse health and ecological impacts. Environmental Protection Agency (EPA) have set it mandatory to treat wastewater before discharging it into the environment. Industries are major polluters of environment. Disposal of treated wastewater below discharge standards from households or other units can result in adverse soil pollution and surface water contamination (Tanner, 2012). The capacity of Water and Sanitation Agency (WASA) has limited number of wastewater treatment plants and need specialized input to enhance their capacities.

Wastewater may be defined as, the outcome of agricultural, public, and industrialized activity (Evans and Ellis, 2004). Domestic wastewater is the water that has been utilized by a society. It consists of human body wastes combined with the water utilized for the purpose of toilet flushing, and silages, which is the wastewater resulting from individual cleaning, laundry, washing and cleaning of utensils.

Pakistan is water strained and will probably face water shortage in the upcoming period of time (Hashmi *et al*., 2009a; WWF, 2007). One possible solution is wastewater reclamation and reuse through treatment.

For wastewater treatment, biological treatment is the best choice as compared to the physical and chemical technologies (Shalaby, 2008). In small communities, wastewater is treated with anaerobic digestion, activated sludge, trickling filter technologies and constructed wetland comes in biological treatment process, where constructed wetland is among the highly suggested techniques (Suliman *et al*., 2007; Alvarez *et al*., 2008). Recent research has proved that wastewater treated with wetland technologies is appropriate for meeting specific national guidelines for irrigation purposes (e.g., Belmont *et al*., 2004; Wang *et al*., 2005).

Bioremediation is the use of microorganisms to eliminate or reduce the concentrations of hazardous wastes at a contaminated site. One important characteristic of bioremediation is that it is carried out in non-sterile open environments comprising of a variety of microorganisms (Huang *et al*., 2013). Out of this diversified group of microorganisms, the central role towards degradation of contaminants is being accomplished by bacteria (Huang *et al*., 2013). A biological treatment system comprising of these microorganisms has various applications such as the rehabilitation of contaminated sites, e.g., water, soils, sludge and waste streams.

Currently, the most common engineered systems of phytopurification are the so called constructed wetlands, which are more and more widely studied and employed throughout the world.

The microbial community in constructed wetlands consists of autochthonous (indigenous) and allochthonous (foreign) microorganisms. Autochthonous microbes exhibit adaptive features and they are able to possess metabolic activity, survive and grow in wetland systems participating in purification processes, while allochthonous microbes (including pathogens entering with wastewater) usually do not survive or have any functional importance in the wetland environment. The purification performance of constructed wetlands is based on combined action between microbes and filter material, which may be complemented by plants. The mineralization of organic matter is mainly carried out by microbes both in aerobic and anaerobic conditions. Nitrogen removal in constructed wetlands has mostly been assumed to be a result of the combination of nitrification–denitrification, but newly discovered pathways such as the anaerobic oxidation of ammonium (ANAMMOX) could have potential significance in certain conditions as well. Microbes may play an important role in phosphorous removal as mineralizers of organic phosphorous via biological mineralization (release of mineral phosphorous during degradation of organic matter) and biochemical mineralization (release of mineral phosphorous through enzymatic hydrolysis by extracellular enzymes.

Despite the knowledge that the elimination of easily degradable organic wastewater compounds, as well as nitrogen and phosphorus transformation processes, is a consequence of a combination of chemical, physical and biological processes and that these processes are mostly driven by microorganisms, only a limited number of studies have focused on microbial community investigations in constructed wetlands. A multitude of different characteristics (several types of constructed wetlands with different kinds of soil matrix and operational parameters used for purification of wastewater from variable sources, but also the presence or absence of vegetation in the system) confound the clarification of understanding about different aspects of microbial community structure, spatial distribution, and different aspects of its activity in constructed environments. Therefore studies in microbial ecology broaden the knowledge about microbial communities in these systems and help to improve the design and performance of constructed wetlands.

In constructed wetlands, several ponds are constructed and different plants are planted in ponds, the phytoremediation process takes place by which the decontamination of wastewater is done. Plants uptake pollutants, nutrients, heavy metals etc. to enhance their growth and to increase their metabolic activity which removes pollutants from the wastewater.

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.

Pilot scale plant is established at National University of Sciences & Technology (NUST), at the back of Isra apartments, where the NUST sewerage lines passes. Those sewerage lines can be considered as the outlet of NUST complete sewer system. Sample for lab scale system is also collected from this sewer line. Treatment efficiency of lab scale system, pilot scale system and individual plants will be examined by physicochemical and biological tests. Water treated from pilot scale plant will be used for horticulture purposes, fish feed purposes and sludge can be used for the production of fuels for domestic use.

***Pistia stratiotes* (water lettuce)**

***Hydrocotyle umbellate* (pennywort)**

Typha domingensis

. ***Lemna minor* (duckweed)**

***Eichhornia crassipes* (water hyacinth)**

<u>Fig 1: Plants used for study</u>

PHYTOREMEDIATION PROCESS

PHYTOEXTRACTION:

Uptake of substances from the environment, with storage in the plant (also known as *phytoaccumulation*).

PHYTOSTABILIZATION:

Reducing the movement or transfer of substances in the environment, for example, limiting the leaching of soil contaminants.

PHYTOSTIMULATION:

Enhancement of microbial activity for the degradation of contaminants, typically around plant roots.

PHYTOTRANSFORMATION:

Uptake of substances from the environment, with degradation occurring within the plant (*phytodegradation*).

PHYTOVOLATILIZATION:

Removal of substances from the soil or water with release into the air, possibly after degradation.

RHIZOFILTRATION:

The removal of toxic materials from groundwater tough root activity.

These processes indicates in the upcoming figure:

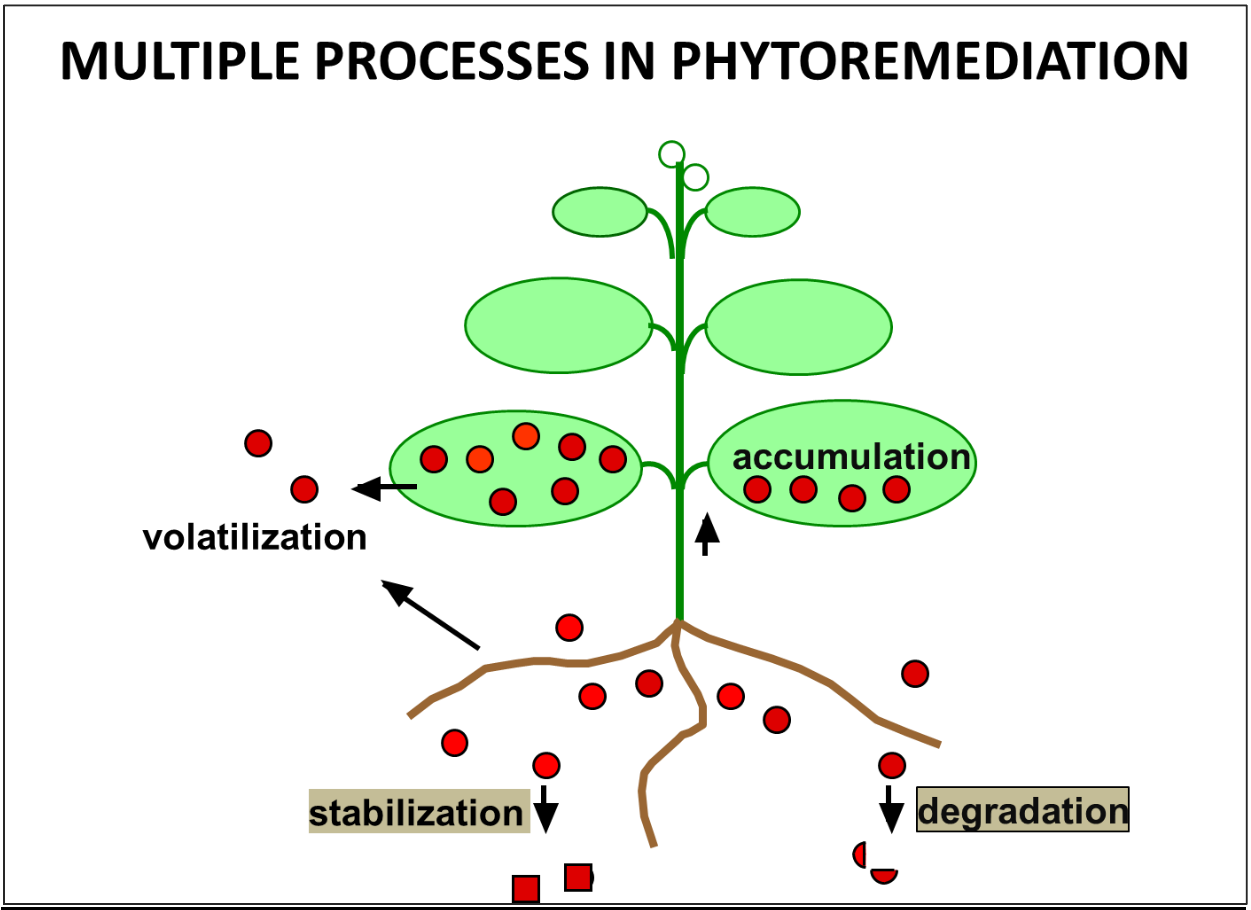


Fig 2: Multiple Processes in Phytoremediation

AIMS AND OBJECTIVES

- Design and comparative study of nutrient removal between lab and pilot scale treatment system
- Performance uptake efficiency of individual plants

LITERATURE REVIEW

All living creatures, including mankind need water for their survival. Living things directly and indirectly uses water for drinking and other purposes. Without food, normal person in good physical condition can survive for 6 weeks but without water, survival potential is measured in days. To assure good health, an adequate intake of water must be of satisfactory sanitary quality.

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. These systems have certain advantages over conventional treatment systems such as

- They can be established in the same place as where the wastewater is produced.
- They can be maintained by relatively untrained personnel.
- They have relatively lower or zero energy requirements.
- They are low-cost systems.

Wetlands are planned systems used to exploit the processes involved in natural wetlands related with plants, soil, microbes and wetland hydrology to treat wastewater (Edwards *et al*., 2006). These systems can be used for the purification of domestic wastewater. 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. (Vymazal, 1998).

Siedel first time introduced the technology of constructed wetland in Germany in 1952. After that, in Netherlands, the initial full-scale wetland scheme was established in 1960s. Subsequently this technology extended briskly. This technology spread widely all over North America and Europe. Hybrid constructed wetlands are now commonly used throughout Europe and in other parts of the world. Hybrid system is usually composed of a combination of horizontal flow and vertical flow arranged in a staged style (Vymazal and Kropfelova, 2011). The subsurface horizontal flow constructed wetland bring about greater removal of suspended solids and organic matter and the seasonal fluctuations does not have any adverse effect on its performance efficiency while the positive aspect of vertical flow constructed wetland is that it offers improved oxygenation and greater oxygenation rates (Cooper, 2005).

