International Journal of Botany Studies
ISSN: 2455-541X; Impact Factor: RJIF 5.12
Received: 12-12-2020; Accepted: 28-12-2020: Published: 12-01-2021
www.botanyjournals.com
Volume 6; Issue 1; 2021; Page No. 116-123

Phytoremedial efficiency of *Chrysopogon zizanioides* for the domestic wastewater treatment in a constructed wetland

Mohd Adil Deva* Sushil Manderia
School of Studies in Botany Jiwaji University Gwalior Madhya Pradesh, India

Abstract
Phytoremedial efficiency of *Chrysopogon zizanioides* against domestic wastewater is demonstrated in a constructed wetland. The physiochemical parameters were taken into consideration and variation in such parameters were recorded in a period of six months per year after the introduction of the said plants into the study area (constructed wetland). The physiochemical parameters studied were pH, Electrical Conductivity (EC), dissolved oxygen (DO), Biological Oxygen Demand (BOD), Total Hardness (TH), Chlorides (Cl^-), Nitrates (NO_3-N), and Phosphates (PO_4^{3-}). The heavy metals like iron (Fe) and Zinc (Zn) were detected by Atomic absorption spectroscopy (AAS). Changes were recorded in the physiochemical parameters as well as in the content of Fe and Zn during the study period. There have been minor changes in pH however, large increment in DO was observed. The said plants have shown good efficiency for the reduction of pollutants and extraction of heavy metals from domestic wastewater in comparison to a lot of already suggested hyperaccumulator plants. The treated water could be utilized for industrial processes, household activities, and irrigation purposes.

Keywords: constructed wetland, wastewater, *chrysopogon zizanioides*, hyperaccumulator

Introduction

Water resources are in abundance on earth but present world faces scarcity of fresh and consumable water. Environmental pollution is unintended outcomes of anthropogenic activities; to this some natural phenomena also contribute (Bhattacharya, 2001) [3]. This issue has got very prominent with the population explosion and industrial revolution. Improper sanitation of the household and industrial wastes results in deterioration of water quality. It may have implications at two different levels i.e. it may alter the physicochemical and microbiological properties of the soil or it may introduce and contribute to the accumulation of chemical and biological contaminants in soil (Cristina *et al* 2009). Rapid industrialization and urbanization had increased the production and release of considerable amounts of wastes into the water sources (Sharma & Pathak, 2014) [5] that has increased the release of metals into the earth's ecosystems. Heavy metal in water sources had caused serious problems and it is posing threats to the ecosystem and more importantly to the human health (Chen *et al*. 2018) [6]. As these metals are non-biodegradable with persistent nature, they are mostly accumulated in vital organs within the human body i.e. in kidneys, bones and liver and cause numerous serious health disorders (Duruibe *et al*., 2007) [8]. So, there is requirement of treating such wastewaters employing some efficient methods. Add-on processes are needed to upgrade the wastewater treatment facilities and more attention should be given to control pollution at point sources. The water quality objectives i.e. Clean Water Act should be fully realized. The water available from surface and groundwater sources is clean and free from any contamination until it comes in contact with the unwanted releases (Morrison *et al*., 2001) [9]. Domestic wastewater treatment plays an important role for the availability of consumable water. The reuse of treated wastewater in particular for irrigation is a common practice, which is encouraged by governments and official entities worldwide.

Constructed wetlands are engineered wastewater treatment systems filled with porous media and planted with emergent wetland plants tolerant of the contaminants present in wastewater (Patel & Dharaiya, 2013) [10]. Biogeochemical cycles occurring in constructed wetlands are same as that of natural wetlands and acts as proper management system for wastewater treatment. Phytoremediation is a promising biotechnological technique in which plant species are used to detoxify and assimilate pollutants. It is an ideal and modern technique for environmental clean-up (Garbisu 2002) [12]. Aquatic macrophytes are used as the natural catalysts to adsorb, absorb and accumulate heavy metals in their tissues from heavy metal polluted water (Vymazal, 2011) [11]. *Chrysopogon zizanioides (*L.*)* Roberty (Vetiver/ Khas-Khas/ Khus-Khus) is not a hydrophyte but persist deep water flow due to its unique morphological characteristics and tolerance to adverse environmental conditions (Troung 2008).

The present study is done to evaluate the impact of said plant on domestic wastewater treatment. Treated water can be utilized for industrial processes, household activities, irrigation purposes like agriculture, horticulture, gardening and social forestry.

Material and Methodology

Gwalior is located at 26.22^0 north 78.18^0 East in northern M.P. The maximum temperature goes upto 47 ^{0}C during summers and minimum to 8.5ºC during winters (Koul, *et al*, 2012) [14]. Hence the limited rain water and surface runoff needs to be conserved in order to ensure the availability of water throughout the year in Gwalior region. The present work on phytoremediation of pollutants from wastewater by root zone of *C. zizanioides* in a Constructed wetland technology was carried out at School of Studies in Botany,

Jiwaji University Gwalior. The plants used during the process were grown in Charak Udhyan (Medicinal plants Garden) near Mahalgaon, City center Gwalior M.P. 474011. The Domestic wastewater (DWW) from open drainage system of Mahalgaon was collected in a settling tank of 750 liters. The domestic drainage effluents were treated with C. *zizanioides* (CWCZ) and without the plants (CWWP). Inlet wastewater from settling tank was made at the top of the experimental units for the treatment. The treated wastewater was collected from the bottom of the unit via an outlet pipe. The various parameters of untreated and treated water were analyzed by standard methods of APHA 2005, 2012, 2016. The influent in the root zone underwent series of physico-chemical and biological processes. Samples were collected into distilled sterile 2-L polyethylene bottles and after collection those samples were immediately transported to the laboratory. Periodic performance of the system was evaluated by analyzing the before treatment and after treatment samples. A Digital electronic pH meter and conductivity meter (Jackson 1967) were used for pH and Electrical Conductivity (EC) calculations. The electrode was washed with distilled water on every reading. The dissolved oxygen (DO) and biological oxygen demand BOD were analyzed by Wrinkler's Azide method. Total Solids were calculated by gravimetric evaporation determination method (APHA 2012). The total hardness of Water samples were calculated by EDTA titrimetric method (APHA 2005) [2].The chlorides of samples were calculated by Argentometric method (APHA 2012).
Nitrates were estimated by absorbance method (APHA 2016) and Phosphates were calculated by Stannous Chloride method (APHA 2005) [2]. Heavy metals were analysed by Atomic Absorption Spectroscopy method (APHA 2005) [2].

