Treatment of wastewater with modified constructed wetland system as a tertiary treatment unit

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Abstract: Incorporation of constructed wetlands into the sewage treatment process is done in order to mimic processes found in the natural ecosystems where wetland plants and their associated microorganisms remove pollutants from wastewater. Vegetation in a wetland provides a substrate upon which microorganisms can grow, and break down organic materials. These organisms and natural chemical processes are responsible for approximately 90% of pollutant removal and waste breakdown in nature. This research work has been undertaken with a view to integrating the natural ecosystem into the existing treatment plant on a large scale, which will be instrumental in minimising the use of machineries and reducing high investment and operating cost as well as energy consumption. The greywater can be reused for purification but the currently adopted process to obtain a secondary water source is complicated and expensive. The conventional process constructed wetlands can be used as a tertiary treatment unit of sewage treatment process.

Keywords: cost analysis; wetland; vegetation; wastewater; model.

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1 Introduction

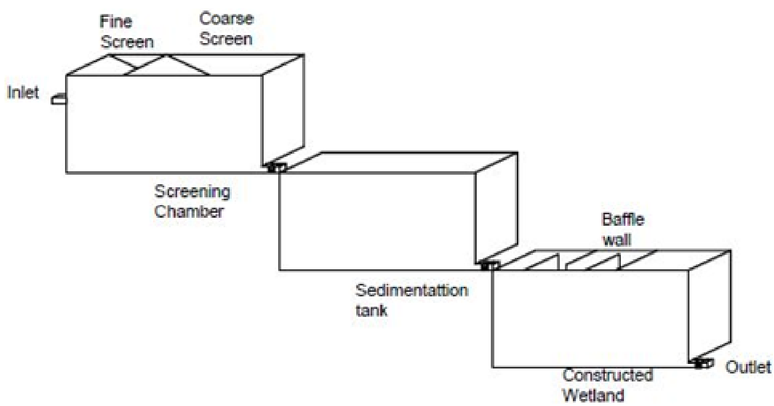
The present investigative research aims to study the feasibility of the constructed wetland unit for tertiary treatment of wastewater from the Sri Ramaswamy Memorial (SRM) Township. It includes a comparative study of the cost of a standard treatment plant and modified treatment plant. It also helps in determining the efficiency of the treatment plant by conducting different test trials on wastewater samples. A comprehensive review of the use of constructed wetlands for wastewater treatment is presented. The review highlights the efficiency and the practical application of the wetlands in the treatment of domestic, agricultural and various other types of wastewater (Vymazal, 2010). Earlier studies clearly show that wetlands are effective in filtering out remaining substances such as nitrogen, phosphate, etc. (Muthukumaran and Ambujam, 2001). Plants growing in the wetland and the microbes associated with them help in decay of the contaminants in the wastewater (Hammer, 2007).

In the present study a cost comparison analysis of constructed wetland unit as tertiary treatment of a sewage treatment plant is carried out and the same is considered as modified treatment plant. An effective sewage treatment plant with constructed wetland as a tertiary treatment unit was designed and the efficiency of the same was also studied with a lab-scale prototype unit (Vymazal and Habers, 2008). The cost comparison analysis of a normal sewage treatment (STP) plant with modified constructed wetlands on a tertiary treatment [modified sewage treatment plant (MSTP)] will help to implement the technology of constructed wetland at large scale (Garg, 2008; Brix, 1994). Modified constructed wetlands are found to be more economical than the construction of further sewage plants (Scholz and Xu, 2002; Soukup et al., 1994; Solano et al., 2003; Babatunde et al., 2008; Safari et al., 2013).

