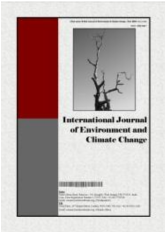

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Influence of Aquatic Plants and Flow Rate on Physico-chemical Characteristics of Sewage Effluent Treated through Constructed Wetland Technology

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate the influence of aquatic plants and flow rate on physico-chemical properties of sewage effluent with constructed wetland technology.
Study Design: Randomized block design
Place and Duration of Study: Department of Environmental Sciences**,** Tamil Nadu Agricultural University, Coimbatore - 03 and June 2020 – Dec 2020
Methodology: Constructed wetland (CW) model was designed and three different aquatic plants *viz., Canna indica*, *Arundo donax*, *and Xanthosoma sagittifolium* were used for the study. Two different flow rates *viz*., 5ml/min and 10 ml/min were compared for assessing their influence in treating sewage effluent in the constructed wetlands.
Results: Among the aquatic plants, the pollutants like BOD, COD,TDS and TSS in the sewage effluent were declined and found to be 320, 1220, 666, 22 mg L^{-1} in *Canna indica* and 340, 1380, 866, 36 mg L^{-1} in *Xanthosoma sagittifolium* and 340, 1380, 866, 36 mg L^{-1} in *Typha angustifolia* utilized treatments at flow rates 5 ml/min respectively during 7[th] day retention time*.* Similar decreasing trend was observed in BOD, COD, TDS and TSS of the sewage effluent at flow rates of 10 ml/min.

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Conclusion: Based on the study, it was evident that constructed wetland (CW) with *Canna indica, Xanthosoma sagittifolium and Typha angustifolia* found to perform better under flow rate of 5 ml/min for treating sewage effluent at the retention time of 7 days.

Keywords: Aquatic plants; sewage effluent; constructed wetland technology.

1. INTRODUCTION

Sewage is wastewater that is released from homes as well as commercial, institutional, and public institutions in the area. Wastewater that is not properly treated can have serious consequences for the environment and human health. Fish and wildlife populations may be affected, oxygen levels may be depleted, beach closures and other restrictions on recreational water use, fish and shellfish harvesting restrictions, and drinking water contamination may occur. Hence, treatment of sewage effluent by using an eco-friendly, viable technology is needed for effective recycling and therefore, constructed wetlands (CWs) will be the best option. CWs are complex, integrated systems that include water, plants, animals, microorganisms, and the environment. Wetlands provide a variety of purposes, including water purification, water storage, carbon and other micro and macronutrient digestion and recycling, shoreline stabilisation, and plant and animal support. CW is a shallow manmade basin filled with substrate (typically soil or gravel) and flora that can withstand saturated conditions. Water is then directed into the system from one end and flows over the surface (surface flow) or through the substrate (subsurface flow) before being released from the other end at a lower position through a weir or other device that regulates the water depth in the wetland [1]. “Wetlands serve a variety of purposes and provide numerous advantages. Wetland functions are the natural processes that take place in wetlands, while wetland values are the characteristics of wetlands that civilization considers to be helpful” [2]. Slow flows with shallow waters or saturated substrates characterise wetland hydrology, allowing sediments and other pollutants, especially emerging toxins, to settle as water moves through the system. Surface flow wetlands, subsurface flow wetlands, and hybrid systems that include surface and subsurface flow wetlands have all been classified under constructed wetlands [3,4]. Hybrid constructed wetlands comprising of horizontal subsurface flow and vertical flow significantly helps in treating the municipal wastewaters compared to conventional treatment methods [5]. “Constructed wetland systems can also be used in conjunction with traditional treatment methods to improve treatment efficiency” [6]. “The selection of constructed wetland types depends on the prevailing environmental conditions and also the type of wastewater to be treated such as domestic wastewater, agricultural wastewater, coal mine drainage, and storm-water” [3]. The present study aims to assess the efficiency of various aquatic plants with different flow rates under CW in treating the sewage effluent.