Vertical flow constructed wetlands showed higher removal in terms of BOD and COD and fulfilled the Italian guidelines for irrigation reuse but the TSS & TP showed lower removal efficiency and limited the water reuse potential.

The main problem associated with wastewater treatment technology is high evapotranspiration rate, if the effluent is intended for reuse. Evapotranspiration is a key factor which reduces the water output. This loss of water can be reduced by using a specific configuration and design of the constructed wetland system i.e. the hybrid system: the combination of horizontal and vertical submerged flow beds is the most appropriate for this purpose. This hybrid conformation allowed a substantial decrease of the total surface required for the treatment and, therefore, a drop of the water losses by evapotranspiration. The checked hybrid system showed only in the hottest summer water evaporation for about the 30–35% of the total influent. (Masi *et al.*, 2007).

Abidi *et al.*, (2009) in her study showed that constructed wetland system is alternative to the classic wastewater treatment systems. The first sequence consisted of an arrangement of vertical flow planted with phragmites bed trailed by a horizontal bed, vegetated with Typha. In the second one, the arrangement was reversed. Wastewater was introduced with a hydraulic load of 0.2 m/day. This load was introduced in two sequences of one hour after giving a gap of six hours rest period. The two hybrid systems showed reasonable treatment efficiencies: yields greater than 90% in organic matter removal was registered. The pathogenic bacteria diminution was reasonable for the two systems but more significant for the second.

Several aquatic, free floating, submerged, plant species (e.g. *Lemna minor* (duckweed), *Pistia stratiotes* (water lettuce) , *Typha*, etc.) are considered to be effective biological agent to remove impurities from wastewaters. The duckweeds have a greater potential for the removal of wastewater nutrients. These are small free-floating aquatic plants and have a high capacity of removing dissolved nutrients from water, especially nitrogen and phosphorous. Other aquatic plants, such as *Eichhornia crassipes* (water hyacinth), *Hydrocotyle umbellate* (pennywort), are known to be effective in single pond wastewater treatment. The *Typha domingensis* is an emergent aquatic macrophyte plant that grows in all tropical and temperate climate regions and it is commonly used in constructed wetlands to improve the water quality in treatment systems (Eid *et al*., 2012a).

A multi-species system is preferable in a constructed wetland as the diversity of species guarantees higher purification efficiency over time, taking changes in environmental conditions and wastewater composition into consideration. A multi-species system ensures a more homogenous root system distribution in the rhizosphere which, in turn, provides greater purification action both spatially and over time. In the construction of a multi-species system, it is of fundamental importance to know the levels of competition between the species in order to avoid dominance by a particular specie (Leto *et al*. 2013).

References	**Phytoremediation agent**	**Findings**
Verma and Suthar, (2014)	Duckweed	• Highest removal was recorded in wastewater. • 42–63% removal in NO_3 • 36–54% removal in SO_4 • 35-82% removal in TP
Dordioa et al., (2010)	Typha	• Efficient removal of pharmaceuticals from waste water • 48–75% clofibric acid • 88–97% carbamazepine • 82–96% Ibuprofen
Valipoura et al., 2009	Duck Weed	• Average reduction of • 75.15% COD, • 86.59% BOD, • 27.54% TDS, • 73.13% TSS, • 8.86% chlorides, • 70.22% NH_3-N and • 31.71% PO_4-P

METHODOLOGY

This study focused on the performance efficiency of a pilot-scale phytoremediation plant which has been installed at NUST. NUST is located in Sector H-12 Islamabad, Pakistan. It covers an area of about 1000 acres. It has a population of about 6000 people. It receives a supply of 0.2 MGD from two sewerage lines. Established phytoremediation plant has the ability to treat supply of one sewerage line i.e. 0.1 MGD. Samples were collected from each pond on weekly basis. In a week, total 10 samples were collected (one from each pond) for analysis and the average values were presented. Detailed analysis of various physico-chemical and bacteriological parameters namely, pH, DO, Conductivity, Turbidity, TSS, TDS, TOC/COD, Total Coliforms and Faecal Coliforms were carried out for all the wastewater samples collected as per standard methods.

ACCLIMATION OF THE PLANTS:

Eight plant species were collected from a local marshy area/nursery. Each specie were planted in a hydroponic culture for three weeks. During the acclimation period and growth phase, the system was supplied with reservoir water. After three weeks of growth, healthy and uniformly sized plants were obtained.

For further study regarding our project, a lab scale setup was fabricated 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 the sedimentation tank of our pilot scale plant and then place it in our lab scale unit. The purpose of establishing a lab scale unit was to analyze different aspects and different working conditions in order to achieve better results. 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.

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 rhizosphere, in the respective ponds. This will help in establishment of a compact bed suitable for wastewater treatment.

COLLECTION OF WASTEWATER SAMPLE:

The wastewater samples were collected to perform Microbiological analysis as well as for physic-chemical examination. The 250 ml sterilized (autoclaved) plastic sample bottles were used whereas 500 ml plastic bottles were used to collect wastewater samples from each different constructed wetland and sedimentation tank from both the lab scale and pilot scale units.

SAMPLE PRESERVATION:

Sample preservation was done ensuring that the sample does not change its physical and chemical characteristics so that the analysis performed represents the object under study, so the samples were kept at 4^0C throughout the study.

The following table represents the required preservation techniques and holding times:

Parameters	Preservatives	Maximum Holding Time
TS	Cool,4^oC	7 days
TSS	Cool,4^oC	7 days
TDS	Cool,4^oC	7 days
COD	Cool,4^oC,H_2SO_4 to pH<2	28 days
Conductivity	Cool,4^oC	7 days
DO	On spot	Within 30 minutes
Turbidity	Cool,4^oC	48 hours

Table 1: Sample Preservations for Physicochemical parameters
Source: US Federal Register, July 1, 1995, 40CFR, part 136.3, pages 643-6

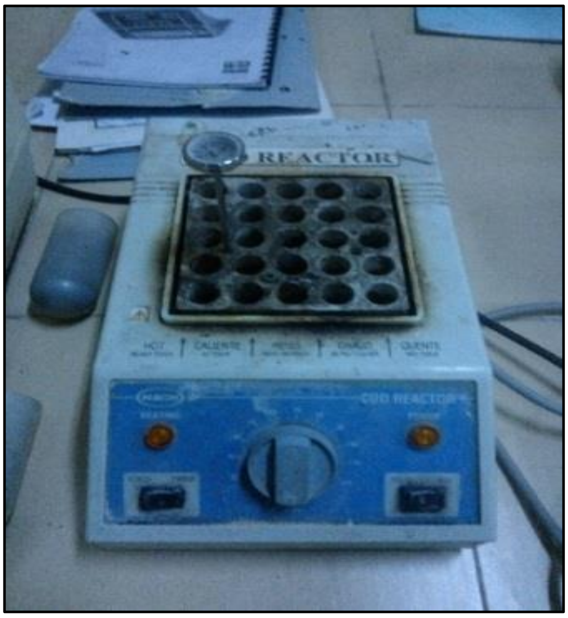
RETENTION TIMES:

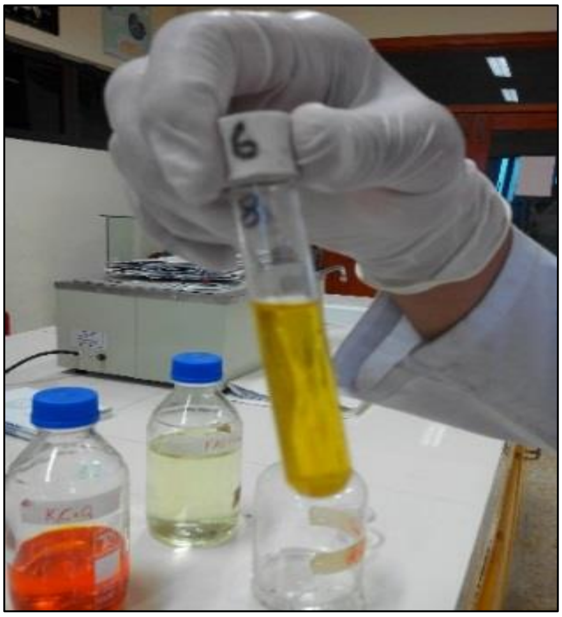
The samples were collected at varied retention times such as 30 minutes, 1 hr., 1.5 hr. . . .

PHYSIOCHEMICAL PARAMETERS:

Parameters	Equipment Used	Method of Analysis
pH	pH Meter	Potentiometric Method
Temperature (^0C)	HACH Sension 1	Laboratory Method
Conductivity (µS/cm)	Conductivity Meter	Potentiometric Method
TDS (mg/L)	Conductivity Meter	Potentiometric Method
COD (mg/L)	Through Titration	The Closed Reflux, Colorimetric Method

Table 2: Equipment used for Physicochemical Parameters
Source: Standard Methods for the Examination of Water and Wastewater (APHA, 2005)



