J. Mater. Environ. Sci. 7 (9) (2016) 3256-3263 *Patil et al.*
ISSN : 2028-2508
CODEN: JMESC

Application of Constructed Wetland using *Eichhornia crassipes* for Sewage Treatment

Satish S Patil[1*], Vinayak P Dhulap[1] and Geetanjali Kaushik[2]

[1]*Department of Environmental Sciences*
Dr. Babasaheb Ambedkar Marathwada University
Aurangabad, 431004, Maharashtra, India
[2]*Department of Civil Engineering, MGM's Jawaharlal Nehru Engineering College, N-6 CIDCO, Aurangabad, Maharashtra, India.*

Received 28 Feb 2016, Revised 09 Jul 2016, Accepted 15 Jul 2016
**Corresponding author. E-mail: geetanjaliac@gmail.com (SS Patil); Phone: +91 9422707261*

Abstract
India is facing acute shortage of clean water for drinking and other purposes. Most of the water resources are polluted by discharge of domestic sewage. The municipal sewage systems used in developed countries are often too expensive to build and operate thus low–cost; low–tech alternatives for treating wastes are needed. An alternative is to use natural or artificial wetlands to dispose of wastes. In this research constructed wetland with water hyacinth plant has been tried to reduce the pollutant load of sewage. It is found that the system is capable of removing pollutants and the hydrophyte has shown its ability to survive in high concentration of nutrients with significant nutrient removal. In all the sets of dilution of wastewater, DO (dissolved oxygen) levels increased after treatment. In 100% sewage dilution BOD (biological oxygen demand) was observed to be 230 mg/L which decreased to 120 mg/L. Reduction of metals was noticed in all treatments with reduction in Co, Cu and Fe were found to be78.78%, 28.90% and 23.42% respectively. The results obtained from analysis of treated wastewater indicated that the treated water can be useful for agriculture, washing, gardening, planting or any other purposes.

Keywords: Wetland, Water hyacinth, sewage treatment, nutrient removal

1. Introduction - Waste water generation in India and application of Constructed Wetlands

In present scenario most of our water bodies, surface as well as groundwater are suffering from pollution by manmade activities. Most of the water resources are polluted by discharge of domestic sewage [1]. Due to indiscriminate discharge of wastes the pollutant load often exceeds the natural ability of that water body to remove the undesirable material or dilute it to a harmless form [28]. Presence of sewage promotes the growth of phytoplanktons. This excessive growth depletes the oxygen of water which adversely impacts the aquatic faunal population. Sewage mostly contains a large number of inorganic and organic impurities [29] cysts of pathogens, bacteria and viruses causing waterborne diseases such as cholera, dysentery, hepatitis, typhoid, gastroenteritis, enteric fever and malaria etc [2].

As per Central Pollution Control Board (CPCB) India observations, there are about 233 class - I cities in 14 major river basins of India. Their population is about 1.05 billion. These cities have been partially covered with sewerage system (about 24% only). Therefore, almost 76% of the untreated sewage from these cities reaches to freshwater bodies mainly rivers and lakes. Class -II cities do not have sewerage systems at all for the collection of sewage. Today, just the collection of sewage is not enough. It has to be treated as well. So, all these urban wastewaters are naturally taken to the nearby rivers and lakes by *nallas* and *odhas* (streams - natural drains). These natural drains in the cities are serving as sewerage lines [3]. Shrishti Eco-Research Institute (SERI) studied water pollution in Western Indian state of Maharashtra and examined the pollution of water bodies in 10 corporation areas – viz. Ulhasnagar, Kolhapur, Pune, Nashik, Sangali–Miraj, Pimpri-Chinchwad, Dhule, Jalgaon, Malegaon and Ahmednagar [4]. Some of the corporations in Pune and Nashik have provided sewerage lines but these are inadequate to cater to the needs of population. So, in most of the cities sewage flows down to the rivers such as Kolhapur's Panchganga, Ulhasnagar's Ulhas, Pune's Mula- Mutha-Pavna, Dhule's Panzara, Solapur's Bhima etc this water pollution problem needs environmental friendly treatment solution [5].