2. MATERIALS AND METHODS

Sewage effluent for the study was collected at the Sewage Treatment Plant (STP) located near staff quarters of Tamil Nadu Agricultural University, Coimbatore. Three different aquatic plants namely Indian shot (*Canna indica*), Giant reed (*Arundo donax*), and Arrow leaf elephant ear (*Xanthosoma sagittifolium*), were collected from Muthanangulam, Nagarajapuram, Telungupalayam in and around lakes of Coimbatore district. The collected plants are authenticated and certified by Botanical Survey of India (BSI), Coimbatore and then plants utilized for the research studies.

A horizontal flow system was designed for a lab scale model constructed wetland. All the nine reactors were in uniform size of 65×40×50 cm (L×B×H). Gravel, coarse sand, and garden soil were employed in the experiment. Each reactor had a 20-mm gravel size, a 50-percent porosity sand, and a 32-percent porosity soil. Saline tubes were placed in the inlet to facilitate the average flow rate inside the created constructed wetland system.The treated effluent collecting outlet was set up with silica tubes at the bottom of the wetland system. Six model constructed wetlands were created, each with two different flow rates for each of the three aquatic plants that were planted [7]. Aquatic plants like *Canna indica*, *Xanthosoma sagittifolium* and *Typha angustifolia* of uniform sizes was selected and washed thoroughly. The initial weight of the plants was recorded and later, (3 nos.) of plants of each species were placed in the model constructed wetland. The collected sewage effluent was placed at an elevated position and the effluent was passed with average flow of 5 ml/min and 10 ml/min in each of two constructed wetlands. The sewage effluent was passed through the model constructed wetland system for a retention time of (1, 2, 3, 4, 5, 6, and 7) while maintaining the average flow in each constructed wetland. The treated effluent was collected after the retention time of 1st, 2nd, 3rd, 4th, 5th, 6th and 7th day. The collected treated effluent was subjected to various water quality analysis following the standard analytical procedures.

3. RESULTS AND DISCUSSION

The initial sewage effluent used for model constructed wetland was alkaline with a pH of 7.98 and an Electrical conductivity (EC) of 2.93 dS m^{-1}. The redox potential (Eh) of the effluent was -699 mV. The total dissolved solids in the effluent were 2448 mg L^{-1} and the total suspended solid was 460 mg L^{-1}. The Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) of the initial sewage effluent were 610 and 2860 mg L^{-1} respectively. The total nitrogen and total phosphorus in the effluent were 0.35 and 0.41 % respectively. Heavy metals observed were Nickel (5.18 mg L^{-1}), Lead (8.62 mg L^{-1}), chromium and Cadmium was below detectable level in the sewage effluent. The total coliforms were 1600 MPN/100 ml.

The effect of the plants on pH of the sewage effluent after treatment in model constructed wetland was showed in Table1. pH shows a decreasing trend on increasing the retention time. *Canna indica* recorded a mean minimum pH of 6.79 and 7.05 at flow rates 5 ml & 10 ml/min respectively followed by *Xanthosoma sagittifolium* with respect to the retention time, 1st day recorded as mean pH of 7.46 and 7.52 at flow rates of 5 ml and 10 ml/min which declined to 6.29 & 6.90 on 7th day for flow rate 5 ml and 10 ml respectively. The present investigation to access the influence of plants, retention time and two different flow rates in the pH of the sewage effluent, through the model constructed wetland, reveal that the pH got decreased from D_1 and D_7. The flow rate 5ml/min performed well compared to flow rate 10 ml/min. Among the aquatic plants, *Canna indica* was significantly superior to other plants. The decrease in the pH in the lower HLR may be due to more contact time of the effluent with the plant and the medium used in the study [8] also reported that “HRT plays a major role in the reduction of pH based on the plants and substrate utilized for the study”. “In general, the physical effects of root structure combined with aeration is the most important mechanism by which plants contributes to the CW process” [9].

