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# PURIFICATION OF GREYWATER USING REEDBED TECHNOLOGY: EFFECT ON TDS, $SO_4^{2-}$, $PO_4^{2-}$ AND $NO_3^-$

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## ABSTRACT

The validity of reedbed system using green technologies for greywater treatment was examined for consecutive two years (2013 and 2014) using three reed grass species including reed grass (*Phragmites karka*), reed mace (*Typha elephantina*) and large sedge grass (*Cyperus iria*). The reedbed technology was installed at Residential Colony of Sindh Agriculture University Tandojam. The seasonal effect on removal of total dissolved solids (TDS), sulphate ($SO_4^{2-}$), phosphate ($PO_4^{2-}$), nitrate ($NO_3^-$) was determined. The statistical analysis suggested that the effect of reed grass species on the greywater contents for TDS, $SO_4^{2-}$, $PO_4^{2-}$, $NO_3^-$ at inlet and out let as well as on their removal was significant. The two years average removal from greywater passing reed grass species *Phragmites karka*, *Typha elephantina* and *Cyperus iria* was for TDS 43.65±8.48, 31.74±11.84 and 29.52±6.21%; $SO_4^{2-}$ 42.41±10.96, 34.15±9.75 and 29.50±5.23%; $PO_4^{2-}$ 80.88±7.44, 71.28 ±5.50 and 46.18±7.20%; $NO_3^-$ 54.53±9.54, 42.91±8.94 and 24.54±9.32%; respectively. The TDS, $SO_4^{2-}$, $PO_4^{2-}$ and $NO_3^{2-}$ removal was highest when greywater was treated with *Phragmites karka*, followed by *Typha elephantina* and lowest removal for all these parameters in most cases was recorded in greywater passing through *Cyperus iria*. The variation in removal showed association with the temperature variation during different months of the year. *Phragmites karka* proved to be more effective grass for maximum removal from greywater and making such waste water useful for agricultural use. The seasonal effect on the removal percentage indicated that highest TDS removal by *Phragmites karka* was highest in December, *Typha elephantina* in December and *Cyperus iria* in July. The sulphate removal in Greywater passing *Phragmites karka* was highest in December, *Typha elephantina* and *Cyperus iria* in November; while highest Phosphate removal by *Phragmites karka* was in March, *Typha elephantina* and *Cyperus iria* in June. Nitrate removal was highest for *Phragmites karka* in July; and in June for *Typha elephantina* and *Cyperus iria* species, respectively.

**Keywords:** greywater, reedbed, reed grass, water treatment

## INTRODUCTION

In the recent past, the water management bodies of the states are convinced to overcome the issues regarding the water security. Mitigatin steps to minimize the

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utilization of water through public participation, use of water harvesting and greywater purification techniques are considered as good solutions particularly for developing societies which are severely affected by water shortage issues (NEERI, 2007). The application of resue of the greywater is maximizing as a component of the water requirement arrangement by supplying water for agricultural industrial purposes (EA Report, 2001). The data from the literature dipictated that the greywater generated from the bathrooms are considered about fiftly to sixty percent of total greywater (Loh and Coghlan 2003) and it is polluted by the huge quantum of oils, fats and chemicals coming from shampoos, different types of soaps, hair dyes, nutrients, tooth pastes and from other cleaning materials. Fecal pollution was also observed (NSW 2007). The greywater from washing comprises about 4% of total greywater (Loh and Coghlan 2003), and all washing needs include 25-30 % of total greywater. It comprises about 10 % of total greywater and even it is not brought under the list of greywater by some people so it maybe purified by applying good techniques before its use (Bixio *et al*., 2006; Friedler, 2004; Ternes and Joss, 2006; Herna ´ndez Leal 2010; Asano *et al*., 2007; du Pisani, 2006; Finley *et al*., 2009; Winward *et al*., 2008; Allen *et al*., 2010; Kadewa, 2010).