- Data collection: The research process involves the design and cost estimation of constructed wetland as a tertiary treatment unit besides in-depth review of literature related to the topic. Numerous articles and books are taken as reference for the design process and they form the basis for the current project. The design and cost estimation of standard and modified treatment plant necessities the collection of standard values are adopted for characterisation of wastewater using parameters like BOD, COD, pH, turbidity, total suspended solids, etc. After the analysis of wastewater, a comparison is made between the experimental values and done with the acquired values of various parameters. The design of the various units of the sewage treatment plants is based on the algorithms specified in the IS codebooks (IS 3370, 1967; IS 10500, 1991; IS 9481, 1981; IS 10261, 1982).

- Analysis of raw wastewater: In order to efficiently design a sewage treatment plant for treating wastewater, it is important to first determine the characteristic properties of the wastewater. So, samples of wastewater are taken from the SRM Township wastewater plant and tests are carried out to determine the properties of the samples (Std. Parameter Data, 2007). Three samples of wastewater were taken-one after primary treatment, one after secondary treatment and one after tertiary treatment (Figure 1). Tests are then conducted to analyse these wastewater samples (Mustafa, 2010). Constructed wetlands play a vital role in the efficient and feasible treatment of wastewater (Rajbhandari, 2010; Sudarsan et al., 2012).

Figure 1 3D view of lab-scale unit



2 Methodology and sewage treatment

The methodology describes the approach adopted for the analysis and the design of the different units of the sewage treatment plant. It is the introduction which gives a brief outline of the study. The method applied for cost estimation of the prototype model is shown in Figure 2. The important parameters considered in this study are also detailed.

A prototype model is developed to show the physical functionality of MSTP with constructed wetland as tertiary treatment unit. The design details of the conventional sewage treatment plant and MSTP help in the comparison of the two different types of treatment processes (Colmenarejo et al., 2006; Karrman, 2001; Nuhoglu et al., 2004). The treatment of wastewater is a chemical, physical and biological process that is energy-intensive and expensive (Jamrah, 1999). On comparison of the standard and MSTPs, it is found that the modified treatment plant is preferable due to the less use of machineries in this process. This leads to a reduction in the energy consumption of the plant. The different units of MSTP in the prototype model are screening, sedimentation and integrated constructed wetland unit (Erbe et al., 2002; Coskuner and Ozdemir, 2006; Metcalf and Eddy Inc., 1991).