The municipal sewage systems used in developed countries are often too expensive to build and operate in the developing world where low–cost, low–tech alternatives for treating wastes are needed. One option is effluent sewerage, a hybrid between traditional septic tank and full sewer system. Another alternative is to use natural or artificial wetlands to dispose of wastes. Wetland waste treatment systems are now operating in many developing countries [6]. A wetland, by definition, must maintain a level of water near the surface of the ground for a long enough time each year to support the growth of aquatic vegetation. Marshes, bogs, and swamps are the examples of naturally occurring wetlands. The system of planting aquatic plants such as reeds or bulrushes in a wet (often gravel) substrate medium for gray water recycling is called a "Constructed Wetland (CW)" or "Artificial Wetland" or "Human Engineered Wetland". The first artificial wetlands were built in the 1970s. By the early 1990s, there were more than 150 constructed wetlands treating municipal and industrial wastewater in the United States [7]. Since then, various designs of constructed wetland systems have been developed and thousands of facilities are currently in use in Europe, Australia and the United States [8, 9, 10]. Recent years have seen the proliferation of constructed wetland systems in Africa and Asia. Wastewater treatment in constructed wetlands occurs by several mechanisms such as dilution with rainfall, chemical reactions and biological activity that transforms and filters the wastewater. They can often be an environmentally acceptable, cost-effective treatment option, particularly for small communities [11].

CW's are designed especially for the pollution control and exist in locations where natural wetlands do not present. Generally, two types of CW's are in common use today such as surface flow and subsurface flow. Reed beds are a particular type of constructed wetland usually consisting of a gravel-filled container or bed planted with reeds. Wastewater flows through the gravel and reed-roots and is purified by the actions of millions of bacteria, fungi and algae (micro-organisms) that digest the sewage (Figure 1). They can be used in several ways: sewage treatment companies commonly use reed beds as a 'polishing' stage at rural works following conventional treatment to give a cleaner effluent. Reed beds also effectively provide complete sewage treatment for households and small communities not served by main sewerage [12].

The FWS wetland removes suspended solids primarily by flocculation/sedimentation and filtration/interception. The aerobic microorganisms consume oxygen to breakdown organics which provides energy and biomass for the microorganisms. The separation processes of organics include sorption and volatilization. The biofilms located on plant surfaces offer pathways for plants to break down organics. Although the amount volatile organic compounds entering wastewater wetlands is fairly low, the removal rate of VOCs are in the 80-96% range [26, 30].

The water hyacinth, for example, can remove phenols, fecal coli forms, suspended particles and heavy metals including lead, mercury, silver, nickel, cobalt, and cadmium from contaminated water. In the absence of heavy metals or toxins, water hyacinths can be harvested as a high-protein livestock feed. It can also be harvested as a feedstock for methane production. Reed-based wetlands can removes a wide range of toxic organic pollutants. Duckweeds also remove organic and inorganic contaminants from water, especially nitrogen and phosphorous [13] Performance data suggested that a well designed reed bed system can remove more than 98% of the organic matter in sewage, 60–80% of the nitrogen and up to 60% of the phosphates. **Water hyacinth (*Eichhornia crassipes*), Duck weed (*Lemna* spp), *Spirodela* spp, *Wolffia* spp** among others are plants that have proven to be highly efficient in removing a wide range of pollutants, suspended materials, BOD, nutrients, heavy metals and pathogens [14]. *Eichhornia Crassipes* is notable in terms of possessing highly glossy leaves, extensive root system and its ability to grown vegetatively [15, 16]. The species has demonstrated its excellent pollutant removal in wastewaters [17, 18].