Results and Discussions

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 give birth to number of diseases either in plants, animals as well as microbial world. As per CPCB guidelines (2012), the pH of wastewater would be remaining between 6 and 8.5 for agricultural reuse. Many plant characteristics like height of plant, their lateral spread, plant biomass, size of flower and number, pollen production and various activities within a plant is influenced by pH (Gentili, *et al*2018). The calculated pH in DWW were 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. The pH on monthly basis in experimental setups showed minor changes. The pH remained almost neutral to slightly alkaline during the whole experimental period. The change of pH within CWCZ was 8.26±0.02 to 7.32±0.02 in 2018 and 7.67±0.05 to 7.37±0.05 in 2019 from January to June. The slight reduction of pH value was observed in the last two months in CWCZ in comparison to CWWP. Almost similar results were observed by Kaseva (2004) in SSCW planted with *Phragmites mauritianus* and *Typha latifolia* and change in pH was 7.29 – 7.64 and 7.12 – 7.60 from Feb. to May in 2003 at Tanzania.

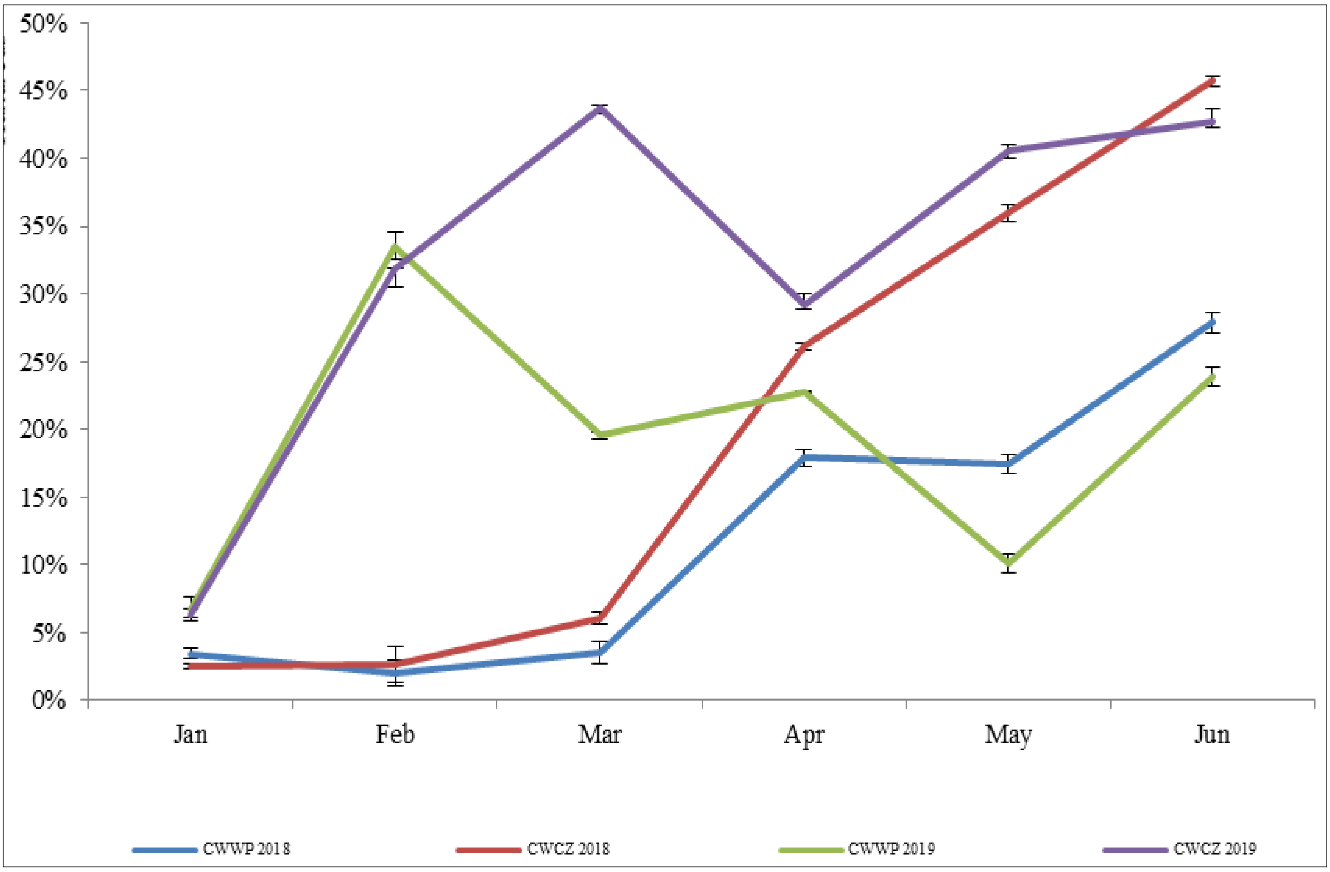

Fig 1: Variation of EC in wetlands in comparison to DWW

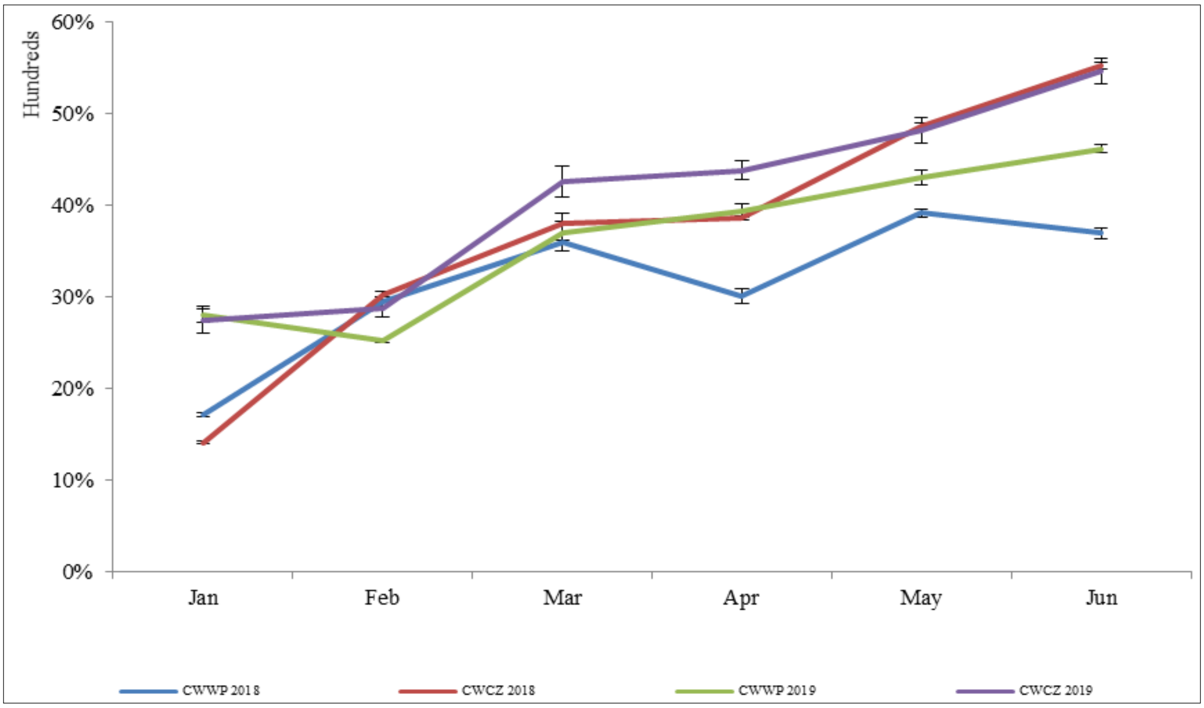

Fig 2: Variation of TS in wetlands in comparison to DWW

