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EFFECT OF REEDBED SYSTEM ON GREY WATER TREATMENT

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ABSTRACT

The cogency of reedbed system was evaluated for the treatment of grey water using three grass species including reed grass (*Phragmites karka*), reed mace (*Typha elephantina*) and large sedge grass (*Cyperus iria*) for consecutive two years (2013 and 2014). The reedbed system was installed at the residential colony of Sindh Agriculture University, Tandojam, Sindh, Pakistan. The statistical analysis of the data indicated that the effect of three grass species on the removal of contaminants from grey water was significant ($P < 0.05$); while the effect of years on removal was non-significant ($P > 0.05$). The average removal (%) of BOD, COD, pH, TSS and turbidity from grey water passing through *Phragmites karka*, *Typha elephantina* and *Cyperus iria* grass species was 60.18±11.34, 38.30±8.10 and 26.09±4.75%; 45.10±4.69, 36.73±8.84 and 35.90±5.84%; 5.63±2.12, 4.75±1.99 and 4.31±2.29%; 45.86±10.51, 37.99±10.35 and 31.44±8.92%; 86.10±4.82, 81.66±16.83 and 86.11±4.88%, respectively. The maximum removal of BOD, COD, pH, TSS and turbidity was found under *Phragmites karka,* followed by *Typha elephantina* and minimum removal of all parameters was recorded under *Cyperus iria*. Hence, *Phragmites karka* proved to be more effective reed grass for maximum removal of contaminants from grey water making it more useful for crop production compared to other two grass species.

Keywords: reedbed, grey water, reed grass, water treatment, removal (%)

INTRODUCTION

Water scarcity is one of the primary factors causing poverty among rural communities throughout the world, which has tremendously reduced the yield of crops (Haq, 1998; Mahmood *et al.,* 2012). In order to achieve the potential production of crops, farmers use wastewater directly for crop production without treatment, which causes adverse effects on the crops, soils and humans that are the ultimate consumers of agriculture produce (IWMI, 2003; Latif and Pomee, 2003; UN Report, 2003; Raza *et al.,* 2008). The wastewater management is one

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of the major growing problems (Poyyamoli *et al.,* 2013); especially in urban areas; where the available freshwater sources are dwindling and are getting scarce; increase in freshwater pollution due to human activities; increase in health hazards and ecosystem damage due to uncontrolled discharge of wastewater into streams and oceans and system of wastewater treatment in developing countries has become ineffective and inefficient. However, studies have shown that there is a great potential for grey water and its reuse in the developing world. The treatment of grey water is simple and low cost than that of wastewater due to its low pollution load and high availability (Jefferson *et al.*, 1999). Grey water refers to the wastewater generated from domestic activities such as bath, hand basins, washing machines, dishwashing, laundry and kitchen. It does not include wastewater from toilet. It is considered to be the largest potential source of water reuse option at point source, accounting for around 50-80% of the total water use (Christova-Boal *et al.,* 1996; Eriksson *et al.*, 2002; Jamrah *et al*., 2006). We hypothesized that reedbeds could provide better treatment of grey water, they are low cost and easy to maintain compared to conventional treatment systems, and that they represent an appropriate and sustainable technology for grey water treatment (Denny, 1997). Reedbeds are used for the purification/treatment of grey water through the different grass species. These are constructed within solid and impermeable containers that contain gravel or other graded media, planted with reed species. Wastewater is allowed to travel slowly through the bed during which the quality of water is improved. Reedbeds have relatively low operational costs, compared to conventional treatment systems (Jefferey and Jefferson, 2003). Therefore a study was carried out to investigate the effect of reedbed system on the treatment of grey water.

