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Comparative Efficiency of Phragmites *karka* and *chrysopogon zizanioides* for the Reduction of Various Pollutants and Metals from Domestic Wastewater in a Constructed Wetland Technology

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Abstract

Remediation efficiency of *Phragmites karka* and *Chrysopogon zizanioides* for wastewater is demonstrated in a constructed wetland technology. The physiochemical parameters which were taken into consideration were studied in a period of six months per year for two years and variation in parameters were recorded during each month after the plantation of the said plants into the study area (constructed wetland). The various physiochemical parameters which were studied pH, EC (Electrical Conductivity), TDS (Total Dissolved Solids), DO (Dissolved Oxygen), COD (Chemical Oxygen Demand), NO_3-N (Nitrates), and PO_4^{3-} (Phosphates). The heavy metals like Fe (iron), Zn (Zinc), Cu (Copper) and Pb (Lead) were detected by Atomic Absorption Spectroscopy (AAS). The effective variation were recorded in the physiochemical parameters as well as in the content of studied metals but minor changes in pH and large increment in DO was observed. The said plants proved to be as good hyperaccumulators of pollutants for the reduction of pollutants and extraction of heavy metals from domestic wastewater in comparison to a lot of already suggested plants. The treated water could be utilized for industrial processes, household activities, and irrigation purposes.

Introduction

The reuse of treated wastewater in particular for irrigation is a common practice, which is encouraged by governments and official entities worldwide [1]. Now a day's adequate treatment of domestic wastewater treatment plays an important role for the availability of water. The treatment of wastewater involves the removal of contaminants from through physical, chemical, and biological methods [2]. The use of natural methods for wastewater treatment in a controlled manner has drawn a special attention. More and more scientific evidences are available which indicated that the artificially designed treatment systems are very efficient treatment technologies [3]. Constructed wetland treatment systems are engineered systems which are also called as constructed filtration systems planted with wetland vegetation are designed to take advantage of many processes that occur in natural wetlands in a more controlled manner [4].

The remedial plant based approach takes the advantage of plants ability to absorb contaminants from contaminated sites

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and then metabolize them in their tissues. These macrophytes are then subsequently harvested, processed and disposed. The macrophytes with strong absorption for pollutants and good tolerance ability could be planted in constructed wetlands which accordingly removes or fixes water pollutants through adsorption, absorption, accumulation and degradation [5]. They provide good conditions for physical filtration and large surface area for attached microbial growth and activity [6]. The macrophytes cultivated in constructed wetlands make them one of the basic components in the treatment process. There is the influence of the plant-microorganisms interactions in wastewater by providing microbial attachment sites, sufficient wastewater residence time, trapping and settlement of suspended wastewater components [7].

Heavy metals and trace elements are of specific interest as they are considered as powerful tracers for monitoring the ill impacts of human activities. Replacement of essential nutrients by heavy metals at cation exchange sites of plants is indirect toxic effect of these metals [8]. Aquatic macrophytes are used as the natural catalysts to adsorb and accumulate heavy metals in their tissues from heavy metal polluted water [9].

India, like other developing countries, also requires economical and cost-effective alternatives for wastewater treatment. There is a great need for wastewater treatment of all kinds of pollution in Central India. So as to solve the problem like water scarcity, it strangulates the economic development, as well as environmental quality throughout the world.

Material and methodology

Gwalior is located at 26.22^0 North 78.18^0 East in northern M.P. The climate of this district is more oppressive during summer as it is too hot and severe cold in the winter season. Every year Gwalior suffers a stern drinking water supply crisis during dry season. The limited rain water and surface runoff needs conservation which can ensure the availability of water throughout the year here in. Farmers in Gwalior mostly irrigate their fields by using localized harvesting methods and by digging tube wells. The drinking supply of water is intermittent in the city.

Site selection

The current study was carried out at School of Studies in Botany, Jiwaji University Gwalior. Constructed wetlands planted Phragmites karka, and Chrysopogon zinzanoides and without plants for wastewater treatment was established in Charak Udhyan near Mahalgaon, City center Gwalior M.P. 474011.

Experimental design

The dimension of wetland and filtration bed was prepared according to previous studies in this field [10]. The constructed wetland of $3m^3$ (1m x 2m x 1.5m) height, length and breadth respectively, was properly designed with a basin that holds the water, a substratum for holding the root system of plants. During the process of Construction of this wetland, the protocols were strictly followed. Different microbes and aquatic invertebrates were grown naturally. The raw domestic wastewater, from the main drainage system of Mahalgaon was collected in the settling tank after the preparation of well designed beds. The wastewater from settling tank was allowed to move into the experimental beds for treatment. The treated wastewater from setups was collected from the bottom of the unit by outlet pipe. The various parameters of untreated and treated water were analyzed by standard methods of [11].

Results and Discussion

The domestic wastewater effluents from rural and urban areas contain a number of toxic elements which includes organic and inorganic components and heavy metals. As these effluents were discharged into fresh water and other water resources it gives birth to number of diseases in plants, animals.

The calculated pH of DWW ranged from 7.55±0.03 (Feb) to 7.79±0.05 (Apr) in 2018 and 7.65±0.04 (Mar) to 7.86±0.06 (Apr) in 2019. Similar ranges of pH were reported by [12-14] while studying the characteristics of urban wastewater. As per CPCB guidelines (2012), the pH of wastewater should remain between 6 and 8.5 for agricultural reuse. Many plant characteristics like height of plant, their lateral spread, plant biomass, number and size of flower, pollen production and various activities within a plant is influenced by pH [15]. The EC of domestic

Table 1: EC, TDS, DO, COD, NO3- and PO43- (mgL-1) values of Domestic Wastewater during 2018 and 2019 (Mean ± SE).