The EC of domestic wastewater were ranged from 1320.67±8.84 (µS/cm) (Apr) to 1419±6.81µS/cm (Jan) in 2018 and 1313.20±6.36 µS/cm (Apr) to 1594.67±9.02 µS/cm (Mar) in 2019. The contribution of *C. zizanioides* was increased from nothing at 1st month to 17.83±1.06% at 6th month in 2018 in comparison to CWWP. Similarly during 2019 there was not too much variation between two wetlands during the time period. The observed EC was totally different from the treatment wetland plant planted with *Hydrilla verticillata* (Xue *et al* 2010). The total solid present in water simply refers the matter either filterable or non-filterable that remains as residue upon evaporation and subsequent drying at a defined temperature. The concentrations of TS in domestic wastewater were ranged from 2963±35.51mgL^{-1} (Apr) to 3358.33±43.43mgL^{-1} (Mar) in 2018 and 3178.67±18.70mgL^{-1} (May) to 3765±31.75mgL^{-1} (Mar) in 2019. The reduction percentage of TS by CWCZ were within the range of 14.11±0.83 (Jan) to 55.28±0.85 (Jun) in 2018 and 27.50±1.43 to 54.67±1.42 in 2019. The ASHFCW planted with *E. crassipes, T. latifolia, C. esculenta, C. indica, P. maximum* and *P. purpureium* showed removal efficiencies of TS during summer season as 36.34%, 34%, 33.33%, 36.79%, 37.01%, and 37.85% (Dhulap *et al*, 2014) which is less compared to our studies. The contribution of *C. zizanioides* for the reduction of TS was increased from 0.73±0.45% at 2nd month to 18.32±0.75% at 6th month in 2018 as taken CWWP in comparison. Similarly 3.48±0.80% at 2nd month to 8.49±1.52% at 6th month was estimated in 2019.