The Electrical conductivity of the sewage effluent collected from two different flow rates *i.e.*, 5 ml/min and 10 ml/min showed a declining trend from D_1 (1st day of sampling) to D_7 (7th day of sampling). The value of the EC of the sewage effluent after treatment in constructed wetland is showed in Table 2. Among the aquatic plants, *Canna indica* recorded a minimum EC of 2.02 and 2.06 dS m^{-1} for flow rate of 5 ml & 10 ml/min respectively which was significantly better than all the plants. The EC of the sewage effluent following treatment with the three aquatic plants, *Canna indica*, *Typha angustifolia*, and *Xanthosoma sagiitifolium*, appears to follow the same pattern as the effluent pH. Sorption is the process of transferring ions or charges from the aqueous to the solid phases. The soluble salt responsible for EC may be absorbed to the medium and roots of the plant growth in the model CW in this investigation. *Canna indica* is a plant with good medicinal property along with the capacity to treat industrial wastewaters was reported by [10]. Hydrology is one of the most important variables in controlling wetland functions, and a suitable treatment performance is obtained by flow rate regulation [11]. To improve the removal efficiency of CWs, the hydraulic loading rate (HLR) and hydraulic retention time (HRT) should be improved. The increased HLR reduces the optimum contact time, allowing wastewater to move through the media more quickly. Furthermore, a suitable microbial community can be developed in CWs with a longer HRT, and it can have sufficient contact time to eliminate pollutants [12].

Redox potential (Eh) of the sewage effluent was observed throughout the experimental period of 7 days. Eh values decreased from D1 to D7 at both flow rates of 5 ml/min and 10 ml/min. The mean Eh values ranged from -663 to -682 @ flow rate of ml/min and -667 to -685 @ flow rate of 10 ml/min (Table 3). The initial redox potential of the effluent is -691mV. *Canna indica* outperformed with -686 mV (Day 1) which on increasing retention time improved to -640mV whereas *Typhaanguistifolia* recorded a redox potential of -672mV (Day 7) for the flow rate of 5ml/min. This fluctuation on increasing the retention time might be due to the release of oxygen to the rhizosphere by plant roots [13]. The wastewater is used by aquatic plants to grow their shoots and roots. The macrophytes are influenced by water movement in a complicated way. Plants growing under running conditions, for example, typically show some morphological modifications. Water movement is one of the major elements that affects the vegetative fragmentation of aquatic plants [14] and some aquatic species may create viable shoot pieces that can disseminate, protecting the biomass below ground [15].

Table 1. Effect of plants and flow rate on pH of sewage effluent in model constructed wetland

Plants	Flow rate 5 ml/min							
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Mean
Canna indica	7.24	7.12	7.02	6.95	6.66	6.40	6.12	6.79
Xanthosoma sagittifolium	7.49	7.21	7.14	7.08	6.82	6.59	6.22	6.94
Typha angustifolia	7.65	7.47	7.29	7.16	6.92	6.77	6.54	7.11
MEAN	7.46	7.27	7.15	7.06	6.80	6.59	6.29	
	P		D		P*D			
SE (d)	0.01		0.01		0.02			
CD (0.05)	0.02		0.03		0.05			
Plants	**Flow rate 10 ml/min**							
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Mean
Canna indica	7.36	7.32	7.13	7.01	6.92	6.87	6.79	7.06
Xanthosoma sagittifolium	7.62	7.53	7.36	7.17	7.14	7.07	6.93	7.26
Typha angustifolia	7.59	7.49	7.37	7.22	7.18	7.12	6.98	7.28
MEAN	7.52	7.45	7.29	7.13	7.08	7.02	6.90	
	P		D		P*D			
SE (d)	0.01		0.01		0.02			
CD (0.05)	0.02		0.03		0.05			

D_1- 1st Day of retention time; D_2- 2nd Day of retention time; D_3-3rd Day of retention time; D_4- 4th Day of retention time; D_5- 5th Day of retention time; D_6-6th Day of retention time; D_7- 7th Day of retention time

Table 2. Effect of plants and flow rate on EC (dS m^{-1}) of sewage effluent in model constructed wetland

