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Role of *Typha* (Cattail) and *Phragmites austrailes* (Reed Plant) in Domestic Wastewater Treatment

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ABSTRACT
Shortage of good quality irrigation water is a serious problem of many arid and semi-arid countries of the world for sustainable irrigated agriculture. Among these, Saudi Arabia is facing acute water shortage due to increased population coupled with recent rural and urban development. Besides, it has resulted in manifolds increases in wastewater production containing organic, inorganic and biological pollutants thus enhancing the environmental and health problems upon its land disposal. Presently, the conventional wastewater treatment technologies available are expensive and difficult to apply at small scale. The main objective of this study was to investigate the use of green plants as a “Natural Way of Wastewater Treatment” that might prove cost effective and can easily be adopted at small scale. A significant reduction in BOD and COD contents was observed in the treated wastewater as compared to the raw effluent. The concentration of trace elements such as Cu and Fe decrease, but those of Zn and Mn increased both under *Typha* and *Phragmites austrailes* green plants. Similarly, NH_4 and PO_4 decreased but NO_3 increased considerably than the control (raw effluent) in the natural treatments. The concentration of all the trace elements was above the maximum allowable limits except NH_4, NO_3 and PO_4 which was within acceptable limits for irrigation use. In conclusion, the research findings showed potential of green plants for heavy metal removal from wastewater to improve its quality acceptable for agriculture use.

Key words: Raw effluent, COD, BOD, trace elements, NH_4, PO_4, NO_3, *Typha*, *Phragmites austrailes*, irrigation, agriculture

INTRODUCTION
Water scarcity in arid and semi-arid regions of the world has prompted projects for wastewater reuse as an alternate source to supplement the growing needs of water for various uses. The waste effluents intended for reuse may contain high concentration of biological, organic or inorganic pollutants. Therefore, reclamation of wastewater is needed prior to its reuse to avoid health and environmental hazards.

Saudi Arabia collects and treats 672 million m^3 of wastewater per day but less than 20% is ultimately reused and the excess is discharged into Wadis called valleys (Al-Musallam, 2006; Abu-Rizaiza, 1999). Saudi Arabia is anticipated to become the third-largest water reuse market in the world after the United States and China (Saudi, 2010). In Saudi Arabia, agricultural sector is by far the largest water user offering an opportunity for freshwater savings, as majority of wastewater is generated outside the agricultural sector (Qadir *et al*., 2010).

Presently, wastewater treatment technologies such as Membrane Bio-reactor (MBR), Reverse Osmosis (RO), Nano-filtration (NF) and different types of membranes are being employed. However, these wastewater treatment technologies involve large capital investments and operating costs. On the other hand, constructed wetlands have gained popularity on economical grounds for treating wastewater from small urbanized areas (Ciria *et al*., 2005). However, an understanding of the complex process involving plants, microorganisms, soil matrix and the substance in wastewater is still a burning issue (Stottmeister *et al*., 2003). Keffala and Ghrabi (2005) observed higher nitrogen removal in planted system than the control without plants. Evaluation of both the Cattails and reeds, the most common plants in constructed and semi-natural wetlands for wastewater treatment in Estonia, showed that harvesting of aboveground biomass does not show any effect on the removal of heavy metals from wetlands (Maddison *et al*., 2009).

In Jordan, subsurface flow constructed wetlands showed potential of reducing Biochemical Oxygen Demand (BOD), different forms of nitrogen, Total Suspended Solids (TSS), Fecal Coliform Count (FCC) and Total Coliform Count (TCC) (Al-Omari and Fayyad, 2003; Garcia *et al*., 2003). They also observed reduction in total nitrogen, ammonia nitrogen and nitrate nitrogen. Whereas, Vertical Flow Constructed Wetlands (VFCWs) proved useful for wastewater treatment in France (Molle *et al*., 2006). Their study showed the robustness of reed beds systems as designed in France to accept hydraulic overloads. Konnerup *et al*. (2009) evaluated the domestic wastewater treatment with *Canna* and *Heliconia* plants at the Asian Institute of Technology (AIT) campus in Bangkok, Thailand. They found that the estimated removal rate constants for COD to be 0.283 and 0.271 md^{-1} for *Canna* and *Heliconia* beds, respectively. In Thialand, high evapo-transpirative water loss from the *Cyperus* systems resulted in higher effluent concentrations of COD and total-P, but the mass removal of COD did not differ significantly between planted and unplanted systems (Kantawanichkul *et al*., 2009).