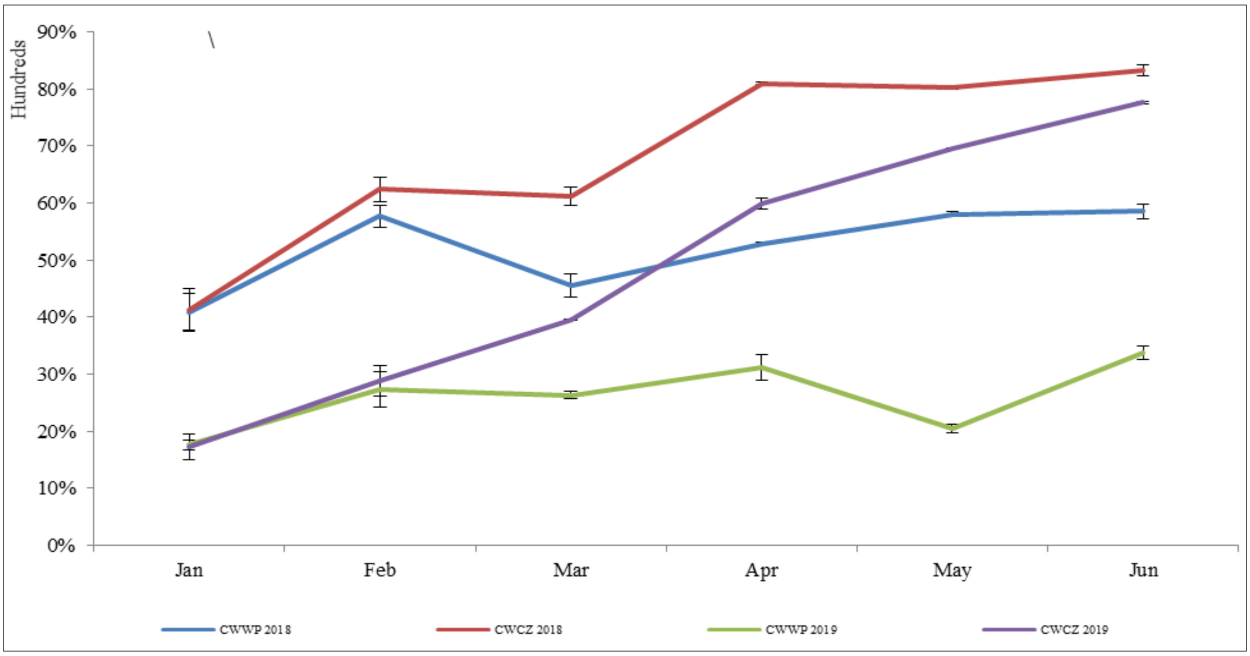

Fig 3: Variation of DO in wetlands in comparison to DWW

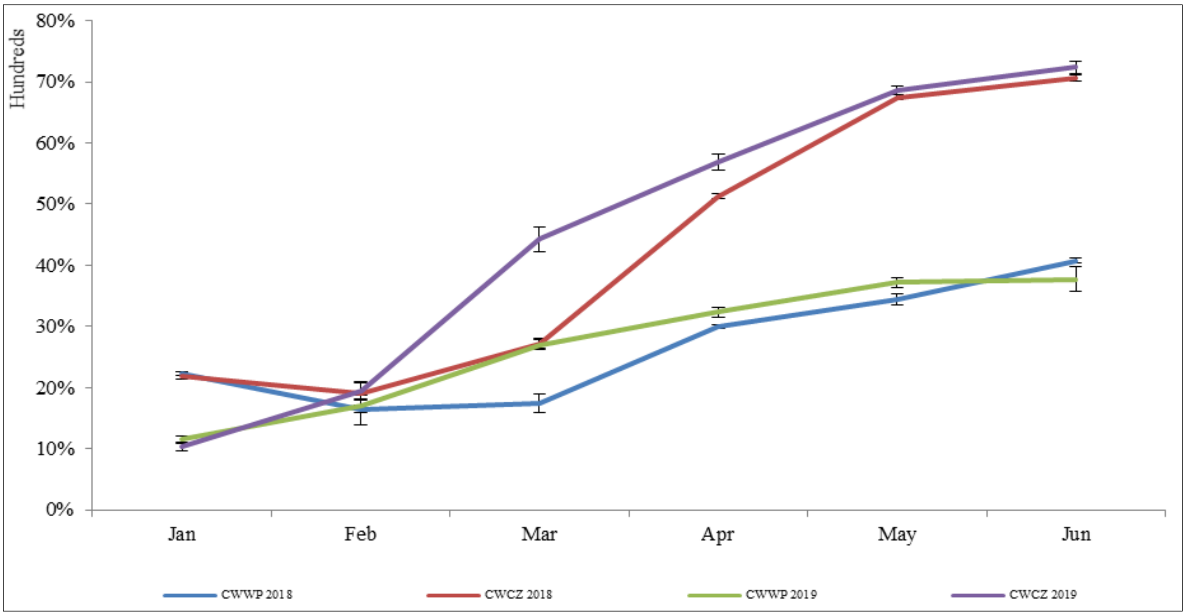

Fig 4: Variation of BOD in wetlands in comparison to DWW

DO factor of water is second, only to water itself as per its essentiality. The analyzed results had shown that DO in DWW were ranged from 0.52±0.03mgL^{-1} (Feb) to 0.77±0.02 mgL^{-1} (May) in 2018 and 0.75±0.04 mgL^{-1} (Jun) to 0.87±0.03 mgL^{-1} (May) in 2019. The percentage increment showed by CWCZ was within a range of 41.35±1.66 (Jan) to 83.23±0.93 (Jun) in 2018 and 17.24±1.25 to 83.23±0.93 in 2019. The SSCW planted with *Phragmites mauritianus* and *Typha latifolia* showed DO percentage increment rate as 54.44% and 51.11% within a time period of Feb. to May in 2003 at Tanzania (Kaseva, 2004) whereas *Salvania molesta* showed similar results in same treatment techonolgy (Acenas *et al*. 2012) [1]. The percentage increment in DO increased during the last months in 2018 and 2019 indicated aerobic conditions in wetlands due to effective transfer of O_2 through the rhizosphere of plant.

The contribution of plant was increased from 0.52±1.18% to 24.66±0.41% in 2018 and 1.39±0.43% to 43.79±1.43% month in 2019 when took CWWP in comparison. The BOD measures the O_2 demand of biodegradable pollutants calculated data had shown that the BOD of DWW ranged from 297.30±3.72 mgL^{-1} (Jun) to 356.94±6.93 mgL^{-1} (Jan) in 2018 and 296.84±5.63mgL^{-1} (Jun) to 375.03±5.27mgL^{-1} (Jan) in 2019. Almost similar results were analysed by Sonune et. al. 2015 [18] while studying domestic wastewater in Vishnupuri. The reduction percentage in BOD shown by CWCZ was 19.11±1.92 (Feb) to 70.59±0.46 (Jun) in 2018 and 10.39±0.66 (Jan) to 72.33±1 (Jun) in 2019. The PSCW planted with *P. australis* showed better efficiency for the reduction of BOD (75.99%) (Sudarsan *et al*, 2015). The removal efficiency of BOD are lower than the results reported by Zurita *et al*. (2009) who found 78.2% removal of BOD by HSSFCW planted *Zantedeschia aethiopica*. The contribution of plant for BOD was increased from 2.72±0.51% to 24.66±0.41% in 2018 and 2.34±0.43% to 34.62±1% in 2019.