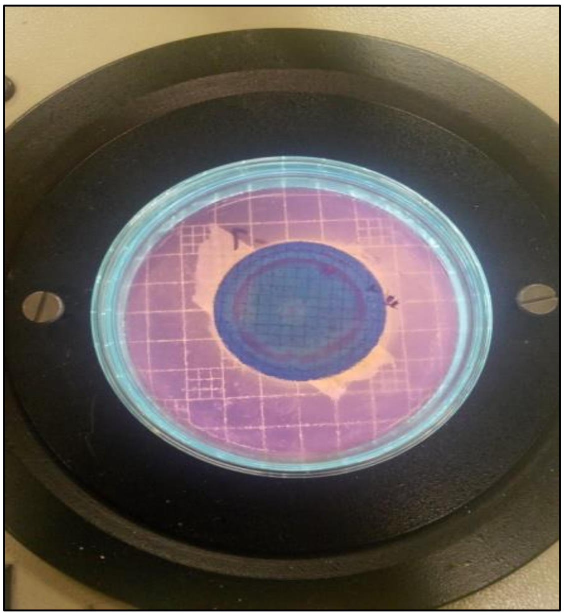


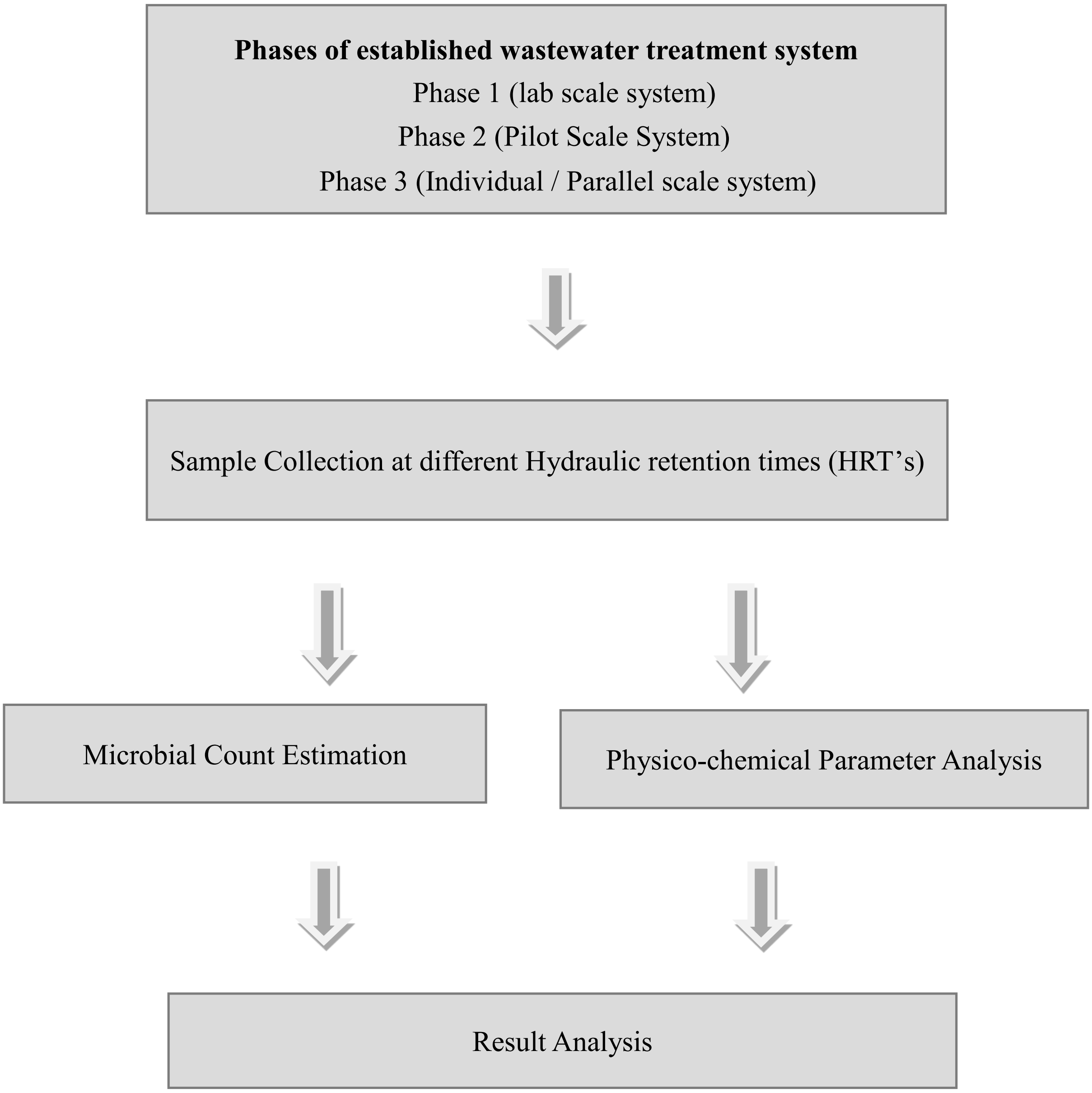
MICROBIOLOGICAL PARAMETERS:

- 250 mL autoclaved sampling bottles were used to collect sample

Parameters	Technique Used	Media Used	Measured Units
Total Coliforms	Membrane Filtration (MF)	Eosin Methylene Blue Agar	CFU/100 ml
Fecal Coliforms	Membrane Filtration (MF)	Eosin Methylene Blue Agar	CFU/100ml

Table 3: Techniques used for Biological Parameters
Source: Bergey's Manual (2005)





Flow Sheet: Methodology

PHASE 1: LAB SCALE UNIT

A lab scale unit was established to treat NUST wastewater. The purpose of establishing a lab scale unit was to analyze different aspects and different working conditions in order to achieve better results. It consisted of a sediment tank and eight wetlands. They were connected with PVC pipes and check valves were 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 to check treatment efficiency and to determine the optimum HRT.

DIMENSIONS OF SEDIMENTATION TANK:

Diameter of tank = 13 inches

Height of the tank = 13 inches

DIMENSION OF TUBS:

Length of Tubs = 13 inches

Width of Tubs = 13 inches

Length of PVC pipes which was used to flow waste water from one tub to another = 2 ft.

The plastic sedimentation tank and rectangular eight plastic tubs of same volume were used as wetlands due to the plastic there was no leakage of water and conditions were maintained so to promote plant growth. The system was established in such a way so that sunlight was available to the plants.

In first wetland Typha was grown, the bed contained gravels mixed with soil so that the roots of typha could get suitable bed for growth. Second and third wetland had Duckweed and its floating so they don't need any bed for the growth. Fourth and fifth wetland had Pennywort it's also a floating plant. Sixth and seventh wetlands had Water lettuce and eight tub contained water hyacinth.

Fig 3: Design of Lab Scale Unit

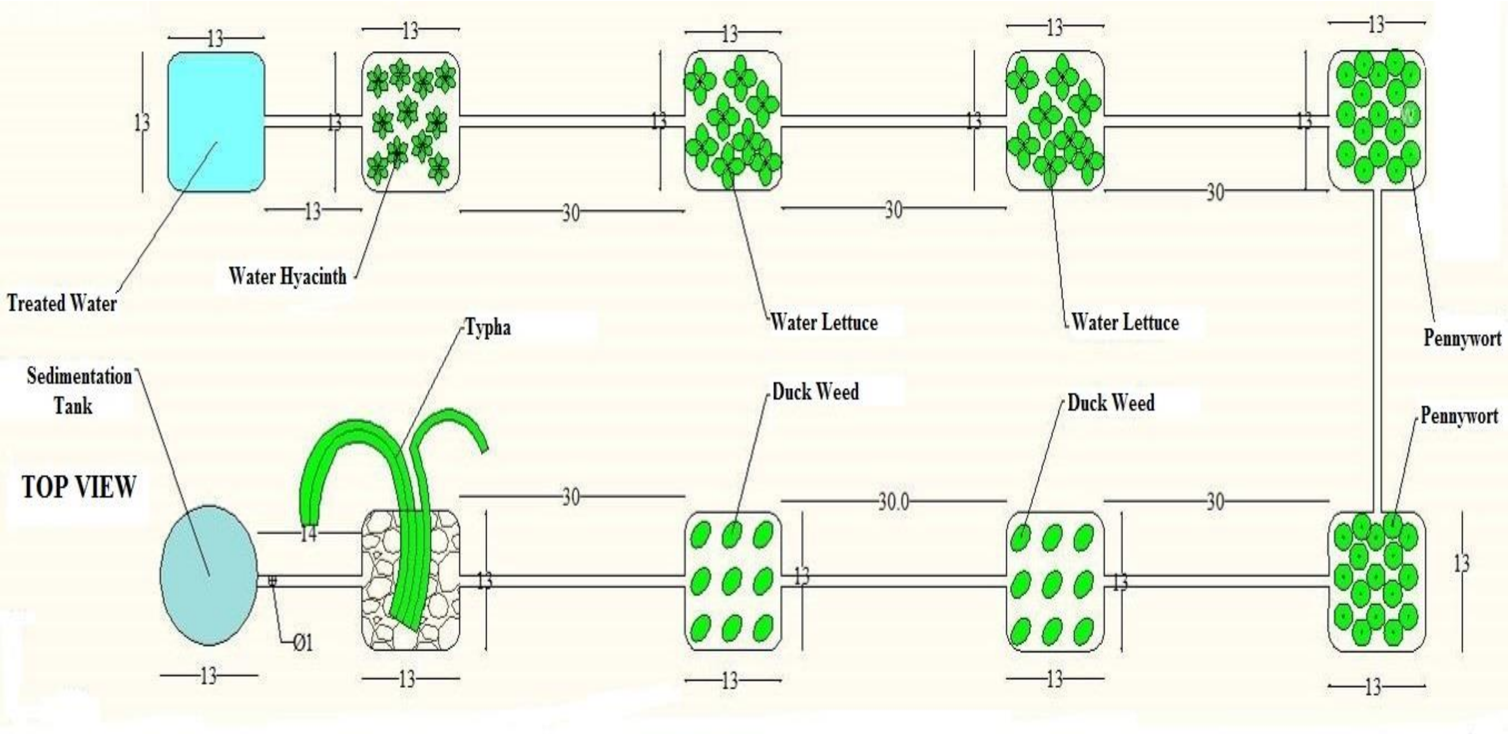
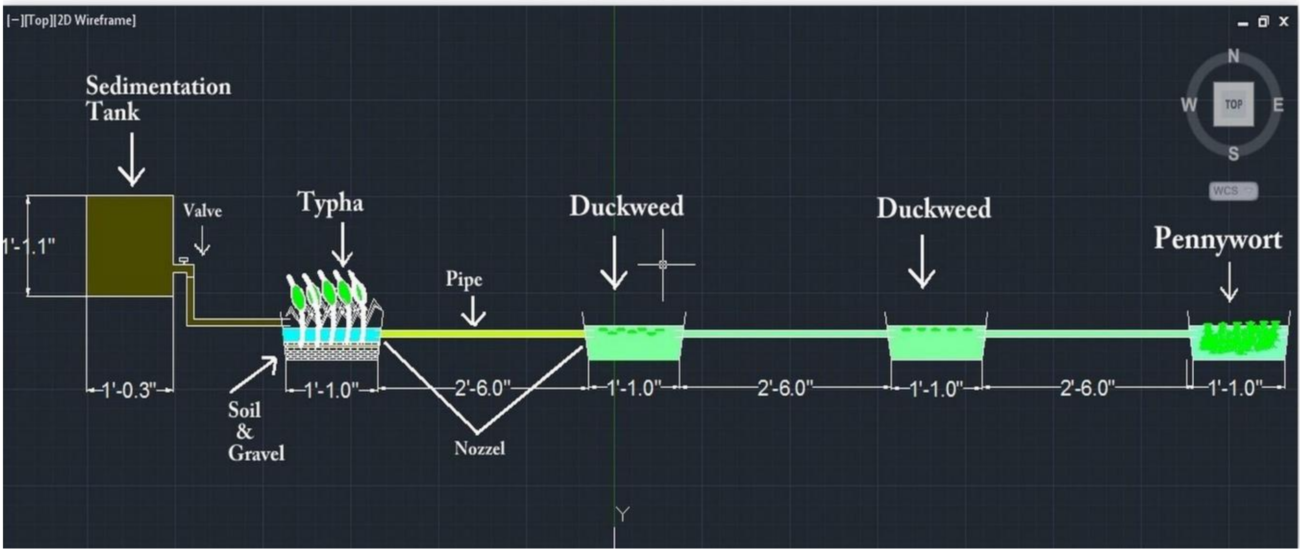
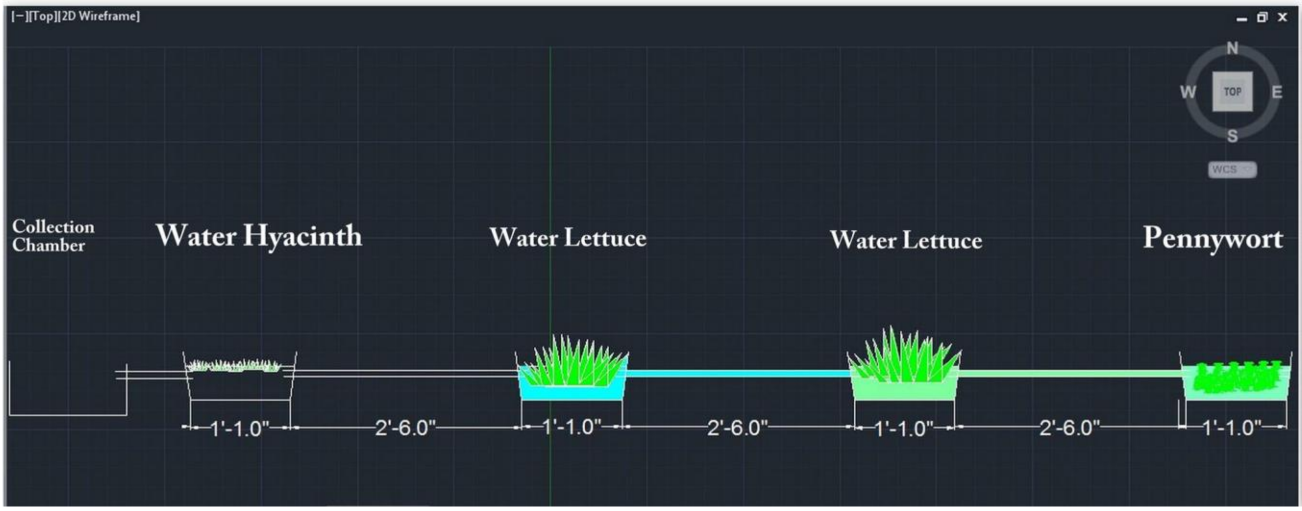