Biforgatting the greywater from the black water decreases the threat caused by pathogens in greywater. However, other bacteria are found in greywater and resulting the fast growth of any fecal contamination observed in pipes and septic systems. As blackwater and greywater much vary from each other and it is suggestable to separate them specially by separating the faces and urine from the black water to purify them separate for best maintenance of health and environment (Sheikh *et al.,* 2005; Sostar-Turk *et al.,* 2005). The research on greywater purification has been continuously conducted in various countries of the world especially in the developed countries and different treatment technologies are used (Pangarkar *et al*., 2010). Lin *et al*., (2005) carriedout his research on the use of electro coagulation system for the greywater treatment. Biological aerated filter, rotating biological contact (RBC), sequencing batch reactor, membrane bioreactor are four major systems for the treatment of water. Research and continuous operation indicated that these systems are able to purify the greywater effectively. The microbiological index of treated water can fulfill the need of quality standard for the reused water. Rotating biological contactor unit can decrease the chemical from detergents in greywater. The water quality of different effluent gets the standards of drinking water (Jefferson, 2001 Nolde, 2005; Friedler, 2005). Lamine *et al*. (2007) conducted thier research on the use of sequencing reactor for greywater treatment deposited at outlet of shower room. Gross *et al*., (2007) concluded his research conducted at Ben-Gurion University (Israel) developed a modular system recycled vertical flow bioreactor (RVFB) for reduction for chemical pollutants from greywater. Edwin *et al.* (2013) distinguished the domestic sources of greywater that are minimum contaminating at city households by analyzing the characteristics of greywater. By distinguishing the literature review with reuse standards and appropriate treatments systems in the light of this qualitative and quantitative properties of household greywater generating from washbasin, bathrooms, laundry and kitchen sources are analyzed and compared with reuses standards for the need of reuse of greywater. Types different greywater sources are analyzed with respect to physico-chemical, bioilogical, nutrient and heavy metal characteristics. Reedbed systes and constructed soil filters are recommended as an appropriate Greywater purification alternative depending upon its ability to treat highly altering contaminants load with low maintainces and operational price which is more feasible for tropical and developing countries looking to the water demand for urban and agricultural use. The study was planned to treat the greywater through reedbed technology by using indigenous reed grass species.

## MATERIALS AND METHODS

The experiments were conducted for a consecutive period of two years (2013 and 2014) under agro-ecological conditions of Tandojam, district Hyderabad, Sindh (Pakistan), located at 25$^{o}$25' 60'N 68o31' 60E 19.5 m asl.

### Study location and treatments

The present study on greywater treatment using reedbed technology was carried out at new residential colony, Sindh Agriculture University Tandojam. Treatments under study include following three different grass species which were grown in three replicated reedbeds at the experimental site.

### Treatments (reed grass species)

$T_1$ = Reed grass: (*Phragmites karka*) locally called "NUR" (irrigated with Greywater)
$T_2$ = Reed mace: (*Typha elephantina)* locally called "Pann" (irrigated with Greywater)
$T_3$ = Large sedge grass: *(Cyperis irria*) locally called "Kall" (irrigated with Greywater)

Among the well known reedbed technologies, the vertical Flow Reedbed (VFRB) Technology was used for this study.

### Dimensions of the system

| | | |
|---|---|---|
| Surface area (reedbed) sand/ soil/ compost mix (≤1mm diameter) | = | 3m$^2$ (2.5 m x 1.2 m) media |
| Depth of reedbed | = | 0.7 m |
| Flowrate/Hydraulic Loading Rate (HLR) | = | 480 L/day in 10 batches of 48L |
| Hydraulic Retention Time (HRT) | = | 2 Hours per batch (Gideon *et al.* (2008) |
| Total reedbeds | = | 9 reedbeds (3 x 3 replicates) |
| Experimental Design | = | RCBD (Randomized Complete Block Design) |
| Liquid depth | = | Reedbed water depth between (300-700 mm) |
| Gravel substrate | = | 20 mm |
| Capacity of plastic tank | = | 240 litres |
| Capacity of greywater collection | = | 7.9296 m$^3$ (7929.6 litres) main tank |

### Separation of greywater from mixed sewage

The greywater from the 10 selected houses was collected by installing separate plumbing system for the houses considered for experiment. The collected greywater then were stored in a tank and supplied separately to the reedbeds for purification.

**Parameters analyzed**

For investigating comparative quality of influent and effluent water parameters like Total Dissolved Solids (TDS), Sulphate ($SO_4$), Phosphate ($PO_4$) and Nitrate ($NO_3$) were analysed.