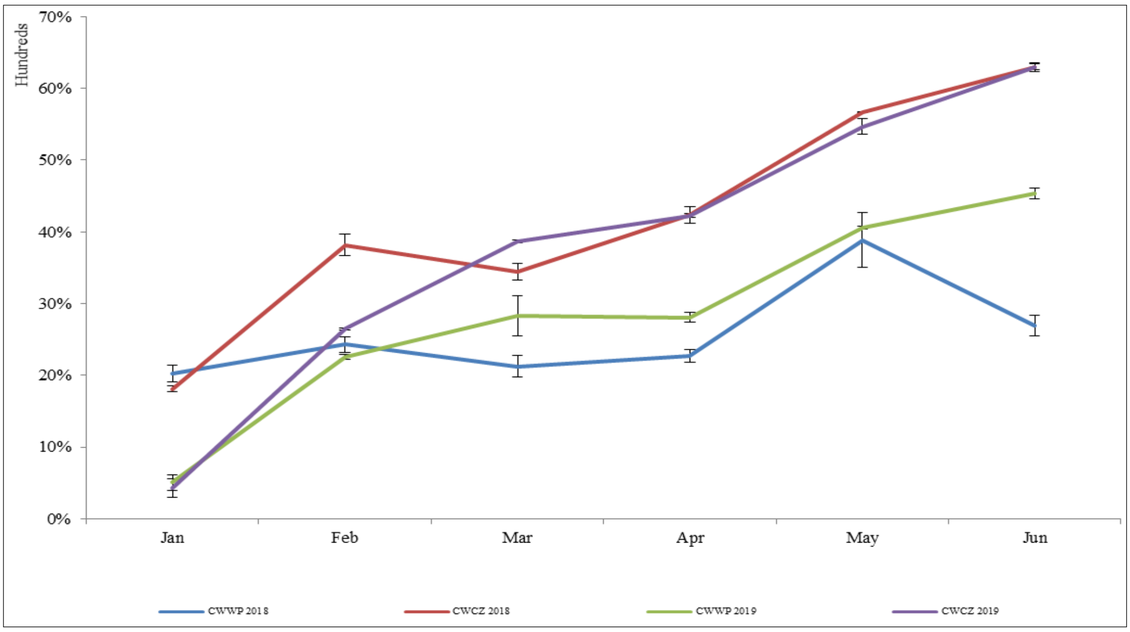

Fig 5: Variation of TH in wetlands in comparison to DWW

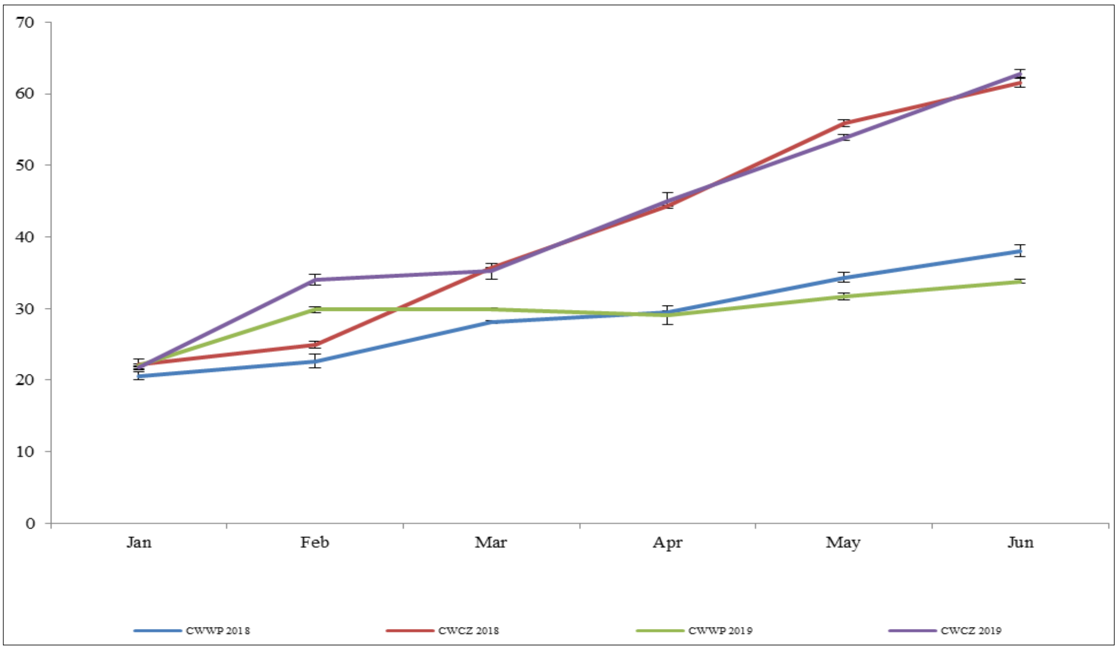

Fig 6: Variation of Cl^- in wetlands in comparison to DWW

Hardness of water is understood as a measure of capacity of the water for precipitating soap. The analysed data had shown that total hardness of DWW ranged from 715.5±6.12mgL^{-1} (Jun) to 825.5±7.76mgL^{-1} (May) in 2018 and 696.33±3.84mgL^{-1} (Jun) to 818.67±7.45mgL^{-1} (Feb) in 2019. The percentage reduction for TH was 18.10±0.40 to 62.92±0.6 in 2018 and 4.28±1.32 to 62.99±0.42 in 2019. Raju *et al*, 2010 treated DWW in Imhoff tank planted with floating weed *Lemna minor* and they observed the reduction percentage of TH as 13.64% which suggested that the said treatment plant is not efficient in comparison to our treatment plant. The contributions of plant were increased from 13.81±2.57% to 35.96±0.78% in 2018 and 13.36±1.39% to 17.67±1.04% in 2019. The significant rate of reduction was observed within the experimental set up, but in comparison to *Typha angustata* and *Phragmites australis* the plant is not too much efficient (Patel & Dharaiya 2014) [21]. *Phragmites australis* and *Typha angustata* planted in VFCW gave 70% and 75.84% reduction in TH from Diary effluent with 7 HRT. Cl^- gives an idea of salinity in water sample and its presence in DWW is one of the main characteristics for the dissolution of salt deposits released from households. The analysed data had shown the concentration of Cl^- as 159.21±2.76mgL^{-1} (Apr) to 181.67±5.54mgL^{-1} (Jun) in 2018 and 159.77±2.23mgL^{-1} (Apr) to 180.64±1.83mgL^{-1} (Feb) in 2019. The percentage reduction of Cl^- by CWCZ was 22.19±0.74 (Jan) to 61.48±0.6 (Jun) in 2018 and 21.75±0.22 (Jan) to 62.76±0.55 (Jun) in 2019. Imhoff tank planted with floating weed *L.minor* reduced 14.28% Chlorides (Raju *et al*, 2010). The contributions of plant were increased from 2.64±0.53 to 23.41±0.28% at in 2018 and 4.19±0.57% to 28.99±0.78% in 2019 as taken CWWP in comparison.