MATERIALS AND METHODS

An experiment was conducted at the residential colony of Sindh Agriculture University, Tandojam, Sindh, Pakistan. It is located at 25°25’ 60’N 68°31’ 60E with an average altitude of 19.5 m. The study investigated the cogency of reedbed system using green technologies for grey water treatment for consecutive two years (2013 and 2014). The grey water was collected from 10 selected houses by installing separate plumbing system and was then supplied to the reedbeds. Reedbeds were constructed on an area of about 9 m^2 (3 m^2 each) and were filled with sand/soil/compost mix media. Three indigenous grass species (i.e. *Phragmites karka*, *Typha elephantina* and *Cyperus iria*) were planted in each reedbed separately. The depth of the reedbed was 0.7 m, while the flow rate/hydraulic loading rate (HLR) was 0.48 m^3/day. The hydraulic retention time (HRT) was maintained at 2 hours per batch (Gideon *et al.,* 2008). Nine (9) reedbeds (3×3 replicates) were constructed using randomized complete block design (RCBD). The depth of water in reedbed was between 0.3-0.7 m and the gravel substrate was 0.20 m. The samples of the grey water passing through the above mentioned three grass species were collected every day from inlet containing untreated grey water and outlet water after treatment through the reedbed. The collected samples were then sent to the National Center of Excellence in Analytical Chemistry (NCEAC) Laboratory, Sindh University, Jamshoro for water quality analysis. The quality of water entering and passing through the reedbed system was analyzed and compared. The parameters include Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), pH, Total Suspended Solids (TSS) and Turbidity. Biological Oxygen Demand (BOD) was determined by Dilution method (APHA, 2005). Chemical Oxygen Demand (COD) was determined following Closed Reflux, Titrimetric method (Greenberg *et al.,* 1998). The pH of water was determined by using a glass electrode pH meter. Total suspended solid (TSS) and turbidity were determined using standard procedures approved by AOAC (1998).

Statistical analysis

The data on relavent parameters were subjected to statsitical analysis (ANOVA) using Statitix (Ver. 8.1) statistical computer software package to evaluate the effect of treatments on the removal of contaminants from grey water; while the means were compared by Least Significant Difference (LSD).

RESULTS

The statistical analysis of the data showed that the removal of contaminants from grey water passing through three grass species (i.e., *Phragmites karka*, *Typha elephantina* and *Cyperus iria*) was significant ($P< 0.05$); while the effect of years on removal was non-significant ($P> 0.05$). The removal of BOD from grey water was 77.06% in December and 39.39% in February under *Phragmites karka*; 52.5% in July and 23.415% in January under *Typha elephantina* and 33.245% in June 17.16% in September under *Cyperus iria*, respectively, during 2013 Table 1). A similar trend was observed in 2014. The average removal of BOD from grey water under three grass species was 60.18±11.34, 38.30±8.10 and 26.09±4.75, respectively.

Table 1. Comparative species wise BOD removal (%) from grey water treated through reedbed system during the year 2013-14.

Month	***Phragmites karka* (Reed grass)**		**Average**	***Typha elephantina* (Reed mace)**		**Average**	***Cyperus iria* (Large sedge grass)**		**Average**
	2013	**2014**		**2013**	**2014**		**2013**	**2014**	
January	51.24	54.29	52.765g	23.33	23.50	23.415 i	25.81	26.32	26.065d
February	37.70	41.08	39.390i	27.81	24.70	26.255 f	30.03	29.48	29.755b
March	48.63	48.00	48.315h	39.27	39.34	39.305h	21.88	16.67	19.275b
April	46.49	46.67	46.580h	32.53	33.33	32.930g	29.41	28.92	29.165b
May	63.27	62.91	63.090e	39.57	41.49	40.530d	30.77	30.80	30.785b
June	60.28	67.01	63.645e	43.24	44.81	44.025c	33.93	32.56	33.245a
July	68.69	68.22	68.455c	51.24	53.76	52.500a	26.69	22.89	24.790d
August	56.62	58.00	57.310f	40.49	40.16	40.325d	27.81	26.74	27.275c
September	69.88	72.00	70.940b	33.93	35.76	34.845f	16.30	18.02	17.160f
October	65.69	67.57	66.630d	38.71	38.82	38.765e	24.76	27.51	26.135c
November	67.39	68.64	68.015c	40.07	40.51	40.290d	26.63	29.07	27.850c
December	77.29	76.83	77.060a	45.00	47.83	46.415b	21.21	22.06	21.635e
Average	59.43	60.93	60.180A	37.93	38.67	38.300B	26.27	25.92	26.095C
SD	11.53	11.24	11.34	7.58	8.66	8.10	4.79	5.00	4.75

LSD 0.05	Species	Months	Years	Species x Months
	0.8739**	1.7479**	0.7136 NS	3.0774**

Table 2. Comparative species wise COD removal (%) of grey water treated through reedbed system during the year 2013-14