Fig 4: Top View of Lab Scale unit

Front Side View



Backside View



PHASE 2: PILOT SCALE UNIT

NUST is located in Sector H-12 Islamabad, Pakistan. It covers an area of about 1000 acres. It has a population of about 6000 people. It receives a supply of 0.2 MGD from two sewerage lines. Our phytoremediation plant has the ability to treat supply of one sewerage line i.e. 0.1 MGD. A pilot scale plant was established for the treatment of wastewater at Northern Corner of NUST so that it could be used for horticulture use in the university (Fig 6: shows the location of pilot scale plant). The wastewater generated from offices, student hostels and staff residential colony led towards a sedimentation tank and then to constructed wetlands (comprising of eight compartments) where wastewater was treated and its quality was improved through Phytoremediation. This treated effluent quality was further be improved by filtration along with irrigated cropping for land treatment and effluent reuse. The effluent from the filter was collected through the tile drainage system and it was used for horticulture purposes as well as for recharging underlying groundwater aquifer. The solid waste (sludge) collected for sedimentation tank was dried and used as the fertilizer thus making whole project as **"Free Waste Project".**

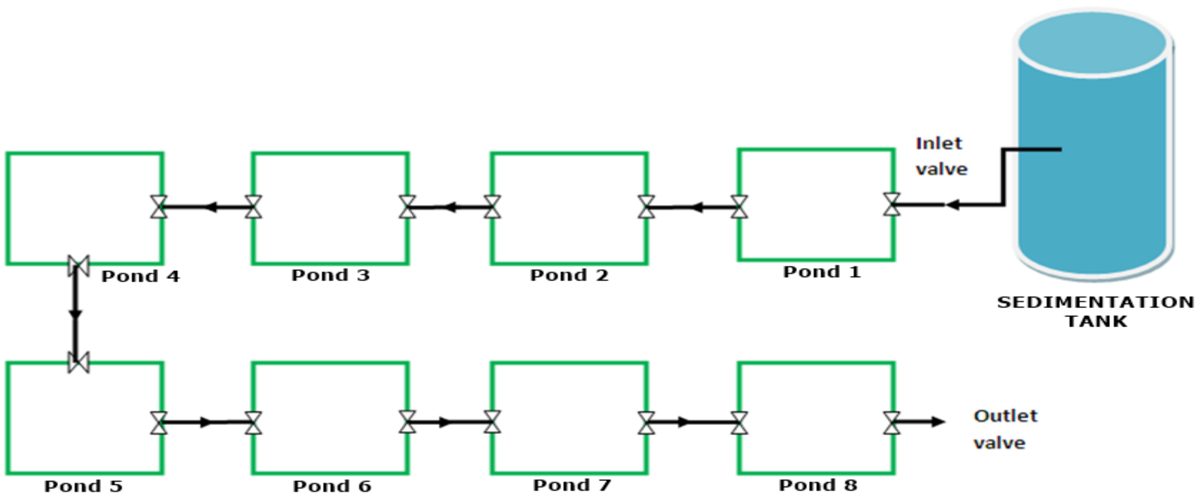


Fig 5: Layout of Pilot Scale Treatment System

- The treatment plant has the capacity to treat 20,000-25,000 Gallons per day.
- It consists of a rectangular sedimentation tank of 35 ft. * 12 ft. * 6 ft.
- Followed by constructed wetlands each of 22 ft. *50 ft.*7 ft.
- Covering total area of 120 ft. * 100 ft.
- The wetlands were covered with Low density polyethylene (LDPE) to prevent the infiltration.
- The size of filter is 120 ft. * 170 ft. and tile drainage system is maintained beneath the soil

There are plastic sheets so that no water is infiltrated, the plants are grown on the filter bed so that they can uptake the remaining nutrients in the water.

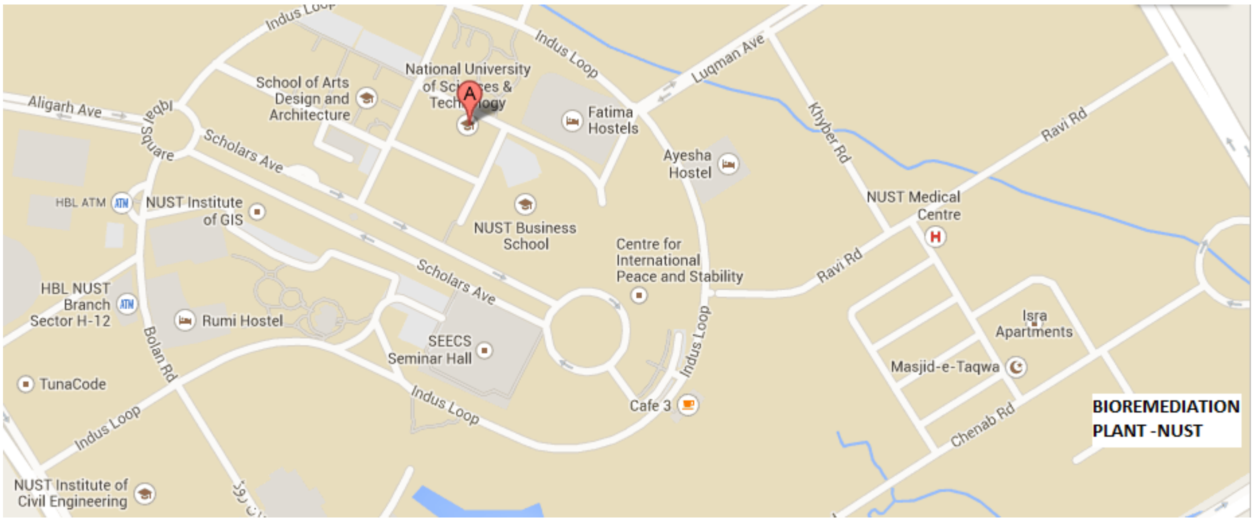


Fig 6: Location of phytoremediation plant at NUST

The vegetation in first constructed wetland is Typha, its roots are submerged the bed consists of the gravel and organic soil. Second and third wetland contains the duckweed it's floating and do not need any bed preparations. Fourth and fifth wetland contains pennywort whereas the sixth and seventh have water lettuce the last one eight wetland has water hyacinth. They all are floating plants having different uptake capacities. They are applied in series in order to achieve better results.

Fig 7: Pilot scale plant during construction phase

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, each tub was connected with 2 feet long pipe. 4 different plants were placed in individual 4 tubs. Those are typha, pennywort, duckweed and water lettuce, each plant species having 100 grams weight in 4 liters of wastewater. Same HRT was applied in all 4 tubs.