Figure 2 Methodology of water treatment

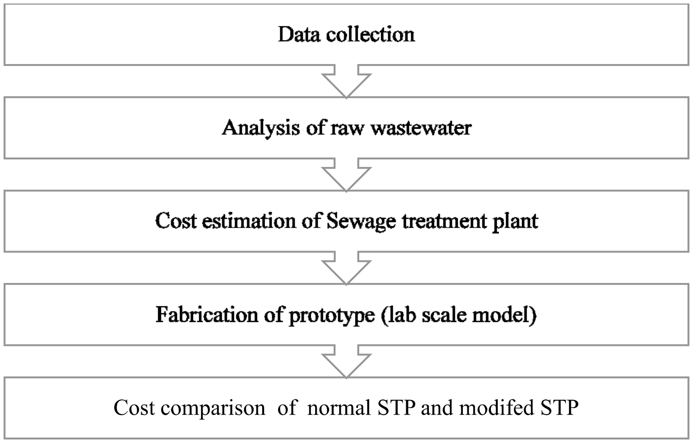
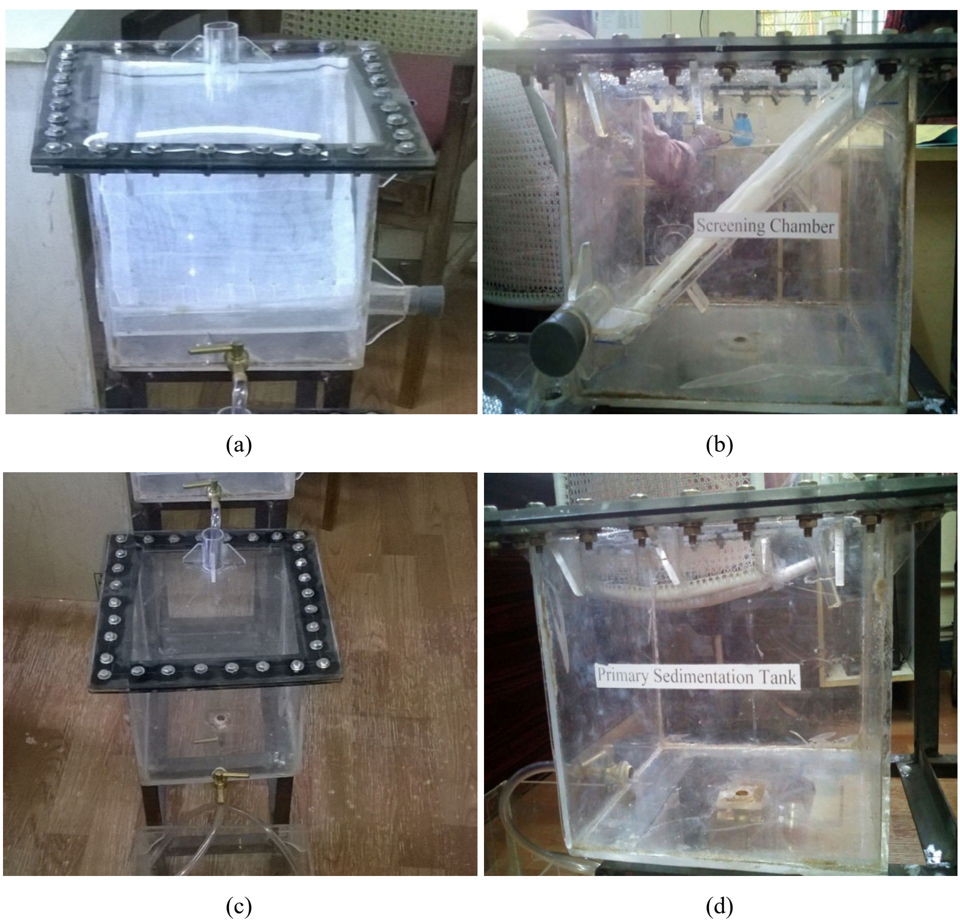


Figure 3 (a) Top view of screen unit (b) Side view of screen unit (c) Top view of sedimentaion tank (d) Side view of sedimentaion tank (see online version for colours)



It is necessary to use a screen for removing floating materials like leaves, sticks, branches, twigs, paper, etc and other debris. The screen is the first operating unit designed for the wastewater treatment plant (Paranychianakis et al., 2015). In the current study a wire mesh screen is provided for the primary treatment. Rectangular screens are widely used in the wastewater treatment plant. Figure 3(a) shows the top view and Figure 3(b) shows the side views of the prototype model of the screen unit.

The sedimentation tank is the second treatment unit of the wastewater treatment plant. After primary treatment, the sedimentation tank is used for removal of large suspended impurities by gravity. Figure 3(c) shows the top view and Figure 3(d) shows the side view of the sedimentation tank. The sedimentation tank is also used to remove the fine colloidal impurities (Angelakis and Gikas, 2014).

Figure 4 (a) Top and (b) side views of constructed wetland (see online version for colours)

(a) (b)

Figure 5 Prototype model of the MSTP (see online version for colours)

The constructed wetland is used in the tertiary treatment unit in the MSTP. Constructed wetlands can be used for removal of harmful bacteria, as well as undesirable colour, taste and odour along with high concentration of dissolved salt (Ren et al., 2007). The wastewater is suspended in this unit for a period of three days. Figure 4(a) shows the top view and Figure 4(b) shows the side view of the constructed wetland. Figure 5 shows the full model of MSTP.

3 Results and discussion

The standard values for various parameters of raw wastewater according to TNPCB are specified in Table 1.