Month	***Phragmites karka*** **(Reed grass)**		**Average**	***Typha elephantina*** **(Reed mace)**		**Average**	***Cyperus iria*** **(Large sedge grass)**		**Average**
	2013	**2014**		**2013**	**2014**		**2013**	**2014**	
January	44.44	47.27	45.855 b	44.95	45.36	45.155a	20.20	21.13	20.665c
February	46.94	49.49	48.215a	40.00	43.03	41.515b	34.03	34.39	34.210b
March	43.75	41.86	42.805b	25.00	24.16	24.580c	38.89	39.55	39.220a
April	45.83	45.97	45.900b	38.46	38.21	38.335d	38.46	40.48	39.470a
May	50.00	50.00	50.000a	44.58	45.41	44.995a	40.00	39.76	39.880a
June	50.00	51.40	50.700a	46.94	46.64	46.790a	20.20	45.03	32.615b
July	43.02	47.86	45.440b	25.00	28.38	26.690c	40.00	38.89	39.445a
August	43.75	48.19	45.970b	40.00	41.03	40.515b	38.89	41.99	40.440a
September	50.00	50.16	50.080a	25.00	25.71	25.355c	34.03	29.82	31.925b
October	42.29	42.76	42.525b	44.29	43.88	44.085a	43.75	39.74	41.745a
November	35.83	36.29	36.060c	38.46	37.74	38.100b	45.83	28.8	37.315a
December	37.50	37.70	37.600c	25.00	24.32	24.660c	34.03	33.68	33.855b
AVERAGE	44.45	45.75	45.100A	36.47	36.99	36.730B	35.69	36.11	35.900B
SD	4.58	5.00	4.69	8.88	8.86	8.84	8.10	6.78	5.84

LSD 0.05	Species	Months	Years	Species x Months
	2.2929**	4.5857**	1.8721 NS	7.9427**

Table 3. Comparative species wise pH of grey water treated through reedbed system during the year 2013-14.

Month	***Phragmites karka*** **(Reed grass)**		**Average**	***Typhaelephantia*** **(Reed mace)**		**Average**	***Cyperus iria*** **(Large sedge grass)**		**Average**
	2013	**2014**		**2013**	**2014**		**2013**	**2014**	
January	10.92	11.54	11.23a	02.45	3.86	3.155e	03.09	03.76	03.425c
February	03.61	05.03	04.32 e	03.84	3.28	3.560e	04.29	04.00	04.145c
March	04.66	04.17	04.415 d	10.92	8.27	9.595a	03.47	03.85	03.660c
April	04.63	04.32	04.475 d	02.74	2.60	2.670f	03.84	03.42	03.630c
May	04.05	06.58	05.315 d	04.05	5.19	4.620d	03.61	03.61	03.610c
June	05.32	05.03	05.175 d	02.90	4.41	3.655e	01.95	04.44	C
July	07.37	08.29	07.83b	05.26	6.33	5.795b	05.26	06.33	05.795b
August	04.56	04.38	04.47 d	06.57	6.67	6.620b	01.57	03.26	02.415d
September	05.16	05.13	05.145 d	01.57	5.35	3.460e	10.92	10.51	10.715a
October	04.56	05.68	05.12 d	05.39	5.90	5.645c	05.39	05.99	05.690b
November	06.57	06.83	06.7c	05.16	5.38	5.270c	01.83	02.93	02.380d
December	02.45	04.23	03.34 e	02.23	3.56	2.895e	01.83	04.18	03.005d
Average	05.32	05.93	05.63A	04.42	5.07	4.750B	03.92	04.69	04.310B
SD	2.17	2.17	2.12	2.55	1.62	1.99	2.56	2.10	2.29

LSD 0.05	Species	Months	Years	Species x Months
	0.4831**	0.9661**	0.3944**	1.6734**

The removal of COD from grey water was 50.70% in June and 36.06% in November *under Phragmites karka*; 46.79% in June and 24.58% in March under *Typha elephantina* and 41.545% in October 20.665% in January under *Cyperus* *iria*, respectively, during 2013 (Table 2). A similar trend was observed in 2014. The average removal of COD from grey water under three grass species was 45.10±4.69, 36.73±8.84 and 35.90±5.84, respectively. pH in grey water was 11.23 in January and 3.34 in December under *Phragmites karka*; 9.595 in March and 2.67 in April under *Typha elephantina* and 10.715 in September 2.38 in November under *Cyperus iria*, respectively, during 2013 (Table 3). A similar trend was observed in 2014. The average pH was 5.63±2.12, 4.75±1.99 and 4.31±2.29, respectively.