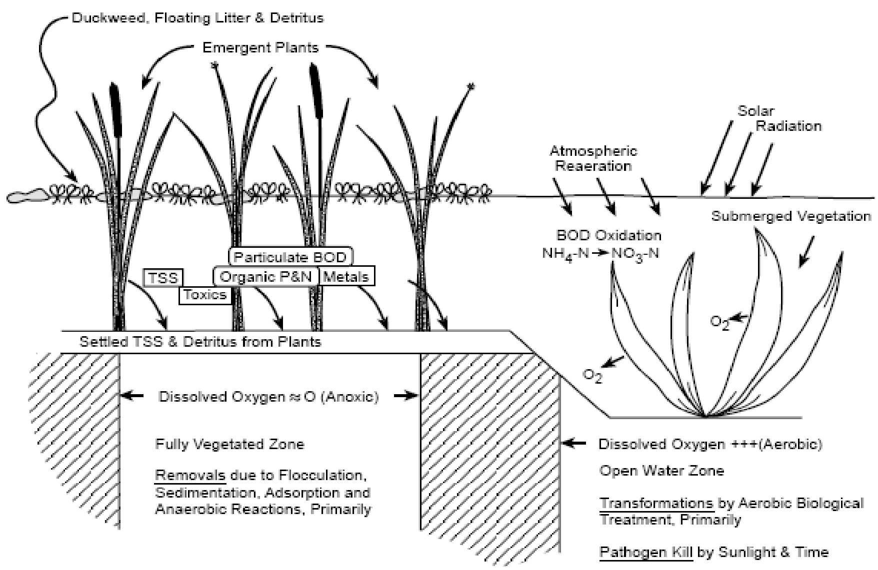

Figure 1: Mechanism of working of a Constructed Wetland

Application of Constructed Wetland Technology in India

The ***phytorid* technology** implemented by the National Environment Engineering Research Institute (NEERI) is an application of constructed wetlands for wastewater treatment. It is a low-cost technology which is simple to construct and can be easily utilized with in residential areas, public and industrial zones. This technology relies on specific plants which include Elephant grass (*Pennisetum purpurem*) several types of cattails, reeds, canna lilies and yellow flag iris (*Iris pseudocorus*). Systems may also use other ornamental plants such as bamboos. The three stages or zones within a phytorid system include inlet, treatment area and outlet zone. In the inlet area of phytorid water passes through bricks and stones. Then, it enters a treatment zone which has different plants. Finally the water exits through the outlet zone. Subsequent to the treatment process, the effluent can be utilized for irrigation purpose or in water fountains. NEERI's phytorid technology has been applied in the Mumbai University Kalina Campus in June 2006. According to estimates the constructed wetland removed 75% of total suspended solids and 91% of the water's fecal coliform. In addition it was 94% effective in reducing the biochemical oxygen demand. Other ongoing projects include the Teen Murthi Bhavan and Smriti Vatika in New Delhi [27].

2. Experimental

2.1 *Study Area*

Solapur is one of the important town places in the state of Maharashtra. It is famous for Handloom and Powerloom industries. This city covers an area 14844.6 sq. kms. The city has been spread approximately between 17^0 36' to 17^0 42' N latitude and 75^0 50' to 75^0 58' E longitude. This city is the 7^{th} largest city in the Maharashtra state by population size heading towards more than 10 lakhs (1 million) in future. Solapur city falls under the arid to semi arid climate and receives irregular, erratic scanty rainfall, with annual average of around 500 mm to 700 mm. Solapur experiences relatively higher temperature throughout the year, reaching up to 45^0 - 47^0 in April-May months and the relative humidity varies between 20 to 90%. The city is situated in the Bhima Basin [5].

2.2 *Collection of Sewage or wastewater*

Wastewater or domestic sewage generated from Solapur is mostly discharged into city by open *nala's* or it is discharged into various parts of city which includes open lands and small and large streams. City has major streams like Shelgi stream, Bale stream, Degaon stream which all are connected to each other and finally combine and meet the Sina River. Sina River is a sub River of Bhima. In the present study, sewage samples were collected from Shelgi Nala, near Pune naka of Solapur city (MH). This nala is a major cause of environmental pollution of Solapur city, as water bodies, agricultural land wells and bore wells were contaminated through this nala [5]. Sewage samples were collected from different locations in a day and all these samples were combined and a separate single sample was prepared. This sample was used for the treatment in the methods of testing in constructed wetland.

2.3 *Analysis of Sewage samples*

Sewage was not directly flowed because the aim is to understand the variation in treated water using percentage wise dilution and to check the pollution removal efficiencies of the plant in the constructed wetland. Analysis of sewage samples was carried out before and after treatment using different parameters (Physico-chemical and biological) for understanding the pollution level (pollution removal efficiency) and the extent of treatment of water quality. Studied parameters mainly included pH, EC, color, odor, solids, BOD, COD, chlorides and nitrates (APHA, 2005). Untreated and treated sewage samples of the constructed wetland were analyzed for heavy metals using acid digestion and their estimation was done through AAS. The healthy natural plants of *E. crassipes* were collected from ponds and used for the surface flow CWs.