Many investigators were keen in the treatment of domestic sewage (Brix, 1987; Vymazal, 1996; Mander and Mauring, 1997). The use of aquatic plants is emerging as a viable alternative especially for small sized communities and isolated areas due to its low costs, easy to operate and maintain than the conventional systems (Brix and Schierup, 1989; Garcia *et al*., 2001). Constructed Wetlands (CWs) for wastewater treatment are potentially considered a good solution for treating domestic and industrial wastewaters in less-developed countries with warm and tropical climates due to the utilization of natural processes, the high process stability and the cost-effectiveness (Denny, 1997; Haberl, 1999; Kivaisi, 2001). In tropical climates, where the plants grow faster and throughout the year, the uptake of nutrients can probably contribute to significantly higher removals of nutrients as reported in several studies (Koottatep and Polprasert, 1997; Greenway and Woolley, 2001; Kyambadde *et al*., 2004, 2005; Kantawanichkul *et al*., 2009).

A review of literature indicated that a lot of work has been accomplished on the use of conventional wastewater treatment technologies around the world. But very little research has been carried on natural wastewater treatment technology using green plants in Saudi Arabia. Therefore, the main objective of this study was to investigate the role of Typha (Cattail) and *Phragmites austrailes* (REED Plant) for the removal of COD, BOD and some of the organic and inorganic pollutants such as total phosphorus (P), nitrates (NO_3-N), Co, Cd, Fe, Mn from domestic wastewater in Riyadh, Saudi Arabia.

MATERIALS AND METHODS

Location of experiment: The experiment was carried near the Pilot Wastewater Treatment Plant (PWTP), King Abdulaziz City for Science and Technology (KACST), Riyadh, Saudi Arabia during

Crushed stone Zeor crush Silicon (Coarse sand) Soil (Medium Texture)

Fig. 1: Different sizes of stones and soil for preparation of sand filter

Fig. 2: Setup of phytoremediation experiment

2011-2012. Because untreated wastewater (mixture of domestic sewage water from KACST residential and drainage effluent from office facilities) was available for study.

Purchase of sand filter materials: Materials for the preparation of sand filter in plastic drums were procured from the local market. The materials consist of crushed stones (around 1 mm size), zero crush (around 1-2 mm size), silicon (similar to coarse sand) and soil (cultivated agriculture field) for the top layer. Different materials for the preparation of sand filter are shown in Fig. 1. The experiment setup is shown in Fig. 2.

Sand filter was prepared in a plastic drum having 55 cm diameter and 85 cm height. There were two drums in the experimental set up. Each sand filter consisted of four layers starting from the bottom layer with crushed stones around 10 mm size (10 cm), zero crush (10 cm), silicon (15 cm) and on the top coarse textured soil (loamy-sand) from an irrigated agricultural field (30 cm). Total quantity of each material was 45, 43.10, 64 and 115 kg for crushed stones, zero crush, silicon and soil, respectively. The crushed tones and zero crush were prewashed with tap water to remove dust or stone powder to avoid blockage of the drainage outlet. Each layer of the sand filter was prepared by adding calculated quantity of each material using a graduated stick for uniform distribution in the drum.

Collection of experimental plants: Two green plants namely *Typha* (Cattail) and *Phragmites austrailes* (commonly called as “REED Plant”) were collected from the main drainage water channel of Wadi Hanifah from the south side of Al-Hire town, Saudi Arabia on19-06-2011.

