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Phytoremediation of Domestic Wastewater by using *Desmostachya bipinnata*

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Abstract

Phytoremediation is a green technology for environmental restoration and can be applied to a broad range of contaminants originating through human activities. It utilizes plants' ability in wastewater treatment and can be helpful in ecosystem rehabilitation. In the present study phytoremediation efficiency of *Desmostachya bipinnata* was assessed for domestic wastewater arising from varied sources. Physico-chemical parameters were analyzed before and after phytoremediation. Results proved that *Desmostachya bipinnata*, being native to India can improve the quality of domestic wastewater in a decentralized approach to wastewater treatment by using constructed wetlands.

***Key words*:** Constructed wetlands, *Desmostachya bipinnata,* Domestic wastewater, Nutrients, Physico-chemical parameters, Phytoremediation

Water is a vital natural resource essential for the survival of all living things on the planet Earth. The growing human population and more demand for water resources for various human activities have raised the challenge of water security. Moreover, the situation is becoming more alarming due to the pollution of water resources. There are three main sources of water pollution-domestic sewage, industrial effluents and agricultural runoff. In India, 61754 MLD sewage is generated, of which 22963 MLD have sewage treatment capacity and 38791 MLD remains untreated [9]. In India, there are a total 1641 number of sewage treatment plants having installed capacity to treat 37921.42 MLD of domestic sewage. But only 1095 STPs are operational having the capacity to treat 26840.83 MLD of sewage. In reality, they are working with an actual utilised capacity of 18439.96 MLD of sewage [8]. According to one estimate, the total cost of establishing treatment plants for entire domestic wastewater generated in India is around 7560 crores with additional costs of operation and maintenance [27]. The high cost of conventional wastewater treatment systems stresses the need for alternative clean-up technologies which should be sustainable and cost-effective. Phytoremediation of domestic wastewater is a technique, which can efficiently remove various types of pollutants from wastewater. The present study was carried out to check the efficiency of *Desmostachya bipinnata* in treating domestic wastewater from different sources.

MATERIALS AND METHODS

Sangli-Miraj-Kupwad is a municipal corporation in Maharashtra, in Western India, district of Sangli. It is situated on the banks of river Krishna and is known as the 'Turmeric City' of Maharashtra. It lies in the Latitude 18°15' to 19°55' and Longitude 77° to 78°25' E. It has a semi-arid climate with an average temperature of 28°C and 54% humidity.

Experimental setup

A phytoremediation unit was set up for domestic wastewater having sources from an individual house and Ladies' Hostel. In the control unit, tap water was utilised. Phyto–treatment unit was also set up for river water which was collected from Krishna River, one of the major rivers in India and flows near Sangli City.

This is a type of subsurface flow phyto-treatment unit. Phyto-treatment assembly included one equalization tank for storage of wastewater, having a capacity of 50 litres. This tank was attached to a rectangular tank, having a length of 61cm, width of 40.5cm and height of 30cm, which served as a phyto-treatment section. This rectangular tank provided a top surface area of 2470.50cm^2 and a total volume of 74.115 lit. Starting from the bottom this unit consisted of layers of pebbles(15cm), medium sized sand (15cm) and a very thin layer of red soil to support plants, respectively.

Phytoremediation of domestic wastewater was done by using *Desmostachya bipinnata* (L.) stapf (*Darbha*). It is a rhizomatous perennial grass (Poaceae) and is widely found in the Indian subcontinent. *Desmostachya bipinnata*, is a drought and salt – tolerant grass with a deep (up to 20-30cm deep), strong rhizome. Although adapted to very dry conditions, it grows on the edges of irrigated areas, rivers and in orchards. *Desmostachya bipinnata* exhibits cultural, medicinal and economic value.

Sampling and analysis

Throughout the year after every fifteen days wastewater samples were collected before and after phyto-treatment. A

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retention time of 24 hours was provided for phytoremediation. Then these samples were analyzed for various physico-chemical characteristics such as temperature, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Solids (TS), pH, Total Alkalinity, Chlorides, Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Nitrates (NO_3-N) and Phosphates (PO_4-P), as per the standard methods given in APHA, 2005.