Plants	Flow rate 5 ml/min							
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Mean
Canna indica	2.47	2.32	2.25	2.07	1.92	1.66	1.47	2.02
Xanthosoma sagittifolium	2.49	2.36	2.3	2.11	1.99	1.74	1.57	2.08
Typha angustifolia	2.63	2.42	2.29	2.2	2.02	1.88	1.6	2.15
Mean	2.53	2.37	2.28	2.13	1.98	1.76	1.55	
	P		D		P*D			
SE (d)	1.15		1.76		3.04			
CD (0.05)	2.39		3.66		6.34			
Plants	**Flow rate 10 ml/min**							
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Mean
Canna indica	2.49	2.36	2.27	2.1	1.96	1.7	1.54	2.06
Xanthosoma sagittifolium	2.53	2.39	2.34	2.15	2.01	1.77	1.59	2.11
Typha angustifolia	2.65	2.45	2.33	2.24	2.05	1.92	1.63	2.18
Mean	2.56	2.4	2.31	2.16	2.01	1.8	1.59	
	P		D		P*D			
SE (d)	0		0		0.013			
CD (0.05)	0.01		0.01		0.028			

Table 3. Effect of plants and flow rate on Eh (mV) of sewage effluent in model constructed wetland

Plants	Flow rate 5 ml/min							
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Mean
Canna indica	-686	-686	-670	-666	-656	-640	-640	-663
Xanthosoma sagittifolium	-691	-690	-684	-684	-676	-650	-648	-675
Typha angustifolia	-690	-690	-687	-682	-680	-674	-672	-682
MEAN	-689	-689	-680	-677	-671	-655	-653	
	P		D		P*D			
SE (d)	1.15		1.76		3.04			
CD (0.05)	2.39		3.66		6.34			
Plants	**Flow rate 10 ml/min**							
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Mean
Canna indica	-690	-689	-672	-670	-660	-645	-644	-667
Xanthosoma sagittifolium	-691	-690	-687	-688	-679	-654	-653	-677
Typha angustifolia	-691	-690	-689	-687	-684	-677	-675	-685
MEAN	-691	-690	-683	-682	-674	-659	-657	
	P		D		P*D			
SE (d)	18.46		28.2		48.85			
CD (0.05)	38.4		58.66		101.6			

The effect of plants on TSS (total suspended solids) of the sewage effluent after treatment in model constructed wetland was analysed (Table4). *Canna indica* seems to have greater influence in significantly reducing the TSS from D_1 (174 & 196 mg L^{-1} at flow rates of 5 ml and 10 ml/minute respectively) to D_7 (22 & 54 mg L^{-1} at the flow rate of 5 ml and 10 ml/min respectively). *Xanthosoma sagittifolium* &*Typha angustifolia* followed the similar trend next to *Canna indica*. TSS of the effluent reduced from the retention time of 1 to 7 days at the flow rate of 5 ml/min and 10 ml/min. The percent reduction was 58%, 55% and 46% at the D_1 *Canna indica, Xanthosoma sagiitifolium* and *Typha angustifolia* respectively @ 5 ml/min (HLR 0.00516 /day) whereas at $D_{7,}$ the percent reduction was 95%, 88%, 80% by *Canna indica, Xanthosoma sagiitifolium* and*Typha angustifolia. "*There was clear evidence in the reduction of TSS at flow rate of 5 ml/min than 10 ml/ min at the 7th day of retention time. This might be because of filtration, interception or flocculation of suspended particles in the medium i.e. sand, gravel and pebbles and aquatic plants used in the study [16] also observed the positive effect of TSS removal of the effluent by aquatic plants *Typhalatifolia".* EWRG (2017) also stated "*Colocasiaesculenta* can be used for a constructed wetland. *Xanthosomasagiitifolium* belongs to the same family of *Colocasia esculenta i.e.*, Araceae seems to have the same property in removing solids and other particles in a constructed wetland" [17] also reported that TSS production was above 90% in the constructed wetland.

The effect of plants on total dissolved solids (TDS) of the sewage effluent with varied retention time and flow rates in model constructed wetland was presented in Table 5. The TDS of the effluent ranged from 666 to 2126 mg L^{-1} for flow rates of 5 ml and 10 ml/min respectively. Among the aquatic plants, *Canna indica* recorded a mean minimum TDS value of 1346.4 & 1452 mg L^{-1} at flow rates of 5 ml and 10 ml/min respectively. With respect to retention time similar trend was observed as that of pH. The percent reduction of TDS in the sewage effluent used in the model constructed wetland was shown in the Fig. 1. The HLR of 0.00516 cm/day (5 ml/min) seems to be superior compared to (0.01033 cm/ day- Flow rate 10 ml/min) at all the retention time of D_1 to D_7. The removal percentage was 75%, 60%, 58% and 60%, 50%, 40% by *Canna indica, Xanthosoma sagiitifolium, Typha angustifolia* respectively at the flow rate of 5 ml per minute and 10 ml per minute at the retention time of D_7. [12] also observed that the two-stage hybrid ecological wastewater treatment systems can be used to improve the quality of wastewater thereby using them for irrigation purposes (Fig 1).