**Statistical analysis of the data**

The data thus colleted on relavent parameters were subjected to statsitical analysis using analysis of variance (ANOVA) to discriminate the significance of treatment effect; while the seasonal variation was distinguished by using LSD (Least Significant Difference) test to compare the outlet removal during different months of the year. The statistical analysis was performed through Statitix (Ver. 8.1) statistical computer software package (Gomez and Gomez, 1984).

## RESULTS

**TDS removal**

The analysis of variance illustrated that TDS removal was significantly influenced by reed grass species (DF=2, F=279.33, P=0.000), months (DF=11, F=62.30, P=0.000) and reed grass species × months interaction (DF=22, F=19.38, P=0.000); while the effect of years on TDS was non-significant (DF=1, F=1.90, P=0.1820). The results are presented in Table 1. It is apparent that the TDS removal was the highest in *Phragmites karka* treated greywater, followed by *Typha elephantina* and lowest in *Cyperus iria* treated greywater. The TDS removal of *Phragmites karka* was highest in December and the lowest was during January in *Typha elephantina*, the TDS removal was the highest also in December and the lowest in April; whereas the TDS removal in *Cyperus iria* treated greywater was the highest in July and the lowest in September. The highest TDS removal under *Phragmites karka* and *Typha elephantina* treatment was in December, while *Cyperus iria* treated greywater showed the highest TDS removal in July, that suggests quite a different trend of effectiveness; because by season December vs July are two extremes of cold and hot climates. However, on the basis of present study results, *Phragmites karka* could be more effectively used for recycling of greywater.

**Sulphate removal**

The sulphate removal by *Phragmites karka*, *Typha elephantina* and *Cyperus iria* reed grass species from greywater was determined from January 2013 to December 2014 and collected data were statistically analyzed. The analysis of variance suggested that sulphate removal was significantly influenced by reed grass species (DF=2, F=111.71, P=0.000), months (DF=11, F=40.82, P=0.000), years (DF=1, F=5.56, P=0.000) and reed grass species × months (DF=22, F=5.99, P=0.000). The results are presented in Table 2.

The sulphate removal was the highest in *Phragmites karka* treatment than *Typha elephantina* and the lowest sulphate removal was observed in *Cyperus iria* treated greywater. The sulphate removal in greywater passing *Phragmites karka* was the highest in December and lowest February, while in *Typha elephantine* and *Cyperus iria* treated greywater, the sulphate removal was the highest in November and the lowest in January. *Typha elephantina* and *Cyperus iria* showed similarity in sulphate removal during these months and it was the highest in November and the lowest during January; while some changes in sulphate removal were observed *Phragmites karka* treated greywater. There was significant increase in the sulphate removal during 2014 as compared to the year 2013. However, on the basis of present results, *Phragmites karka* could be considered as the most effective reed grass species for high sulphate removal from greywater and wastewater recycling in the reedbed.

**Table 1.** Comparative species wise TDS removal (%) of greywater 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** | |
| Jan. | 22.86 | 36.59 | 29.725 e | 26 | 26.28 | 26.14 f | 27.33 | 27.56 | 27.445 e |
| Feb. | 37.5 | 33.73 | 35.615 b | 30.3 | 30.77 | 30.535 e | 33.55 | 33.76 | 33.655 c |
| Mar. | 44.44 | 44.35 | 44.395 b | 28.81 | 29.17 | 28.99 e | 26 | 25.24 | 25.62 e |
| Apr. | 45.83 | 46.78 | 46.305 b | 14.29 | 15.46 | 14.875 g | 30.46 | 30.19 | 30.325 d |
| May | 53 | 52.31 | 52.655 a | 14.81 | 15.55 | 15.18 g | 24.14 | 24.59 | 24.365 f |
| Jun. | 51.47 | 50.85 | 51.16 a | 34.38 | 34.23 | 34.305 d | 26.32 | 26.48 | 26.4 e |
| Jul. | 50.96 | 51.02 | 50.99 a | 47.64 | 47.69 | 47.665 b | 39.76 | 39.96 | 39.86 a |
| Aug. | 40.61 | 40.38 | 40.495 c | 35.24 | 35.65 | 35.445 d | 28.81 | 29.87 | 29.34 d |
| Sep. | 25.29 | 37.81 | 31.55 e | 26 | 25.49 | 25.745 f | 16.23 | 16.61 | 16.42 g |
| Oct. | 37.24 | 37.3 | 37.27 d | 27.27 | 27.33 | 27.3 f | 30.46 | 30.52 | 30.49 d |
| Nov. | 50 | 51.06 | 50.53 a | 39.39 | 39.47 | 39.43 c | 33.55 | 32.91 | 33.23 c |
| Dec. | 53.11 | 53.16 | 53.135 a | 55.4 | 55.15 | 55.275 a | 37.5 | 36.73 | 37.115 b |
| Average | 42.69 | 44.61 | 43.65 A | 31.63 | 31.85 | 31.74 B | 29.51 | 29.54 | 29.52 C |
| SD | 10.37 | 7.13 | 8.48 | 11.98 | 11.70 | 11.84 | 6.30 | 6.14 | 6.21 |

