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Construction and performance evaluation of reed bed wastewater treatment unit

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ABSTRACT

Water plays an indispensable role in our life and it is said that without water there would not be any survival of human being. With this great importance, the conservation and treatment of water becomes necessary in order to use this scarce resource in an efficient manner. The water gets polluted due to the presence and actions of various inorganic and organic substances and waste water treatment is a good practice to reuse the sewage water for different purposes especially for Irrigation in Agriculture. In that, Reed Bed System is an economically viable technology to treat the sewage using subsurface flow technique.

KEYWORDS: treatment, bed, wastewater.

1. INTRODUCTION

Water is a common chemical substance that is essential to all known forms of life. In typical usage, water refers only to its liquid form or state, but the substance also has a solid state, ice, and a gaseous state, water vapour. About 1,460 tera tonnes (Tt) of water covers 71% of the Earth's surface, mostly in oceans and other large water bodies, with 1.6% of water below ground in aquifers and 0.001% in the air as vapour, clouds (formed of solid and liquid water particles suspended in air), and precipitation. So, the conservation and treatment of the water become more important in order to preserve this fast depleting resource.

1.1. Water pollution: Water pollution is the major obstacle for the efficient use of water and causes the problem of water scarcity. Water pollution is also defined by WHO (1989) that any alteration in composition or condition directly or indirectly- as a result of anthropogenic activities, so that it becomes less suitable for any or all the functions and purposes for which it would be suitable in its natural state.

Besides, increasing man made degradation of water quality has become a great concern in the present context of growing population, intensive industrial development, speedy urbanisation and diversification of human activities with the consequent ever increasing uses and abuses of this vital natural resource. In India, the total polluted water production was estimated to be 6×10^8 m^3 per day combining all sources (Gopichandran and Prakash, 2003). Pollution of natural water with water effluents arising from various industries has become a serious problem, as industrial growth and development have been on a very large scale. At this juncture, waste water treatment becomes an important practice to recycle and use this scarce resource for different purposes.

1.2. Waste water treatment: Generally, waste water is defined as a combination of the liquid or water-carried wastes removed from residences, institutions, and commercial and industrial establishments, together with such groundwater, surface water, and storm water as may be present. The main aim of waste water treatment is the removal of contaminants from waste water so that treated water can be safely let out in rivers or streams. The waste water treatment is carried out in three states: (1) Primary treatment– to remove suspended solids, odour, colour, and to neutralise the PH, (2) Secondary treatment – a biological treatment of effluents obtained from primary treatment to remove BOD of waste water and (3) Sludge disposal – to remove the solids as much as possible and stabilise the solids into stable products.

There is a great possibility for waste water treatment in India. The sanitary or municipal wastewater from an urban population of roughly 45 million people in India is systematically collected through sewers (Gopichandran and Prakash, 2003). The estimated wastewater volume thus collected is nearly 1137.5 million gallons per day (MGD) or179361m ^{3}/day.

1.3. Reed bed system- an overview: Reed Bed System is the artificial wastewater treatment system consisting of shallow ponds or channels which have been planted with aquatic plants, and which rely upon natural, biological, physical and chemical processes to treat wastewater. It typically has impervious clay or synthetic layer and engineered structures to control the flow direction, water level and liquid retention time. These plants can be used to treat variety of wastewaters including urban run-off, municipal, industrial, agricultural and acid mine drainage (Gersberg, 1984). Reed beds have positive characteristics of a natural wetland and can also be controlled to eliminate the negative aspects of natural wetlands. There are two basic types of reed beds, viz., free water surface reed bed and subsurface reed bed.

1.4. Free water surface reed bed (FWS): These systems typically consist of basins or channels with some sort of subsurface barrier to prevent seepage, soil or another suitable medium to support the emergent vegetation and water at a relatively shallow depth flowing through the system. The shallow water depth, low flow velocity, and presence of the plant stalks and litter regulate water flow and, especially in long, narrow channels minimize short circuiting. (Gearheart, 1996).

Table.1.Waste water discharged data in India (1990-2001)

Industrial Sector	Annual Wastewater discharge (million cubic meters) (%)	Annual consumption (million cubic meters)	Proportion of water consumed in industry
Thermal power plants	27000.9	35157.4	87.87
Engineering	1551.3	2019.9	5.05
Pulp and paper	695.3	905.8	2.26
Textiles	637.3	829.8	2.07
Steel	396.8	516.6	1.29
Sugar	149.7	194.9	0.49
Fertiliser	56.4	73.5	0.18
Others	241.3	314.2	0.78
Total	**30729.2**	**40012.0**	**100.0**

1.5. Sub surface flow reed bed (SF): A subsurface flow reed bed consists of a trench or bed underlain with an impermeable layer of clay or synthetic liner. The bed contains media which will support the growth of emergent vegetation. The system is built with a slight inclination (1-3 percent) between inlet and outlet. Rock and gravels are generally used as media (Reed, 1988).