Plant transplantation: Five healthy off-shoots of each plant were transplanted in the experimental drums on 20-06-2011. The plants were planted at a depth of 10-15 cm from the surface. After plantation, wastewater was allowed to flow from the main source to the drums. The drainage outlets were opened at the bottom of each drum for treated wastewater sampling.

Collection of water samples: Water samples were collected at an interval of 2 months. In order to collect water samples, small containers (2 L capacity) were kept under each drum at the time of sample collection. Water samples were immediately transferred to the analytical laboratory for physical, organic, chemical and biological analysis.

Collection of sediment samples: Sediment samples were collected from 0-30 cm depth from all the experimental drums during October, 2012. A total of six samples were collected. The samples were air-dried, passed through 2 mm sieved and stored for analysis. The sediment samples were analyzed by standard analytical methods according to USDA (1954), APHA (1998) and AOAC (2003).

Analytical procedures: The standard analytical procedures given in AOAC (2003) were followed for water analysis. The laboratory equipments/instruments used for soil extract and water samples analysis were ICP OPTIMA 2000DV (Perken Elmer) for Trace Elements, Ion Chromatography for anions (Cl, SO_4, NO_3, F, PO_4 , NO_2, Br, I), Ion-Chromatography for cations (Na, NH_4 K, Mg, Ca, Ba), Mars-5 Digestion/Extraction Sample Preparation and pH/ Conductivity meter/DO Star-5 for field Analysis (EC, DO, Temperature, pH, turbidity) by following Methods Nos 3-7 as described in USDA (1954). The COD and BOD of water samples were determined by methods described in AOAC (2003).

Data analysis: Data were analyzed by ANOVA and regression techniques for treatment evaluation at 5% level of significance according to SAS Institute (2001).

RESULTS AND DISCUSSION

Effect of treatments on COD and BOD of wastewater: The COD ranged between 68-105 mg L^{-1} with a mean value of 81 mg L^{-1} for raw effluent, 34-53 mg L^{-1} with a mean value of 42 mg L^{-1} under *Typha* and 30-40 mg L^{-1} with a mean value of 33.67 mg L^{-1} under *Phragmites austrailes* plant (Table 1a). Overall, the reduction in COD was 48.15 and 58.43% in *Typha* and *Phragmites austrailes*, respectively. This indicated the consumption of oxygen from the raw effluent by the microorganisms around the plant roots during growth for carrying different physiological functions in the plant roots.

Table 1: Effect of *Typha* (cattail) and *Phragmites austrailes* (reed plant) on COD and BOD of Wastewater

	COD of Wastewater		
Sample No.	Raw effluent	*Typha* (cattail)	*Phragmites austrailes* (reed plant)
(a) COD (mg L^{-1})			
1	105	53 (49.52)	40 (61.9)
2	70	34 (51.43)	31 (55.71)
3	68	39 (42.65)	30 (55.88)
Mean	81	42 (48.15)	33.67 (58.43)
(SD±)	20.81	9.85	5.51
BOD of wastewater			
(b) BOD (mg L^{-1})			
1	91.00	46 (49.45)	30 (67.03)
2	72.00	12 (83.33)	28 (61.11)
3	55.00	15 (72.7)	18 (67.27)
Mean	72.67	24.33 (66.52)	25.33 (65.14)
(SD±) of mean	18.01	18.82	6.43

The BOD ranged between 55-91 mg L^{-1} with a mean value of 72.67 mg L^{-1} for raw effluent, 12-46 mg L^{-1} with a mean value of 24.33 mg L^{-1} under *Typha* and 18-30 mg L^{-1} with a mean value of 25.33 mg L^{-1} under *Phragmites austrailes* plant (Table 1a). Results showed overall reduction of 66.52 and 65.14% in BOD for *Typha* and *Phragmites austrailes*, respectively (Table 1b) during the experimental period. The reduction in BOD may be due to the consumption of organic matter by the microorganisms in the vicinity of plant roots for their growth and multiplication. However, the difference in BOD reduction was not significant between the two plants.