Removal of TSS from grey water was 57.845% in December and 19.245% in January under *Phragmites karka*; 47.685% in November and 13.365% in January under *Typha elephantina* and 46.765% in July and 14.965% in August under *Cyperus iria*, respectively, during 2013 (Table 4). A similar trend was observed in 2014. The average removal of TSS was 45.86±10.51, 37.99±10.35 and 31.44±8.92, percent, respectively.

Table 4. Comparative species wise TSS removal (%) of grey water treated through reedbed system during the year 2013-14.

Month	***Phragmites karka* (Reed grass)**		**Average**	***Typha elephantina* (Reed mace)**		**Average**	***Cyperus iria* (Large sedge grass)**		**Average**
	2013	**2014**		**2013**	**2014**		**2013**	**2014**	
January	14.65	23.84	19.245g	12.87	13.86	13.365g	34.69	35.58	35.135c
February	31.75	32.48	32.115f	29.35	30.93	30.140f	31.09	30.84	30.965d
March	43.74	44.09	43.915e	30.43	31.58	31.005e	37.50	36.03	36.765b
April	46.21	47.83	47.020d	34.78	35.29	35.035d	15.27	16.24	15.755f
May	46.79	45.95	46.370d	42.86	43.65	43.255b	32.49	31.69	32.090d
June	48.28	51.11	49.695c	47.22	48.15	47.685a	34.78	34.89	34.835c
July	53.57	54.04	53.805b	43.74	45.45	44.595b	48.28	45.25	46.765a
August	48.28	49.16	48.720c	46.21	46.71	46.460a	14.35	15.58	14.965f
September	47.25	48.21	47.730d	38.61	37.50	38.055c	25.71	27.07	26.390e
October	53.70	53.77	53.735b	31.43	31.79	31.610e	32.06	31.35	31.705d
November	50.00	50.16	50.080c	47.67	47.70	47.685a	34.74	35.05	34.895c
December	57.63	58.06	57.845a	46.79	47.14	46.965a	37.24	36.89	37.065b
Average	45.15	46.56	45.860A	37.66	38.31	37.990B	31.52	31.37	31.440C
SD	11.53	9.56	10.51	10.43	10.28	10.35	9.41	8.45	8.92

LSD 0.05	Species	Months	Years	Species x Months
	0.6956**	1.3911**	0.5679*	2.4055**

The turbidity removal from grey water was 92.47% in May and 78.28% in December under *Phragmites karka*; 91.96% in June and 31.11% in April under *Typha elephantina* and 93.40% in May and 76.855% in December under *Cyperus iria*, respectively, during 2013 (Table 5). A similar trend was observed in 2014. The average removal of TSS was 86.10±4.82, 81.66±16.83 and 86.11±4.88, respectively.

Table 5. Comparative species wise turbidity removal (%) of grey water treated through reedbed system during the year 2013-14.

Month	***Phragmites karka* (Reed grass)**		**Average**	***Typha elephantina* (Reed mace)**		**Average**	***Cyperus iria* (Large sedge grass)**		**Average**
	2013	**2014**		**2013**	**2014**		**2013**	**2014**	
January	83.89	80.00	81.945b	89.66	87.50	88.580a	92.59	77.78	85.185a
February	89.66	84.62	87.140a	88.46	82.78	85.620a	88.85	86.36	87.605a
March	91.20	78.33	84.765a	93.55	86.19	89.870a	88.62	90.48	89.550a
April	93.33	88.89	91.110a	82.22	-20.00	51.110c	86.77	85.60	86.185a
May	94.44	90.50	92.470a	90.00	92.00	91.000a	93.94	92.86	93.400a
June	93.64	90.91	92.275a	91.92	92.00	91.960a	91.89	90.68	91.285a
July	90.72	87.50	89.110a	90.34	92.90	91.620a	92.05	86.00	89.025a
August	92.00	86.73	89.365a	87.50	90.96	89.230a	88.57	85.19	86.880a
September	86.21	80.26	83.235a	88.24	83.33	85.785a	90.32	81.43	85.875a
October	88.89	71.43	80.160b	89.29	76.47	82.880a	90.33	76.67	83.500b
November	86.67	80.00	83.335a	88.00	64.57	76.285b	85.36	70.63	77.995b
December	88.50	68.06	78.280b	90.48	61.54	76.010b	88.00	65.71	76.855b
Average	89.93	82.27	86.100A	89.14	74.19	81.660A	89.78	82.45	86.110A
SD	03.25	07.31	04.82	02.77	31.44	16.83	02.54	08.32	04.88