| | **Species** | **Months** | **Years** | **Species x Months** |
|---|---|---|---|---|
| LSD 0.05 | 1.3335** | 2.6670** | 1.0881 NS | 4.6194** |

**Table 2.** Comparative species wise sulphate removal (%) of greywater treated through reedbed system during the year 2013-14

| **Month** | ***Phragmites karka* (Reed grass)** | | **Average** | ***Typha elephantia* (Reed mace)** | | **Average** | ***Cyperus iria* (Large sedge grass)** | | **Average** |
|---|---|---|---|---|---|---|---|---|---|
| | **2013** | **2014** | | **2013** | **2014** | | **2013** | **2014** | |
| Jan. | 25.06 | 24.91 | 24.985 e | 7.04 | 22.94 | 14.99 g | 14.09 | 20.14 | 17.115 d |
| Feb. | 13.96 | 31.82 | 22.89 e | 25.5 | 26.82 | 26.16 e | 23.21 | 23.13 | 23.17 c |
| Mar. | 33.59 | 34.58 | 34.085 d | 15.86 | 28.76 | 22.31 f | 25.58 | 26.16 | 25.87 c |
| Apr. | 51.96 | 52 | 51.98 a | 32.73 | 32.65 | 32.69 d | 33.89 | 33.84 | 33.865 a |
| May | 55.2 | 55.29 | 55.245 a | 41.45 | 42.08 | 41.765 b | 28.41 | 28.79 | 28.6 b |
| Jun. | 49.15 | 49.16 | 49.155 b | 33.87 | 34.08 | 33.975 c | 30.73 | 30.33 | 30.53 b |
| Jul. | 40.28 | 41.1 | 40.69 c | 31.82 | 31.88 | 31.85 d | 32.89 | 33.48 | 33.185 a |
| Aug. | 46.51 | 47.02 | 46.765 b | 32.89 | 33.03 | 32.96 d | 28.57 | 29.53 | 29.05 b |
| Sep. | 41.7 | 42 | 41.85 c | 44.29 | 45.1 | 44.695 b | 33.15 | 33.29 | 33.22 a |
| Oct. | 48.93 | 49.05 | 48.99 b | 36.67 | 37.05 | 36.86 c | 32.89 | 33.12 | 33.005 a |
| Nov. | 55.62 | 55.3 | 55.46 a | 48.81 | 48.92 | 48.865 a | 35.21 | 34.63 | 34.92 a |
| Dec. | 36.66 | 37.09 | 36.875 d | 42.7 | 42.66 | 42.68 b | 31.58 | 31.4 | 31.49 a |
| Average | 41.55 | 43.28 | 42.41 A | 32.80 | 35.50 | 34.15 B | 29.18 | 29.82 | 29.50 c |
| SD | 12.62 | 9.70 | 10.96 | 11.99 | 7.85 | 9.75 | 5.93 | 4.59 | 5.23 |

| | **Species** | **Months** | **Years** | **Species x Months** |
|---|---|---|---|---|
| LSD 0.05 | 1.8149** | 3.6297** | 1.4818* | 6.2868** |

## Phosphate removal

The phosphate removal by different reed grass species (*Phragmites karka*, *Typha elephantina* and *Cyperus iria*) from greywater was recorded from January 2013 to December 2014. The analysis of variance indicated that phosphate removal was significantly affected by reed grass species (DF=2, F=2004.19, P=0.000), months (DF=11, F=19.82, P=0.000), years (DF=1, F=4.72, P=0.0409) and reed grass species × months (DF=22, F=25.84, P=0.000). The results are presented in Table 3.