Fig 8: Design of Parallel Scale Unit

RESULTS & DISCUSSIONS

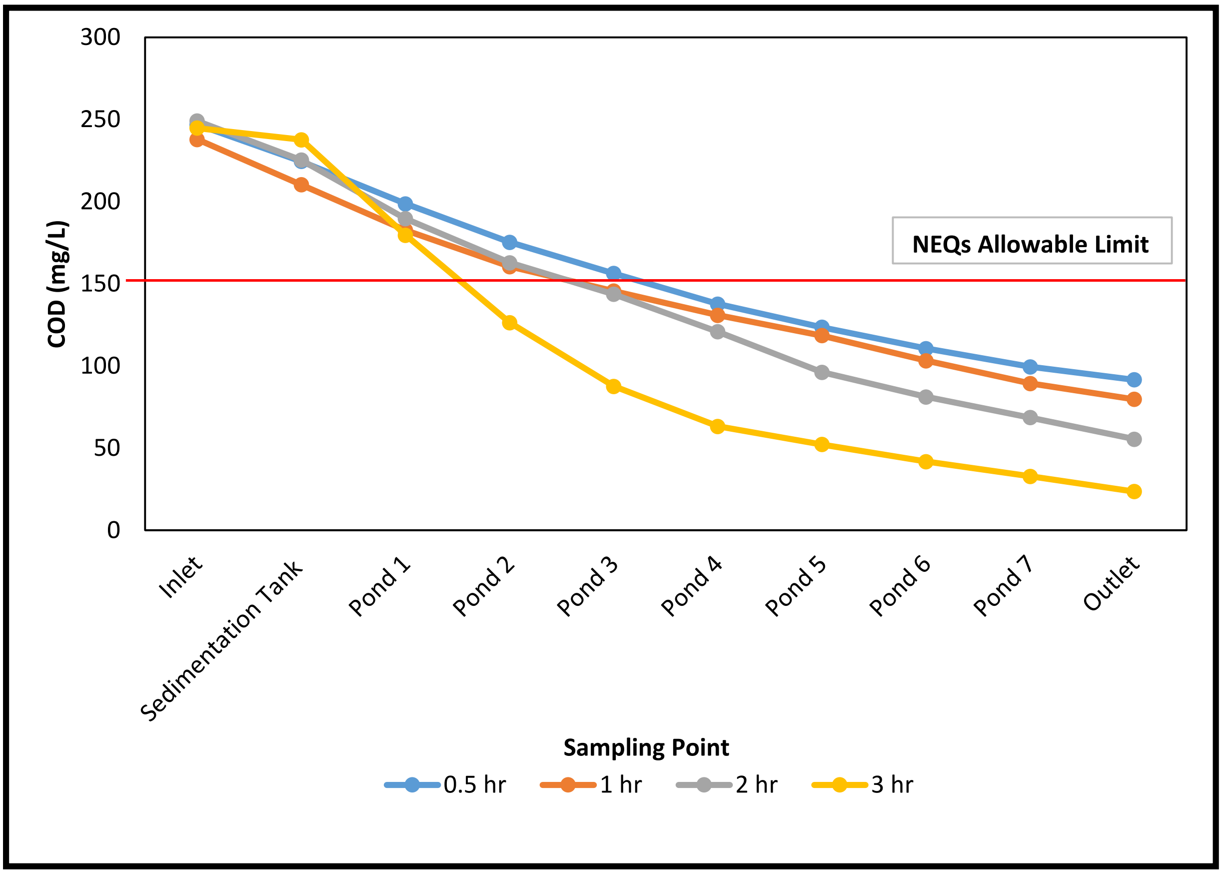
LAB SCALE SYSTEM:

Sample	Hydraulic Retention Time (hr)			
	0.5	**1.0**	**2.0**	**3.0**
Inlet	246.8 (240.7 - 251.6)	237.8 (232.7 - 246.5)	249 (241.3 - 256.7)	244.8 (239.6 - 254.1)
S.T	224.5 (218.1 - 223.1)	210.3 (204.6 - 218.4)	225.3 (220.0 - 231.6)	217.6 (211.2 - 223.9)
Pond 1	198.7 (195.6 - 206)	182.6 (175 - 190.3)	189.6 (185.4 - 196.1)	179.6 (172.5 - 182.6)
Pond 2	175.3 (170.3 - 182.7)	160.5 (156.3 - 164.8)	162.8 (157.9 - 176.2)	126.4 (120.9 - 131.8)
Pond 3	156.3 (148.9 - 164.0)	145.6 (139.4 - 151.7)	143.6 (139.4 - 148.2)	87.6 (84.1 - 90.4)
Pond 4	137.7 (132.5 - 141.2)	130.9 (127.1 - 135.9)	120.8 (115.9 - 127.3)	63.2 (60.7 - 66.9)
Pond 5	123.5 (119.2 - 127.8)	118.5 (113.2 - 121.6)	96.2 (93.0 - 101.6)	52.2 (47.7 - 56.4)
Pond 6	110.6 (108.3 - 113.5)	103.2 (97.4 - 111.2)	81.2 (76.3 - 86.2)	41.8 (38.4 - 44.6)
Pond 7	99.5 (93.7 - 103.4)	89.3 (85.9 - 94.1)	68.6 (64.2 - 73.9)	32.8 (29.7 - 35.8)
Outlet	91.6 (87.3 - 94.6)	79.7 (74.2 - 84.0)	55.4 (50.7 - 59.8)	23.6 (21.5 - 25.2)

Table 4: COD results by applying different HRTs

Different hydraulic retentions were given and results were recorded. Upper values show the mean values and lower values show the minimum – maximum values.

- 62.88% COD removal was achieved at HRT of 0.5 hrs.
- 66.48% COD removal was achieved at HRT of 1.0 hrs.
- 77.75% COD removal was achieved at HRT of 2.0 hrs.
- 90.36% COD removal was achieved at HRT of 3.0 hrs.



Graph 1: COD removal of lab scale system.

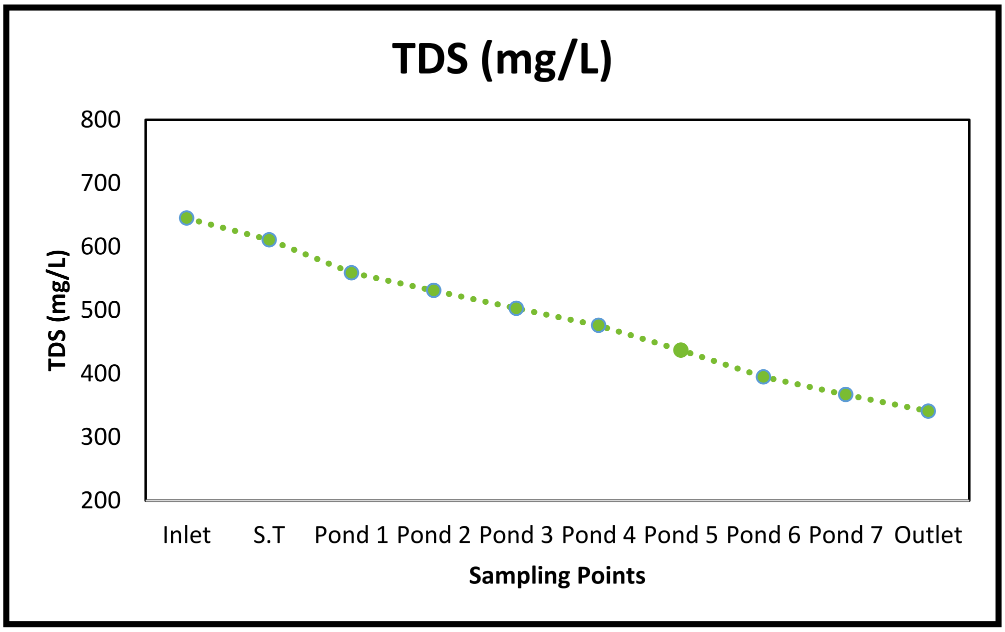
PILOT SCALE SYSTEM:

MEAN PHYSICOCHEMICAL PROFILE OF MARCH, 2O14:

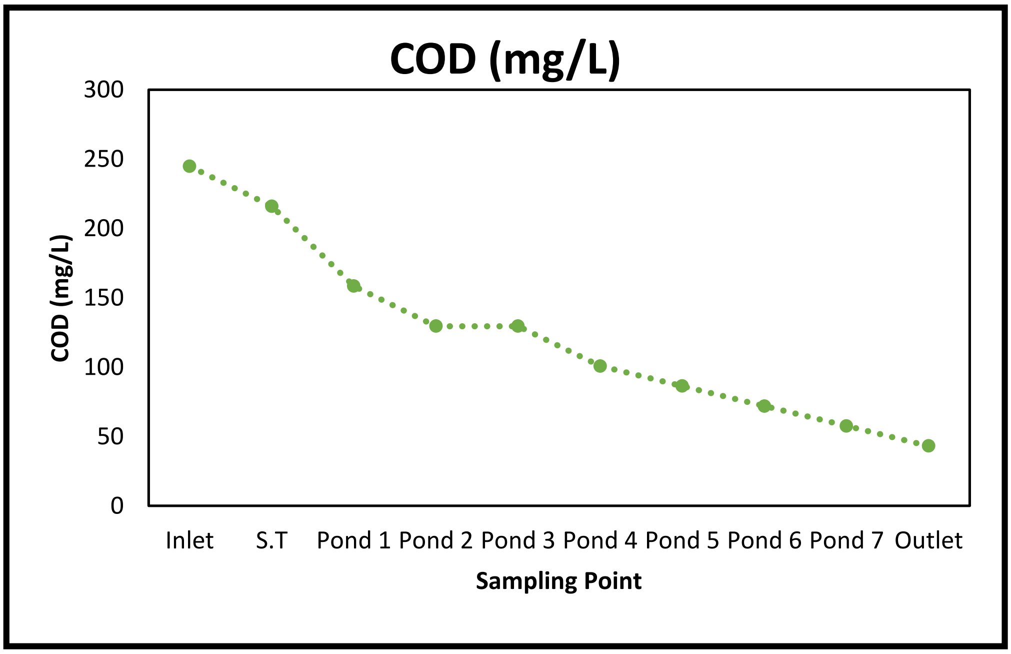
Sample	pH	Temperature (°C)	TDS (mg/L)	COD (mg/L)
Inlet	7.5 (7.4 - 7.6)	19 (18 - 21)	645 (641 - 651)	244 (230 - 259)
S.T	7.2 (7.1 - 7.3)	18 (17 - 20)	611 (605 - 618)	216 (211 - 226)
Pond 1	7.1 (7 - 7.2)	19 (17 - 20)	559 (546 - 569)	168 (158 - 172)
Pond 2	7.1 (6.9 - 7.3)	19 (18 - 20)	531 (526 - 542)	132 (129 - 136)
Pond 3	7.3 (7.2 - 7.4)	20 (18 - 21)	503 (496 - 513)	119 (100 - 129)
Pond 4	7.4 (7.2 - 7.6)	19 (17 - 21)	476 462 - 485)	100 (93 - 106)
Pond 5	7.5 (7.4 - 7.6)	18 (17 - 19)	437 (426 - 451)	86. (81 - 92)
Pond 6	7.6 (7.4 - 7.8)	19 (18 - 20)	395 (384 - 406)	72 (65 - 78)
Pond 7	7.6 (7.5 - 7.8)	18 (17 - 20)	367 (356 - 375)	57 (53 - 61)
Outlet	7.6 (7.4 - 7.7)	19 (18 - 20)	341 (334 - 352)	43 (40 - 47)

Table 5: Physicochemical results for March, 2014

Upper values show the mean values and lower values show the minimum – maximum values. COD removal and TDS removal for March, 2014 are 82.37% and 47.13% respectively. No visible change was observed pH and temperature.