Effect of natural treatments on micro-elements of wastewater

Copper (Cu): Mean concentration of Cu ranged from 23.5-57.20 mg L^{-1} with a mean value of 44.98 mg L^{-1} in raw effluent, 4.45-6.50 mg L^{-1} with a mean value of 5.30 mg L^{-1} under *Typha* (Cattail) and 4.30-9.53 mg L^{-1} with a mean value of 7.26 mg L^{-1} under *Phragmites austrailes* (Reed Plant) (Table 2a). The mean reduction in the concentration of Cu was 88.22 and 83.86% under *Typha* and *Phragmites austrailes*, respectively. This reduction may be due to the uptake of Cu by the growing plants and the formation of ion complex with other elements such as SO_4 or PO_4.

Zinc (Zn): Mean concentration of Zn ranged from 10.1-12.7 mg L^{-1} with a mean value of 11.60 mg L^{-1} in raw effluent, 14.3-17.1 mg L^{-1} with a mean value of 15.80 mg L^{-1} under *Typha* (Cattail) and 13.6-20.0 mg L^{-1} with a mean value of 15.93 mg L^{-1} under *Phragmites austrailes* (Reed Plant) (Table 2b). The concentration of Zn increased to 36.21 and 37.31%, under Tyha and *Phragmites austrailes*, respectively.

Iron (Fe): Mean concentration of Fe ranged from 23.6-30.0 mg L^{-1} with a mean value of 27.27 mg L^{-1} in raw effluent, 16.7-21.0 mg L^{-1} with a mean value of 18.26 mg L^{-1} under *Typha* (Cattail) and 16.1-26.0 mg L^{-1} with a mean value of 19.70 mg L^{-1} under *Phragmites austrailes* (Reed Plant) (Table 2c). Mean reduction in the concentration of Fe was 33.04 and 27.76% under *Typha* and *Phragmites austrailes*, respectively. The reduction in Fe concentration in the treated wastewater may be due to uptake by the plants to meet growth requirements.

Table 2: Effect of *Typha* (cattail) and *Phragmites austrailes* (reed plant) on Cu, Zn, Fe and Mn contents of wastewater

Sample No.	Raw effluent	*Typha* (cattail)	*Phragmites austrailes* (reed plant)
(a) Cu (mg L^{-1})			
1	23.5	6.5	4.3
2	57.2	4.95	7.94
3	54.24	4.45	9.53
Mean	44.98	5.30 (88.22)	7.26 (83.86)
(SD±)	18.66	1.07	2.68
(b) Zn (mg L^{-1})			
1	10.1	14.3	13.6
2	12.7	17.1	14.2
3	12	16	20
Mean	11.6	15.80 (36.21)	15.93 (37.33)
(SD±) of mean	1.35	1.41	3.53
(c) Fe (mg L^{-1})			
1	23.6	16.7	17
2	30	21	26
3	28.2	17.1	16.1
Mean	27.27	18.26 (33.04)	19.70 (27.76)
(SD±)	3.3	2.38	5.47
(d) Mn (mg L^{-1})			
1	16.1	20.1	18.6
2	25.8	50.6	46.5
3	20	30	33
Mean	20.63	33.56 (62.68)	32.70 (58.51)
(SD±) of mean	4.88	15.55	13.95

SD: Standard deviation of mean, No. in parenthesis represent percent increase relative to raw effluent

Manganese (Mn): Mean concentration of Mn ranged from 16.1-25.8 mg L^{-1} with a mean value of 20.63 mg L^{-1} in raw effluent, 20.1-50.6 mg L^{-1} with a mean value of 33.60 mg L^{-1} under *Typha* (Cattail) and 18.6-46.5 mg L^{-1} with a mean value of 32.70 mg L^{-1} under *Phragmites austrailes* (Reed Plant) (Table 2d). The concentration of Mn increased to 62.68 and 58.51% under *Typha* and *Phragmites austrailes*, respectively.