Table 4. Effect of plants and flow rate on total suspended solids (mg L^{-1}) of sewage effluent in model constructed wetland

Plants	Flow rate 5 ml/min							
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Mean
Canna indica	174	162	154	124	96	70	22	115
Xanthosoma sagittifolium	186	170	160	134	122	64	36	125
Typha angustifolia	200	188	164	146	124	86	48	137
MEAN	187	173	159	135	114	73	35	
	P		D		P*D			
SE (d)	0.23		0.35		0.61			
CD (0.05)	0.48		0.73		1.27			
Plants	**Flow rate 10 ml/min**							
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Mean
Canna indica	196	210	182	154	130	104	54	147
Xanthosoma sagittifolium	224	204	190	170	156	92	72	158
Typha angustifolia	234	214	192	184	160	118	70	167
MEAN	218	209	188	169	149	105	65	
	P		D		P*D			
SE (d)	0.28		0.43		0.74			
CD (0.05)	0.58		0.89		1.55			

Table 5. Effect of plants and flow rate on total dissolved solids (mg L^{-1}) of sewage effluent in model constructed wetland

Plants	Flow rate 5 ml/min							
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Mean
Canna indica	1984	1856	1520	1334	1142	923	666	1346
Xanthosoma sagittifolium	1986	1888	1668	1524	1284	1023	866	1463
Typha angustifolia	2126	1956	1772	1684	1364	1140	964	1572
MEAN	2032	1900	1653	1514	1263	1029	832	
	P		D		P*D			
SE (d)	2.6		3.97		6.87			
CD (0.05)	5.4		8.26		14.3			
Plants	**Flow rate 10 ml/min**							
	D_1	D_2	D_3	D_4	D_5	D_6	D_7	Mean
Canna indica	2044	1950	1700	1512	1680	1002	776	1523
Xanthosoma sagittifolium	2050	2056	1820	1686	1372	1106	912	1572
Typha angustifolia	2218	2014	1874	1796	1494	1240	994	1661
MEAN	2104	2006.67	1798	1664.67	1515.33	1116	894	
	P		D		P*D			
SE (d)	2.79		4.26		7.38			
CD (0.05)	5.8		8.86		15.35			