The efficiency of *Desmostachya bipinnata* in reducing pollutants from domestic wastewater and river water (% reduction) was calculated as follows:

$$\text{Removal efficiency (\%)} = \frac{C_{inf} - C_{eff}}{C_{inf}} \times 100$$

Where;
C_{inf} = average influent concentrations
C_{eff} = average effluent concentrations

RESULTS AND DISCUSSION

Phytoremediation utilizes plants' ability to remove harmful substances from soil sediments, and surface or ground waters which are polluted with domestic or industrial wastes. The efficiency of *Desmostachya bipinnata* (L.) stapf in the reduction of contaminants from domestic wastewater was assessed for its physico-chemical characteristics before and after phytoremediation (Table 1).

Table 1 Results of physico–chemical analysis of domestic wastewater before and after phytoremediation with*Desmostachya bipinnata* (L.) Stapf.

Control														
Sr.No.	Parameter	Unit	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction
1	Solids													
	i)Total suspended solids	mg/lit.	56.11	22.94	59.11	46.50	7.67	83.51	44.67	5.00	88.81	35.52	4.96	86.03
	ii)Total Dissolved solids	mg/lit.	346.83	164.61	52.54	300.83	43.83	85.43	267.67	29.89	88.83	281.22	40.08	85.75
	iii)Total solids	mg/lit.	407.39	187.56	53.96	347.33	51.50	85.17	312.33	34.89	88.83	316.74	45.04	85.78
2	pH		8.11	7.86	3.15	7.87	7.75	1.48	7.51	7.48	0.37	7.99	7.58	5.11
3	Alkalinity	mg/lit.	176.06	136.78	22.31	151.67	119.50	21.21	144.33	116.67	19.17	137.89	113.80	17.47
4	Chlorides	mg/lit.	56.72	38.67	31.83	45.50	35.83	21.25	31.78	25.33	20.28	44.59	37.19	16.60
5	BOD 5 at 20°C	mg/lit.	<1	<1		<1	<1		<1	<1		<1	<1	
6	COD	mg/lit.	9.00	4.94	45.06	9.17	1.83	80.00	9.00	1.00	88.89	9.63	1.93	80.00
7	Phosphates (as PO_4)	mg/lit.	0.22	0.10	51.62	0.25	0.05	80.47	0.26	0.03	87.83	0.24	0.04	84.29
8	Nitrates (as NO_3)	mg/lit.	4.59	3.34	27.24	1.23	0.26	78.70	0.54	0.07	87.86	1.06	0.18	83.30
Domestic wastewater														
Sr.No.	Parameter	Unit	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction	Inlet	Outlet	%Reduction
1	Solids													
	i)Total suspended solids	mg/lit.	121.44	33.78	72.19	161.33	28.00	82.64	174.56	21.67	87.59	133.54	19.19	85.63
	ii)Total Dissolved solids	mg/lit.	606.67	276.67	54.40	696.50	117.83	83.08	732.44	86.94	88.13	791.49	102.59	87.04
	iii)Total solids	mg/lit.	727.67	311.00	57.26	857.83	145.83	83.00	907.00	107.78	88.12	925.04	121.40	86.88
2	pH		7.07	7.36	3.99	7.29	7.43	1.87	6.99	7.17	2.56	7.11	7.33	3.05
3	Alkalinity	mg/lit.	337.67	279.56	17.21	318.33	253.83	20.26	290.11	238.06	17.94	304.72	256.27	15.90
4	Chlorides	mg/lit.	170.11	128.67	24.36	171.33	134.83	21.30	158.28	133.72	15.51	214.40	118.73	44.62