Overall, the concentration of Cu and Fe decreased while those of Zn and Mn increased in the treated wastewater. There may be attributed to the antagonistic behavior among the different microelements in the sediment-water system. Because, during ion uptake, there is a competition among different ions in the sediment-water system by the ion exchange capacity and selectivity of roots being more for certain elements as compared to others in the system.

The study of analytical data of treated wastewater indicated that the concentration of trace elements and heavy metals such as Cu, Fe, Zn and Mn) is still above the maximum allowable limits according to Ayers and Westcot (1985) for irrigation purposes. But, the natural wastewater treatments by growing green plants showed potential for the removal of certain trace elements from wastewater.

Effect of treatments on organic pollutants

NH_4 concentration: Mean concentration of NH_4 ranged from 76.4-110.0 mg L^{-1} with a mean value of 94.23 mg L^{-1} in raw effluent, 23.0-43.7 mg L^{-1} with a mean value of 31.90 mg L^{-1} under *Typha* (Cattail) and 32.0-49.6 mg L^{-1} with a mean value of 38.33 mg L^{-1} under Phragmites

Table 3: Effect of *Typha* (cattail) and *Phragmites austrailes* (reed plant) on NH4, NO3-N and PO4 contents of wastewater

Sample No.	Raw effluent	*Typha* (cattail)	*Phragmites austrailes* (reed plant)
(a) NH4 (mg L^{-1})			
1	76.4	43.7	49.6
2	96.3	23	33.4
3	110	29	32
Mean	94.23	31.90 (66.15)	38.33 (59.32)
(SD±)	16.89	10.65	9.78
(b) NO3-N (mg L^{-1})			
1	9.32	19.32	16.36
2	7.7	9.8	11.5
3	8.32	11.5	12.3
Mean	8.45	13.54 (60.24)	13.39 (58.46)
(SD±) of mean	0.81	5.07	2.61
(c) PO4 (mg L^{-1})			
1	17.53	6.83	6.86
2	21.4	9.5	11.9
3	17	5.22	9.11
Mean	18.64	7.18 (61.48)	9.29 (51.16)
(SD±)	2.4	2.16	2.52

SD: Standard Deviation of mean, No. in parenthesis represent percent reduction relative to raw effluent

austrailes (Reed Plant) (Table 3a). On relative basis, the reduction in the concentration of NH_4 was 66.15 and 59.32% under *Typha* and *Phragmites austrailes*, respectively. The considerable reduction in the NH_4 concentration may be attributed to the volatization loss of organic nitrogen during its mineralization from NH_4 to nitrate (NO_3) by oxidation-reduction processes.

NO_3 concentration: Mean concentration of NO_3 ranged from 7.7-9.32 mg L^{-1} with a mean value of 8.45 mg L^{-1} in raw effluent, 9.8-19.32 mg L^{-1} with a mean value of 13.54 mg L^{-1} under *Typha* (Cattail) and 11.5-16.36 mg L^{-1} with a mean value of 13.39 mg L^{-1} under *Phragmites austrailes* (Reed Plant) (Table 3b). The concentration of NO_3 increased up to 60.24 and 58.64% under Tyha and *Phragmites austrailes*, respectively. The considerable increase in NO_3 concentration may be due to the mineralization of organic nitrogen to a more stable form such as nitrate (NO_3) due to oxidation and nitrification processes.

PO_4 concentration: Mean concentration of PO_4 ranged from 17.0-21.4 mg L^{-1} with a mean value of 18.64 mg L^{-1} in raw effluent, 5.22-9.50 mg L^{-1} with a mean value of 7.18 mg L^{-1} under *Typha* (Cattail) and 6.86-11.90 mg L^{-1} with a mean value of 9.29 mg L^{-1} under *Phragmites austrailes* (Reed Plant) (Table 3c). Overall, the concentration of PO_4 decreased up to 61.48% and 51.16% under *Typha* and *Phragmites austrailes*, respectively. The considerable reduction in PO_4 concentration may be due to the mineralization of organic phosphorus to more stable phosphors compound such as di-phosphate and triple phosphate (PO_4) due to oxidation process.