In this study, the subsurface flow reed bed is constructed in the tamarind block of Agricultural Engineering College and Research Institute, Kumulur with the consideration of following advantages;

❖ As water surface is maintained below the media surface, there is little risk of odour, direct exposure and insects.

❖ The filter media provides greater available surface area for wastewater treatment.

❖ Sub surface flow reed beds generally have smaller area than free water surface reed beds for the same wastewater conditions.

❖ The subsurface position of water and the accumulated plant debris on the surface of the sub surface flow reed bed offer greater thermal protection in cold climate than free water surface reed bed.

1.6. Objectives: The study has conducted to accomplish the following objectives;

a. To design and construct a reed bed for the treatment of Boy's hostel sewage at Agricultural Engineering College and Research Institute, Kumulur.

b. To evaluate the performance of reed bed with respect to influent and effluent characteristics (*Typha sp.*).
To work out the component-wise cost of the designed reed bed system.

2. MATERIALS AND METHODS

This study describes the method of designing an economically viable technology for treating the sewage water of Boy's hostel at Agricultural Engineering College and Research Institute, Kumulur, so that it can be reused or disposed safely.

2.1. Study area: The study area is situated at tamarind block, which receives wastewater from a nearby Boy's hostel. The field is located at 10°56' N latitude and 78°49'E longitude, with an altitude of 70 m from MSL. The soil type is loamy sand having depth of 1.08 m. The climate is tropical with two monsoons. The South-West (SW) monsoon occurs during June to September and North-East (NE) monsoon occurs during October to December. The annual rainfall is about 915 mm. About 53 per cent of annual rainfall receives during NE monsoon and 33.27 percent during SW monsoon. The minimum and maximum temperature prevails between 22^0 C and 39^0 C.

The drainage ditch is carrying the wastewater from nearby Boy's hostel and the average waste water discharge into the drain is around 3 m^3 per day. Constructed wetlands (Reed beds) are the cheapest option, easily be operated, maintained and have a strong potential for application. To study the feasibility of this technology, a small pilot scale reed bed was designed, developed and short term evaluation was carried out through this study. To design any wastewater treatment system, thorough analysis of the wastewater under consideration is of prime importance. This investigation includes the collection of data about wastewater discharge, pH, EC, Carbonate, bi-carbonate, and BOD_5.

2.2. Components of reed bed: The main components of the system are briefly explained as below:

2.2.1. Basin: Reed Bed is generally constructed as a basin, anywhere by shaping the land surface to collect the surface water and by sealing the basin to retain the water for sufficient time period without much seepage and percolation.

2.2.2. Filter substrata: The filter substrata generally include soil, sand, gravels and pebbles. They support most of the organisms within the bed. The macrophytes which have the major role in water purification are supported by the same substrata. The bed material should have good adsorption quality which causes the sediments to be filtered out. More surface area of the filter material results increase in reaction constant of the material which is essential for chemical decay of pollutants. This bed also supports the micro-organisms which play an important role in bio-degradation of waste material.

2.2.3. Vegetation: The emergent plants most frequently found in wetlands are cattails, reeds, rushes, bulrushes and sedges. The most important function of vegetations in relation to the treatment of wastewater is the physical effect brought about by the presence of plants. The macrophytes stabilize the surface of bed, provide good condition for physical filtration, prevent vertical flow system from clogging, insulate against frost in winter and provide huge surface area for attached microbial growth. Macrophyte-mediated transfer of oxygen to the rhizosphere by leakage from roots increases nitrification and aerobic degradation of organic matter.

2.3. Design elements of reed bed system: In this section, major design elements were discussed. The prime design elements considered are given below:

2.4. Site selection for reed bed: For this study, subsurface flow reed bed system was purposefully proposed due to its merits over the other engineered systems. Following points were considered for site selection for the proposed reed bed:

a) Availability of waste water, b) Site topography, c) Soil permeability and soil horizons

The selected site near the Boy's hostel has enough slopes for the free movement of water with gravitational force and this was an important criterion to select the site for the performance study of subsurface flow reed bed system. Besides, the non-stop availability of waste water from the Boy's hostel was the vital reason for the successful completion of this study without any time delay.