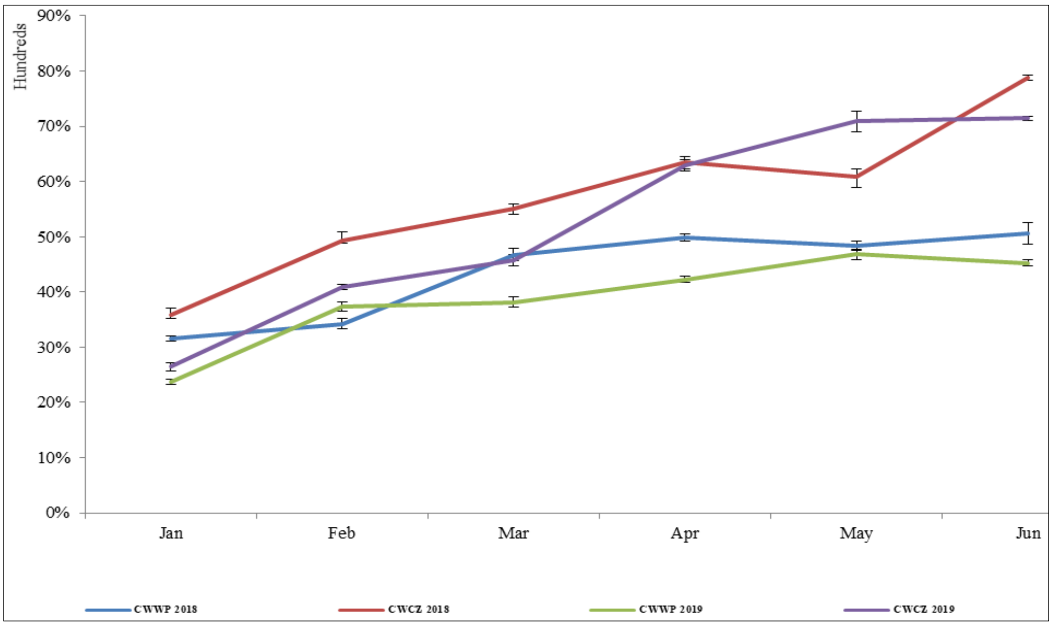

Fig 7: Variation of NO_3-N in wetlands in comparison to DWW

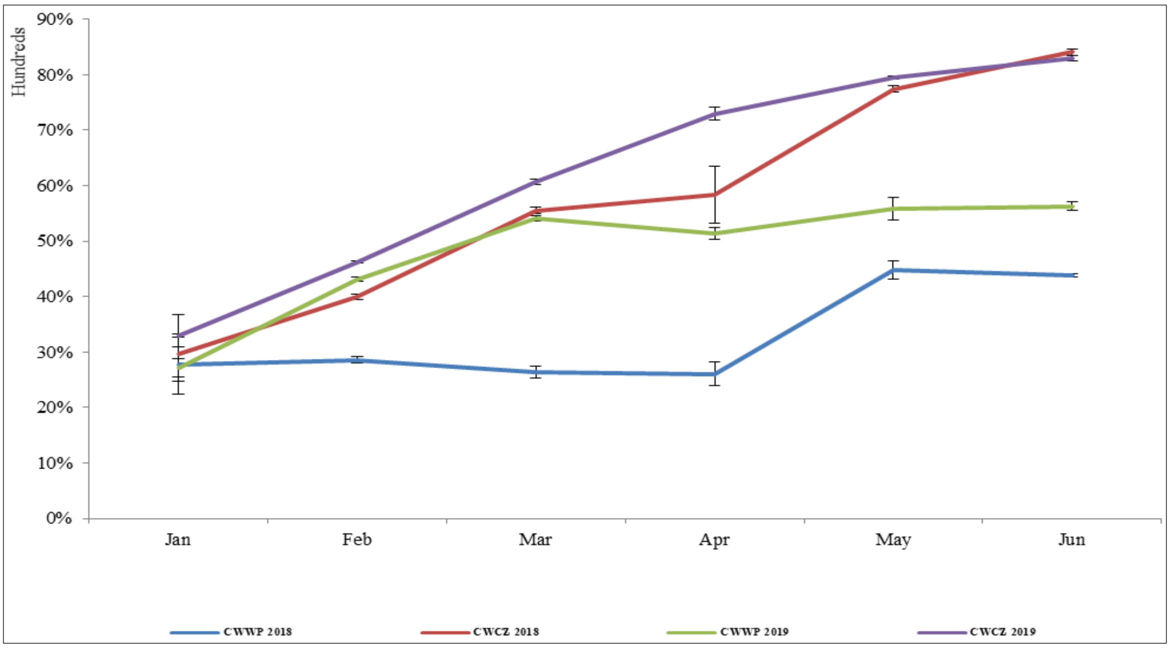

Fig 8: Variation of PO_4^{3-} in wetlands in comparison to DWW

PO_4^{3-} and NO_3-N are required for the growth and development of plants as P is a main constituent of several biomolecules and is significantly needed for the functioning of terrestrial as well as aquatic ecosystem. The analysed data had shown in DWW were ranged from 38.59±1.19mgL^{-1} (Feb) to 46.12±0.95mgL^{-1} (Apr) in 2018 and 40.99±1.37mgL^{-1} (Jun) to 47.56±1.09mgL^{-1} (Apr) in 2019 and phosphates as 10.54±0.22mgL^{-1} (Jan) to 12.56±0.59mgL^{-1} (Jun) in 2018 and 10.99±0.28mgL^{-1} (Feb) to 12.34±0.25mgL^{-1} (Apr) in 2019. The NO_3-N and PO_4^{3-} of MWW in Kuwait was higher than our calculated results and the concentration were ranged from 44–100 mgL^{-1} and 14–64mgL^{-1} (Enezi *et al*, 2013).

The reduction percentage as shown by CWCZ was 35.87±1.26 (Jan) to 78.71±0.48 (Jun) in 2018 and 26.46±0.68 (Jan) to 71.42±0.32 (Jun) in 2019 for NO_3-N and 29.58±1.23 (Jan) to 84.10±0.6 (Jun) in 2018 and 32.92±0.3 (Jan) to 82.93±0.44 (Jun) in 2019 for PO_4^{3-}. Hussain *et al*, (2014) reported the removal rates NO_3-N and PO_4^{3-} from DWW treated in CW planted with *T. latifolia* and *P. australis* and calculated results were 60.24% and 58.64% for NO_3-N 61.48% and 51.16% for PO_4^{3-}. The contribution of plant was increased from 2.64±0.53% to 28±0.74% in 2018 for NO_3-N and 1.76±1.54% at to 40.29±0.52% in 2018 for PO_4^{3-} as taken CWWP in comparison. Similarly during 2019, the contribution was increased from 3.59±1% to 26.15±0.63% for NO_3-N and 3.15±0.31% to 26.67±0.96% for PO_4^{3-}. Enhanced Chemical Coagulation showed 66% reduction of TP from DWW which is less than planted constructed wetland after 6 months of treatment (Sarparastzadeh, 2007).