Plant analysis: Mean concentration (mg kg^{-1}) of cations and anions in the plant tissue was 45.5 (Ca), 7.1 (Mg), 311 (Na), 321 (K), 544 (Cl), 214 (SO_4), 1.65% (N) and 2.05% (PO_4) in *Typha* (Cattail) while it was 8.0 (Ca), 3.2 (Mg), 33 (Na), 184 (K), 88 (Cl), 122 (SO_4), 3.58% (N) and 4.26% (PO_4) in Phragmits austrailes (Reed Plant) (Table 4a). The concentration of all the cations and

Table 4: Mean Concentration (mg L^{-1}) of major Cations, Anions and Trace Elements in Plant Tissue

Plant	Sample No.	Ca	Mg	Na	K	Cl	SO_4	Total N (%)	PO_4	Protein (%)
(a) Major cations and anions										
Typha	1	42	7.5	301	307	546	211	1.63	2.08	10.19
	2	46	7.3	312	325	470	210	1.61	2.07	10.06
	3	48.5	6.4	320	330	615	220	1.71	2.01	10.69
	Mean	45.5	7.1	311	321	544	214	1.65	2.05	10.31
	SD±	3.28	0.59	9.54	12.1	72.53	5.51	0.053	0.04	0.33
P. austrailes	1	8.3	3.3	33	173	85	118	3.64	4.26	22.75
	2	7.8	3.5	28	180	86	116	3.41	3.3	21.31
	3	7.9	2.8	39	200	94	131	3.69	5.22	23.06
	Mean	8	3.2	33	184	88	122	3.58	4.26	22.37
	SD±	0.26	0.36	5.51	14.01	4.93	8.14	0.15	0.96	0.93

Plant	Sample No.	Fe	Mn	Cu	Cr	Ni	As	Se	Zn	Co	Pb
	mg L^{-1}										
(b) Trace elements and heavy metals											
Typha	1	342	3078	30	16	433	170	142	1413	10	33
	2	340	3274	61	13	448	135	127	1442	7	19
	3	341	3132	52	16	692	165	145	1382	6	28
	Mean	341	3161	48	15	524	157	138	1412	7.7	27
	SD±	1	101.23	15.95	1.73	145.39	18.93	9.64	30	2.08	7.09
P. austrailes	1	198	1817	53	25	180	44	25	1207	6	26
	2	241	2174	29	26	181	62	27	1560	6	17
	3	213	1801	33	27	273	56	20	1383	6	16
	Mean	217	1930	38	26	211	54	24	1383	6	20
	SD±	21.83	210.88	12.85	1	53.4	9.16	3.6	176.5	0	5.51

SD: Standard deviation of mean

anions except phosphate ion (PO_4) was significantly higher in *Typha* (Cattail) as compared to *Phragmites austrailes* (Reed Plant). This indicates that ion uptake was more by *Typha* (Cattail) than *Phragmites austrailes* (Reed Plant). Mean concentration of protein was 10.31% in *Typha* and 22.37% in *Phragmites austrailes* which is significantly more in *Phragmites austrailes* than *Typha*. Furthermore, high protein contents of *Phragmites austrailes* seem be a good protein source and can be used as fodder for range animals (sheep, goats, camels and cows). Besides, it can be utilized as an alternate energy source by burning after cutting and drying the plants.