2.5. Hydraulic design of reed bed: Hydraulic Design of reed bed is nothing but determination of its dimensions to achieve necessary (required) performance level. Following data were required to design the reed bed.

a) Quantity of Waste water inflow, b) Influent BOD_5, c) Required effluent BOD_5, d) Characteristics of filter media (porosity, hydraulic conductivity, reaction constant), e) Root depth of proposed macrophyte.

All the above mentioned data/parameters were collected.

2.6. Inflow of influent: The readings were taken at the time interval of one hour for the seven days from morning 7 AM to 6 PM. The readings taken were averaged to get the discharge of influent waste water and the discharge was found out to be $3m^3$.

2.7. Influent BOD_5: For design purpose BOD_5 values of waste water is necessary. The wastewater sample analysis showed that the maximum BOD_5 in present sewage was 160 mg/l at 20^oC.

2.8. Effluent BOD_5: For the unrestricted irrigation of any crop, the maximum tolerable BOD_5 of water is 50 mg/l. For safer side, the required effluent BOD_5 in the present study was taken as 30 mg/l at 20^oC.

2.9. Characteristics of filter media: Generally, it is advisable to use locally available low cost material as filter media. The media properties such as media size, hydraulic conductivity, porosity and reaction constant should be considered for scientific design. Also the material should support the vegetation growth. According to material availability, following materials were selected as main filter media. Table 3.1 also shows the properties of the selected filter media.

Table.2.Proposed media and their characteristics

Media	Thickness of layer (m)	**Reaction constant (K_{20}) day^{-1}	*Porosity (n)
Soil	0.10	2.00	0.62
Fine sand	0.15	1.84	0.34
Pebbles	0.35	1.35	0.22

** EPA, 1988

2.10. Root depth of proposed macrophyte: Macrophyte is one of the major parts of reed bed system which affect the treatment efficiency. "*Typha sp.*" is everywhere in distribution, hardy, capable of thriving under diverse environmental conditions and easy to propagate. Also the rhizomes planted at approximately 1 m intervals can produce dense stand within 3 months (Miller, 1985). Considering all above points, *Typha sp.* was chosen as reed bed vegetation. The roots of these plants generally penetrate up to depth of 30 cm in its supporting media.

2.11. Area computation: Based upon influent flow rate, influent characteristics, filter material characteristics and desired effluent water qualities necessary, the reed bed area was calculated as per the design procedure mentioned in the EPA manual (1988) and given by Ronald Crites (1994). The derivation of the reed bed area equation was described in above mentioned EPA manual. It is briefly given below:

The BOD_5 removal in wetland was described by First-order reaction model as given below (Reed, 1987),

$$\frac{C_e}{C_i} = e^{-K_T t}$$

Where, C_e= Influent BOD_5 (mg/l), C_i= Proposed level of effluent BOD_5 (mg/l), K_T= Reaction constant for selected filter material at temperature T ^0C (day^{-1}), t= Hydraulic Retention Time (day).

According to the definition, Hydraulic Retention Time (HRT) was represented as:

$$t = \frac{L \times W \times n \times d}{Q} = \frac{A_s \times n \times d}{Q}$$

Where, L=Length of reed bed (m), W=Width of reed bed (m), d=depth of reed bed (m), Q=Waste water flow rate (m^3/day), n=porosity, A_s=(L*W) Surface area of the Reed bed (m^2).

By Substituting

$$\frac{C_e}{C_i} = e^{-K_t \frac{L \times W \times n \times d}{Q}}$$

By Solving Equation

$$A_s = \frac{Q[LnC_i - LnC_e]}{K_T.d.n}$$

In this study the surface area of reed bed was computed by using above equation.

2.12. Retention time computation: For maximum purification to achieve, the waste water should be provided with sufficient retention time. This increases the contact time of waste water with filter media and macrophyte roots. The result of which is better adsorption, more oxygen diffusion, more uptake of pollutants by macrophyte and more microbial activity. The retention time required for the proposed BOD_5 removal was computed using the following equation.

$$t = \frac{LnC_i - LnC_e}{K_T}$$

Where, C_i= Influent BOD_5 (mg/l), C_e= Proposed level of effluent BOD_5 (mg/l), K= Reaction constant for selected filter $_T$ material at temperature T ^{0}C (day^{-1}), t= Hydraulic Retention Time (day).