Sites	Parametes	Year	Jan	Feb	Mar	Apr	May	Jun
Domestic Wastewater	pH	2018	7.57±0.01	7.55±0.03	7.69±0.03	7.79±0.05	7.63±0.05	7.71±0.03
		2019	7.79±0.05	7.67±0.05	7.65±0.04	7.86±0.06	7.85±0.03	7.85±0.04
	EC (µScm^{-1})	2018	1419±6.81	1334±12.66	1324.67±5.21	1320.67±8.84	1310.67±3.53	1412±6.66
		2019	1501.33±9.96	1456±10.02	1594.67±9.02	1313.20±6.36	1317.33±6.94	1338±7.37
	TDS (mgL^{-1})	2018	1943.33±22.05	1850.00±21.79	1908.33±21.67	1846.67±23.33	1859.00±30.35	1866.67±30.32
		2019	2178.50±23.27	2255.00±28.87	2323.00±22.59	2353.33±27.72	2205.67±21.88	2075.33±16.15
	DO (mgL^{-1})	2018	0.63±0.03	0.52±0.03	0.68±0.03	0.64±0.01	0.77±0.02	0.73±0.05
		2019	0.78±0.01	0.75±0.04	0.80±0.020	0.79±0.04	0.87±0.03	0.75±0.02
	COD (mgL^{-1})	2018	1247.67±8.76	1283.33±9.7	1294.67±4.06	1281.67±8.76	1332.00±6.81	1266.67±6.94
		2019	1364.00±17.15	1264.33±8.19	1324.67±9.13	1272.50±4.49	1320.67±5.31	1277.67±5.24
	NO_3^- (mgL^{-1})	2018	41.72±0.87	38.59±1.19	45.6±1.95	46.12±0.95	45.26±0.53	43.99±0.99
		2019	42.72±0.86	46.92±0.87	41.93±0.97	47.56±1.09	44.39±0.94	40.99±1.37
	PO_4^{3-} (mgL^{-1})	2018	11±0.9	10.99±0.28	12.14±0.44	12.15±0.91	12.34±0.25	11.53±0.25
		2019	10.54±0.22	11.06±0.19	11.77±0.40	12.48±0.46	12.28±0.91	12.56±0.59

wastewater ranged from 1320.67±8.84 μScm^{-1} to 1419±6.81 μScm^{-1} in 2018 and 1313.20±6.36 μScm^{-1} to 1594.67±9.02 μScm^{-1} in 2019. Similar results of EC were reported by [14] and higher EC in H_2O creates adverse effects on soil when salt content in water is high [16]. The %age reduction shown by CWWP ranged from 2.03±1.07 (Feb) to 27.90±-0.71 (Jun) in 2018 and 6.75±0.36 (Jan) to 23.91±0.74 (Jun) in 2019. The removal percentages shown by CWPK during last 2 months i.e. May and June were 30.60±0.51 and 42.89±0.54 in 2018 and 41.01±0.87 and 47.20±0.79 in 2019. Similarly CWCZ showed 35.99±0.61 and 45.73±0.4 in 2018 and 40.62±0.37 and 42.71±1.01 in 2019. Total Dissolved Solids (TDS) are the sum total of all inorganic and organic substances dissolved in water which includes positive and negative ions of chlorides, sulphates, phosphates, carbonates, bicarbonates, soluble metals ions etc., whereas COD measures the O_2 demand of biodegradable and non-biodegradable oxidizable pollutants. The aquatic environment is affected due to high levels of COD which leads to the depletion of O_2 levels and in turn water becomes unsuitable for reuse [17].

Table 2: EC, TDS, DO, COD, NO3- and PO43- (mgL-1) values of Settling Tank Wastewater during 2018 and 2019 (Mean ± SE).

Sites	Parameters	Year	Jan	Feb	Mar	Apr	May	Jun
Settling Tank	pH	2018	7.5±0.01	7.43±0.02	7.4±0.02	7.46±0.02	7.44±0.04	7.32±0.04
		2019	7.76±0.04	7.56±0.04	7.67±0.06	7.68±0.04	7.73±0.03	7.71±0.03
	EC (μScm^{-1})	2018	1357.33±12.42	1315.67±6.39	1295.67±5.81	1246.67±10.49	1208.67±4.63	1302.33±7.62
		2019	1415.67±6.36	1062.33±8.88	1305.67±4.06	1174.33±9.53	1263.33±5.78	1300.33±8.19
	TDS (mgL^{-1})	2018	1858.33±18.78	1780.00±20.21	1830.00±16.07	1775.00±20.21	1725.00±28.43	1748.33±24.55
		2019	2010.00±20.41	2005.00±20.26	1858.00±24.38	1876.67±20.95	2007.67±22.45	1766.67±29.63
	DO (mgL^{-1})	2018	0.90±0.04	0.87±0.03	0.87±0.03	0.96±0.03	1.05±0.04	0.92±0.02
		2019	0.84±0.02	0.90±0.01	0.94±0.01	0.97±0.02	1.04±0.02	1.04±0.02
	COD (mgL^{-1})	2018	1116.67±4.75	1078.00±7.51	1102.00±11.15	1062.33±12.25	1104.33±11.86	1019.50±6.94
		2019	1032.67±8.57	1000.00±4.08	973.33±4.10	991.50±4.49	966.67±8.29	931.00±5.29
	NO_3^- (mgL^{-1})	2018	35.66±0.78	32.42±1.05	33.14±1.08	34.36±0.71	31.99±1.41	32.57±0.76
		2019	36.59±0.94	37.42±1.29	32.81±0.64	35.24±0.64	34.99±1.81	31.90±1.57
	PO_4^{3-} (mgL^{-1})	2018	9.26±0.36	9.13±0.18	10.49±0.67	9.58±0.32	9.41±0.26	9.12±0.26