2.4 *Constructed Wetland set up*

In the experimental set up, three sets of buckets (with different dimensions) were used. Vertical bucket was used as holding tank (Inlet) to hold the waste water with an inlet (30L capacity). The rectangular tub (10L) of 17052 cm^3 area was used as a bed for root zone treatment. The plastic cans were used for the collection of treated water flowing out from the root zone bed through the outlet. Treated water samples were collected and analyzed in laboratory. All three tubs i.e. 1) Inlet 2) Root zone tub and 3) Outlet were connected to each other with taps and water pipes (Figures 2 and 3). Flow rate was maintained same at inlet and outlet. Horizontal with flow rate of 0.5 L/ hr surface flow method was preferred for the treatment tests. Flow rate was adjusted by Bucket method with the help of timer and setting of tap. Retention time of about 96 hrs (4 days) was provided for achievement of significant pollution reduction efficiency. Initially young and new plants weeds were acclimatized in the laboratory and then wastewater sample was passed through the bed. The waste water sample with different dilutions or concentrations viz. 20%, 40%, 50%, 60%, 80% and 100% were prepared and passed through plant bed. Each of these dilutions was studied for assessment of pollution reduction efficiency [5]. As mentioned earlier the sewage samples were analyzed before and after treatment for various physic-chemical and biological parameters by using standard methods [20].

Figure 2 and 3: Constructed Wetland design and set up using *E. crassipes*

3. Results and Discussion

The study focused on the overall performance of *E. crassipes* for the treatment of domestic wastewater. Water quality parameters studied such as pH, DO, BOD, COD, Nitrate, Chloride, TS, TDS, TSS and heavy metals reflected different treatment efficiencies. The color and odor were removed and hence treated samples were observed clear and odorless. The pH values before and after treatment changed at different sets of dilutions. In all sets of dilutions the results obtained were in near to the neutral form (Table 1, Figure 4). In 100% dilution the pH was 6.7 in before treatment but after treatment it was 7.2. The effluent standard enacted by Central Pollution Control Board, India specifies the pH of effluent to range between 6.5 and 7.5 which was achieved in all treatment tests. The DO values changed after treatment of wastewater through *E. crassipes* in various sets of dilutions. Without dilution of sewage it was observed to contain very less DO due to the presence of high amount of organic and inorganic matter and had noxious smell. But, after treatment the DO values improved. In 20% dilution the DO mg/L in before treatment was 0.0 and after treatment it increased to 1.3 mg/L. Similar trend was noticed in 100% dilution the DO before treatment was 0.6 and after treatment it became 3.2 mg/L. In all the sets of dilution of wastewater, dissolved oxygen levels increased after treatment.

Solid contents such as TDS (Total dissolved solids), TSS (Total suspended solids) and TS (Total solids) estimated through this technique reflected better treatment. The maximum reduction of solids was found in 80 % dilution. The BOD_5 was estimated in the samples before and after treatment. In 20 % dilution BOD was 210 mg/L before treatment and after treatment it reduced to 160 mg/L. Likewise in 100% sewage dilution BOD was observed to be 230 mg/L which decreased to 120 mg/L. Better BOD reduction was observed from 20% to 80% and then reduction was less. This BOD removal efficiency is a function of Hydraulic Retention Time (HRT). Longer HRT increases the interaction within the aquatic plant system, which results in higher organic matter which can further improve treatment efficiency [21]. The COD values before treatment and after treatment varied in all sets of dilutions. In the 20% dilution, COD before treatment was 290 mg/L and after treatment reduced to 220 mg/L. The COD reductions were found in increasing order up to 80 % then there was less reduction. Similar trend has been reported 75% reduction of BOD at 80% and 71% at 100% concentration of Lake Water [14]. The values of nitrate showed variable concentration at various dilutions. In 80% and 100% sets of dilution, maximum reduction was observed. The values of chlorides in before treatment and after treatment varied in all sets of dilutions.

Table 1: Physico- Chemical Parameters of waste water before and after treatment with *E. crassipes*

Parameters / Treatment	pH		DO mg /L		TSS mg /L		TDS Mg /L		TS mg /L		BOD mg /L		COD mg /L		NO_3 mg /L		Chlorides mg /L	
	B.T*	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T	B.T	A.T
20% Sewage	7.5	7.2	1.1	1.3	710	595	840	545	1550	1140	210	165	290	220	4.0	3.0	24.14	22.10
40% Sewage	7.4	7.2	0.9	1.4	806	710	950	520	1756	1230	200	144	310	192	5.1	3.5	26.98	24.15
50% Sewage	7.2	7.1	0.8	1.9	844	749	990	495	1834	1244	220	138	330	186	6.0	3.2	27.13	23.16
60% Sewage	7.1	7.0	0.7	2.2	888	690	1123	450	2011	1140	220	130	342	156	8.0	3.9	27.20	24.10
80% Sewage	6.9	7.1	0.0	2.8	1805	600	1140	580	2945	1180	230	118	320	172	8.5	3.0	28.40	22.80
100% Sewage	6.7	7.2	0.0	3.2	1920	970	1240	610	3160	1580	230	120	315	160	9.2	1.23	44.02	36.10