2.13. Design procedure: For designing the reed bed system following design steps were used.

2.14. Selection of basin depth: For this study, Cattail (*Typha sp.*) was selected as a wetland macrophyte. The rhizomes of these plants generally penetrate up to depth of 0.3 m in its supporting media. Also, there is domination of horizontal spreading of roots of this species. The recommended maximum bed depth is 0.7 m. By considering these factors; the bed depth was chosen as 0.6 m.

2.15. Selection of basin bed slope: The bed slope is based upon the topography of area. Most constructed wetlands have been designed with the bed slope of 1.0 per cent. The same bed slope was proposed for this study. A dumpy level is used to determine the bed slope.

2.16. Calculation for weighted reaction constant (k_t): The thickness of layers and reaction constants for different filter materials was shown in Table3.1. The weighted reaction constant for these material was worked out as follows:

$$WeightedK_{20} = \frac{k_1 d_1 + k_2 d_2 + k_3 d_3}{d_1 + d_2 + d_3}$$

$$WeightedK_{20} = \frac{(2 \times 0.1) + (1.84 \times 0.15) + (1.35 \times 0.35)}{(0.1 + 0.15 + 0.35)} = 1.581 day^{-1}$$

The system was designed for the minimum temperature that attain at the respective site. In this study area, 21°C was recorded as minimum temperature. Thus the first-order temperature dependent rate constant (K_T) was calculated using the following equation given by Ronald Crites (1994).

$$K_T = K_{20} \times (1.1)^{T-20}$$

Where, K_T= Reaction constant at temp T (day^{-1}), K_{20}= Reaction constant at 20°C (day^{-1})

Hence, $K_{21} = K_{20} \times (1.1)^{21-20} = 1.581 \times (1.1)$, $K_{21} = 1.74$ day^{-1}

2.17. Determination of surface area of reed bed: By assigning the values of various parameters the reed bed surface area was computed using Equation

$$A_s = \frac{Q[LnC_i - LnC_e]}{K_T.d.n}$$

Where, A_s= Area of proposed reed bed (m^2), Q= Proposed discharge to the reed bed (3m^3/day), C_i= Influent BOD_5 = 160 (mg/l), C_e= Effluent BOD_5 = 30 (mg/l), K_T= Wetted reaction constant = 1.74 day^{-1},
d= Proposed depth of filter bed = 0.60 m, n= Average porosity of media = 0.39

By putting all input values in above equation the area required was calculated is 12.33 m^2**.** The recommended aspect ratio (length: width) ranges from 2:1 to 6:1, to avoid the short-circuiting. For the study area 3.1:1 was selected as aspect ratio. Using this aspect ratio, the length and width for above mentioned area was 6.17 m and 2.0 m respectively.

2.18. Retention time required for proposed purification: Retention time was computed by using the Equation as follows: $t = \frac{LnC_i - LnC_e}{K_T} = \frac{(Ln160 - Ln30)}{1.74}$

Retention time, t = 0.96 days.

In addition to this, the inlet zone of 0.75 m length and drainage zone of 0.75 m were also proposed. Inlet zone (lined, filled with broken bricks) was proposed for initial settling as well as adsorption and absorption purpose.

To drain out the treated wastewater from the reed bed, the outlet zone (lined, filled with broken bricks) was proposed.

2.19. Construction of reed bed: For achieving decided performance from the system, it was constructed precisely according to the design dimensions. Site selection, site preparation, basin excavation, basin shaping and lining, filling of filter material, inlet and drainage zone construction and filling, macrophyte selection and transplantation and water level control mechanism were considered as the major construction components.

2.20. Site preparation: Site preparation activities such as vegetation removing, cleaning, and rough grading were carried out to give initial shape to the site.

2.21. Basin shaping and lining: Basin shaping was carried out in order to stabilize the side slopes of the basin. The side shaping carried out by keeping the side slope as1:1. The mixture of cement and fine sand in water was used as a low cost lining material. This was applied on the side slopes of the basin to arrest side seepage. The thickness of lining was kept as 2 cm. For sealing the bottom of the basin, a mixture of cement and fine sand was spread uniformly along the basin bed.

Lining material required = Length of the Bottom x Length xThickness

Two side wall width channel of the lining = [(1 + 1) + 1] x 7.67 x 0.02 = 0.4602 m^3.

2.22. Inlet zone: Inlet zone length was kept as 0.75 m. The width was same (*i.e.* 2 m). This was separated from filter zone with the help of inlet brick wall. For initial adsorption, absorption and settling purpose, 0.28 m^3 of broken bricks was laid. Three orifice openings were kept in wall along its length at height of 0.65 m from bottom to divert the wastewater from inlet zone to the filter zone (fig.1).