Phosphates and nitrates are vital for the growth and development of plants. The untreated discharge of sewage and domestic waste acts as the main sources of nitrates and phosphates that cause the water pollution. The calculated data of samples collected from DWW ranged from 1846.67±23.33 mgL^{-1} to 1943.33±22.05 mgL^{-1} in 2018 and 2075.33±16.15 mgL^{-1} to 2323±22.59 mgL^{-1} in 2019 for TDS; 0.52±0.03 mgL^{-1} to 0.77±0.02 mgL^{-1} in 2018 and 0.75±0.04 mgL^{-1} to 0.87±0.03 mgL^{-1} in 2019 for DO, 1247.67±8.76 mgL^{-1} to 1332±6.81 mgL^{-1} in 2018 and 1264.33±8.19 mgL^{-1} to 1364.00±17.15 mgL^{-1} in 2019 for COD; 38.59±1.19 mgL^{-1} to 46.12±0.95 mgL^{-1} in 2018 and 40.99±1.37 mgL^{-1} to 47.56±1.09 mgL^{-1} in 2019 for NO_3-N while 10.54±0.22 mgL^{-1} to 12.56±0.59 mgL^{-1} in 2018 and 10.99±0.28 mgL^{-1} to 12.34±0.25 mgL^{-1} in 2019 for PO_4^{3-}. The concentration of pollutants of samples collected from ST ranged from 1725.00±28.43 mgL^{-1} to 1858.33±18.78 mgL^{-1} in 2018 and 1766.67±29.63 mgL^{-1} to 2010.00±20.41 mgL^{-1} in 2019 for TDS; 0.87±0.03 mgL^{-1} to 1.05±0.04 mgL-1 in 2018 and 0.84±0.02 mgL^{-1} to 1.04±0.02 mgL^{-1} in 2019 for DO; 1019.5±6.94 mgL^{-1} to 1116.67±4.75 mgL^{-1} in 2018 and 931±5.29 mgL^{-1} to 1032.67±8.57 mgL^{-1} in 2019 for COD; 31.99±1.41 mgL^{-1} to 35.66±0.78 mgL^{-1} in 2018 and 31.90±1.57 mgL^{-1} to 37.42±1.29 mgL^{-1} in 2019 for NO^{3-} while 9.12±0.26 mgL^{-1} to 10.49±0.67 mgL^{-1} in 2018 and 8.12±0.15 mgL^{-1} to 8.93±0.37 mgL^{-1} in 2019 for PO_4^{3-} [18]. Reported higher concentration of TDS from paper industries effluents while [19] at Haifa in Israel reported lower concentration of TDS in wastewater. [13,20] recorded similar concentration of pollutants while studying the physico-chemical parameters of wastewater whereas [14,21] reported higher concentration of DO in DWW. [22] Reported similar concentrations of COD (1200 mgL^{-1}) in Black/faecal wastewater while COD values found by [23] in the raw industrial wastewater of coffee plants were between 4000 mgL^{-1} and 4600 mgL^{-1}. Comparatively, wastewater showed higher concentrations of NO_3^- and lower concentration of PO_4^{3-} in Iran [24]. The value of EC, TDS and COD of wastewater illustrates that the water is not ideal for irrigation purposes whereas the concentration of Nitrates and phosphates without treatment are within permissible limits according to FAO 2005/APHA 2016. The percentage reduction of TDS by CWPK ranged from 9.86±0.3 to 40.53±0.5 in 2018 while 14.45±0.6 to 48.33±1.88 in 2019. The reduction percentage shown by CWCZ for TDS ranged from 8.66±0.8 to 47.19±0.85 in 2018 while 13.37±0.18 to 50.98±1.3 in 2019. The PSCW planted with P. australis showed better efficiency for the reduction of TDS (57.34%) [25] The observed results were similar to the results of Chale, (2012) for TDS in HFCW planted with *P. mauritianus* in Tanzania.

The percentage increment in DO range from 40.83±1.36 to 58.57±1.25 in CWWP; 41.48±2.35 to 82.42±0.97 in CWPK while 41.35±1.66 to 83.23±0.93 in CWCZ respectively in 2018. Similarly in 2019 the increment ranged from 17.61±0.92 to 33.82±1.18 in CWWP; 41.35±1.66 to 83.23±0.93 in CWPK and 17.24±1.25 to 83.23±0.93 in CWCZ. The DO increased upto 80 to 85% in planted wetlands during the last months i.e. May and June in both wetlands in 2018 and 2019. This indicates effective transfer of O2 through the rhizosphere of plants and diffusion of oxygen occurred through the gravel bed. [26] reported maximum percentage increment of DO by *T. latifolia* in Pune during the treatment of MWWT. The percentage reduction shown by CWWP varied from 7.02±0.65 to 14.37±0.26 in 2018 and 12.82±0.33 to 30.67±0.31 in 2019 for TDS; 9.84± 0.6 to 35.12±0.54 in 2018 and 29.22±0.48 to 43.4±0.49 for COD; 31.61±0.48 to 50.64± 2.01 in 2018 and 23.68±0.49 to 46.8±0.93 in 2019 for NO_3-N; 26.07±1.09 to 44.82±1.07 in 2018 and 27.18±1.03 to 56.26±0.8 in 2019 for PO_4^{3-}. The percentage reduction by CWPK varied from 9.86±0.3 to 40.53±0.5 in 2018 and 14.45±0.6 to

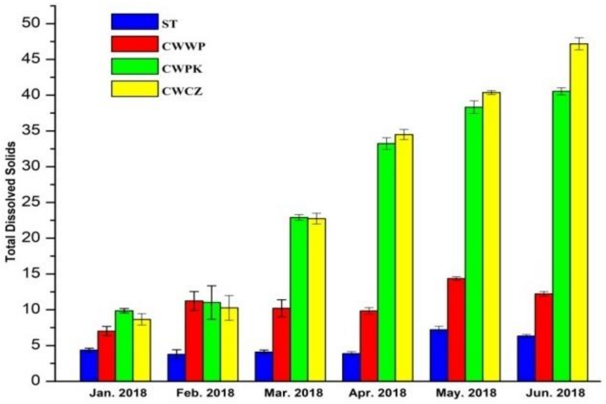

Figure 4.5: Percentage reduction in TDS during. 2018.