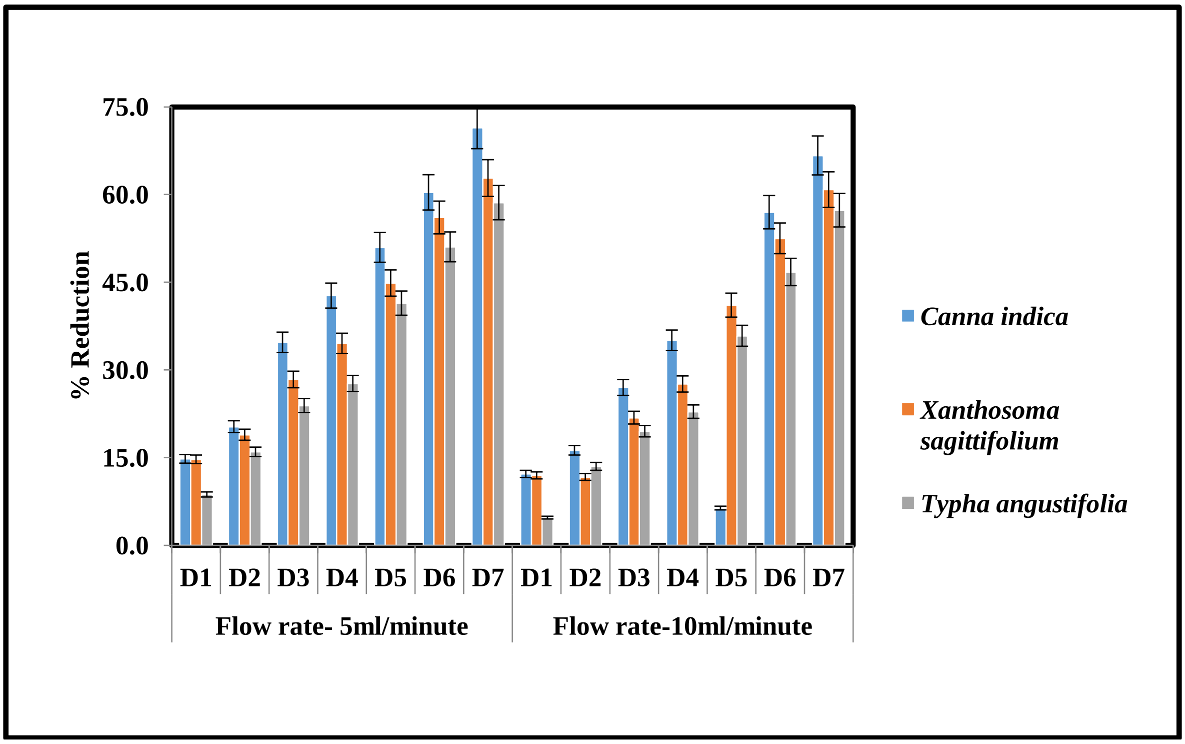

Fig. 1.Effect of plants and flow rate on total dissolved solids (mg L^{-1}) of sewage effluent in model constructed wetland

An increase in biochemical oxygen demand (BOD) removal efficiency was observed in the model constructed wetland with the flow rate of 5ml/min using three aquatic plants. At the retention time of 7days, the BOD content ranged from 320 to 360 mg L^{-1}@ flow rate of 5ml/min and varied between 330 to 380 mg L^{-1} @ flow rate of 10ml/min by the plants *viz.,Canna indica, Xanthosoma sagiitifolium and Typhaangustifolia* respectively (Table. 6).

“The organic matter in the effluent may undergo hydrolysis and converts into a soluble form and enters the media and attach to biofilm and then further decomposed. Aerobic bacteria in the biofilm release oxygen through the roots of plants which in turn supports organic pollutant degradation” [18]. The root system of the aquatic plants gives a larger surface area for microorganism which will facilitate the decomposition of organic matter. Microorganisms are based on the Rhizosphere: [19] and [20] pointed that microorganisms in CWs are significantly influenced by the rhizosphere. The decrease in BOD after treating with aquatic plants is corroborated with the findings of [21]. ”The aquatic plants used in the study especially *Canna indica* possess thick leaves and large surface area for gas transmission and in turn, helps in reduction of BOD. These findings are supported” by [20]. “*Xanthosoma sagiitifolium* was significantly on par with *Canna indica* [22] also reported that utilization of *Colacasia esculenta* has higher BOD and COD reduction during domestic wastewater treatment. *Xanthosoma sagiitifolium* has similar morphological characteristics to *Colacasia esculenta* and hence it may also have attributed to BOD removal in constructed wetland” [23] reported that the HSSF CWs planted with *Arundo donax* removed up to 61%, 71%, 78%, and 75% of biological oxygen demand TSS, (BOD), TN, and TP, respectively, from the hard-pan with untreated storm water and other surfaces of a dairy processing factory in south-west Victoria, Australia.

The chemical oxygen demand (COD) of the treated sewage effluent ranged from 800 to 2560 mg L^{-1} in treated effluent with respective of retention time (Table 7). The lower mean COD of 1666 mg L^{-1} was reported in *Canna indica* followed by *Xanthosoma sagittifolium* (1783 mg L^{-1}). Similar declining trend in COD with inumental retention time. Mean COD value of 2476 mg L^{-1} on 1^{st} day to 1016 mg L^{-1}. The COD of the effluent gradually showed declining trend as the retention time increased from D_1 to D_7. COD can be decomposed by aerobic and anaerobic microbial processes and also by physical processes such as sedimentation and filtration. The percentage removal of COD at D_7 at the flow rate of 5ml/min and 10 ml/min was 44%, 37.6%, 36.7% & 41%, 35.7 %, 34.4% by *Canna indica, Xanthosoma sagiitifolium* and *Typha angustifolia* respectively. The flow rate of 10ml/min