5	BOD 5 at 20°C	mg/lit.	18.56	7.44	59.88	20.50	3.83	81.30	23.78	3.28	86.21	39.36	5.23	86.70
6	COD	mg/lit.	48.11	17.11	64.43	56.00	10.00	82.14	51.22	7.89	84.60	87.58	13.88	84.16
7	Phosphates (as PO_4)	mg/lit.	2.66	1.30	50.88	2.86	0.52	81.90	2.64	0.34	87.06	2.35	0.36	84.72
8	Nitrates (as NO_3)	mg/lit.	0.14	0.07	52.40	0.16	0.04	75.53	0.20	0.03	86.51	0.83	0.11	86.73
Ladies Hostel wastewater														
Sr.No.	Parameter	Unit	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction
1	Solids													
	i)Total suspended solids	mg/lit.	135.56	25.78	80.98	135.00	20.67	84.69	147.39	18.83	87.22	104.10	15.28	85.32
	ii)Total Dissolved solids	mg/lit.	876.67	499.44	43.03	837.50	129.83	84.50	887.17	101.00	88.62	913.30	125.09	86.30
	iii)Total solids	mg/lit.	1012.22	525.22	48.11	972.50	156.50	83.91	1034.56	119.83	88.42	1017.40	143.04	85.94
2	pH		7.42	7.50	1.09	7.49	7.47	0.24	7.40	7.41	0.15	7.65	7.51	1.83
3	Alkalinity	mg/lit.	398.22	323.78	18.69	394.67	325.17	17.61	329.11	277.22	15.77	324.48	264.49	18.49
4	Chlorides	mg/lit.	120.78	79.11	34.50	114.83	90.17	21.48	115.06	94.08	18.23	130.54	104.11	20.25
5	BOD 5 at 20°C	mg/lit.	11.67	4.67	60.00	13.67	2.33	82.93	20.11	3.00	85.08	12.42	2.43	80.47
6	COD	mg/lit.	38.56	15.67	59.37	42.00	8.00	80.95	52.56	8.44	83.93	38.23	7.22	81.12
7	Phosphates (as PO_4)	mg/lit.	0.50	0.27	45.19	0.59	0.10	83.62	0.87	0.10	88.75	0.61	0.08	86.73
8	Nitrates (as NO_3)	mg/lit.	12.50	5.03	59.73	9.37	1.61	82.86	6.85	0.80	88.39	8.68	1.31	84.88
River water														
Sr.No.	Parameter	Unit	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction
1	Solids													
	i)Total suspended solids	mg/lit.	160.00	40.22	74.86	191.67	26.50	86.17	369.94	42.83	88.42	207.44	25.76	87.58
	ii)Total Dissolved solids	mg/lit.	806.67	283.89	64.81	842.50	110.83	86.84	1388.89	137.61	90.09	936.88	106.96	88.58
	iii)Total solids	mg/lit.	966.67	324.11	66.47	1034.17	137.33	86.72	1758.83	181.56	89.68	1144.32	132.84	88.39
2	pH		7.11	7.47	5.00	7.55	7.46	1.15	7.48	7.38	1.35	7.59	7.56	0.35
3	Alkalinity	mg/lit.	170.56	135.78	20.39	170.00	134.67	20.78	177.67	146.11	17.76	195.13	161.36	17.30
4	Chlorides	mg/lit.	175.00	139.00	20.57	182.50	146.33	19.82	169.22	140.22	17.14	137.14	111.34	18.81
5	BOD 5 at 20°C	mg/lit.	47.89	13.89	71.00	48.33	8.50	82.41	50.94	6.94	86.37	33.75	5.72	83.07
6	COD	mg/lit.	76.67	23.78	68.99	79.00	15.67	80.17	81.11	13.00	83.97	55.29	9.85	82.18
7	Phosphates (as PO_4)	mg/lit.	0.41	0.16	61.82	0.49	0.09	82.10	0.69	0.09	86.86	0.49	0.08	83.69
8	Nitrates (as NO_3)	mg/lit.	0.46	0.20	57.36	0.83	0.11	86.49	2.11	0.27	86.95	3.86	0.68	82.49