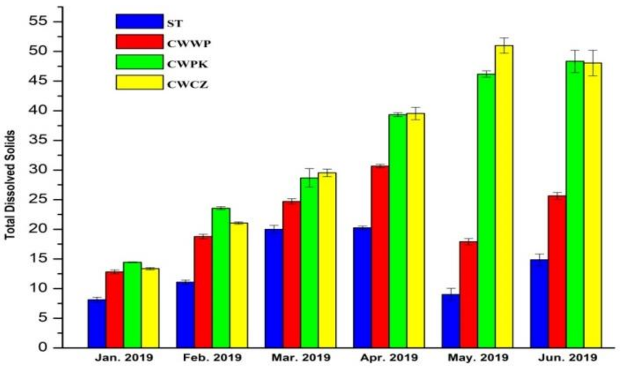

Figure 4.6: P=

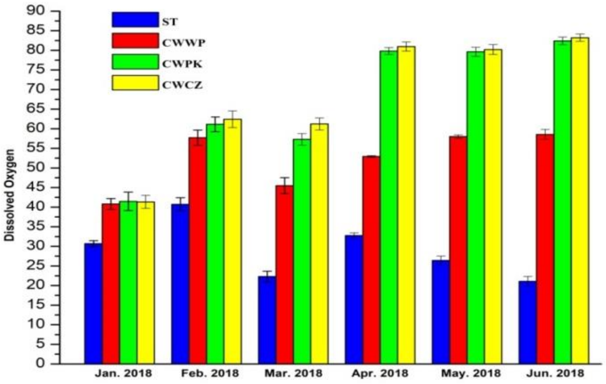

Figure 4.9: Percentage increment in DO during 2018.

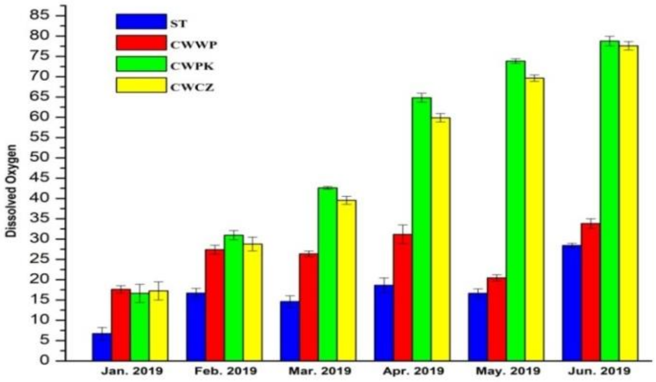

Figure 4.10: Percentage increment in DO during 2019.

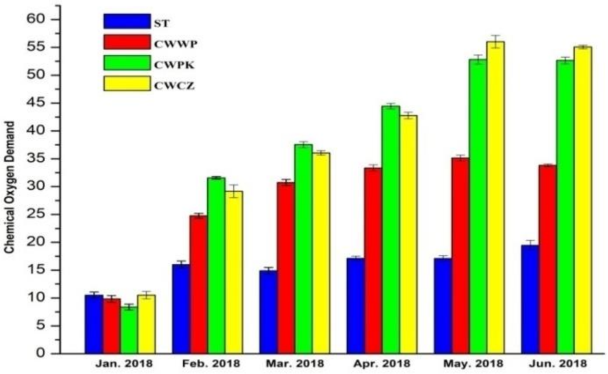

Figure 4.13: Percentage reduction in COD during 2018.

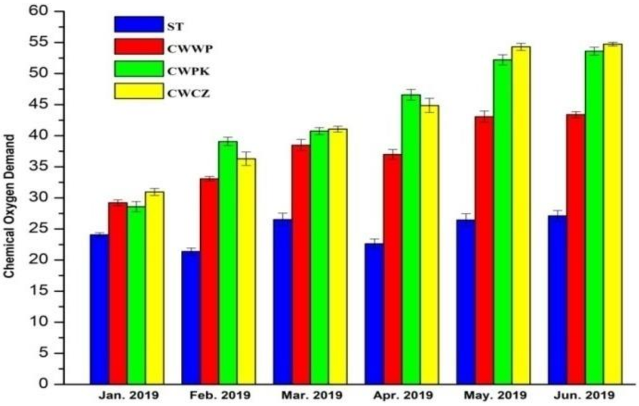

Figure 4.14: Percentage reduction in COD during 2019.

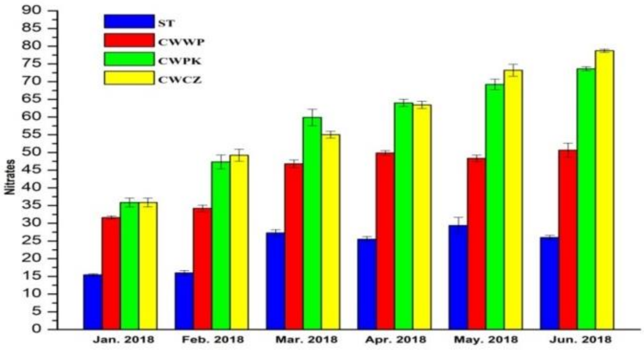

Figure 4.25: Percentage reduction in Nitrates during 2018.

