Effectiveness of Reed Bed Technology for Waste Water Treatment at Surface Level and Root Zone Level

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Abstract: ***Reed bed technology for wastewater treatment has been proven to be effective and eco-friendly sustainable alternative for conventional wastewater treatment technologies such as oxidation ponds, activated sludge process etc., which are expensive to erect and run. This technology mainly utilizes the root zone filtration technology which is an engineered method for purifying wastewater as it passes through an artificially constructed wetland system. This technique is sustainable one and it has already gained popularity in developed countries like Canada, however this technique is best suited for areas with water shortage since the water can be reused, with no operation cost, low maintenance, sustainable, eco-friendly and enhances the natural landscape. It is also preferred for rural areas which are isolated and are not connected to a proper sewage treatment facility. They also provide us with various ecosystem services such as rainwater harvest, recreation of flooded land area. When coupled with anaerobic digestion it leads to bio-energy production. The preliminary studies show that the artificial wetland which was planted with the reed species like Phragmites australis effectively reduces the BOD, COD and total solids content of the domestic wastewater. Also, the reed species effectively removes the nitrogen and phosphate content of domestic wastewater. So, this is very well suited for a developing country like India, where the aspect of wastewater treatment plants is mostly neglected and the facilities to treat wastewater do not function properly and remain closed for most of the time due to lack of proper infrastructure, improper design, poor maintenance, high operation cost, lack of technical manpower etc. This study evaluates the efficiency of the reed bed system in the removal of pollutants from municipal wastewater when wastewater was applied to the reed bed system at fixed intervals. Also, the variation in the efficiency of the reed bed system when the wastewater was applied at the surface and at the root zone of the reed species was also studied. It was found that that the treated water can be used for irrigation in places where there is acute water shortage.***

Keywords: Root zone filtration, wastewater treatment, Constructed wetland, Sewage, Reed bed technology

1. Introduction

Rapid urbanisation and industrialisation, and increase in population, makes domestic waste water collection and disposal, one of the most critical environmental issues in our country. Nowadays, the wastewater discharged to environment without any treatment is polluting our environment and also it is a great threat to human health too. So, it is necessary to treat contaminant loads of wastewater in a sustainable and ecofriendly manner since the existing technologies for treatment of wastewater are very much expensive to erect and run. So as a substitute to these expensive techniques root zone filtration technology using the Phragmites australis species has been reported very effective.

Artificial wetlands like reed bed systems are more efficient in the treatment of wastewater than other systems because they are composed of a substrate, aquatic plants and microorganisms. Wastewater flows into or under the surface layer of the support, and the plants incorporate air to support microorganisms that degrade water compounds through serial processes contained in a single system (Shibaoetal.,2015). They can be classified according to three important criteria: hydrology (surface and subsurface flow), the way in which macrophytes grow (emergent, submerged, floating or floating foliage) and the flow path for subsurface wetlands (horizontal and vertical) (Vymazal, 2014).

In an artificial wetland system, chemical, physical and biological processes occur in combination and are responsible for pollutant removal from wastewater. Treatment in CW includes processes such as sedimentation, filtration, sorption, precipitation, plant uptake and microbial degradation (Kadlec et al., 2000). The treatment occurs when wastewater flows through the wetland filter media and plants. Within the wetland filter medium, wastewater interacts with plant roots. This interaction leads to rhizofiltration and sedimentation. Interaction between microbes and pollutants results in biological degradation of organic pollutants. (Mthembu et al., 2013). Root hairs of the plants provide aerobic conditions that support microbial activities. Degradation of organic and inorganic matter occurs due to presence of aerobic and anaerobic microorganisms (Sharma et al.,2018).

In this study, the vertical flow (VF) reed bed system has been adopted. In a VF reed bed system, the wastewater flows vertically through the filter media during which the removal of pollutants occurs by a variety of physical, chemical and biological processes. The VF reed bed system has been adopted since it is very much efficient in removal of pollutants especially nitrogen. It supports ammonium oxidation process too (Felde and Kunst, 1996).

Root zone technology is a low energy, low maintenance and natural approach to treat domestic sewage. The process is a clean, economic and eco-friendly method used as an alternative to conventional systems. It is a live, self-cleaning biological filter where breakdown of contaminants and the treatment is achieved by the controlled seepage of the waterborne pollutants through the root-zone of plants.