The results indicated that phosphate removal marked higher in June followed by the months of high temperature and relatively lower in the months of low temperature. However, in *Phragmites karka* treated greywater the phosphate removal was higher than *Typha elephantina* treated greywater and lower phosphate removal was observed in *Cyperus iria* treated greywater. Generally, the phosphate removal in greywater passing *Phragmites karka* was the highest in March, while in *Typha elephantina* and *Cyperus iria* treated greywater, the phosphate removal was the highest in June. There was some increase in the phosphate removal during 2014 over 2013.

**Table 3.** Comparative species wise phosphate removal (%) of greywater 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** | |
| Jan. | 85.71 | 83.33 | 84.52 b | 60.32 | 62.5 | 61.41 f | 45.95 | 41.67 | 43.81 e |
| Feb. | 80 | 80 | 80 c | 64.62 | 70.67 | 67.645 d | 53.49 | 52.38 | 52.935 b |
| Mar. | 93.75 | 94.29 | 94.02 a | 65.75 | 66.67 | 66.21 e | 46.94 | 48.94 | 47.94 d |
| Apr. | 70.67 | 71.23 | 70.95 e | 70.67 | 71.23 | 70.95 c | 44.44 | 48.57 | 46.505 d |
| May | 90.67 | 93.06 | 91.865 a | 73.08 | 75.32 | 74.2 b | 51.16 | 50 | 50.58 c |
| Jun. | 80 | 78.33 | 79.165 d | 82.67 | 78.08 | 80.375 a | 54.9 | 57.69 | 56.295 a |
| Jul. | 82.43 | 81.58 | 82.005 c | 74.03 | 76.32 | 75.175 d | 39.58 | 41.3 | 40.44 f |
| Aug. | 70.67 | 71.62 | 71.145 e | 80.26 | 79.49 | 79.875 a | 34.38 | 44.12 | 39.25 f |
| Sep. | 80 | 81.48 | 80.74 c | 72.37 | 71.43 | 71.9 c | 32.35 | 36.36 | 34.355 h |
| Oct. | 83.12 | 82.89 | 83.005 b | 67.69 | 69.7 | 68.695 d | 35.48 | 38.24 | 36.86 g |
| Nov. | 70.67 | 71.23 | 70.95 e | 69.44 | 67.61 | 68.525 d | 53.49 | 54.55 | 54.02 a |
| Dec. | 81.43 | 82.86 | 82.145 c | 69.74 | 71.05 | 70.395 c | 50 | 52.27 | 51.135 b |
| Average | 80.76 | 80.99 | 80.88 A | 70.89 | 71.67 | 71.28 B | 45.18 | 47.17 | 46.18 C |
| SD | 7.43 | 7.52 | 7.44 | 6.29 | 4.94 | 5.50 | 7.99 | 6.76 | 7.20 |

| | **Species** | **Months** | **Years** | **Species x Months** |
|---|---|---|---|---|
| LSD 0.05 | 1.1738** | 2.3477** | 0.9584* | 4.0663** |

## Nitrate removal

The data in relation to nitrate removal by *Phragmites karka*, *Typha elephantina* and *Cyperus iria* reed grass species from greywater was collected from January 2013 to December 2014 and statistically analyzed. The analysis of variance showed that nitrate removal was significantly influenced by reed grass species (DF=2, F=929.83, P=0.000), months (DF=11, F=42.38, P=0.000), years (DF=1, F=5.29, P=0.0313) and reed grass species × months (DF=22, F=22.54, P=0.000). The results are presented in Table 4.