Graph 2: Change in TDS for March, 2014



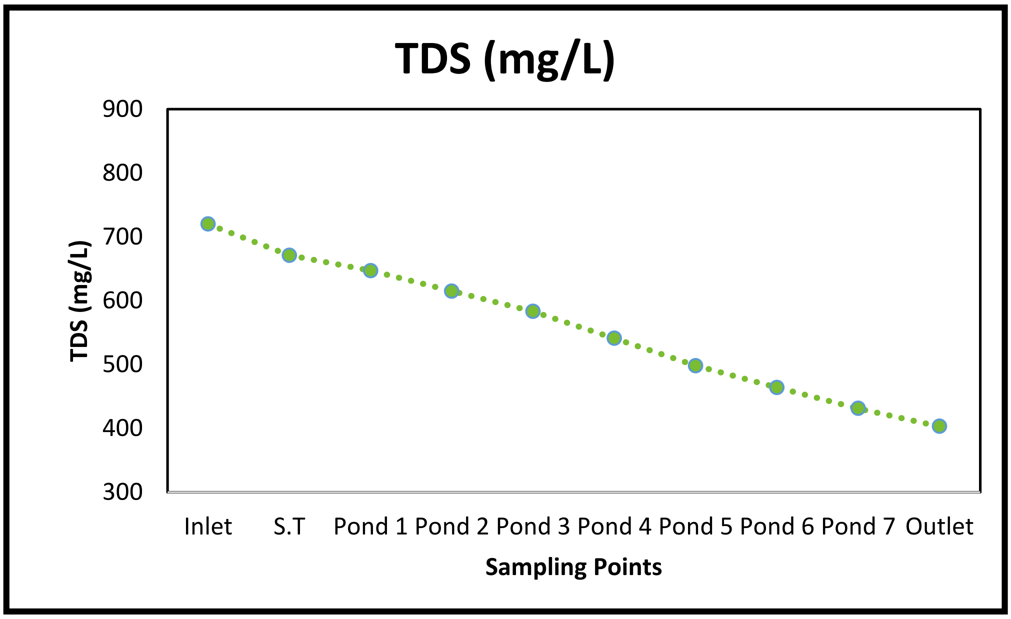
Graph 3: Change in COD for March, 2014

MEAN PHYSICOCHEMICAL PROFILE OF APRIL, 2O14:

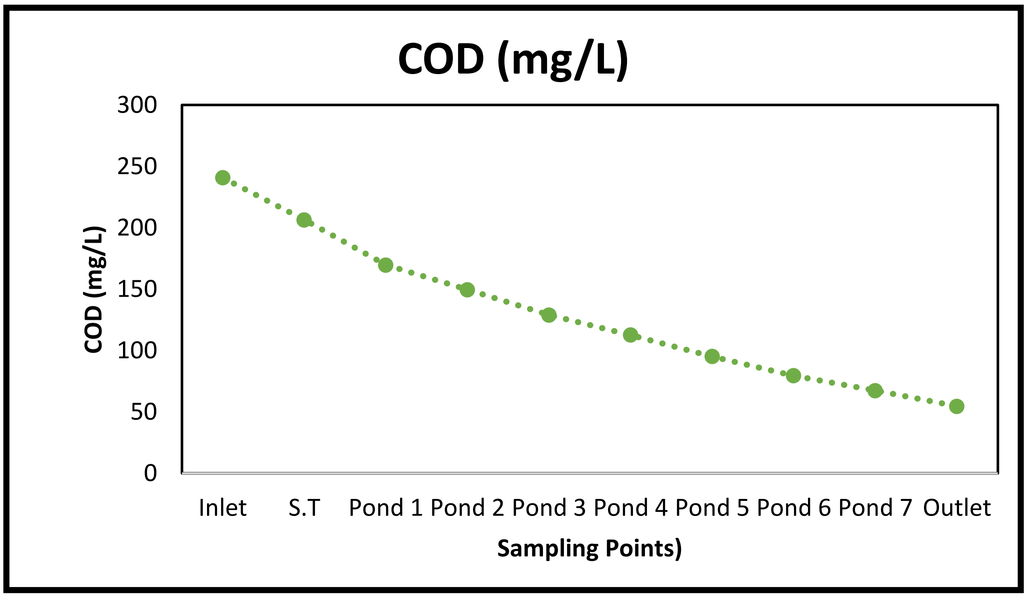
Sample	pH	Temperature (°C)	TDS (mg/L)	COD (mg/L)
Inlet	7.3 (7.1 - 7.5)	27 (26 - 28)	720 (709 - 728)	240 (230 - 255)
S.T	7.0 (6.9 - 7.1)	27 (26 - 29)	671 (664 - 684)	206 (197 - 217)
Pond 1	7.2 (7.1 - 7.3)	27 (26 - 28)	647 (639 - 657)	169 (157 - 178)
Pond 2	7.1 (7.1 - 7.1)	26 (25 - 28)	615 (604 - 623)	149 (142 - 156)
Pond 3	6.9 (6.8 - 7.1)	26 (25 - 27)	583 (574 - 591)	128 (119 - 138)
Pond 4	6.9 (6.8 - 7.2)	26 (26 - 27)	541 (530 - 554)	112 (106 - 119)
Pond 5	6.8 (6.7 - 7.0)	26 (24 - 28)	498 (492 - 509)	95 (91 - 102)
Pond 6	6.9 (6.6 - 7.3)	26 (26 - 26)	464 (457 - 470)	79 (73 - 85)
Pond 7	6.9 (6.8 - 7.0)	26 (25 - 27)	431 (421 - 447)	67 (62 - 73)
Outlet	6.9 (6.7 - 7.1)	26 (25 - 28)	403 (387 - 412)	54 (47 - 59)

Table 6: Physicochemical results for April, 2014

Upper values show the mean values and lower values show the minimum – maximum values. COD removal and TDS removal for April, 2014 are 77.50% and 44.02% respectively. No visible change was observed pH and temperature.



Graph 4: Change in TDS for April, 2014



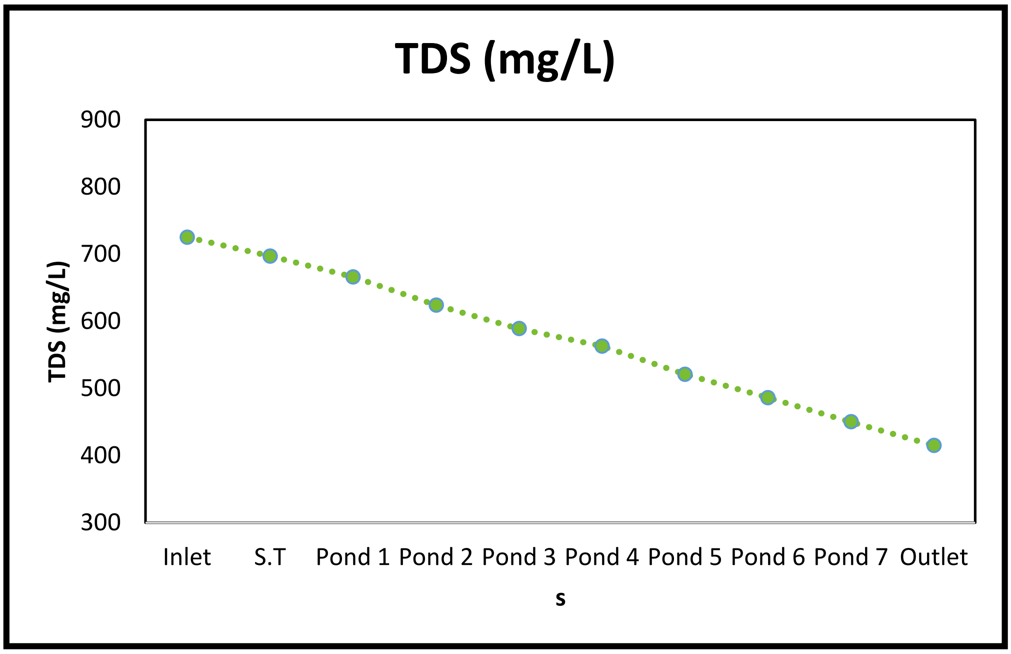
Graph 5: Change in COD for April, 2014

MEAN PHYSICOCHEMICAL PROFILE OF MAY, 2O14:

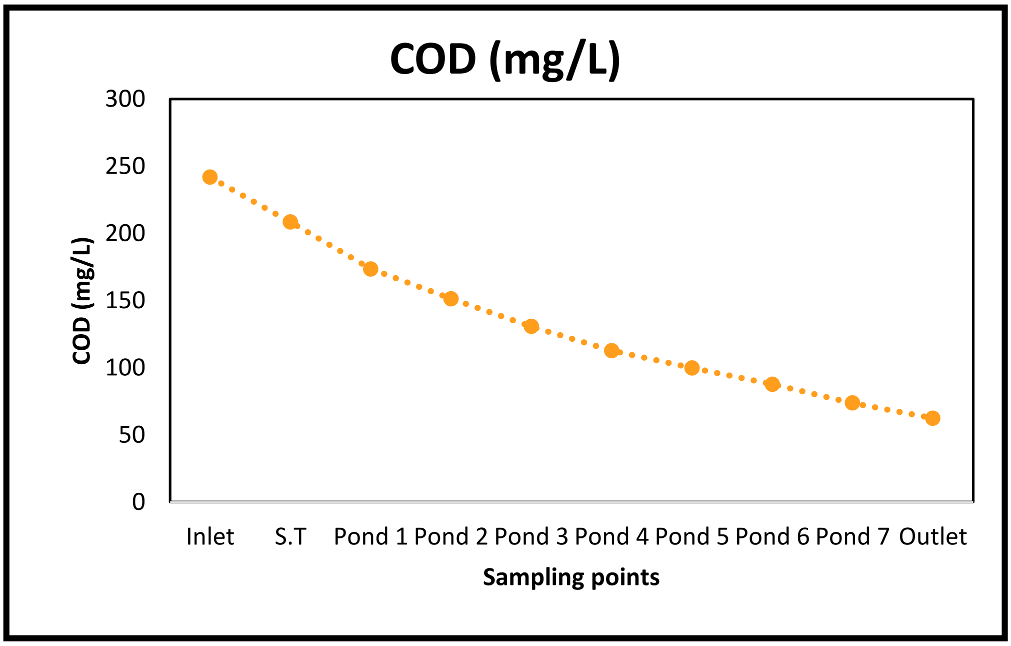
Sample	pH	Temperature (°C)	TDS (mg/L)	COD (mg/L)
Inlet	7.4 (7.3 - 7.5)	29 (28 - 31)	725 (718 - 732)	241 (233 - 251)
S.T	7.0 (6.8 - 7.2)	29 (29 - 30)	697 (686 - 709)	208 (201 - 221)
Pond 1	7.2 (7.0 - 7.3)	29 (27 - 31)	666 (657 - 675)	173 (165 - 179)
Pond 2	7.1 (7.1 - 7.1)	28 (27 - 29)	624 (618 - 631)	151 (142 - 158)
Pond 3	7.0 (6.8 - 7.1)	28 (27 - 29)	589 (581 - 596)	130 (121 - 139)
Pond 4	6.9 (6.8 - 7.2)	27 (26 - 29)	563 (559 - 567)	112 (106 - 118)
Pond 5	6.9 (6.8 - 7.0)	28 (26 - 30)	521 (514 - 529)	99 (92 - 105)
Pond 6	6.8 (6.7 - 7.1)	29 (28 - 29)	486 (480 - 495)	87 (82 - 93)
Pond 7	6.8 (6.7 - 7.0)	29 (27 - 30)	450 (439 -461)	73 (70 - 76)
Outlet	7.0 (6.7 - 7.1)	28 (27 - 30)	415 (404 - 423)	62 (55 - 68)

Table 7: Physicochemical results for May, 2014

Upper values show the mean values and lower values show the minimum – maximum values. COD removal and TDS removal for May, 2014 are 74.27% and 42.76% respectively. No visible change was observed pH and temperature.