Mean concentration (mg kg^{-1}) of trace and heavy metal ions in plant tissue was 341 (Fe), 3161 (Mn), 48 (Cu), 15 (Cr), 524 (Ni), 157 (As), 138 (Se), 1412 (Zn), 7.7 (Co) and 27 (Pb) in *Typha* (Cattail) while it was 217 (Fe), 1930 (Mn), 38 (Cu), 26 (Cr), 211(Ni), 54 (As), 24 (Se), 1383 (Zn), 6 (Co) and 20 (Pb) in *Phragmites austrailes* (Reed Plant) (Table 4b). The concentration of Fe, Mn and Zn was higher in *Phragmites austrailes* than *Typha*. While the concentration of Cu, Cr, Ni, As, Co and Pb was higher in *Typha* than *Phragmites austrailes*. This variability in the uptake of different ions may be subjected to the plant roots selectivity for different ions and nutrient imbalance in sediment-water system in the vicinity of around plant roots.

Sediment analysis: Mean concentration (mg L^{-1}) of major cations and anions in the sediments was 717, 392 and 1034 (Ca); 482, 115 and 249 (Mg); 744, 464 and 847 (Na); 101, 66 and 345 (K); 944, 1182, 2163 (Cl); 2955, 587 and 1590 (SO_4); 0.98, 6.1 and 258 (NO_3) and 1.70, 4.14 and 30.74 in C, T and P treatment, respectively (Table 5a). The pH was 8.21, 8.18 and 8.30 in C, T amd P

Table 5: Chemical composition of sediments of phytoremediation experiment

Treatment	pH	ECe dS m^{-1}	Ca	Mg	Na	K	Cl	SO\	NO_3	NH_4	NO_2	PO_4
	----	----	----	----	----	----	mg L^{-1}	----	----	----	----	----
Cations and anions												
C	8.21	1.07	717	482	744	101	944	2955	0.98	21	12.3	1.7
T	8.18	1.05	392	115	464	66	1182	587	6.1	138	18.32	4.14
P	8.3	1.17	1034	249	847	345	2163	1590	258	177	518.5	30.74
Mean	8.23	1.1	714	282	685	170.67	1430	1711	88.36	112	183	12.19
SD±	0.06	0.06	321	185.71	198.2	151.99	646.14	1189	146.93	81.18	290.53	16.1

Treatment	Fe	Mn	Cu	Cr	Ni	As	Se	Zn	Pb	Cd	Co
	----	----	----	----	----	mg L^{-1}	----	----	----	----	----
Trace elements and heavy metals											
C	49.16	0.064	ND	ND	0.86	ND	ND	ND	0.53	0.016	3.68
T	27.04	0.002	ND	ND	1.73	ND	ND	ND	1.2	ND	2.14
P	26.42	0.022	ND	ND	1.45	ND	ND	ND	0.27	ND	2.06
Mean	34.2	0.029	--	--	1.35	--	--	--	0.67	--	2.63
SD±	12.95	0.032	--	--	0.44	--	--	--	0.48	--	0.91

treatments respectively. The sediment total salinity (expressed by dS m^{-1}) was 1.07, 1.05 and 1.17 in C, T and P treatments, respectively. The concentration of all cations and anions was considerably higher in the sediments around *Phragmites austrailes* followed by the control (C) and *Typha* (Cattail Plant) treatments, respectively.

In the present study, only the concentration of Fe, Mn, Ni, Pb and Co was determined in the sediment samples (Table 5b). The concentration of Fe, Mn and Co was higher in the control than the sediment samples with *Typha* and *Phragmites austrailes* while the concentration of Ni and Pb was less than that found in the sediment samples under *Typha* and *Phragmites austrailes*. Although, the concentration of all the trace and heavy metal ions was slightly higher in sediments under *Typha* than under *Phragmites austrailes*, but there was no difference in the metal concentration between the two plants.