The nitrate removal was relatively higher in the months of high temperature. However, in *Phragmites karka* treatment than *Typha elephantina* and the lowest nitrate removal was observed in *Cyperus iria* treated greywater. The nitrate removal in greywater passing *Phragmites karka* was highest in July, while in *Typha elephantina* and *Cyperus iria* treated greywater, the nitrate removal was the highest in June. There was significant increase in the nitrate removal during 2014 as compared to the year 2013. On the basis of the findings, *Phragmites karka* could be considered as the most effective reed grass species removing the highest level of nitrate from greywater and would be useful for wastewater recycling in the reedbed.

**Table 4.** Comparative species wise nitrate removal (%) of greywater 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** | |
| Jan. | 45.33 | 45.51 | 45.42 e | 37.79 | 38.91 | 38.35 e | 15.49 | 19.05 | 17.27 e |
| Feb. | 45.5 | 45.43 | 45.465 e | 33.96 | 35.19 | 34.575 f | 26.61 | 22.73 | 24.67 c |
| Mar. | 50.09 | 58.14 | 54.115 d | 42.11 | 45 | 43.555 d | 30.51 | 26.04 | 28.275 b |
| Apr. | 44 | 46.67 | 45.335 e | 37.78 | 34.12 | 35.95 e | 20.48 | 19.05 | 19.765 d |
| May | 69.41 | 70.45 | 69.93 a | 48.11 | 47.66 | 47.885 c | 25.93 | 16.67 | 21.3 d |
| Jun. | 45.27 | 46.07 | 45.67 e | 62.11 | 63.37 | 62.74 a | 42.86 | 38.75 | 40.805 a |
| Jul. | 69.41 | 71.08 | 70.245 a | 50.46 | 52.64 | 51.55 b | 34.71 | 42.11 | 38.41 a |
| Aug. | 45.33 | 46.69 | 46.01 e | 47.04 | 46.38 | 46.71 c | 19.43 | 21.3 | 20.365 d |
| Sep. | 50.09 | 59.94 | 55.015 d | 48.41 | 47.18 | 47.795 c | 11.63 | 13.12 | 12.375 f |
| Oct. | 56.6 | 60.32 | 58.46c | 37.13 | 39.67 | 38.4 e | 8.26 | 14.48 | 11.37 f |
| Nov. | 62.5 | 66.67 | 64.585 b | 36.14 | 37.35 | 36.745 e | 30.82 | 28.04 | 29.43 b |
| Dec. | 50.37 | 57.79 | 54.08 d | 27.91 | 33.33 | 30.62 g | 30.47 | 30.54 | 30.505 b |
| Average | 52.82 | 56.23 | 54.53 A | 42.41 | 43.40 | 42.91 B | 24.77 | 24.32 | 24.54 C |
| SD | 9.44 | 9.94 | 9.54 | 9.22 | 8.81 | 8.94 | 10.05 | 9.19 | 9.32 |

| | **Species** | **Months** | **Years** | **Species x Months** |
|---|---|---|---|---|
| LSD 0.05 | 1.4540** | 2.9080** | 1.1872* | 5.0368** |

## DISCUSSION

Reuse of greywater is getting importance with the time because of various benefits. As safe disposal of wastewater has become one of the major issues in the countries like Pakistan and by the reuse of greywater, not only this effluent will be safely disposed off but its reuse will be regular source of crop irrigation. According to Poyyamoli *et al*. (2013), waste water management is a fast growing problem of urban societies where the available freshwater sources are dwindling and are getting scarce and wastewater management in this way is highly economical and beneficial. The greywater treatment by development of reedbed system is gaining importance; as in the urban areas increase in fresh water pollution due to human activities; increase in health hazards and ecosystem damage due to uncontrolled discharge of wastewater and ineffective and inefficient existing drainage system. The reedbed system using green technologies for greywater treatment was examined for consecutive two years (2013 and 2014) using three reed grass species including reed grass (*Phragmites karka*), reed mace (*Typha elephantina*) and large sedge grass

(*Cyperus iria*). The findings of the present study showed that the effect of reed grass species on the greywater contents for TDS, $SO_4$, $PO_4$ and $NO_3$ at inlet and out let as well as on their removal was significant ($P$<0.05).