The phragmites australis species commonly known as the reed was used as the plant medium in this work. Reeds are coarse grasses growing in wet places. Phragmites, the common reed, is a large perennial grass found in wetlands throughout temperate and tropical regions of the world. It can grow in damp ground, in standing water up to 1 metre depth, or even as a floating mat. The erect stems grow to 2–6 meters. It is a helophyte, especially common in alkaline habitats, and it also tolerates brackish water. It is grazed regularly by livestock. P. australis is cultivated as an ornamental plant in aquatic and marginal settings such as pond- and lakesides.

Reed bed is one of the natural and cheap methods of treating domestic, industrial and agricultural liquid wastes. Reed bed is considered as an effective and reliable secondary and tertiary treatment method where land area is not a major constraint. Generally, reed bed is made in shallow pits, installed with a drain pipe in a bed of pieces of lime stones and filled up with pebbles and graded sand. In this sandy body, reed plants generally with hollow root which bring oxygen into the filter bed are planted.

The main aim of the study was to evaluate the efficiency of the reed bed system in the removal of pollutants from municipal wastewater when wastewater was applied to the reed bed system at fixed intervals. Also the variation in the efficiency of the reed bed system when the wastewater was applied at the surface and at the root zone of the reed species was also studied. It was found that that the treated water can be used for irrigation in places where there is acute water shortage.

2. Materials and Methodology

In this study, phragmitis australis reed is used for treating the waste water. The reed is capable of reducing alkalinity, acidity chloride and pH content of the waste water. The reed was taken from the Muttathara sewage plant at Trivandrum. They were initially allowed to grow in grow bags and later on after a period of 2 weeks they were transferred to the reed bed which had settled.

The treatment units consist of five impermeable plastic tubs of size of 54 litre capacity with PVC sheet separation. The plants were allowed to grow for 2 months so that the roots spread well throughout the bed as the working is based on the root zone technology.

Design Characteristics

Construction of Reed Bed System

- Two Units of dimension– 600mm x 400mm x 320mm each.
- Volume of 1 unit - 54 x 106 mm^3
- Assume freeboard - 20cm
- Total volume -40.5 x 106 mm^3
- 15 mm hole- lower portion drilled- tap fixed using M-seal
- PVC separation with perforations of 6cm.
- Panel attached using M seal and silicon sealant.

Pipe System

- Main pipe of diameter-15mm.
- Elbows, T-joints and end caps
- Perforations of 1mm diameter were made with the drilling machine
- The centre to centre distance between two holes is 25mm

Fabrication of the Lab Scale Filter Bed

Five units, a conventional lab scale filter bed and four lab scale testing bed, were constructed using an impermeable plastic material each having two compartments: one for the reed bed, which is to filter the contaminated water and the other compartment to collect the filtrate. The separation board is a composite material- PVC (Poly Vinyl Chloride Panel). The prepared filter bed consists of four layers.

First layer (brick bats)

1) The bottom most layer consists of brick bats which is of 7 cm high

2) Second layer is composed of coarse gravel which is of 9 cm height

Second layer (coarse gravel)

3) Third layer is composed of fine sand. River sand is more preferred as the third layer because of its high filtration capacity. This layer is 12 cm high

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Third layer – fine sand (river sand)

4) Reed plants are planted over this layer. In each plastic tub 4 plants are planted, 2 in each row

Treatment bed with Australia plant

Vertical Reed Bed System

This flow method uses a network of pipes using either a pumping or a siphon system for dosing the bed surface. The idea is to flood the surface of the reed bed a number of times per day. As the water flows down through the bed, it draws air in, creating the right bacterial environment. Vertical flow reed beds are very effective in removal of BOD, ammonia and some heavy metals and take up less area for similar treatment compared to Subsurface horizontal flow.

Root Zone Technology

Root zone technology is a low energy, low maintenance and natural approach to treat domestic sewage. The process is a clean, economic and eco-friendly method used as an alternative to conventional systems. Root Zone filters are type of constructed wetlands commonly known as subsurface flow wetland. Root Zone Treatment System are planted filter-beds consisting of sand / gravel/ soil. This Technology was developed in 1970"s in

Germany and is successfully running in different countries, mainly in Europe, India and America. Root Zone System uses ecological principles, which simulate the natural processes for treatment of wastewater. It is a live, self-cleaning biological filter. It removes disease organisms, nutrients, organic loads and a range of other polluting compounds. The breakdown of contaminants and the treatment of wastewater are achieved by the controlled seepage of the waterborne pollutants through a root-zone of plants. Organic pollutants are broken down as a food source for the extraordinary variety of microorganisms that are present in the soil and plants. Root zone treatment systems have self-contained engineered ecosystems that utilize particular combinations of plants, soil, bacterial and hydraulic flow systems to optimize the physical, chemical and micro-biological processes present within the root zone.