*Inlet and outlet values are three monthly means of triplicates over one year

Temperature: The temperature of water is a very important factor which affects the rate of chemical reactions in aquatic media. In the present study, throughout the year, the temperature range was 25-30˚C and 24-29˚C before and after phytoremediation of domestic wastewater. The temperature value recorded for river water was highest in the summer season

and lowest in the winter season, which shows clear seasonal variation. Throughout the study period, there was a reduction in temperature by 1°C after phyto-treatment. Similar results in temperature reduction after phytoremediation were observed by various researchers [4]. As the surface area of the phyto-treatment unit is covered by vegetative growth of *Desmostachya bipinnata*, there was a reduction in temperature after phytoremediation due to less light penetration [18].

*The efficiency of *Desmostachya bipinnata* in reducing total solids, alkalinity, chlorides and BOD 5 at 20 °C from domestic wastewater and river water (% reduction)

Fig 1 The efficiency of *Desmostachya bipinnata* (L.) Stapf in reducing different parameters from domestic wastewater and river water (% reduction)

Total suspended solids (TSS): Wastewater consists of a variety of solids and is an important physical characteristic of wastewater. Laboratory tests of TSS are useful in routine assessment of the performance of wastewater treatment processes. In the present study, for the control unit, TSS values before and after phytoremediation were recorded in the range of 35.52 to 56.11mg/lit. and from 4.96 to 22.94mg/lit. respectively. For domestic wastewater from an individual house, these values ranged from 121.44 to 174.56mg/lit. for inlet samples and 19.19 to 33.78mg/lit. for outlet samples of the phyto-treatment unit. For the Ladies' Hostel unit, observed TSS values were in the range of 104.10 to 135.56mg/lit. and 15.28 to 25.78mg/lit. before and after phytoremediation respectively. TSS values for river water were in the range of 160 to 369.94mg/lit. and after phyto-treatment, there was a reduction from 26.50 to 42.83mg/lit. Phyto-treatment successfully

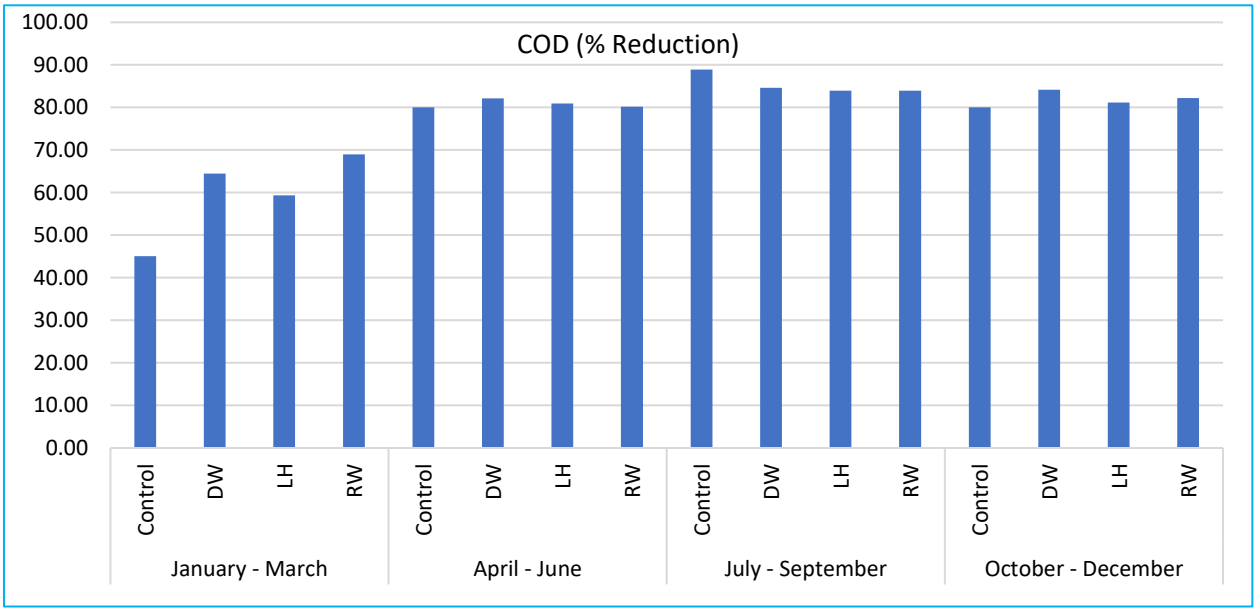
reduced the TSS content. The per cent reduction in TSS for the control unit was about 59.11 to 88.81%, for an individual house (72.19 to 87.59%), for the Ladies' Hostel unit (80.98 to 87.22%) and river water (74.86 to 88.42%).

Total dissolved solids (TDS): In the control unit, TDS values were in the range of 267.67 to 346.83mg/lit. and 29.89 to 164.61mg/lit. before and after phyto-treatment respectively. For an individual house, observed TDS values were 606.67 to 791.49mg/lit. before and after phyto-treatment respectively. TDS values for the Ladies' hostel unit varied from 837.50 to 913.30mg/lit. for inlet samples and from 101 to 499.44 mg/lit. for outlet samples. The concentration of TDS in river water was about 806.67 to 1388.89mg/lit. before and after phytoremediation, was in the range of 106.96 to 283.89mg/lit.