2.23. Filter zone: The length of the planted filter zone was kept as 6.17 m of the width as 2 m as per the design calculations. The depth of basin was 1 m. The selected filter material i.e., pebbles, fine sand and soil were spread uniformly over the bed in the layers of 0.35 m, 0.15 m and 0.1 m respectively so as to get total filter bed thickness of 0.6 m. The quantities of pebbles, sand and clay required for filter bed were 2.93 m^3, 1.40 m^3 and 1.00 m^3 respectively at the inlet zone side, filter was supported by brick wall and on outlet zone side, it was supported by a solid GI mesh (fig.2).

	
Fig. 1. Inlet zone of the reed bed system	**Fig.2. Inlet zone side, filter zone was supported by brick wall and**

2.24. Outlet zone: Outlet side Supported by GI mesh. The main purpose of this zone is to achieve proper drainage of treated water to the effluent channel. The length of this zone was kept as 0.75 m to accommodate the drainage system. The width was kept as 2 m. The outlet zone was filled with broken bricks up to depth of 0.7 m. Thus, the quantity of broken bricks required was 1.05 m^3 for the outlet zone (fig.3).

2.25. Identification of wetland vegetations: Macrophyte is one of the major parts of reed bed system which affect the treatment efficiency. For this study *Typha latifolia* was chosen according to literature recommendations and local availability. These plants were identified near the pullambadi canal, situated about 0.5 km from Boy's hostel, Agricultural Engineering College and Research Institute, Kumulur.

2.26. Transplanting the vegetation on the filter bed: The selected rhizomes of *Typha latifolia were* planted on the filter bed with the depth of 10 cm and spacing of 0.3 m x 0.3 m in staggered manner. A buffer of 0.5 m from inlet zone was kept for proper maintenance and to prevent initial clogging (fig.4).

2.27. Operational process of water purification: The waste water released in the inlet zone through inlet channel. This rises up to the openings provided to the wall and diverted to the filter zone. Then it infiltrates the filter vertically up to the bottom of the filter. It moves horizontally throughout the filter length, through different media layers. This movement depends upon the overall hydraulic conductivity of the bed and hydraulic gradient provided. The purification of water takes place due to the following reactions in the reed bed system. Reed beds work by the cleansing power of three main elements: soil dwelling microbes, the physical and chemical properties of the base material (soil, sand or gravel), and finally the plants themselves. The choice of base material is dependent upon the particular type of waste that needs processing.

	
Fig. 3. Out zone of the reed bed system	**Fig. 4. Vegetation was planted 0.5 from inlet zone**

Wetland plants transfer atmospheric oxygen down through their roots in order to survive in waterlogged conditions. This creates both aerobic and anaerobic soil conditions, allowing an enormous diversity of microbial species to flourish. The plants have three functions. Firstly, their very extensive root systems create channels for the wastewater to pass through. Secondly, the roots introduce oxygen down into the body of soil and provide an environment where aerobic bacteria can thrive. These organisms are necessary to break down many types of compound, in particular the oxidation of ammonia to nitrate (ammonia can be found in high concentrations in sewage and other nutrient-rich wastes). Finally, the plants themselves take up a certain amount of nutrients from the wastewater, which acts as a natural fertiliser.

2.28. Water quality monitoring in the reed bed: After construction of reed bed system with well-established *Typha latifolia* three observations were taken out to different water quality parameters. Water samples were collected from the influent and effluent. The following table 3.2 summarizes the water quality parameters studied with standard procedures:

Table.3.Wastewater quality parameters

Parameter	Unit	Method of Analysis
Temperature	°C	Standard Method
pH	-	pH meter
EC	dS/m	EC meter
BOD_5	mg/l	Standard Method
Carbonates	meql-1	Standard procedure
Bi-carbonate	meql-1	Standard procedure

2.29. System cost: Major cost parameters in this case are site preparation earthwork, construction work and filter material. Other parameters such as labours, lining material, screening and supporting meshes were also considered.

2.30. System maintenance: The Overall view and cross sectional view of the reed bed System shown in fig.5 and fig.6. To run the system efficiently, majors following maintenance were followed.

1. The sediment layer deposited on the bed at the entry zone was scraped weekly.
2. Periodic weeding was carried out (once in 15 days).
3. The designed flow was allowed only to the system to avoid surface flow problem.