Application of root zone technology (RZT) is finding wider acceptability in developing and developed countries, as it appears to offer more economical and ecologically acceptable solution to water pollution management problems. In this project, the effectiveness in using RZT to treat waste water is compared to that of a conventional filter bed system, with the help of constructed lab scale reed bed unit using Phragmitis Australis and another lab scale unit of a conventional filter.

Collection of treated water

The waste water was poured on the reed bed system using a trickling filter method. We used a 1.5cm diameter pipe system, having perforations of 1mm diameter, and at a centre to centre spacing of 2.5cm. The sewage is sprinkled over the filter bed and purified water is collected after two days from the tap. Characterization of this collected water is done by certain tests as mentioned above.

3. Results and Discussions

Sewage is generated when we use water for domestic use. The untreated sewage can lead to further pollution of drinking water sources. Diseases like dysentery, gastroenteritis, typhoid, hepatitis etc.

There are different types of pollutants in the water that may cause contamination of water sources, mainly they are organic and inorganic. So in order to make the water good for reuse and recreational purpose the waste water shall be out of pollutants that is mentioned earlier, It is to be noted that the standards for drinking water and the treated effluent is entirely different and the following tests are mandatory functions that may result in the quality of water. Following parameter is being used for the analysis of reed bed with surface flow and the root zone.

pH

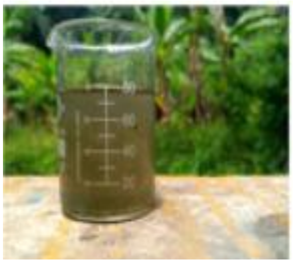
pH is referred to the hydrogen ionsconcentration. It is an important factor that can access the proper function of biological units. The pH of the fresh sewage that is supplied to the filter unit has more pH than the water supplied to the community. However, the rise in pH of the sewage can be compensated by the decomposition of organic matter.

Temperature

Temperature plays an important role in the presence of dissolved oxygen.As the temperature increases, the dissolved oxygen will be drastically reduced,and at extreme lower temperature the working of the biological filter is seriously affected.

Color and Odour

The fresh sewage that was collected and utilised for the purification purpose has slightly soapy and cloudy appearance depending up on its concentration, as the time passes the sewage starts to stale, and the colour of the sewage starts to get darker and the smell will liberate.



Raw sewage (Inlet)

Treated water (Outlet)

Solids

Though the sewage used contain small quantity of solids of about 0.1 percentage, the nuisance caused by the solids cannot be overlooked. Knowledge of the volatile or the organic fraction of solid is a necessary factor that determines the load on the biological filter that's created. organic matter in the filter bed need more dissolved oxygen to facilitate the proper decomposition of the volatile matter.

Organic Material

Organic compound present is the sewage are of particular interest for sanitary engineering. In sanitary engineering there are two standard tests based on oxidation of organic matter.

Biochemical Oxygen Demand (BOD)

The BOD of the sewage is the total amount of oxygen required to decompose biodegradable organic matter under aerobic condition. The oxygen consumed for this purpose is related to the amount of decomposable organic matter. General range vary from 100 to 400 mg/L. BOD of the collected sample was very high. Then the sample was allowed to pass through the two beds and collected filtrated water was checked for BOD test. The result obtain were noted and compared with two bed. The BOD content was reduced more effectively in bed with plant than the conventional.

Chemical Oxygen Demand (COD)

COD gives the measure of the oxygen required for the chemical oxidation of organic matter. It does not differentiate between biological oxidisable and nonoxidisable material. However, the ratio of COD to BOD does not significantly change for particular waste, hence the test can be used conveniently for interpreting performance efficiency of the treatment units. The COD of sewage in various place is reported to be at a range of 200 mg/l. Here the removal increases more in plant with reed bed than a conventional bed. Initial COD content was very high.

Dissolved oxygen

Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. In sewage, depending on the amount of organic matter, the amount of the dissolved oxygen reduces. The variation of DO with respect to each bed was noted and listed below.