The per cent reduction in TDS was, for control unit (52.54 to 88.83%), for an individual house (54.40 to 88.13%), for Ladies hostel unit (43.03 to 88.62%) and river water (64.81 to 90.09%).

Total solids (TS): Thus, per cent reduction in TS ranged, for the control unit (53.96 to 88.83%), for the domestic unit (57.26 to 88.12%), for the Ladies' Hostel unit (48.11 to 88.42%) and river water unit (66.47 to 89.68%). TSS, TDS and TS values for river water were higher during the monsoon season i.e., from June to September and clearly showed seasonal variation, as more run-off from the catchment area joined the river. From bottom to top phyto-treatment unit consists of layers of pebbles, medium sized sand and red soil as a filter media. In the initial phases of the phytoremediation process, the percentage removal of solids was less, which was later enhanced for the time being, as there was plant growth. Filter media support the growth of microorganisms, accomplish the task of rhizosphere degradation of organic pollutants in the form of total solids and then a series of mechanisms such as phytodegradation and phytoextraction take place. Thus, there was considerable reduction in the amount of total solids. There is removal of TSS up to 70 to 80% in 'Phytorid Wastewater Technology' developed by NEERI [30]. *Lippia nodiflora* reduced TSS by 100% and TDS by up to 80% in decentralized greywater management [17]. *Thalia geniculata* reduced TDS in the range of 86 to 91% in different phases of its lifecycle [32]. Hybrid-constructed wetlands consisting of both vertical and horizontal flow types by using *Phragmites australis* reduced TSS at the maximum rate of 99.12% [21].

pH: The initial pH for the control unit was in the range of 7.51 to 8.11. For domestic unit, it was 6.99 to 7.29. For Ladies Hostel unit the initial pH range was 7.40 to 7.65. For river water recorded pH values were in the range of 7.11 to 7.59. All four phytoremediation units did not show any clear trend in a per cent increase or decrease in pH value.



*(DW – Domestic Wastewater, LH – Ladies Hostel Wastewater, RW – River Water)

Fig 2 The efficiency of *Desmostachya bipinnata* (L.) Stapf in reducing COD from domestic wastewater and river water (% reduction)

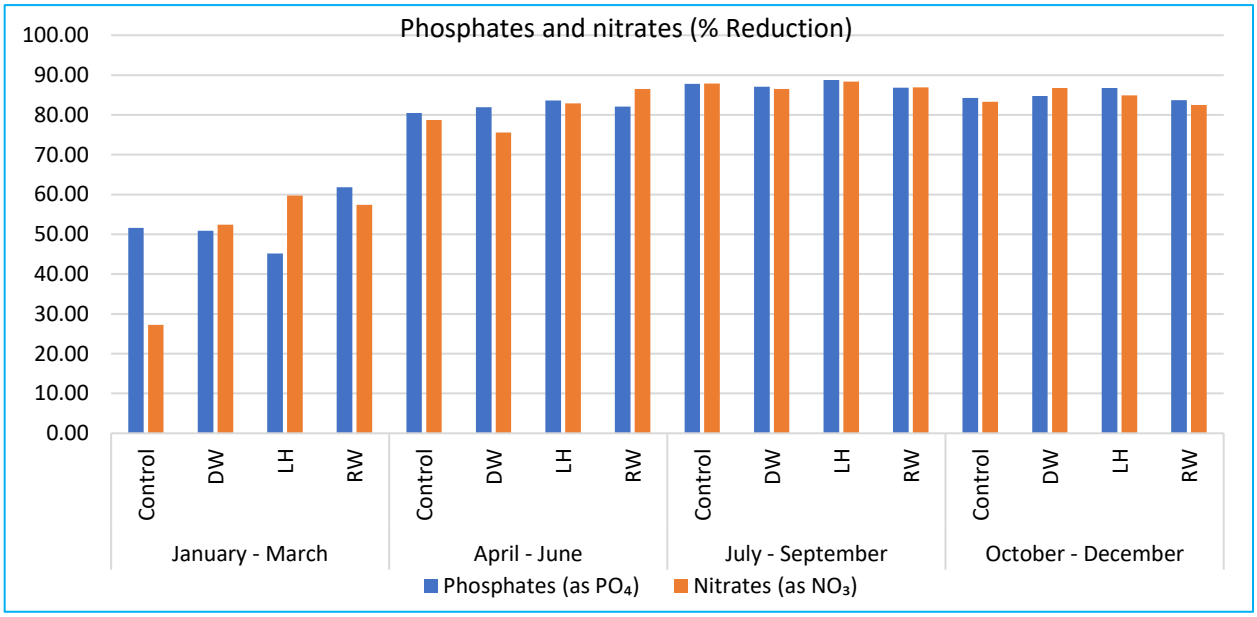
Total alkalinity: Water supply, the groundwater and the substances added during domestic use, gives alkalinity to the wastewater. Alkalinity values in the control unit ranged from 137.89 to 176.06mg/lit. for inlet samples of the phyto-treatment unit and from 113.80 to 136.78mg/lit. for outlet samples. In the domestic wastewater unit observed values for alkalinity were 290.11 to 337.67mg/lit. for inlet samples and 238.06 to 279.56mg/lit. for outlet samples. The total alkalinity values for the Ladies' hostel unit were higher as compared to the domestic wastewater unit and were in the range of 324.48 to 398.22mg/lit. for inlet samples and 264.49 to 325.17mg/lit. for outlet samples. For river water, alkalinity values ranged from 170 to 195.13mg/lit. before phyto-treatment and from 134.67 to 161.36mg/lit. after phyto-treatment.