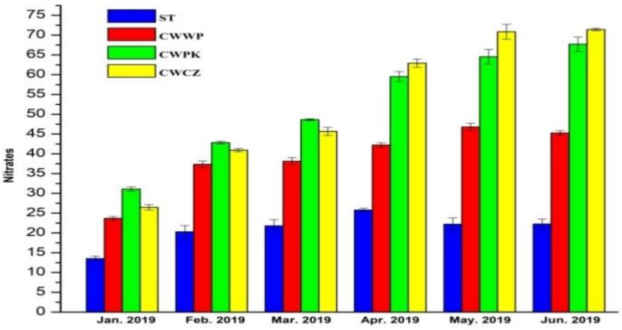

Figure 4.26: Percentage reduction in Nitrates during 2019.

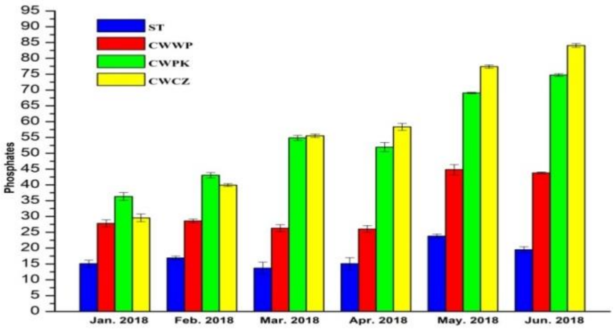

Figure 4.27: Percentage reduction in Phosphates during 2018.

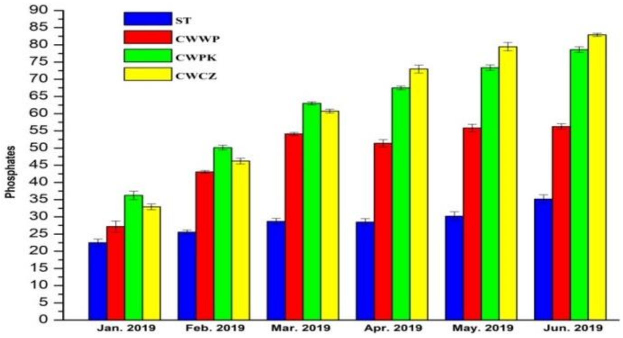

Figure 4.28: Percentage reduction in Phosphates during 2019.

48.33±1.88 in 2019 for TDS; 8.37±0.53 to 52.65±0.6 in 2018 and 28.59±0.28 to 53.6±0.64 in 2019 for COD; 35.87±1.26 to 73.42±0.59 in 2018 and 31.09±0.54 to 67.71±1.85 in 2019 for NO$_3$-N while 36.32±1.23 to 74.74±0.43 in 2018 and 36.24±1.25 to 78.61±0.15 in 2019 for PO$_4^{3-}$. Similarly percentage reduction shown by CWCZ varied from 8.66±0.8 to 47.19±0.85 in 2018 and 13.37±0.18 to 50.98±1.3 in 2019 for TDS; 10.51±0.67 to 56.01±1.14 in 2018 and 30.95±0.56 to 54.57±0.31 in 2019 for COD; 35.87±1.26 to 78.71±0.48 in 2018 and 26.46±0.68 to 71.42±0.32 in 2019 for NO$_3$-N while 29.58±1.23 to 84.10±0.6 in 2018 and 32.92±0.3 to 82.93±0.44 in 2019 for PO$_4^{3-}$.

The concentration of various parameters in DWW treated in CWWP decreased sharply with time. When it was compared with wetlands with plants, the contribution of *P. karka* and *C. zizanioides* for the reduction were increased from 2.84±0.47% and 1.64±0.58% respectively during 1st month to 28.31±0.32% and 34.97±0.28% respectively during 6th month for TDS; 6.80±0.18% and 4.41±0.38% respectively during 2nd month to 18.82±0.44% and 21.26±0.1% respectively during 6th month for COD; 4.25±0.78% and 2.64±0.53% respectively during 1st month to 22.98±1.47% and 28±0.74% respectively during 6th month for NO$_3^-$ while 8.5±0.83% and 1.76±1.54% respectively during 1st month to 30.93±0.65% and 40.29±0.52% respectively during 6th month for PO$_4^{3-}$. Similarly, in 2019, the contribution of *P. karka* and *C. zizanioides* for reduction increased from 4.78±0.57% and 2.28±0.6% respectively during 2nd month to 22.68±2% and 22.40±2.6% respectively during 6th month for TDS; 6±0.37% and 3.21±0.4% respectively during 2nd month to 10.19±1.13% and 11.35±0.19% respectively during 6th month in 2019 for COD; 5.51±0.52% and 3.59±1% respectively during 2nd month to 22.44±2.30% and 26.15±0.63% respectively during 6th month for NO$_3$-N while 7.07±0.32% and 3.15±0.31% respectively during 2nd month to 23.34±0.78% and 26.67±0.96% respectively during 6th month for PO$_4^{3-}$. The calculated efficiency showed that *P.karka* and *C. zizanioides* are more efficient than *T. latifolia* and *Croton* plants in SSFCW for the reduction of TDS [27]. The calculations suggested the hydrophyte possesses the ability of absorbing anions and cations from wastewater. Higher solids concentration decreases the passage of light through water, thereby slowing photosynthesis by aquatic plants. COD of influents were reduced significantly in treatment beds during the entire treatment period particularly during the last 3 months i.e. April to June of 2018 as well as 2019. However, the COD removal efficiency didn't vary too much between two plant species but *C. zizanioides* showed a slightly higher level of reduction efficiency in comparison to *P. karka*. The PSCW planted with *P. australis* [25] and HSSFCW planted *Zantedeschia aethiopica* [28] showed better reduction efficiency for COD while *S. molesta* showed less reduction of COD reducing the treatment of DWW [29]. Reported lower concentrations of NO$_3^-$ and PO$_4^{3-}$ while studying DWW in Vishnupuri. MWW analysed in Kuwait illustrated higher concentration of NO$_3^-$ and PO$_4^{3-}$ compared to our results. Quality membrane treatment followed by complement treatments showed similar reduction efficiency for NO$_3$-N [19]. Studied CW planted with *T. latifolia* and *P* [30]. Australia whose calculated results were not as efficient as our results whereas WTTP planted by *Brassica*, *Apium graveolens* and *Nasturtium officinale* showed similar results [31] as reported by us. *Pennisetum purpurem* and *Pennisetum alopecuroides* reduced 83.2% for PO$_4^{3-}$ and 82.3% for NO$_3$-N under Channel Dyke System in America [32]. CWWP showed less percentage reduction for NO$_3$-N and PO$_4^{3-}$ compared to CWPK and CWCZ. The PO$_4^{3-}$ concentration reduction was found to be highest when the plants had vast root zone area. Some macrophytes like *Canna indica* and *Phragmites australis* possesses less efficiency for reduction of PO$_4^{3-}$ from wastewater whereas *Typha latifolia* was as efficient as our experimental plants [33].