Graph 6: Change in TDS for May, 2014



Graph 7: Change in COD for May, 2014

MICROBIAL PROFILE OF PILOT SCALE SYSTEM:

TOTAL COLIFORMS:

Months	Inlet	Outlet	% Efficiency
March	1.53×10^7	3.92×10^6	74.37
April	1.67×10^7	4.48×10^6	73.17
May	1.72×10^7	4.28×10^6	75.42

Table 8: Total Coliforms results for different months

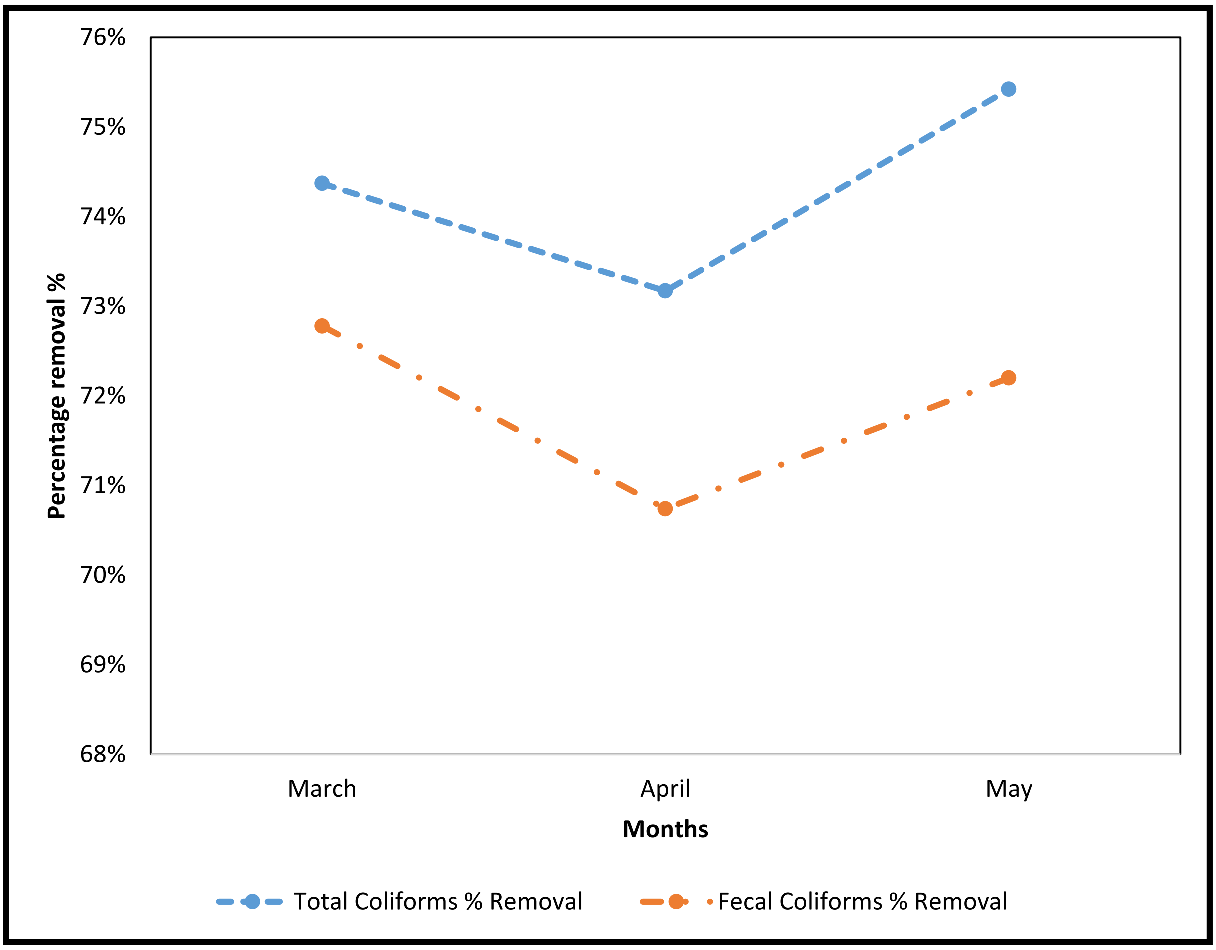
FECAL COLIFORMS:

Months	Inlet	Outlet	% Efficiency
March	1.19×10^7	3.24×10^6	72.78
April	1.31×10^7	3.62×10^6	70.74
May	1.36×10^7	3.78×10^6	72.2

Table 9: Fecal Coliforms results for different months

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

Graph shows the pictorial change of removal efficiencies of total coliforms and fecal coliforms in the month of March, April and May.



Graph 8: Removal efficiencies of total coliforms and fecal coliforms for different months

PARALLEL SCALE SYSTEM:

Inlet COD: 249.4 mg/L (239.7 – 258.6)

Time (Hr)	Typha	Duckweed	Pennywort	Water Lettuce
3	172.8 (164.5 - 180.3)	158.4 (150.5 -164.7)	187.2 (181.7 - 196.8)	146.3 (139.7 - 151.1)
6	115.2 (109.6 - 121.6)	109.4 (107.5 - 113.0)	141.1 (135.4 - 144.2)	100.8 (94.2 - 106.1)
9	88.3 (81.3 - 95.6)	86.5 (83.7 - 89.3)	106.8 (101.8 - 113.6)	85.9 (82.9 - 89.3)
12	76.9 (72.8 - 80.4)	76.3 (71.2 - 79.6)	89.3 (85.7 - 94.2)	73.2 (68.5 - 78.3)
15	66.3 (63.5 - 69.1)	65.4 (63.0-68.7)	77.5 (74.8 - 81.2)	63.8 (60.7 - 65.2)
18	59.2 (48.6 - 66.7)	59.2 (56.2 - 64.3)	69.2 (65.7 - 73.0)	52.8 (47.6 - 56.7)
21	45.3 (42.6 - 50.7)	45.6 (41.3 - 48.0)	58.6 (56.7 -61.3)	40.8 (37.8 – 46.1)
24	39.6 (37.2 - 41.4)	40.9 (35.7 - 44.3)	50.5 (47.6 - 53.8)	33.4 (30.0 – 35.4)

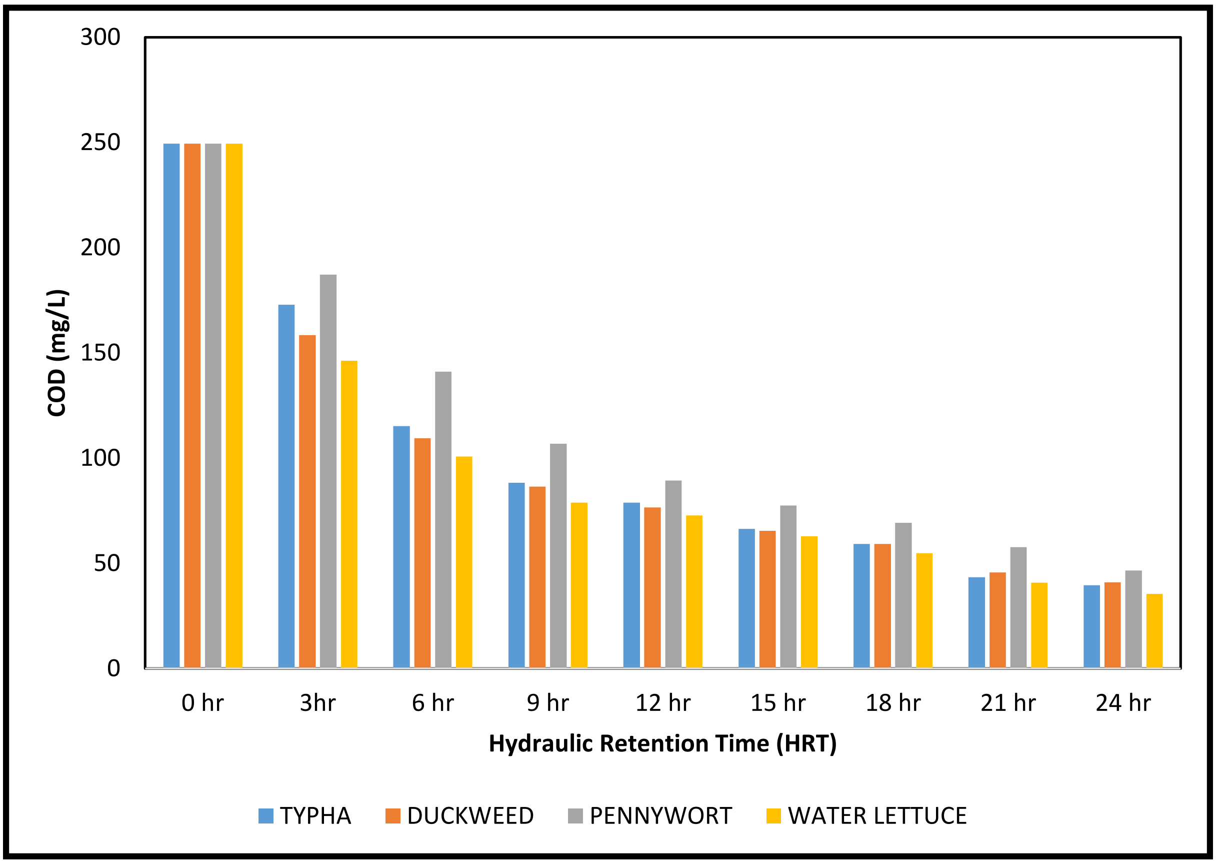
Table 10: COD results by applying different HRTs for individual plants

Upper values show the mean values and lower values show the minimum – maximum values.