DISCUSSION

The study showed significant reduction both in the COD and BOD of the treated wastewater. Mean reduction of COD was 48% and 58% while that of BOD was 67 and 65% under *Typha* and phragmites austrailes, respectively. Similarly, Liu *et al.* (2000) reported the removal rates of 83.2, 82.3, 76.3, 96.2, 73.5 and 85.8% for total Phosphurus (TP), phosphate, Total nitrogen (TN), ammonia, critical level of chemical oxygen demand (COD_{cr}) and BOD_5 in the channel-dyke system with napiergrass (*Pennisetum purpurem* Schumach. *Pennisetum alopecuroides* (L.) Spreng American), respectively. Also, Klomjek and Nitisoravut (2005) tried eight different plants to remove pollutants from saline wastewater. Treatment performances of planted units were 72.4-78.9% for BOD_5, 43.2-56.0% for SS, 67.4-76.5% for NH_3-N and 28.9-44.9% for TP. The most satisfactory plant growth and nitrogen assimilation were found for cattail (*Typha* angustifolia) with limited plant growth. The reduction in BOD_5, SS, NH_3-N and TP ranged from 44.4-67.9, 41.4-70.4, 18.0-65.3 and 12.2-40.5%, respectively. In China, Lan *et al.* (1992) reported the reduction of total suspended solids, chemical oxygen demand, Pb and Zn in natural wastewater treatments up to 99, 55, 95 and 80%, respectively.

The concentration of Cu and Fe decreased while that of Zn and Mn increased in natural wastewater treatments i.e.by growing green plants. The study results did not agree with the findings of Lan *et al.* (1992) who found reduction in Zn under natural wastewater treatments. Regarding the organic pollutants, the concentration of NH_4 decreased between 66% and 59% while PO_4 decreased between 61 and 51% under *Typha* and *Phragmites austrailes*, respectively. These findings agree with the results of Klomjek and Nitisoravut (2005) who found reduction in NH_3-N and TP ranging from 18.0-65.3 and 12.2-40.5%, respectively. Also, the concentration of NO_3 increased up to 60 and 58% under *Typha* and *Phragmites austrailes*, respectively. Similarly, Jia *et al.* (2010) studied the role of *Phragmites austrailes* for wastewater treatment in a continuous and intermittent flood system. They found that the intermittent operation caused more oxidizing conditions in the microcosm wetlands and thus greatly enhanced the removal of ammonium and the removal efficiency was more than 90%.

CONCLUSION

The study showed significant BOD and COD reduction in the treated wastewater as compared to the raw effluent. The concentration of trace elements such as Cu and Fe decreased, but Zn and Mn increased both under Typh and *Phragmites austrailes*. Similarly, NH_4 and PO_4 decreased but NO_3 increased appreciably as compared to the control (raw effluent) treatment. The concentration of all the investigated trace elements was above the maximum allowable limits except NH_4, NO_3 and PO_4 which was within acceptable limits for irrigation purpose.

There is no significant change in the total salinity and pH of sediments with domestic wastewater application. The concentration of all the major cations and anions was significantly higher except phosphate ion (PO_4) in *Typha* (Cattail) as compared to the *Phragmites austrailes* (Reed Plant). The ion uptake was higher by *Typha* (Cattail) than *Phragmites austrailes* (Reed Plant). Mean protein contents were 10.31 and 22.37% in *Typha* and *Phragmites austrailes*, respectively. The higher protein contents of *Phragmites austrailes* seem potential protein source and can be used as fodder for range animals (sheep, goats, camels and cows). The concentration of Fe, Mn and Zn was high in *Phragmites austrailes* than *Typha*. While the concentration of Cu, Cr, Ni, As, Co and Pb was higher in *Typha* as compared to *Phragmites austrailes*. The concentration of all cations and anions in the sediments was considerably higher under Phragmites austrailes followed by the control (C) and *Typha* (Cattail Plant) treatments, respectively. The concentration of Fe, Mn and Co was higher in the control than the sediment samples with *Typha* and *Phragmites austrailes* plants, Also, the concentration of Ni and Pb was less in the control than that found in the sediment samples under *Typha* and *Phragmites austrailes*. In conclusion, the research findings showed promising potential for the removal of heavy metals and other pollutants from domestic wastewater by growing green plants (*Typha* and *Phragmites austrailes*) to improve treated wastewater quality acceptable for agriculture use.

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