Table 1 TNPCB discharge standard

	According to TNPCB norms: standard values
Total suspended solids	<100 mg/l
PH	6 to 9
Conductivity	1.5 ms
TDS	<2,100 mg/l
Turbidity	5 NTU
Hardness	500 mg/l
Chlorides	100 mg/l
COD	<250 mg/l
BOD	<30 mg/l

Table 2 Wastewater property after primary, secondary and tertiary treatment

Total suspended solids	*Primary*	*Secondary*	*Tertiary*
	700 mg/l	*400 mg/l*	*400 mg/l*
PH	7.1	7.5	7.51
TDS	2,100 mg/l	1,300 mg/l	900 mg/l
Turbidity	0.08 NTU	2.1 NTU	3.8 NTU
Chlorides	469.71 mg/l	538.84 mg/l	499.52 mg/l
COD	310 mg/l	253 mg/l	190 mg/l
BOD	200 mg/l	125 mg/l	90 mg/l

Samples are collected of the wastewater after it is subjected to primary, secondary and tertiary treatment. The samples are collected from the SRM treatment plant and various characteristic tests are then conducted. The analysis of wastewater after primary, secondary and tertiary treatment is done in order to ascertain the characteristics of wastewater, which are given in Table 3. This is done in order to ensure that the domestic wastewater is suitable for treatment with constructed wetland as a tertiary treatment unit.

Cost estimation: the cost and quantity estimation of the treatment units such as screening, primary sedimentation tank and constructed wetland are done for treating 1mld of wastewater and the results are given in Table 3. It is evident from Table 3, that the screening chamber and grit chamber have enough bags that cost rupees 1,517 and 84,173, respectively. The sedimentation tank and aeration tank are constructed with 410 and

10,080 bricks, at a cost of rupees 217,717 and 105,638, respectively. The wetland unit and filtration unit are constructed with 975 and 2,832 bricks, at a cost of rupees 17,712 and 105,730, respectively.

In brief, the construction cost of a normal sewage standard treatment plant is about Rs.1.48478 million, the machinery cost is around Rs.3.20000 million, and the operation and maintenance cost is 2.0 million excluding the land cost. In addition, a maintenance cost of the system is around Rs.0.002 million per year. But, the MSTP only costs Rs.0.26327 million which is about 23% less when compared to a normal sewage treatment plant with the same efficiency (Mitsch and Gosselink, 2000). The quantities and cost estimate for units such as screening chamber, sedimentation tank, constructed wetland, grit chamber, aeration tank, filtration tank along with plastering cost and white wash cost are shown in Table 3. Similar work has also been carried out earlier by some researchers (Mitsch and Gosselink, 2000).

Table 3 Cost and estimation

Description		*Quantity (m^3)*	*Units*	*Rate*	*Amount (rs)*
Screening chamber					
a	Bricks	0.35	155	6/bricks	930
b	Cement	0.38	1/2 bags	340/bags	170
c	Sand	0.087	-	1,412/m^3	123
Plastering					
a	Cement	0.006	-	340/bags	170
b	Sand	0.04	5.64 kg	1,412/m^3	56
c	Whitewash	2.82	-	12/kg	68
Total = Rs.1,517					
Sedimentation tank					
a	Bricks	14.21	410	6/bricks	139,400
b	Cement	21.35	21 bags	340/bags	30,146
c	Sand	42.63	-	1,412/m^3	48,171
Plastering					7,140
a	Cement	0.7	-	340/bags	4,236
b	Sand	3,165.48	-	1,412/m^3	7,056
c	Whitewash		-	12/kg	
Total = Rs.217,717					
Constructed wetland					
a	Bricks	1.95	975	6/brick	5,850
b	Cement	3.8	15 bags	340/bags	5,100
c	Sand	4.8	-	1,412/m^3	6,777
Plastering					
a	Cement	1.2	-	340/bags	4,080
b	Sand	3.8	34	1,412/m^3	3,388
c	Whitewash	4.8	-	121/kg	408
Total = Rs.17,727					

Table 3 Cost and estimation (continued)