Heavy metals from Domestic wastewater

The Domestic Wastewater carries an appreciable amount of toxic heavy metals. The concentration of metals in DWW ranged from 2.54±0.04 mgL^{-1} to 3.18±0.01 mgL^{-1} in 2018 and 2.45±0.01 mgL^{-1} to 2.92±0.05 mgL^{-1} in 2019 for Fe; 72.67±1.20 µgL^{-1} to 87.77±2.39 µgL^{-1} in 2018 and 70.73±1.2 µgL^{-1} to 88.33±0.58 µgL^{-1} in 2019 for Zn; 0.61±0.02 µgL^{-1} to 1.07±0.03 µgL^{-1} in 2018 and 0.62±0.01 µgL^{-1} to 1.09±0.01µgL^{-1} in 2019 for Pb; 2.00±0.12 µgL^{-1} to 2.77±0.23 µgL^{-1} in 2018 and 1.83±0.03 µgL^{-1} to 2.6±0.12 µgL^{-1} in 2019 for Cu.

[34] Reported the concentration of Cu (126.9-143.5 mgKg^{-1}), Pb (27.6-35.7 mgKg^{-1}) and Zn (843.1-986.5 mgKg^{-1}) in Sewage Sludge, which is totally different as compared to the results observed. [35] reported higher concentrations of Pb in sewage wastewater while concentration of Pb was similar in the water drawn from deep tube well. The calculated results of Fe, Zn, Cu and Pb depicted that the DWW before treatment is suitable for irrigation according to FAO 1985/WHO 2005/APHA 2002 [36].

There wasn't too much change in concentration of metals in ST. The concentration of Fe in ST ranged from 2.15±0.01 mgL^{-1} (Apr) to 2.89±0.04 mgL^{-1} (Feb) in 2018 and 2.14±0.01 mgL^{-1} (May) to 2.45±0.03 mgL^{-1} (Jun) in 2019; Zn as 6.08±0.46 µgL^{-1} (Jun) to 18.17±1.85 µgL^{-1} (Jan) in 2018 and 5.52±1.6 µgL^{-1} (Jun) to 18.75± 1.2 µgL^{-1} (Feb) in 2019; Pb as 0.43±0.01 µgL^{-1} (Jun) to 0.87±0.01 µgL^{-1} (Jan) in 2018 and 0.49±0.02 µgL^{-1} (Jun) to 0.8±0.02 µgL^{-1} (Feb) in 2019 while Cu as 1.73±0.03 µgL^{-1} (Jan) to 2.03±0.12 µgL^{-1} (Mar) in 2018 and1.6±0.06 µgL^{-1} (Jan) to 1.97± 0.09 µgL^{-1} (Jun) in 2019.

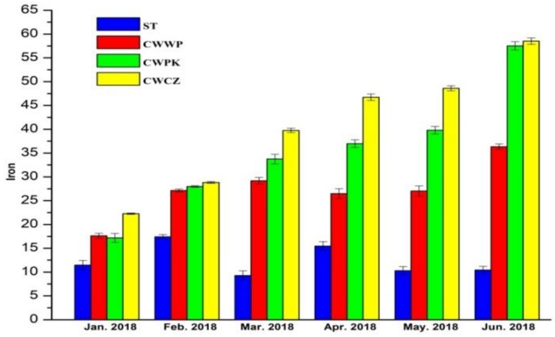

Figure 4.33: Percentage reduction in Iron during 2018.

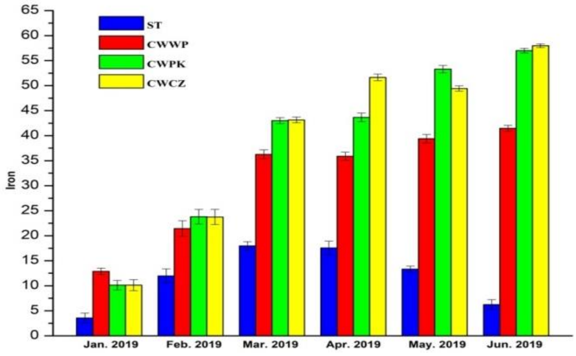

Figure 4.34: Percentage reduction in Iron during 2019.