After phytoremediation, the percent reduction for total alkalinity was always less than 23% for all phyto-treatment units, throughout the study period. The per cent reduction in alkalinity for the control unit (17.47 to 22.31%), for domestic wastewater (15.90 to 20.26%), for the Ladies Hostel unit (15.77 to 18.69%) and river water (17.30 to 20.78%) was observed. Some researchers found a per cent reduction in total alkalinity by using *Ceratophyllum demersum* L. (13.95 to 32.20%) and *Lemna minor* (2.29 to 18.28%) [18-19]. Although less, the decrease in total alkalinity may be the result of the partial absorption of bicarbonate ions by *Desmostachya bipinnata.*

Chlorides: The source of chlorides in natural water is from the leaching of chloride-containing rocks and soils. Agricultural, industrial and domestic wastewater is also responsible for chloride concentration in surface waters. Chloride is an important constituent of concern in domestic wastewater and is excreted through human excreta, urine etc. In

the control unit, the observed values were in the range of 31.78 to 56.72mg/lit. for inlet samples and 25.33 to 38.67mg/lit. for outlet samples. In domestic unit chloride values for inlet samples were 158.28 to 214.40mg/lit. For Ladies' Hostel, chloride values ranged from 114.83 to 130.54mg/lit. for inlet samples and outlet samples, they were in the range of 79.11 to 104.11mg/lit. For river water, these values were 137.14 to 182.50mg/lit. and 111.34 to 146.33mg/lit. for inlet and outlet samples respectively.

The per cent reduction in chloride was, for control (16.60 to 31.83%), for the domestic unit (15.51 to 44.62%), for Ladies' Hostel (18.23 to 34.50%) and river water (17.14 to 20.57%). As compared to total alkalinity, the rate of per cent reduction for chlorides was a little bit higher but did not exceed more than 45%. Few studies agree with a very low rate of percent reduction in chlorides in the range of 1.87 to 12.44% by using *Ceratophyllum demersum* L., *Canna*, Umbrella palm and lemon grass, *Phragmites spp.*, Water hyacinth etc. [18]. The low rate of the per cent reduction in chlorides after phytoremediation may be due to less requirement of chlorides in various mechanisms and pathways in plant metabolism and probably nutrition [7].



(DW – Domestic Wastewater, LH – Ladies Hostel Wastewater, RW – River Water)

Fig 3 The efficiency of *Desmostachya bipinnata* (L.) Stapf in reducing phosphates and nitrates from domestic wastewater and river water (% reduction)

Biochemical oxygen demand (BOD_5): The efficiency of treatment processes can be checked with the help of a 5-day Biochemical Oxygen Demand test which measures organic content in wastewater. It is also applied to surface waters. In the present study, inlet and outlet BOD values in the control unit always remained less than 1mg/lit. in all seasons. In domestic unit, inlet values were in the range of 18.56 to 39.36mg/lit. and outlet values ranged from 3.28 to 7.44mg/lit. In the Ladies' Hostel, before phytoremediation, values were 11.67 to 20.11mg/lit. for inlet samples and 2.33 to 4.67mg/lit. after phytoremediation. In river water, BOD values were 33.75 to 50.94mg/lit. and 5.72 to 13.89mg/lit. for inlet and outlet samples respectively.