S. No	Parameters		Influent (Raw Sample)	Effluent	
				Applying sewage at surface	Applying sewage at root zone
	pH	7th day	6.71	6.9	6.82
		14th day	6.74	7.1	7.2
	DO	7th day	0.3	2.9	2.3
		14th day	0.2	3.5	3.2
	COD	7th day	430	212	226
		14th day	425	198	203
	BOD	7th day	168	53	60
		14th day	165	23	30
	Hardness	7th day	312	130	132
		14th day	320	96	120
	Total solids	7th day	156	132	133
		14th day	157	127	129
	Turbidity	7th day	27.7	2.6	2.9
		14th day	26.5	1.2	1.8

Hardness

Water described as "hard" is high in dissolved minerals, specifically calcium and magnesium.It is not a health risk, but a nuisance because of its tendency to cause mineral buildup in water pipes and heating systems, and its poor soap and/or detergent performance when compared to with soft water.

Water is a good solvent and picks up impurities easily. As water moves through soil and rock, it dissolves minerals and holds them in solution. Calcium and magnesium dissolved in water are the two most common minerals that make water "hard." The degree of hardness becomes greater as the calcium and magnesium content increases.

Observations

Turbidity

The scattering of the light is generally proportional to the turbidity. The turbidity of a sample is thus measured from the amount of light scattered by the sample taking a reference with standard turbidity suspension. Thus the turbidity of the sample was found out using a nephelometer and the value recorded in Nephelometric Turbidity Units (NTU).

Based on the above mentioned laboratory test result of the effluent that is treated using the biological filter surface show the greater efficiency in the result comparison of COD, BOD, Hardness and Turbidity.

But in the case of total solids and the filtration root zone gains its predominance.