** B.T. means Before treatment and A.T. means After Treatment*

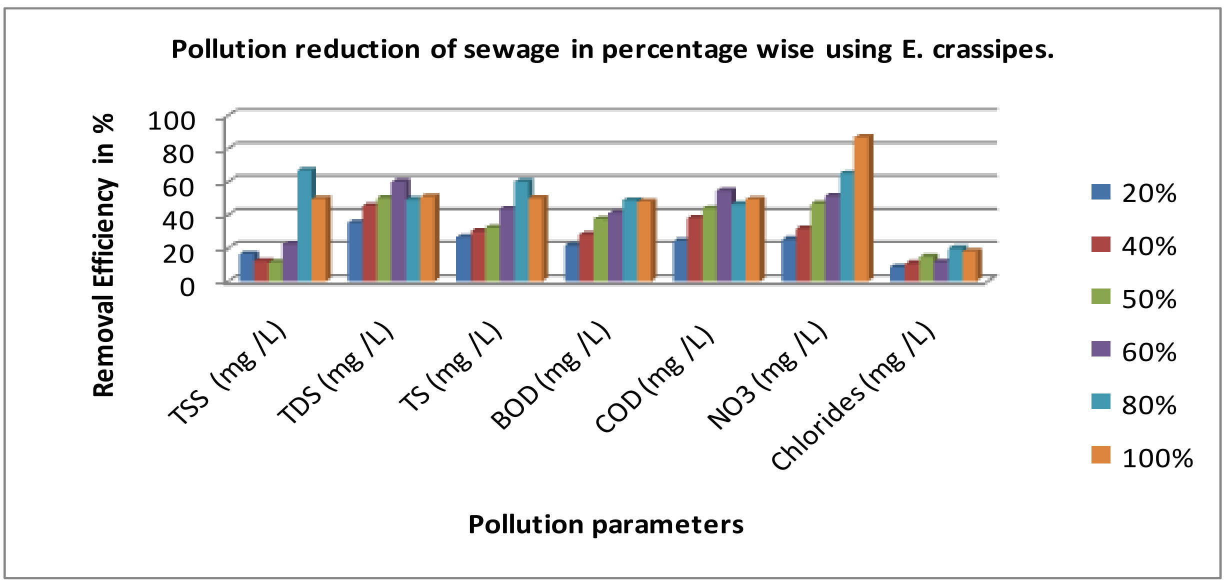

Figure 4: Reduction in physico-chemical parameters of sewage using *E. crassipes*

Presence of common heavy metals viz. Cu, Ni, Co, and Fe in domestic wastewater was determined before and after treatment (table 2). Selected plant parts such as root, stem and leaves were used for the estimation of heavy metals.

The metal reduction was noticed in all treatments. The Co was reduced by 78.78%, Cu was reduced by 28.90%, Fe by 23.42% and Ni by 1.32%. The results obtained from analysis of treated wastewater indicated that the treated water can be useful for agriculture, washing, gardening, planting or any other purposes.

Table 2: Analysis of metals in the plant parts of *E. crassipes*

Metals	Metals Before Treatment in the plant parts (mg)	Metals After Treatment in the plant parts (mg)	(%) Efficiency
Cu	2.069	2.667	28.90
Ni	0.227	0.230	1.32
Co	0.033	0.059	78.78
Fe	0.175	0.216	23.42

Wetland is a useful technique for the cleanup of waste water [22]. It has shown the ability of bioaccumulation and degradation of contaminants with *E. crassipes.* This plant has been studied and reported as suitable for wastewater treatment [23]. Experiments were performed in tanks with semi-continuous sewage flow in the presence and absence of water hyacinths and pennywort. In these fixed flow rate experiments (1.5 L /min), removal of BOD from 130 down to 10 mg/L was established [24].
Eichhornia Crassipes wetland achieved a high performance in removing 70% of BOD, 68% of COD, 41% of Total Solids (TS), 100% zinc, 30% nitrate, 38% chloride and 94% sulphates respectively [16]. The effectiveness of sewage purification by aquatic plants, such as water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*) was tested on laboratory and pilot scales. Cascade and semi-continuous pilot experiments verified that the plants were capable of decreasing all tested indicators of water quality (BOD, COD, TSS and turbidity) to levels that permit the use of the purified water for irrigation of tree crops. The laboratory-scale tests confirmed the capacity of the plants to reach and hold reasonably low levels of BOD (5–7 mg/ L) and COD (40–50 mg /L) and very low levels of TSS (3–5 mg/L) [25]. The mean COD and BOD5 reduction were 80% and 86% at 14 h HRT in a water hyacinth wetland system [26].