BOD values in river water were higher as compared to the remaining three units and these were higher during monsoon season. Though surface water is diluted in monsoon season, there is a profound impact on the characteristics of river water by getting contaminated through human activities and surface run-off from catchment areas. Thus, higher BOD values during monsoon season and in general, clearly indicate river water is getting organic load through human activities on the river bank.

The per cent reduction in BOD after phyto-treatment for domestic wastewater (59.88 to 86.70%), for Ladies' Hostel (60 to 85.08%) and river water (71 to 86.37%) was observed.

In the present study, phyto–treatment unit was designed by using coarse sand and pebbles. This type of filter media is getting aerated naturally and the rhizomatous nature of *Desmostachya bipinnata* roots harbours an enormous number of aerobic microorganisms. These microbes degrade organic content in wastewater and these decomposed simple structured nutrients are absorbed by plants. These dual actions reduce organic content in wastewater. Earlier studies have also recorded a reduction in BOD by the process of phytoremediation. The domestic wastewater treatment by using phytoremediation can considerably reduce organic load by 45 to 98.08% [2], [4-6], [12-13], [17], [21], [28-29].

Chemical oxygen demand (COD): The COD test is a rapid test for the estimation of organic pollutants in fresh water and wastewater, as compared to the 5 days required in the BOD test and can be completed within 3 hours. The organic substances which are difficult to oxidize biologically can be oxidized chemically by using dichromate in an acid solution [15]. In the control unit, inlet COD values were from 9 to 9.63mg/lit. and from 1 to 4.94mg/lit. for outlet samples after phyto-treatment. The COD values in domestic wastewater unit ranged from 48.11 to 87.58mg/lit. for inlet samples and from 7.89 to 17.11 mg/lit. for outlet samples. COD values in the Ladies' Hostel unit were in the range of 38.23 to 52.56mg/lit. before phytoremediation and from 7.22 to 15.67 mg/lit. after phytoremediation. In river water recorded COD values, for the inlet samples were from 55.29 to 81.11mg/lit. and from 9.85 to 23.78mg/lit. for outlet samples.

The COD values were highest in river water as compared to the control, domestic wastewater unit and Ladies' Hostel unit. Relatively higher COD values in river water can be attributed to urban sewage, which is getting poured directly into the river through various *nullahs* near the sampling site.

The per cent reduction in COD was, for control (45.06 to 88.89%), for the domestic unit (64.43 to 84.60%), for the

Ladies' Hostel unit (59.37 to 83.93%) and river water (68.99 to 83.97%). In earlier studies, by using *C. vulgaris* there was COD reduction, a maximum of up to 94.44% at 24 hours HRT [14]. Another study found that there was a COD reduction by using *Ilex glabra* (87.01%) at the wetland edge, *Typha angustifolia* (90.47%) and *Phragmites australis* (88.84%) [25]. Thus, COD reduction is a function of different integrated mechanisms in a phytoremediation unit by using constructed wetlands [25].

Phosphates (PO_4^{3-}): In the present study, the phosphate concentration in the control unit was in the range of 0.22 to 0.26mg/lit. before phytoremediation and from 0.03 to 0.10mg/lit. after phytoremediation. In domestic wastewater unit phosphate concentration ranged from 2.35 to 2.86mg/lit. and from 0.34 to 1.30mg/lit. for inlet and outlet samples respectively. In the Ladies' Hostel unit, the observed values were in the range of 0.50 to 0.87mg/lit. and 0.08 to 0.27mg/lit. before and after phytoremediation respectively. Phosphate values for river water were in the range of, 0.41 to 0.69mg/lit. and 0.08 to 0.16mg/lit. for inlet and outlet samples respectively. The per cent reduction in phosphates after phytoremediation was about, for the control unit (51.62 to 87.83%), for the domestic unit (50.88 to 87.06%), Ladies Hostel unit (45.19 to 88.75%) and the river water (57.36 to 86.95%).