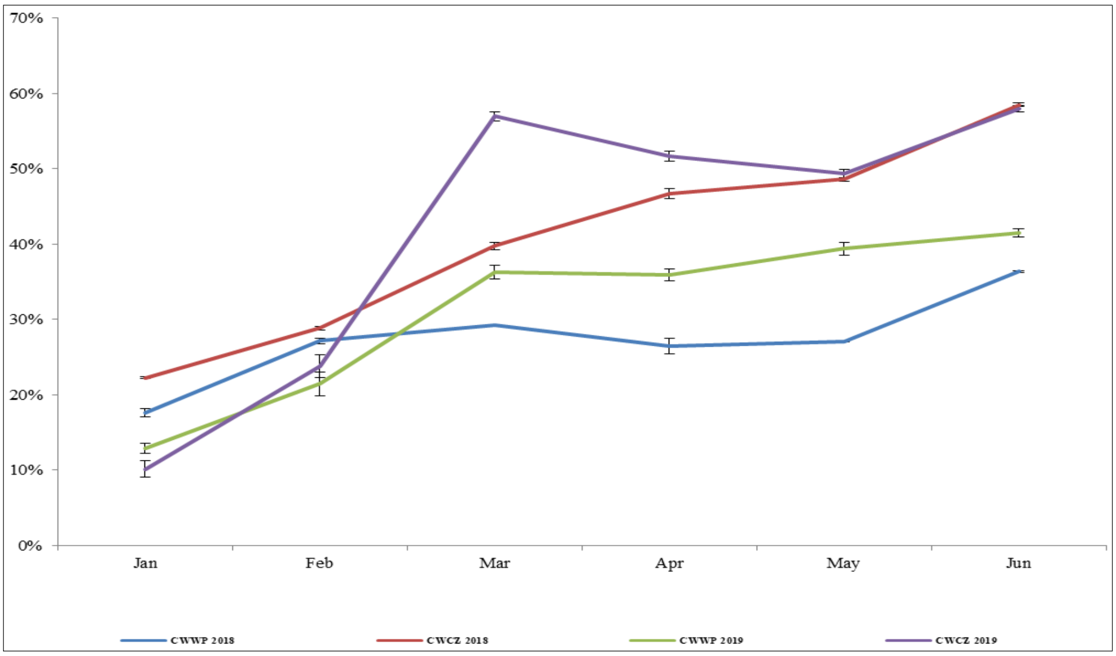

Fig 9: Variation of Fe in wetlands in comparison to DWW

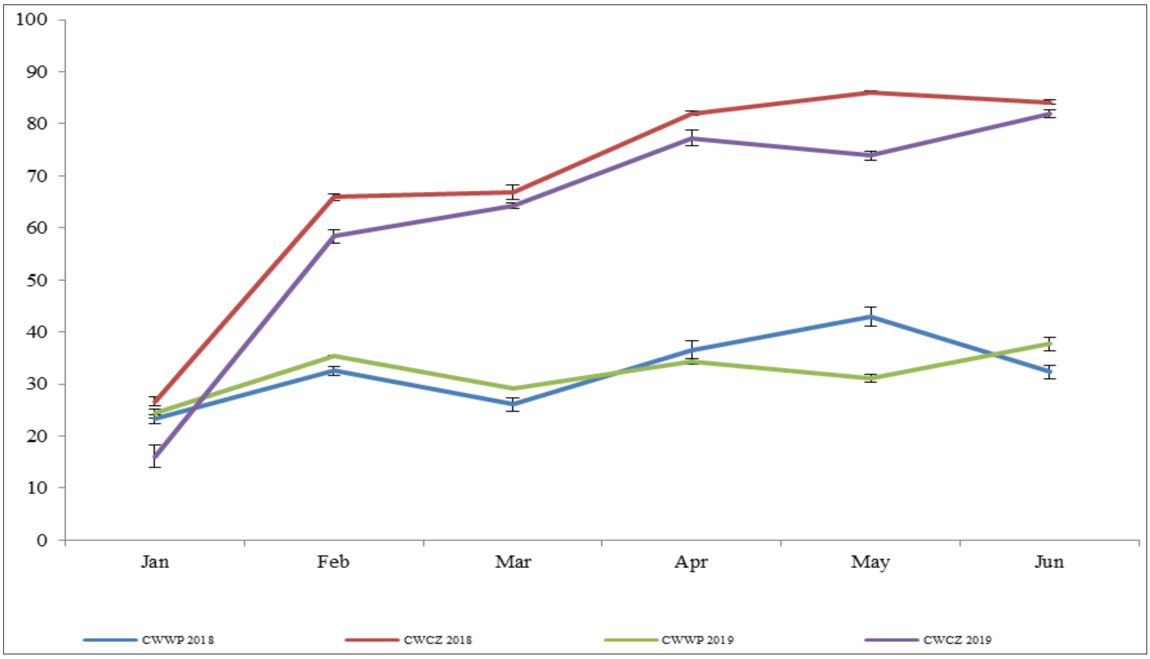

Fig 10: Variation of Zn in wetlands in comparison to DWW

The heavy metals readily accumulate either in soil and organisms upto toxic levels. So long term application of heavy metals on land in any form results in the elevated levels of heavy metals in soil. The concentration of Fe in DWW were ranged from 2.54±0.04mgL^{-1} (Apr) to 3.18±0.0 mgL^{-1} (Feb) in 2018 and 2.45±0.01mgL^{-1} (May) to 2.92±0.05mgL^{-1} (Feb) in 2019 (May), Zn were ranged from 72.67±1.20 µgL^{-1} (Jun) to 87.77±2.39µgL^{-1} (May) in 2018 and 70.73±1.2µgL^{-1} (May) to 88.33±0.58 µgL^{-1} (Feb) in 2019 (May). The concentration of Zn in DWW at Titagarh West Bengal was ranged from 0.21 mgL^{-1} to 4.3mgL^{-1} and after treatment the concentration was 0.1mgL^{-1} to 3.9mgL^{-1} for Zn (Gupta *et al*, 2008). The percentage reduction was 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 and 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. Hussain *et al*, (2014) reported the removal rates for heavy metals from DWW treated in CW planted with *T. latifolia* and *P. australis* were 33.04% and 27.76% for Fe; 36.21% and 37.31 for Zn which were not efficient as experimental plant. The contribution of plant for reduction was increased from 4.63±0.59% at 1st month to 22.17±0.18% at 6th month for Fe, 3.42±1.27% at 1st month to 51.86±1.61% at 6th month in 2018 for Zn. Similarly during 2019, it was increased from 2.31±0.1% at 2nd month to 16.49±0.26% at 6th month for Fe, 23.11±1.06% at 2nd month to 44.24±0.57% at 6th month for Zn.

Conclusion

Constructed wetland treatment technology is a natural, cost effective, adaptable, environmental friendly and effective manner for treating Domestic wastewater. Two year round experimental study had concluded that there was a minor change in pH and the EC doesn't lowered too much. There was an improvement in the DO concentration. The demand for oxygen in the treatment plant and the performance of wetland in the treatment of DWW during both the