Study limitations

On account of limited time and resources the author studied one plant species within the constructed wetland system however; other species should also be investigated for their treatment potential. Another limitation of the study was its being conducted in one season, season also impacts plant performance and hence treatment potential, therefore a comprehensive study investigating performance in whole year needs to be undertaken.

Future Scope

In future studies a constructed wetland with a combination of plant species could be used for better treatment potential. The performance of this combination should be studied for the whole year i.e. during different seasons for a better assessment of treatment potential of species within the different seasons.

Conclusions

The Constructed Wetland with hydrophytes (water hyacinth plant) is capable of removing pollutants and the hydrophyte (*Eichhornia crassipes)* has shown its ability to survive in high concentration of nutrients with significant nutrient removal. The use of water hyacinth plant aquatic system can help reduce pollutant load, improve water quality and the treated water can be useful for agriculture, washing, gardening, planting or any other purposes.

References

1. Dhote S., Dixit S., *Environ. Monitor. Assess.* 152 (2009) 149–153.
2. Benyamine M., Backstrom N., Sanden, P., *Environ. Monitor. Assess*. 90 (2004) 171-185.
3. Kumar S. G., Joseph N., *Indian J Occup Environ Med*. 16 (2012) 150-151.

4. Joshi S., *J. Int. Emer. Med.* 27 (2000) 98-102.
5. Chavan B. L., Dhulap V.P., *J. Environ. Res. Develop*. 7 (2014) 660-667.
6. Gupta P.K., Kumar N., Kumar M., *Int. J. Res. Eng. Technol*. 4 (2015) 243-252.
7. Zhang L., Wang M-H., Hu J., Ho Y-S., *Ecol. Eng*. 36 (2010) 973-980.
8. Scholz M., Harrington R., Carroll P., Mustafa A., *Wetlands* 27(2007) 337-354.
9. Vymazal J., *Sci. Total Environ*. 380 (2007) 48-65.
10. Brix H., *Water Sci. Technol*. 30 (1994) 209-223.
11. Moreno D., Pedrocchi C., Comin F.A., Garcia M., Cabezas A., *Ecol. Eng.* 30 (2007) 103–111
12. Shivanand Y.A., *Poll. Res.* 27(2008) 501-502.
13. Mitsch W.J., Tejada J., Nahlik A., Kohlmann B., Bernala B., Hernandez C.E., *Ecol. Eng* 34 (2008) 276–288.
14. Dhote S., Dixit S., *Asian J. Exp. Sci*. 21(2007) 427-430.
15. Kumari M., Tripathi, B.D., *Ecol. Eng*. 62(2014) 48–53.
16. Olukanni D.O., Kokumo K.O., *Am. J. Eng. Res*. 2 (2013) 450–454.
17. Maine M. A., *Ecol. Eng*. 26 (2006) 341-347.
18. Skinner K., *Environ. Poll*.145 (2007) 234-237.
19. *American Public Health Association (APHA),* (2005) Washington, DC.
20. Kanabkaew T., Puetpaiboon U., *Songklanakarin J. Sci. Technol*. 26(2004)749-756.
21. Mander U., Mitsch W.J. *Ecol. Eng.* 35 (2009) 153–158.
22. Sooknah R., *J. Sci. Tech. Res.* 6 (2000) 49-57.
23. DeBusk T.A., Reddy, K.R., *Water Sci. Technol.* 19 (1987) 273–279.
24. Zimmels Y., Kirzhner F., Malkovskaja A., *J. Environ. Manage*. 81 (2006) 420– 428.
25. Valipour A., Raman V. K., Ahn Young-Ho., *Water* 7 (2015) 329-347.
26. Vymazal J., *Sci. Total Environ*. 380 (2006) 48-65.
27. http://www.neeri.res.in/content/phytorid-wastewater-treatment-technology.
28. Patil, S. S., Kaushik, G.K., *Int. J. Env.* 5 (2016) 75-88.
29. Bandela N.N., Babrekar M.G., Jogdand O.K., Kaushik, G.K., *J. Mater. Environ. Sci.* 7 (2016) 1972-1978.
30. Kulasekaran A., Gopal A., Alexander J. J., *J. Mater. Environ. Sci.* 5 (2014) 859-864.

(2016) ; http://www.jmaterenvironsci.com