Phosphorus is an essential element for biological metabolism usually available in the form of orthophosphates without further breakdown [15]. Though it is a macronutrient required for plant growth, higher concentrations of phosphates and nitrates are responsible for imbalance in aquatic ecosystems. The sources of phosphorous compounds that enter surface water are domestic and industrial waste discharges and agricultural run-off. *Desmostachya bipinnata* produced extensive biomass above ground. Thus, by absorbing phosphates and converting them into organic matter, these plants contributed reduction of phosphates in all phyto-treatment units. This is consistent with results from many research attempts in the treatment of domestic wastewater by using constructed wetlands [2-4], [21], [25], [31].

Nitrates (NO_3^-): The nitrogen present in fresh wastewater is mainly combined in proteinaceous matter and by different pathways it is immediately oxidized to nitrate–nitrogen [15].

The initial nitrate concentration in the control unit was found in the range of 0.54 to 4.59mg/lit. and after phyto-treatment, it was 0.07 to 3.34mg/lit. In the domestic wastewater unit, nitrate ranged from 0.14 to 0.83mg/lit. before phytoremediation and from 0.03 to 0.11mg/lit. after phytoremediation. In the Ladies' Hostel unit nitrates concentration was in the range of 8.68 to 12.50mg/lit. and 0.80 to 5.08mg/lit. for inlet and outlet samples respectively. For river water, the nitrate values were observed as,0.46 to 3.086mg/lit. before phytoremediation and 0.11 to 0.68 mg/lit. after phytoremediation.

Thus, phytoremediation of domestic wastewater reduced nitrates in the control unit (27.24 to 87.86%), for the domestic unit (52.40 to 86.73%), for the Ladies' Hostel unit (59.73 to 88.39%) and in river water (57.36 to 86.95%). Plants absorb nitrates from soil or aquatic media to produce plant protein. Thus, reduction in nitrate concentration after phytoremediation can be attributed to its uptake by plants as a nutrient. Similar results of nitrate reduction by using phytoremediation are obtained by several researchers [1-2], [16], [20-21], [26], [29].

The difference between inlet and outlet observations of wastewater after phytoremediation by using *Desmostachya bipinnata* (L.) Stapf was assessed by using a paired t-test. The results are given in (Table 2).

Table 2 Results of paired t-test for inlet and outlet observations after phytoremediation by using *Desmostachya bipinnata* (L.) Stapf

Parameter	Control t – Statistic	Domestic waste water unit t – Statistic	Ladies hostel waste water unit t – Statistic	River water t – Statistic
Total suspended solids	19.1931	18.1506	22.6492	9.5239
Total dissolved solids	21.4524	14.7289	14.3425	12.1252
Alkalinity	16.1888	13.9151	18.6525	23.1954
Chlorides	9.7348	3.6275	11.2043	16.1017
BOD 5 at 20 °C	3.7796	8.0652	11.5716	17.9715
COD	3.6467	10.0395	16.4798	17.7199
Phosphates	13.4515	14.6869	9.7846	13.0281
Nitrates	10.3593	3.0301	17.1511	3.1009

*t-Critical value - 1.6972

*t-Statistic value > t-Critical value

For the parameters total suspended solids (TSS), total dissolved solids (TDS), alkalinity, chlorides, BOD 5 at 20°C, COD, phosphates and nitrates t- statistic values were greater than t-critical values at a 5% level of significance, which shows that outlet values for the corresponding parameters are less than inlet values after phytoremediation. Thus, it can be concluded that *Desmostachya bipinnata* is efficient in reducing the concentration of above said parameters after giving phyto-treatment by using a constructed wetland system.

CONCLUSION

The present study focused on assessing the efficiency of *Desmostachya bipinnata* in removing pollutants from domestic wastewater by using phytoremediation techniques. It was found that *Desmostachya bipinnata* can treat domestic wastewater arising from various sources very efficiently when operated at 24-hour HRT. *Desmostachya bipinnata* is a rhizomatous plant and being native to India can be utilized in a decentralized manner to treat domestic wastewater by using constructed wetlands. Thus, phytoremediation by using *Desmostachya bipinnata* is a cost–effective, solar-driven pumping and filtering system to treat domestic wastewater.

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