Fig. 5. Overall view of the Reed Bed System

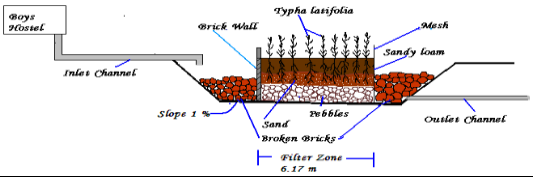

Fig. 6. Cross sectional view of the reed bed system

3. RESULTS AND DISCUSSION

The study was undertaken to design and develop this eco-friendly wastewater treatment system to treat the sewage water from Boy's hostel of Agricultural Engineering College and Research Institute, Kumulur. Experiments were carried out for determining these parameters; pH, Electrical Conductivity (EC), Biochemical Oxygen Demand(BOD_5), Carbonate, Bicarbonate. The results obtained from different laboratory and field experiments are discussed in this chapter.

3.1. pH: The results obtained from the pH analysis of influent and effluent water samples of Reed Bed System are given in Table 4.

Table 4.1 pH value of influent and effluent water

Date of Observation	pH Value	
	Influent Water	Effluent Water
25 Sep 2007	8.25	8.20
18 Oct 2007	8.15	8.13
5 Nov 2007	8.20	8.19

Average pH range of influent was found to be 8.2. In this study pH value of influent to effluent was slightly differ. But the values were within acceptable limits of 6.5-8.5 for irrigation.

3.2. Electrical conductivity: EC values obtained from the influent and effluent water sample collected from reed bed system are tabulated in Table 5.

Table 5. EC value of influent and effluent water

Date of Observation	EC Value (dS/m)	
	Influent Water	Effluent Water
25 Sep 2007	0.85	0.62
18 Oct 2007	1.19	0.98
5 Nov 2007	0.80	0.67

It was found that range of EC value for influent was varying between 0.8 dS/m to 1.19 dS/m. The effluent EC was found in the range of 0.62 dS/m to 0.98 dS/m. It was found that there was a decreasing trend of EC removal along bed length. The higher value of EC (more than 1 dS/m) in water is not suitable for continuous irrigation. So, the effluent water was found to be more suitable for irrigation purpose. There is a possibility that the removal would become higher when macrophytes develop their complete root system, due to the positive effect of higher aeration and chemical reactions in future.

3.3. Biochemical Oxygen Demand (BOD_5): BOD_5 is the amount of oxygen required by bacteria for stabilizing decomposable organic matter under aerobic conditions. It is the major criteria used in stream pollution control, where organic loading must be restricted to maintain desired Dissolved Oxygen (DO) levels. It is the only quality parameter that gives the measure of amount of biologically oxidisable organic matter.

Table.6. BOD_5 value of influent and effluent water

Date of Observation	BOD_5 (mg/l)	
	Influent Water	Effluent Water
25 Sep 2007	160	124
18 Oct 2007	153	115
5 Nov 2007	142	090
Average	151.6	109.7

BOD_5 measurement of water, to be treated is the first step in design of reed bed system. Sewage at this site has a maximum BOD_5 of 160mg/l. BOD_5 of the influent and effluent were analyzed using standard procedure and the results are shown in Table.6. It was seen that BOD_5 values for the influent was in the range of 142 mg/l to 160 mg/l during the study period. The effluent BOD_5 range was 90 mg/l to 124 mg/l. Purification efficiency of the system is based on reduction of BOD_5 value. Continuously increasing BOD_5 removal trend was observed with respected to time.

3.4. Carbonates & bicarbonates: Influent and effluent water was collected from the reed bed. These were analysed for carbonates and bi-carbonates. Results of carbonate analysis are shown in Table.7 .

Table.7. Carbonate value of influent and effluent water

Date of Observation	Carbonate Value (m.eq/l)	
	Influent Water	Effluent Water
25 Sep 2007	1.848	1.665
18 Oct 2007	1.952	1.745
5 Nov 2007	1.855	1.670

Average Carbonate value of influent and effulent waste water range from 1.885 m.eq/l to 1.693 m.eq/l. This variation showed steady reduction in carbonate value up to the effluent. The values of bi-carbonates are shown in Table.8.

Table.8. Bi-Carbonate value of influent and effluent water

Date of Observation	Bicarbonate Value (m.eq/l)	
	Influent Water	Effluent Water
25 Sep 2007	10.55	9.12
18 Oct 2007	8.94	7.56
5 Nov 2007	11.80	10.11

Average Bi-carbonate value of influent and effluent waste water range from 10.43 meq/l to 8.93 meq/l. Then the reducing trend was observed up to the effluent.