- COD removal achieved by Typha for 1 day HRT was 84.12%
- COD removal achieved by Duckweed for 1 day HRT was 83.60%
- COD removal achieved by Pennywort for 1 day HRT was 79.75%
- COD removal achieved by Water Lettuce for 1 day HRT was 86.60%

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 graphs shows the pictorial change in the values of COD. Graph depicts that as the HRT is increasing, removal efficiencies of COD are also increasing.



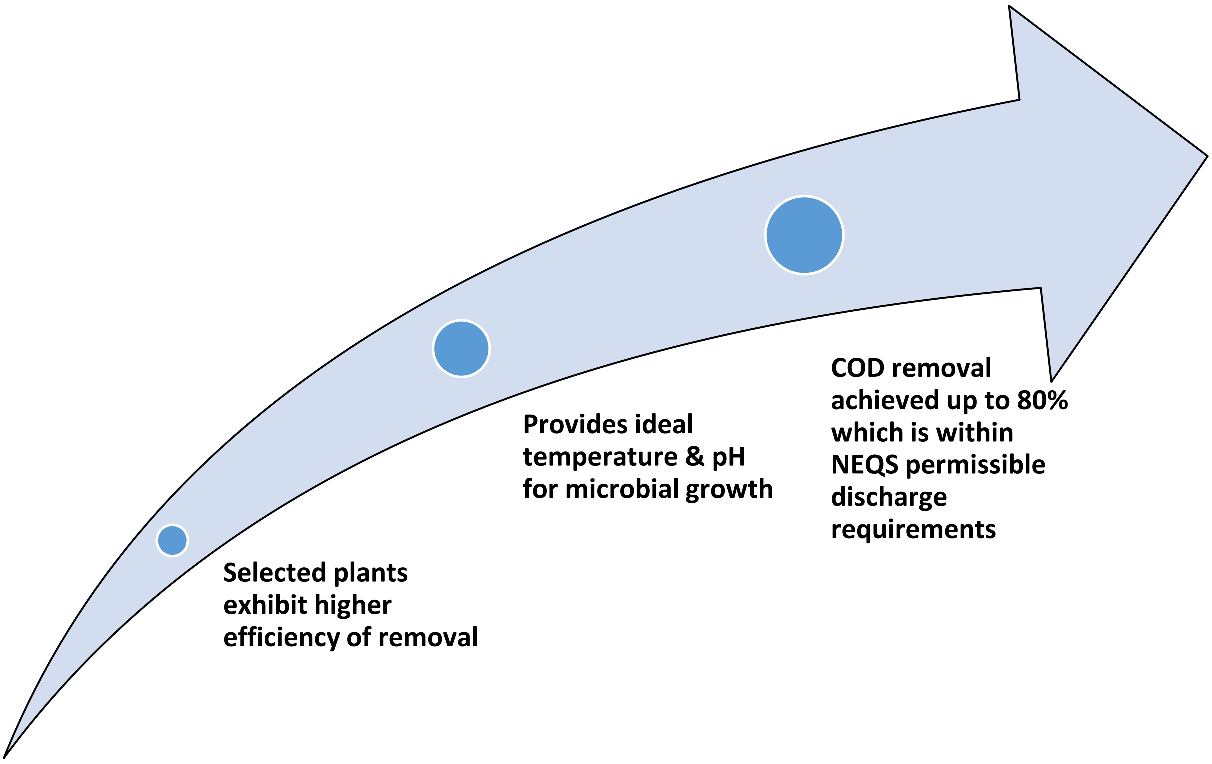
<u>Graph 9: Change in the values of COD for individual plants when different HRTs are given</u>

PROBLEMS / OBSTACLES DURING IMPLEMENTATION:

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.

CONCLUSIONS



LOW COST WASTEWATER TREATMENT TECHNOLOGY:

Constructed wetlands are alternative wastewater treatment systems that are low-cost, easy to operate, and require less maintenance than conventional technologies, such as activated sludge processes. Once established, this technique would be commercialized for treating wastewater at domestic and industrial levels.

RECREATION:

Wetlands are often inviting places for popular recreational activities including hiking, fishing, bird watching, photography and hunting.

FISHERIES:

The Nation's wetlands are vital to fish health and thus to the Nation's multibillion dollar fishing industry. Wetlands provide a consistent food supply, shelter and nursery grounds for both marine and freshwater species.

RESERVOIRS OF BIODIVERSITY:

Diverse species of mammals, plants, insects, amphibians, reptiles, birds and fish rely on wetlands for food, habitat or shelter. Wetlands are some of the most biologically productive natural ecosystems in the world, comparable to tropical rain forests or coral reefs in the number and variety of species they support.

OTHER COMMERCIAL BENEFITS:

Constructed wetlands' economic value 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 year.

Wetlands also provide employment opportunities, including such positions as surveyor or park ranger. The production of raw materials from wetlands provides jobs to those employed in the commercial fishing, specialty food and cosmetic industries.

TECHNICAL AND ECONOMIC MERITS OF THE PROJECT:

- The project will bring socio-economic benefits to the institute. It will provide baseline data for onward research.
- It will provide information how to handle the wastewater at large scale. Furthermore, various microbes' strains will be identified with respect to changing climatic conditions.

- It will increase the capacity of microbiological based research at IESE, NUST and will lead to the improvement in the field of science and on community.
- It will provide opportunity to students and research fellows to be trained for advance research. Hand on experience on advance analytical techniques and methods for assessing the removal of contaminants from the wastewater.
- It will create awareness among the masses in the form of research papers, newspaper clippings, seminars, and short training programs, poster presentations at local and international levels.

RECOMMENDATIONS

The areas which need to be further investigated are:

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

REFERENCES

- **Abidi, S., Kallali, H., Jedidi, N., Bouzaiane, O., Hassen, A. 2009.** Comparative pilot study of the performances of two constructed wetland wastewater treatment hybrid systems. Desalination; 248: 49–56.

- **APHA, American Public Health Association**, American Water Works Association (AWWA), Pollution Control Federation (PCF), 2005. Standard Methods of Analysis of Water and Wastewater, sixteenth ed. American Public Health Water Association, Washington.

- **Cooper, P. 2005.** The performance of vertical flow constructed wetland systems with special reference to the significance of oxygen transfer and hydraulic loading rates. Water Sci. Technol.; 51(9): 91-97.

- **Dordio, A., Carvalho, A. J., Teixeira, D. M., Dias, C. B. and Pinto, P. A. 2010.** Removal of pharmaceuticals in microcosm constructed wetlands using *Typha* spp. and LECA. Bioresource Technology. 101 (3): 886-892.

- **Verma, R. and Suthar, S. 2014.** Synchronized urban wastewater treatment and biomass production using duckweed *Lemna gibba* L. Ecological Engineering. 64: 337-343.

- **Vymazal, J. 1998.** Introduction. In: Vymazal, J., Brix, H., Cooper, P. F., Green, M. B., Haberl, R. (Eds.), Constructed Wetlands for Wastewater Treatment in Europe. Backhuys Publishers, Leiden. 1–15.

- **Vymazal, J. 2010.** Water and nutrient management in natural and constructed wetlands. Dordrecht: Springer Science.

- **Vymazal, J., Kropfelova, L. 2011.** A three-stage experimental constructed wetland for treatment of domestic sewage: First 2 years of operation. Ecol. Eng.; 37: 90-98.

- **Masi, F., Martinuzzi, N. 2007.** Constructed wetlands for the Mediterranean countries: hybrid systems for water reuse and sustainable sanitation. Desalination.; 215: 44–55.

- **WWF. 2007.** Pakistan's waters at risk Water and health related issues in Pakistan and key recommendations; 1-33.

- **Government of Pakistan Ministry of Water and Power. 2002.** Pakistan Water Sector Strategy. Executive Summary; 5: 54-67. Retrieved at February 8, 2012 from http://cms.waterinfo.net.pk/pdf/vol5.pdf.

- **Valipoura, A. and Ramanb, V. K. 2009**. A new approach in wetland systems for domestic wastewater treatment using Phragmites sp. Ecological Engineering. 35(15): 1797-1803.

- **Hinrichsen, D., Robey, B. K. and Upadhyay, U. D. 1997.** Solutions for a Water-Short World. Population Reports, Series M, No. 14. Baltimore, Johns Hopkins School of Public Health, Population Information Program, Maryland, United States.

- **Alvarez, J. A., Ruiz, I. and Soto, M. 2008.** Anaerobic digesters as a pre-treatment for contructed wetlands. Ecol. Eng.; 33(1): 54-67 .

- **Belmont, M.A., Cantellano, E., Thompson, S., Williamson, M., Sanchez, A., Metcalfe, C.D. 2004.** Treatment of domestic wastewater in a pilot-scale natural treatment system in central Mexico. Ecol. Eng.; 23: 299–311.

- **Evans, K. M. and Ellis, T. G. 2004**. Fundamentals of the static Granular Bed Reactor. PhD's Thesis, Lowa State University, IA.

- **World Report on Disability – 2011** from this website *www.unicef.org/protection/World_report_on_disability_eng.pdf*

- **Tanner, C. C., Clayton, J. S., Upsdell, M. P. 1995.** Effect of loading rate and planting on treatment of dairy farm wastewaters in constructed wetlands. 1. Removal of oxygen-demand, suspended-solids and faecal-coliforms. Water Res; 29: 17–26.

- **Hashmi, I., Farooq, S., Qaiser, S. 2009a.** Chlorination and water quality monitoring within a public drinking water supply in Rawalpindi Cantt (Westridge and Tench) area, Pakistan. Environ. Monit. Assess.;158: 393–403.

- **Shalaby, I.M. I., Altalhy, A. D. and Mosallam, H. A. 2008.** Preliminary field study of a model plant for sewage water treatment using gravel bed hydroponics method.World Appl. Sci. J; 4(2): 238-243.

- **Suliman, F., Futsaether, C. and Oxaal, U. 2007**. Hydraulic performance of horizontal subsurface flow contructed wetlands for diffferent strategies of filling the filter medium into the filter basin. Ecol. Eng.; 29: 45-55.

- **Wang, X., Bai, X., Qiu, J., Wang, B. 2005.** Municipal wastewater treatment with pond-constructed wetland system: a case study. Water Sci. Tecnol.; 51: 325–329.

Annexure 1

Work Plan

WORK	MONTHS							
	Nov, 2013	Dec, 2013	Jan, 2014	Feb, 2014	Mar, 2014	Apr, 2014	May, 2014	Jun, 2014
Proposal	★							
Literature Review	★	★	★	★	★	★		
Making of Prototype		★	★	★				
Cutting of Sewage Pipe	★							
Water Quality Analysis (Lab Work)			★	★	★	★	★	
Data Compilation							★	
Defence								★
Thesis Submission								★