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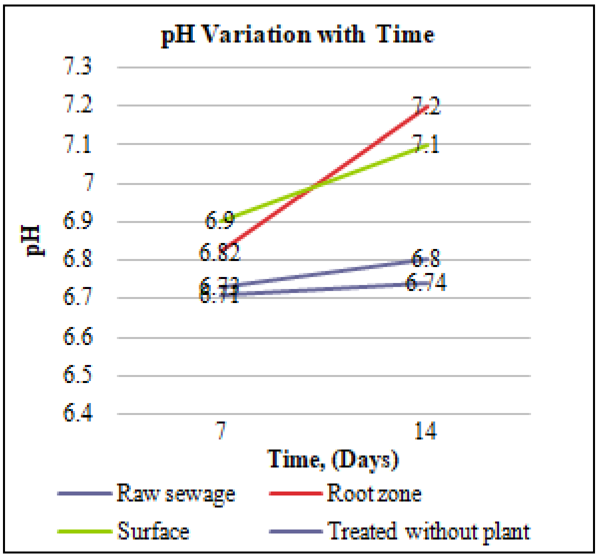
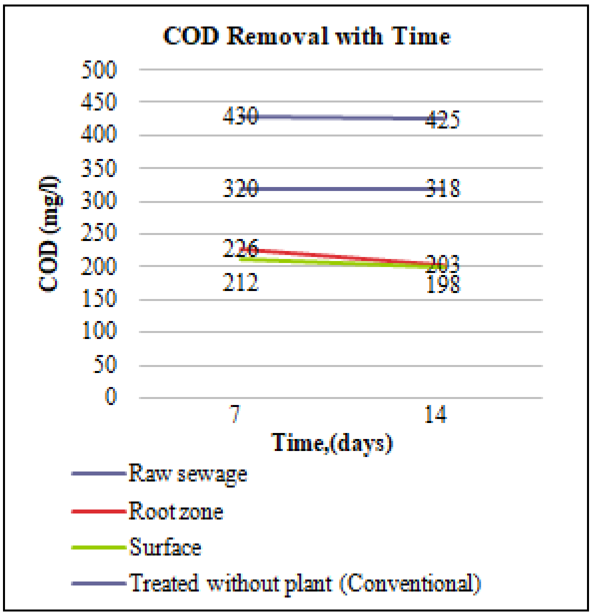
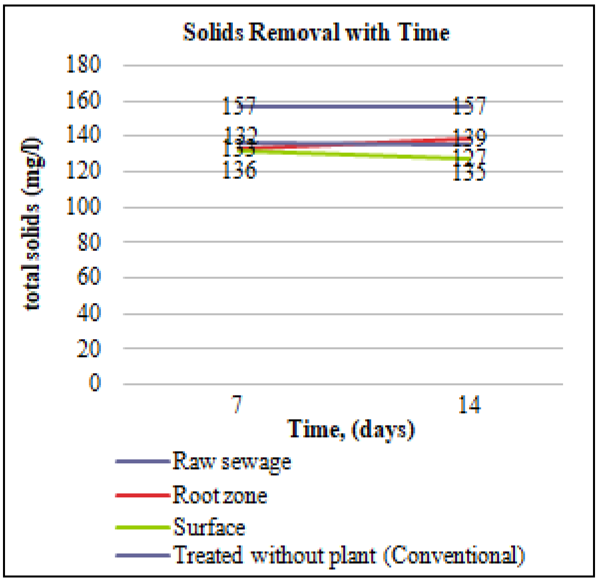
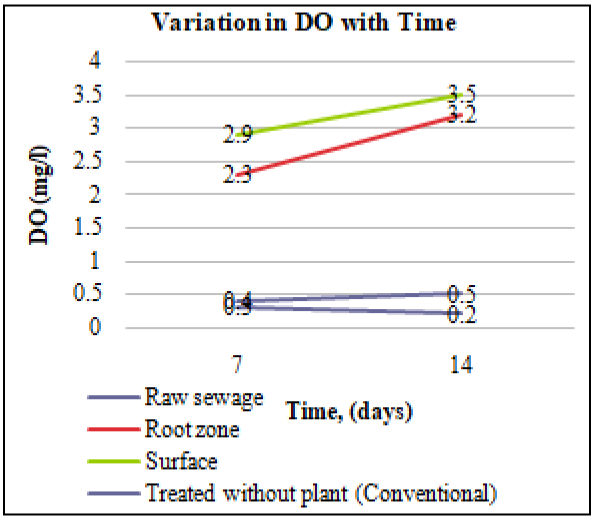
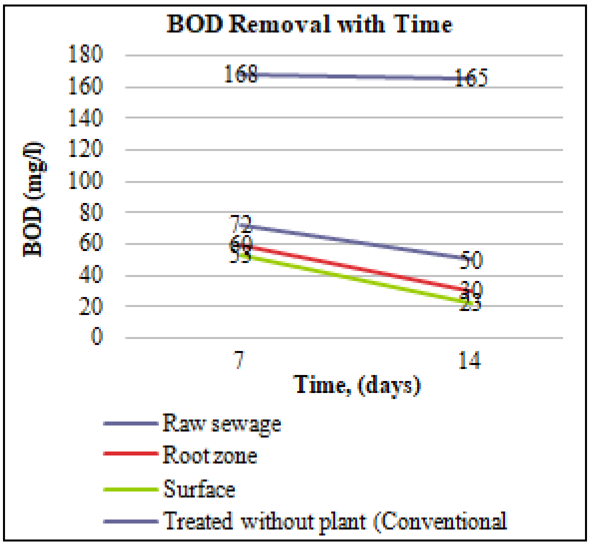
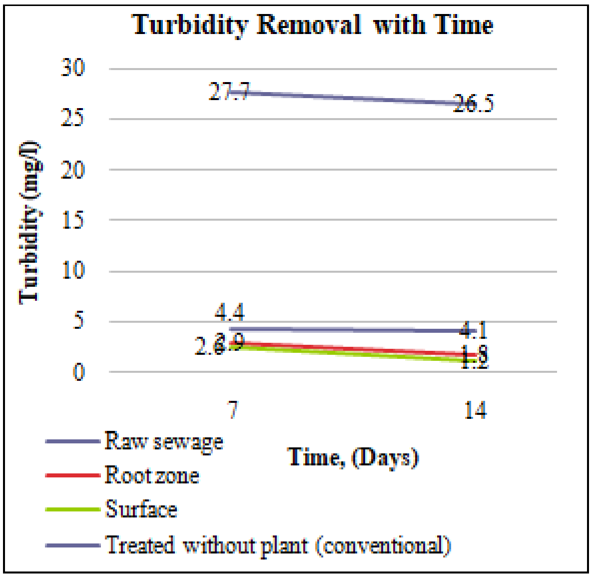

pH Variation with Time
pH
Time, (Days)
Raw sewage
Root zone
Surface
Treated without plant

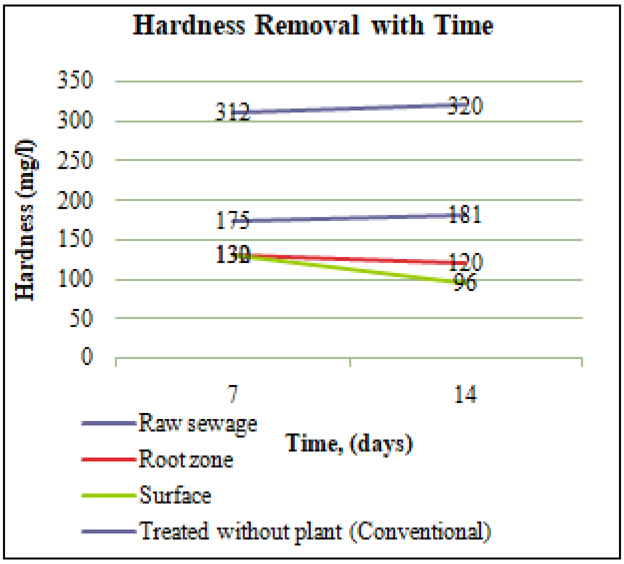

COD Removal with Time
COD (mg/l)
Time,(days)
Raw sewage
Root zone
Surface
Treated without plant (Conventional)