3.5. Hydraulic design of reed bed system: Using the design procedure the reed bed system was designed. Preliminary information needed was collected using standard methods. The results are shown in Table 9.

Table.9. Preliminary data required for reed bed design

Parameter	Unit	Magnitude
Influent inflow	m^3/d	3
Inflow BOD_5	mg/l	160
Proposed level of effluent BOD_5	mg/l	30
Cattail *(Typha sp.)* root depth	m	0.3
Bed slope	per cent	1
Weighted reaction constant	day^{-1}	1.74

3.6. Construction of reed bed: Specific wastewater characteristics (wastewater quality and quantity monitoring), construction aspects (site topography, soil type and soil depth, slope stability, lining material, filter substrate, drainage system) and vegetation features (vegetation selection, transplanting geometry and depth) were considered in the planning and design phase of a subsurface flow (SF) constructed wetland project. Based upon all the above aspects the reed bed was exactly constructed as per the design dimensions arrived in Table 10 and Fig.7.

Table. 10. Dimensions of reed bed

Particulars	Magnitude	Unit
Reed Bed Area	12.33	m^2
Aspect Ratio	3.1 : 1	-
Depth of Reed Bed	0.6	m
Bottom Width of Reed Bed	1	m
Side Slope	1 : 1	-

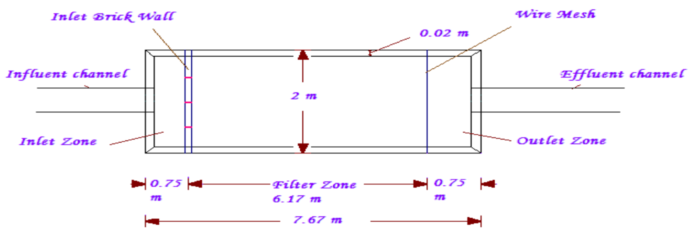

Figure. 7. Top view of Reed bed sysytem

3.7. Cost estimation of the system: Major cost components contributing the total system cost are given in Table 11. It was found that construction cost and filter material cost were major cost components.

Table. 11. Major Cost Parameters in Reed

Parameters	Quantity	Unit rate (Rupees)	Cost (Rupees)
Earth work			
Influent channel	15 m^3	64.50/m^3	907.50
Reed bed system	14 m^3		903.00
Effluent channel	10 m^3		645.00
Plastering			
C:M 1:5	0.46 m^3	385.84/ m^3	177.50
Filling material			
Pebbles	2.93 m^3	170.0/ m^3	498.00
Sand	1.43 m^3	190.0/ m^3	266.00
Soil	1 m^3	180.0/ m^3	180.00
Transplanting			
	4 Persons	82.0/person	328.00
Wire mesh			
21 Sq.Ft	1.951 m^2	240.0/ m^2	468.00
Angle			
	15 kg	45.0/kg	675.00
Brick work			
C:M 1:5	0.27 m^3	1930.0/ m^3	521.00
Total			5569.00

4. SUMMARY AND CONCLUSIONS

In this study, the design of an economically viable technology called "Reed Bed" was attempted for treating the sewage from Boy's hostel of Agricultural Engineering College and Research Institute, Kumulur so as to reuse its effluent for irrigation or for safe disposal to the nearby water bodies. A waste water drain carrying a mean discharge of 3 m^3/d was used for this study.

The waste water coming from the drain (influent) was analysed for its characterization with respect to discharge, pH, EC, BOD_5, Carbonate and Bicarbonate. Based upon the influent characteristics, root zone depth of proposed macrophyte (*Typha sp.*), a reed bed was designed with suitable dimensions with respect to area, depth and bed slope.

Based upon the computed design dimensions, a reed bed was constructed and the emergent macrophyte *Typha latifolia* was planted. The system was tested for its functional performance using three observations in consecutive three months after establishment of macrophytes, including its cost components. The system is still functioning satisfactorily.

The major conclusions drawn from monitoring of the data are summarized below:

Bed Construction:

a) pH values obtained from effluent water was slightly lower compared to influent water.

b) EC showed descending trends from the influent to effluent channel through the reed bed system. The maximum EC values declined from 1.19 to 0.98 dS/m.

c) The decline in BOD_5 trend was found from influent up to the end of effluent channel.

d) Carbonates and bicarbonates showed the falling trend as waster water passes though the reed bed system.

e) As the system was continuously operated, the quantum of pollutant removal performance of the system increased as the duration of system operation increased.

f) Overall analysis with reference to EC and pH showed that the effluent water could be used for irrigation purpose without much deleterious effect on the soil and plant system.