LSD 0.05	Species	Months	Years	Species x Months
	4.7229 NS	9.4418**	3.8546**	16.354 NS

DISCUSSION

To enhance the potential production of crops, the farmers have become addicted to employing wastewater directly for crop production without treatment, which causes adverse effects on the crops, soils and humans. According to Poyyamoli *et al*. (2013), wastewater treatment is a fast growing problem in urban areas, where the available freshwater sources are dwindling and are getting scarce. However, studies have shown that there is a great potential for grey water and its reuse in the developing world. The treatment of grey water is simple and low cost than that of wastewater due to its low pollution load and high availability (Jefferson *et al.*, 1999). We hypothesized that reedbeds could provide better treatment of grey water, they are low cost and easy to maintain compared to conventional treatment systems, and that they represent an appropriate and sustainable technology for grey water treatment (Denny, 1997). The reedbed system was examined for consecutive two years (2013 and 2014) using three grass species including reed grass (*Phragmites karka*), reed mace (*Typha elephantina*) and large sedge grass (*Cyperus iria*). The maximum removal of BOD, COD, pH, TSS and turbidity from grey water was found under *Phragmites karka*, followed by *Typha elephantina* and minimum removal of all parameters was recorded under *Cyperus iria*. Hence, *Phragmites karka* proved to be more effective reed grass for maximum removal of contaminants from grey water, making it more useful for crop production, compared to other two species. This is possible because *Phragmites karka* contains large volume compared to *Typha elephantina* and *Cyperus iria*. The above findings are in line with many past researchers, who have conducted research on grey water treatment in different parts of the world. Poyyamoli *et al*. (2013) reported more than 50 % removal of BOD, COD and TSS under *Phragmites karka* compared to any other reedgrass species. However, the minor variation might have associated with the reedbed system management and weather fluctuations. In a study Bixio *et al*. (2006) reported high BOD (64.54%), COD (37.33%) and TSS (45.67%) removal under *Phragmites karka* based reedbed system. This is consistent with Friedler (2004), who reported that *Phragmites karka* based reedbed system was more effective for removal of BOD (71.2%), COD (44.1%) and TSS (45.11%). Dallas (2005) also suggested *Phragmites australis* plantation for effective removal of BOD, COD, turbidity and TSS from wastewater. Du Pisani (2006) reported that the grey water at inlet had pH around 8.2 which at the outlet from the reedbed system came down to 7.3, showing significantly effective system for tackling the wastewater problem. The study has also found different values of BOD, COD, pH, TSS and turbidity in different months of year. This may be attributable to the more amount of water used by occupants in various months of the year. This is linked to Tilve (2014), who concluded that most of the measured parameters of the study showed seasonal effect with higher values for September and January. This is likely due to the more amount of water used by more/less occupants in a house during September and due to less dilution occurred in grey water during January. Christova-Boal *et al*. (1996) concluded that grey water contains oils, trace elements and chemicals from detergents, soaps and nutrients, which were effectively treated with reedbed system, and the treated water was useful for many urban and agriculture uses. Ternes and Joss (2006) reported high efficiency of reedbed system for effective treatment of grey water from the residential areas of the cities and the treated water was safe to use for growing vegetables as well as fodder crops. The treated water was highly economical to produce vegetables, where the soil irrigated with this treated grey water needed remarkably less NPK nutrients for crop production as compared to normal irrigated soils. This is consistent with Allen *et al*. (2010), who found that grey water treated with reedbed system was equally useful for crop production as the canal water.

CONCLUSION

It can be concluded from the study that the reed grass species improved the quality of grey water by minimizing the BOD, COD, pH, TSS and turbidity. All three grass species under study were effective in improving the grey water quality. However, *Phragmites karka* proved to be more effective reed grass specie for grey water treatment as compared to other two grass species *(Typha elephantina and Cyperus iria)* to fulfill the water demand for urban and agricultural use.

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