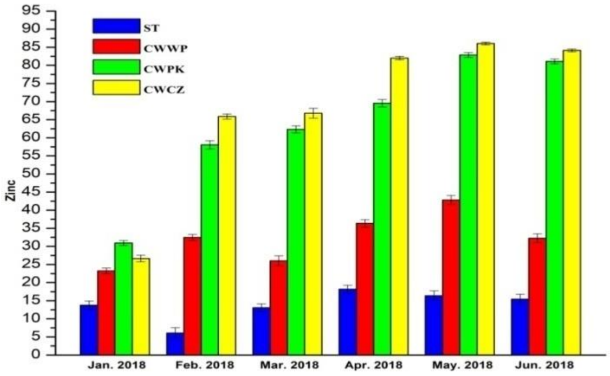

Figure 4.35: Percentage reduction in Zinc during 2018.

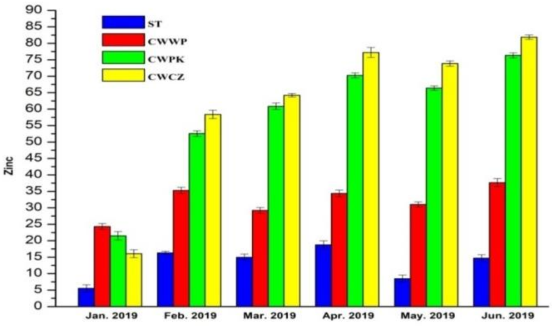

Figure 4.36: Percentage reduction in Zinc during 2019.

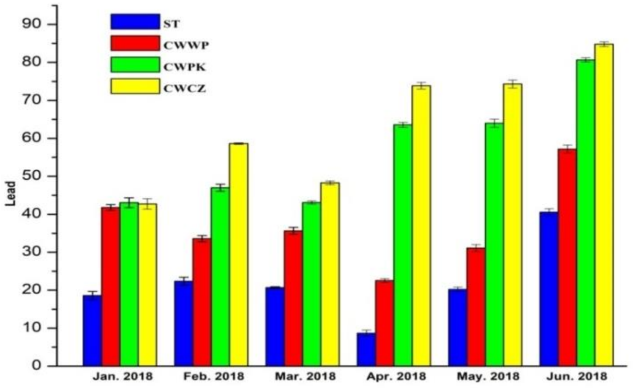

Figure 4.37: Percentage reduction in Lead during 2018.

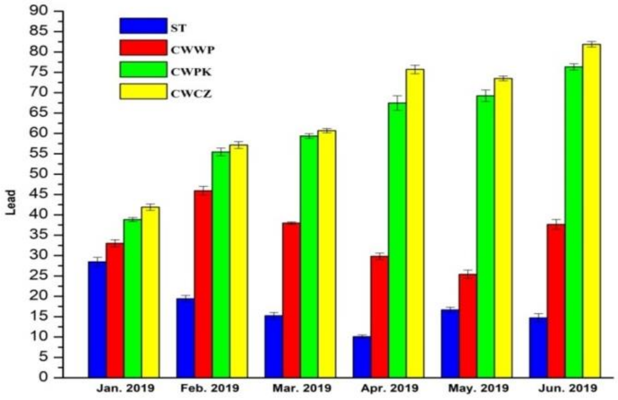

Figure 4.38: Percentage reduction in Lead during 2019.

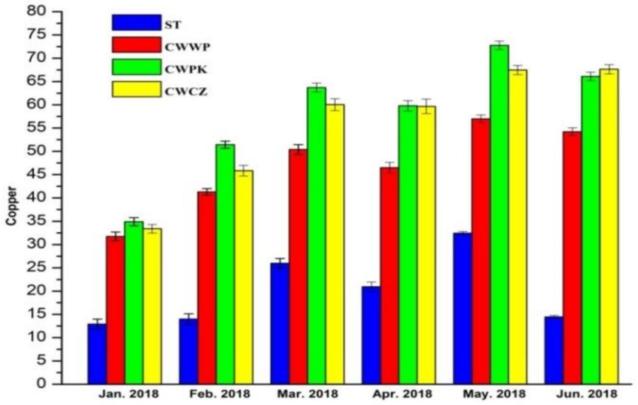

Figure 4.39: Percentage reduction in Copper during 2018.

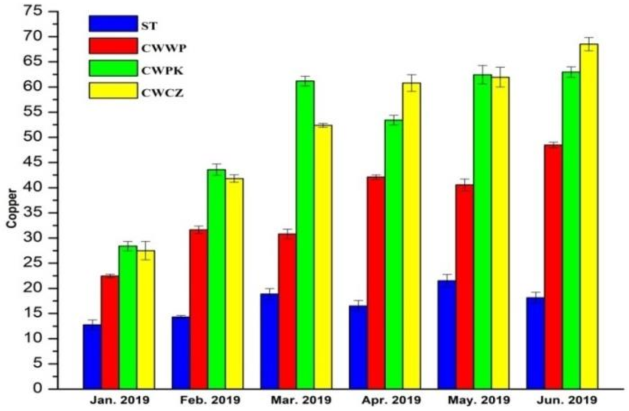

Figure 4.39: Percentage reduction in Copper during 2018.

Table 3: Heavy metals (Iron, Zinc, Lead and Copper) (mgL-1) values of Domestic wastewater during 2018 and 2019 (Mean±SE).

Sites	Parameters		Jan	Feb	Mar	Apr	May	Jun
Domestic Wastewater	Fe (mgL^{-1})	2018	2.89±0.04	3.18±0.01	3.18±0.01	2.54±0.04	2.56±0.01	2.89±0.01
		2019	2.51±0.04	2.92±0.05	2.92±0.05	2.71±0.04	2.45±0.01	2.64±0.05
	Zn (µgL^{-1})	2018	86.67±1.86	77.87±2.14	84.33±5.36	81.37±3.86	87.77±2.39	72.67±1.85
		2019	76.67±1.86	88.33±0.58	87±2.08	81.50±1.46	70.73±1.20	72±2.2
	Pb (µgL^{-1})	2018	1.07±0.03	0.77±0.01	0.58±0.01	0.65±0.02	0.61±0.02	0.72±0.01
		2019	1.09±0.01	0.99±0.01	0.75±0.02	0.73±0.01	0.62±0.01	0.70±0.01
	Cu (µgL^{-1})	2018	2.00±0.12	2.23±0.2	2.77±0.23	2.23±0.09	2.57±0.09	2.27±0.09
		2019	1.83±0.03	2.13±0.07	2.60±0.12	2.13±0.12	2.20±0.17	2.40±0.06

Table 4: Heavy metals (Iron, Zinc, Lead and Copper) (mgL-1) values of wastewater from Settling tank during 2018 and 2019 (Mean±SE).