The increasing trend of the pollutant removal with the growth of macrophytes for further improvement in the BOD_5 reduction and other quality parameters looks to bring still better results in future.

REFERANCES

Bavor H.J, Roser D.J and McKersie S.A, Treatment of wastewater using artificial wetlands: Large scale fixed film bioreactors, Australian Journal of Biotechnology, 1, 1987, 67-73.

Bavor H.J, Roser D.J, Fisher P.J, Smalls L.C, Joint Study on Sewage Treatment Using Shallow Lagoon-Aquatic Plant Systems, Water Research Laboratory, Hawkesbury Agricultural College, Richmond, NSW, Australia, 1988.

Brix H, An Overview of Wetlands for Water Pollution Control in Europe, In proceedings: Wetland System in Water Pollution Control, University of New South Water, Sydney, Australia, 1992, 321 – 329.

Brix H, Functions of macrophytes in constructed wetlands, Water Science & Technology, 29(4), 1994, 71-78.

Crites R.W, Design criteria and practice for constructed wetlands, Water Science & Technology, 29(4), 1994, 1-6.

EPA (Environmental Protection Agency), Design Manual: Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment, EPA/625/1-88/022, USA, 1988.

EPA (Environmental Protection Agency), Subsurface Flow Constructed Wetland for wastewater treatment, EPA 832-R-93-008, U.S.A, 1993.

European Commission Guide, Extensive wastewater treatment processes- Adapted to small and Medium sized Communities, 1991.

Gearheart R.A and Finney B.A, Criteria For Design of Free Surface Constructed Wetlands Based Upon a Coupled Ecological And Water Quality Model, Presented at the Fifth International Conference on Wetland Systems for Water Pollution Control, 1996.

George M.H, Gillespie W.B and Rodgers H, Use of constructed wetland to treat BOD and ammonia associated with a refinery effluent, Eco-toxicity and environmental safety, 45, 2000, 188-193.

Gersberg R.M, Elkins B.V, Lyons S.R and Goldman C.R, Role of Aquatic Plants in Wastewater Treatment by Artificial Wetlands, Water Research, 20, 1985, 363-367.

Gopichandran R and Prakash P, Environmental efficiency means greater economic benefits and improved competitiveness: Lesson for Indian chemical industries in particular, J. Environ. Poll. Con., 6(4), 2003, 45-47.

Hammer D.A, Constructed Wetlands for Waste water Treatment - Municipal, Industrial and Agricultural, Lewis Publishers, Chelsea, Ml, 1989.

Kikuth R, Degradation and incorporation of nutrients from rural wastewaters by plant rhizosphere under liminic conditions, Utilization of Manure by Land Spreading, Comm.of the Europ.Communities, EUR 5672e, London, 1977, 235-243.

King A.C, Mitchell C.A and Howers T, Hydraulic tracer studies in pilot scale subsurface flow constructed wetland, Water Science & Technology, 35(5), 1997, 189-196.

Metcalf & Eddy, 1991, 1979, 1972, Waste water Engineering, Volume 3,1.

Pastor R, Benqliou C, Cardenao G, Espura A and Puigjaner L, Design optimization of Constructed Wetland for wastewater treatment, Resource conservation and recycling, 37, 2003, 193-204.

Reed S.C, and Bastian R.K, Wetlands for Wastewater Treatment: An Engineering Perspective, In: Ecological Considerations in Wetlands Treatment of Municipal Wastewaters, Van Nostrand Reinhold, NY, 1985, 444-450.

Reed S.C, Brown D, Constructed Wetland Design -The First Generation, Jour.WEF, 64(6), 1992, 776-781.

Reed S.C, Middlebrooks E.J and Crites R.W, Natural Systems for waste management and treatment, McGraw-hill, NY, 1988.

Watson J.T, Constructed Wetlands for Municipal Wastewater Treatment: State-of-the-Art, Presented at: Symposium Epuration Des Eaux Usses Par Les Plants: Perspectives D'Avenir Au Quebec, Montreal, Quebec, and March 20, 1992.

WHO, Health guidelines for the use of wastewater in agriculture and aquaculture, Technical Report No. 778, Geneva, 1989, 74.

Zirschky J, Basic design rational for artificial Wetlands, Erm-southeast, inc, prepared for Usepa rskerl, ada, 1986.