The two years average removal from greywater passing reed grass species *Phragmites karka* for TDS 43.65±8.48, $SO_4$ 42.41±10.96, $PO_4$ 80.88±7.44, and $NO_3$ 54.53±9.54. The TDS, $SO_4$, $PO_{4,}$ and $NO_3$ removal was highest when greywater was treated with *Phragmites karka*, followed by *Typha elephantina* and lowest removal for all these parameters in most cases was recorded in greywater passing through *Cyperus iria*. The variation in removal showed association with the temperature variation during different months of the year. *Phragmites karka* proved to be more effective grass for maximum removal from greywater and making such waste water useful for agriculture use. The above findings from the present research are in line with many past researchers, who have conducted research on greywater treatment in different parts of the world. Loh and Coghlan (2003) reported that greywater from bathroom sources accounts for about 50-60 percent of total greywater and reedbed treated greywater was useful for producing agricultural crops; while Poyyamoli *et al*. (2013) reported that more than 50 percent removal of TDS at the outlet. *Phragmites karka* resulted in higher removal of these elements as compared to any other reedgrass species.

However, the minor variation might have associated with the reedbed system management and weather fluctuations. They found that the greywater was mostly contaminated with large quantities of oils, body fats and chemicals originating from soap, shampoo, hair dyes, toothpaste, nutrients and from other cleaning products. Christova-Boal *et al*. (1996) found that oils, trace elements and chemicals from detergents, soaps and nutrients contaminated greywater was effectively treated with reedbed system and the treated water was useful for many urban and agriculture uses. Bixio *et al*. (2006) reported that TSS (45.67%) and $NO_3$ (31.22%); and the greywater treated at the reedbed outlet was normally useful for the agriculture purposes. Friedler (2004) reported that *Phragmites karka* based reedbed system was more effective for removal of $PO_4$ (34.98%) and they reported that the treated water was most suitable for agriculture purposes and was similar to the effectiveness as the normal canal water. Ternes and Joss (2006) reported high efficiency of reedbed system for effective treatment of waste water from the residential areas of the cities and the treated water was safe to use for growing vegetables as well as fodder crops. Herna ´ndez Leal (2010) reported that reedbed system proved to be an effective management of the municipal waste water (laundaries, bathrooms, etc.) and the treated waste water was safe for crop production in peri urban areas. Finley *et al*. (2009) reported that $PO_4$ removal from waste water from the municipal areas was 80.34% with *Phragmites karka* based reedbed system. Winward *et al*. (2008) reported that reedbed system is the major component of green technologies for waste water treatment; while Allen *et al*. (2010) found that Greywater treated with reedbed system was found to be equally used for crop production as the canal water. Finley *et al*. (2009) reported that EC level of the greywater was settled after passing through *Phragmites karka* at higher levels and this water was very useful for various agricultural purposes. The studies (Dixon *et al.,* 2000) showed that greywater share in the total water consumption may be about 40%; while, Lu Weizhen *et al.* (2003) suggested categorizing municipal wastewater potential, developing grey storm water recycling system in public housing estate and investigating the feasibility and potential of using reclaimed greywater etc. Davison *et al.* (2005) reported reedbed with *Phragmites australis* effective for pan evaporation of 2.6. Moir *et al.* (2005) found substantial reduction in concentrate of suspended solids, ammonium, nitrate and phosphorus in the waste water being discharged with concentration suspended solids in wetlands planted with *Phragmites australis*. Ross Mars (2005) estimated that the oxygen release rate in *Phragmites* to be from 0.02 $mg^{-2}$/day to 12 $mg^{-2}$/ day. Pidou *et al.* (2007) reported that the best overall performances were observed within schemes that combine different types of methods to ensure effective treatment of all the fractions. Gideon Winward *et al.* (2008) indicating aerobic unsaturated wet lands to be the most suitable form of the technology for pathogen removal.

## CONCLUSION

It was concluded from the study that *Phragmites karka* proved to be more effective reed grass specie in terms of minimizing the TDS, $SO_4^{2-}$, $PO_4^{2-}$ and $NO_3^-$ followed by *Typha elephantina* and *Cyperus iria*, respectively. Phragmites karka showed most promising results regarding the greywater treatment possibly due to its dense tillering and morphological traits to treat the greywater effectively.

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