Sites	Parameters		Jan	Feb	Mar	Apr	May	Jun
Settling Tank	Fe (mgL^{-1})	2018	2.56±0.02	2.89±0.04	2.89±0.04	2.15±0.01	2.3±0.01	2.58±0.01
		2019	2.42±0.06	2.40±0.11	2.40±0.11	2.24±0.01	2.14±0.01	2.45±0.03
	Zn (µgL^{-1})	2018	74.70±0.85	73.07±0.91	72.96±1.96	66.3±2.97	73.22±1.04	61.40±0.58
		2019	72.37±0.55	79.40±0.59	73.93±0.91	66.21±1.48	69.37±0.90	61.35±1.20
	Pb (µgL^{-1})	2018	0.87±0.00	0.60±0.01	0.46±0.01	0.59±0.01	0.49±0.01	0.43±0.01
		2019	0.75±0.03	0.80±0.02	0.64±0.01	0.65±0.02	0.51±0.01	0.49±0.02
	Cu (µgL^{-1})	2018	1.73±0.03	1.9±0.12	2.03±0.12	1.77±0.09	1.73±0.09	1.93±0.03
		2019	1.6±0.06	1.82±0.04	2.10±0.05	1.77±0.03	1.7±0.06	1.97±0.09

The main reason for lower quantity of Pb present in DWW was that it is not used in scooters and other motor vehicles anymore these days.

The reduction percentage shown by CWPK for Fe ranging from 17.81±0.94 (Jan) to 57.52±0.8 (Jun) in 2018 and 10.12±0.95 (Jan) to 57±0.47 (Jun) in 2019; 30.94±0.68 (Jan) to 82.88±0.21 (Jun) in 2018 and 21.5±1.3 (Jan) to 76.33±0.77 (Jun) in 2019 for Zn; 43.06±1.3 (Jan) to 80.6±0.57 (Jun) in 2018 and 38.84±0.5 (Jan) to 79.13±1.34 (Jun) in 2019 for Pb while 34.9±0.88 (Jan) to 72.77±1.07 (May) in 2018 and 28.4±0.91 (Jan) to 62.97±1.03 (Jun) in 2019 for Cu. Similarly the CWCZ reduction percentage varied from 22.27±0.14 (Jan) to 58.52±0.22 (Jun) in 2018 and 10.12±1.11 (Jan) to 57.97±0.39 (Jun) in 2019 for Fe; 26.66±0.91 (Jan) to 86.06±0.26 (Jun) in 2018 and 16.06±1.19 (Jan) to 81.9±0.69 (Jun) in 2019 for Zn; 42.73±1.39 (Jan) to 84.81±0.62 (Jun) in 2018 and 41.9±0.16 (Jan) to 85.31±0.51 (Jun) in 2019 for Pb while 33.38±0.92 (Jan) to 67.63±0.97 (Jun) in 2018 and 27.5±1.82 (Jan) to 68.51±1.33 (Jun) in 2019 for Cu (Table 25-28 & Figure 33-40). [37] reported better reduction results for mentioned metals as 68.59% to 99.25% removal efficiency for Fe; 24.49% to 98.17% for Cu and 22.22% to 87.17% for Pb at varied adsorbent doses of 20 mg/L, 30 mg/L, 40 mg/L, 50 mg/L and 60 mg/L by rice husk. Similarly *T. latifolia* and *P. australis* showed 33.04% and 27.76% respectively reduction efficiency for Fe; 36.21% and 37.31 respectively for Zn; 88.22% and 83.66% respectively for Cu. 120 grams of *E. crassipes* removed 73% and 78.6% Pb and Cu respectively from 10 L wastewater effluents of Steel industries [38]. Almost similar results were observed by [39] as the concentration of heavy metals like Cu and Mn were decreased by 70% from WWTP and 37% to 53% in the case of Pb, Fe, Ni and Zn.

Conclusion

The removal efficiency of TDS, COD, PO_4^{3-}, NO_3-N were significantly improved in all seasons. The study concluded that phytoremediation of pollutants by *Phragmites karka* and *Chrysopogon zizanioides* for the remediation of pollutants from DWW is good. The design and management of substrate profile is of great importance for the contribution towards an efficient and sustainable performance of treatment plant. Experimental study performed during two year had concluded that there was a little change in pH and the EC in all the three wetlands doesn't lowered too much. There was a better improvement in the concentration of DO. Satisfactory results were specified that both plants played an important role in scavenging the metals from the wastewater. The present research which dealt with analysis of DWW before treatment and after treatment in Constructed wetlands with or without plants depicted that DWW contained essential organic and inorganic nutrients for the utilization of plants. But due to the presence of components beyond limits, the direct use of untreated wastewater is not suitable for agricultural purposes. Polluted water affects crop yield due to the accumulation of high concentration of salts within their rhizosphere and uptake of water from the medium into the plants is hampered. Parameters which were found at very high in concentration were reduced to a significant level which indicates that the *P. karka* and *C. zizanioides* are very much effective for the removal of pollutants. The treated water is clear for common uses and is beneficial for gardening, washing, irrigation and general uses like cooling and floor washing, cleaning application in households and industries etc.

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