Description		*Quantity (m³)*	*Units*	*Rate*	*Amount (rs)*
Grit chamber					
a	Bricks	7.68	3,840	6/bricks	23,040
b	Cement	21.42	154.4 bags	340/bags	52,436
c	Sand	4.28	-	1,412/m³	8,697
Total = Rs.84,173					
Aeration tank					
a	Bricks	20.16	10,080	6/bricks	60,480
b	Cement	15.84	114 bags	340/bags	38,776
c	Sand	3.14	-	1,412/m³	6,382
Total = Rs.105,638					
Filtration unit					
a	Bricks	56.64	2,832	6/bricks	76,132.8
b	Cement	31.10	223.92 bags	340/bags	16,992
c	Sand	6.2		1,412/m³	12,606
Total = Rs.105,730					

The integration of constructed wetland into the sewage treatment plant as a tertiary treatment unit serves as an effective option for domestic wastewater treatment (Crites, 1994). If the wetland unit is properly designed, installed and maintained it will increase the efficiency of wastewater treatment in the MSTP. The lab-scale prototype integrated constructed wetland unit along with the primary and secondary treatment units are designed according to the standard specifications and codes that serve as the design guidelines. MSTP is an option to consider when land is available at a reasonable cost. It is also environment-friendly as the application of chemical and mechanical equipment is very less. Constructed wetland is effective in the treatment of wastewater; it is best suited for community wastewater treatment (He et al., 2007). There are different types of vegetation used but wetland plants like Phragmites and Typha are ideally suited best for field conditions. The species has the ability to survive in wet conditions whereas Typha needs standing water all the time (Calheiros et al., 2008). Fabrication of a lab-scale model of treatment unit with *Typha* plant is done and trial study was carried out for 20 litres of domestic wastewater. A detailed analysis of SRM Township wastewater is done to assess the characteristics of wastewater and to identify the efficiency of the treatment unit in treating the wastewater the modified prototype STP was used and based on the analysis, it was found that BOD, COD, total solids and total suspended solids are very high at the primary and secondary treatment levels (Kayranli et al., 2010). After passing through the constructed wetland unit, there is a drastic reduction in the organic characteristics of domestic wastewater. It is found that the total solids, TSS, BOD, COD are slightly higher than the discharge standard values (suspended solids = 100 mg/l, BOD = 30 mg/l, COD = 250 mg/l). Based on the analysis, it is evident that constructed wetland can be used for effective treatment of domestic wastewater and it can be used as a tertiary treatment unit in the MSTP (Wu et al., 2015).

To ascertain the feasibility of using constructed wetland as a part of the tertiary treatment unit and to check the economic, ecological and technical aspects of MSTP for treating 1 MLD of wastewater, a detailed cost comparison with standard STP is carried out. Based on the study, the MSTP appears to be eco-friendly as well as technically and financially feasible when compared to the standard STP (Kaiser, 2003).

The detailed cost estimation of a standard STP and the proposed MSTP is carried out. The standard wastewater treatment plant has a total cost of Rs.1.4847 million whereas the cost of the modified treatment plant is only Rs.0.26327 million. Therefore, it is clear that the MSTP is far economical than the standard STP. If land is easily available at a reasonable cost and if the unit is properly maintained, MSTP will be very useful in the small-scale treatment of domestic wastewater (Richardson et al., 1996).

4 Conclusions

The recycled use of grey water as a secondary source of water is common practice all over the world. The study clearly shows that a constructed wetland successfully used as a tertiary treatment unit in a sewage treatment plant as it is a more economical as well as more efficient method to remove the impurities in wastewater when compared to the conventional sewage treatment plant. The MSTP model with the low construction cost of Rs.0.26327 million and low maintenance cost, can be considered as a viable alternative to the construction of an increased number of sewage treatment plants. It can be effectively deployed in developed and undeveloped countries to reduce the impact of sewage treatment on the environment.

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