Table 6. Effect of plants and flow rate on biological oxygen demand (BOD) of sewage effluent in model constructed wetland

Plants	Flow rate 5 ml/min							
	D_1	**D_2**	**D_3**	**D_4**	**D_5**	**D_6**	**D_7**	**Mean**
Canna indica	540	520	480	420	400	360	320	**434**
Xanthosoma sagittifolium	560	530	500	460	440	380	340	**459**
Typha angustifolia	540	540	500	480	460	420	360	**471**
MEAN	**547**	**530**	**493**	**453**	**433**	**387**	**340**	
	P		D		P*D			
SE (d)	0.78		1.20		2.08			
CD (0.05)	1.63		2.50		4.33			
Plants	**Flow rate 10 ml/min**							
	D_1	**D_2**	**D_3**	**D_4**	**D_5**	**D_6**	**D_7**	**Mean**
Canna indica	560	530	500	440	420	380	330	**451**
Xanthosoma sagittifolium	570	550	520	480	450	400	350	**474**
Typha angustifolia	550	560	530	500	480	430	380	**490**
MEAN	**560**	**547**	**517**	**473**	**450**	**403**		
	P		D		P*D			
SE (d)	13.01		19.88		34.43			
CD (0.05)	27.06		41.34		71.61			

Table 7. Effect of plants and flow rate on chemical oxygen demand (mg L^{-1}) of sewage effluent in model constructed wetland

Plants	Flow rate 5 ml/min							
	D_1	**D_2**	**D_3**	**D_4**	**D_5**	**D_6**	**D_7**	**Mean**
Canna indica	1880	1840	1760	1660	1520	1440	1220	1880
Xanthosoma sagittifolium	1920	1860	1820	1700	1620	1530	1360	1920
Typha angustifolia	1920	1880	1840	1720	1640	1560	1380	1920
MEAN	1907	1860	1807	1693	1593	1510	1320	
	P		D		P*D			
SE (d)	2.87		4.39		7.61			
CD (0.05)	5.98		9.13		15.82			
Plants	**Flow rate 10 ml/min**							
	D_1	**D_2**	**D_3**	**D_4**	**D_5**	**D_6**	**D_7**	**Mean**
Canna indica	1920	1880	1800	1560	1580	1500	1280	1646
Xanthosoma sagittifolium	1980	1900	1880	1760	1660	1570	1400	1736
Typha angustifolia	1960	1940	1900	1780	1680	1600	1430	1756
MEAN	1953	1906	1860	1700	1640	1556	1370	
	P		D		P*D			
SE (d)	47.00		71.79		124.36			
CD (0.05)	97.75		149.31		25.62			

was found to have lesser performance than 5ml/min. “All the three plants used comes under the category of emergent macrophytes which would have an extensive lacunar system that includes 60% of plant tissue helping in substantial oxygen release to the rhizosphere thereby reducing the oxygen demand for decomposition. These findings corroborated with the results of [23] who stated that *Canna* plants has higher COD removal efficiency at lower HRT of seven days in treating sewage wastewater through CWs”.

4. CONCLUSION

The efficiency of constructed wetland is greatly influenced by the aquatic plants, and different retention time in reducing the salt and pollutant load of the sewage water. Aquatic plants in CW undergo various mechanisms *viz*., adsorption, precipitation, rhizo-filtration and photodegradation of pollutants. Aquatic plants undergo these mechanisms for reducing the pollutants in sewage water. All the sewage water quality parameters showed a decreasing trend on increasing the retention time and regarding the plants with it followed the order *Canna indica* > *Xanthosoma sagittifolium* > *Typha angustifolia* . There was a significant reduction in the redox potential, EC, TDS, TSS, BOD and COD of the sewage water @ 5 ml/min followed by 10 ml/min. Based on the study it was evident that CW with *Canna indica, Xanthosoma sagittifolium and Typha angustifolia* proved to perform better under flow rate of 5 ml/min.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. Authors are thankful to the Department of Environmental sciences, Tamil Nadu Agricultural University, Coimbatore for rendering technical and financial support to carry out the above research work.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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