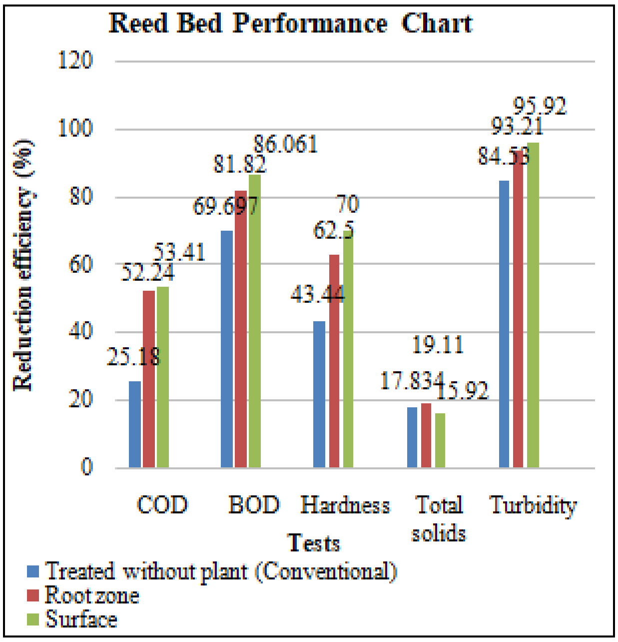

Solids Removal with Time
total solids (mg/l)
Time, (days)
Raw sewage
Root zone
Surface
Treated without plant (Conventional)


Variation in DO with Time
DO (mg/l)
Time, (days)
Raw sewage
Root zone
Surface
Treated without plant (Conventional)


BOD Removal with Time
BOD (mg/l)
Time, (days)
Raw sewage
Root zone
Surface
Treated without plant (Conventional


Turbidity Removal with Time
Turbidity (mg/l)
Time, (Days)
Raw sewage
Root zone
Surface
Treated without plant (conventional)





4. Conclusion

The observations recorded with reed bed using Phragmitis Australis to treat effluent water showed that the dissolved oxygen (DO) was 3.5 mg/l for surface application and 3.2 mg/l for root zone application of sewage. The pH observed was 7.1 for surface application and 7.2 for root zone application of sewage. All these values obtained during the experiment were within the BIS standard limits. Also this technique can be considered to be cost effective because of the limited and minimum material requirements. This concludes that the reed bed technology using Phragmitis Australis can be employed to treat effluent water and can be discharged into natural water bodies without any concerns of contamination.

References

[1] APHA, AWWA &WPCF, “Standard methods for the determination of Water and Waste water”, 16th Edition, American Public Health Association, Washington DC, USA, 1995.

[2] Bansari M. Ribadiya, Mehali J. Mehta, “Treatment of municipal and industrial wastewater by reed bed technology: A low cost treatment approach”, IJERA, ISSN: 2248-9622, Vol. 4, Issue 12(Part 3), December 2014.

[3] Ram Prasad. C. “Experimental study on waste water treatment using lab scale reed bed system using Phragmitis Australis”, IJES, Volume 3, No 1, 2012.

[4] Byoung-Hwa Lee, Miklas Scholz, “What is the role of Phragmites Australis in experimental constructed wetland filters treating urban runoff”, ELSEVIER, 2007.

[5] “REED-BED Sewage Treatment: The Theory”.Available: http://www.wteltd.co.uk/reed_bed_sewage_treatment.html

[6] Kartikey Tiwari, Shivendra Jha, Kandarp Vyas, Kavan Patel, Mihir Patel, “REED BED TECHNOLOGY: A REVIEW” International Journal of Engineering Science Invention Research & Development; Vol. III, Issue IX, March 2017.

[7] M.B Green,J.Upton,”Constructed Reed Beds-Appropriate Technology for small communities” Water Science and Technology Volume 32, Issue 3, 1995, Pages 339-348