seasons revealed that there was enhanced the nitrification/ denitrification processes and aerobic decomposition of organic matter. The removal efficiency of TS, BOD_5 Cl^-TH, PO_4^{3-}, NO_3-N were significantly improved in all seasons. The study revealed that phytoremediation ability of *Chrysopogon zizanioides* to remediate pollutants from DWW is good for some parameters. The management and design of substrate profile are of great of importance for the contribution towards an efficient and sustainable performance of treatment plant. The application of wetlands for treatment of contaminated water will make people of Gwalior able to dispose of their wastes hygienically and efficiently.

Comparatively during 2019, the said treatment showed best performance. The treated water could be utilized for industrial processes, household activities, and irrigation purposes.

Acknowledgments

The Authors are highly thankful to SOS in Botany Jiwaji University Gwalior for providing lab facilities and we are also thankful AIPTR Gwalior for providing instrumental facilities.

References

1. Acenas FDG, Liezel TM, Mallari AKP, Dedumo CS, Macarimbang NO, Trozo SMP, et al. An experimental study on the efficacy of aquatic fern (Salvinia molesta) in the treatment of blackwater effluent from a constructed wetland, Cagayan de Oro City. Student Research Competition, Philippine National Health Research System (PNHRS), Sofitel Philippine Plaza, Pasay City, 2012.
2. APHA, Standard Methods for the Examination of Water and Waste Water (21th Ed.). Washington DC: American Public Health Association, 2005.
3. Bhattacharya A. Osmosis and reverse osmosis: Regulator of life. Science and Culture, 2001, 47-48.
4. Cristina SC, Antonio C, Rangel OS, Castro ML. Constructed wetland systems vegetated with different plants applied to the treatment of tannery wastewater. Water resource Research. 2007; 41:1790-1798.

5. Sharma S, Pathak H. Basic Techniques of Phytoremediation. International Journal of scientific and Engineering Research. 2014; 5(4):584-605.
6. Chen L, Zhou S, Shi Y, Wang C, Li B, Li Y, et al. Heavy metals in food crops, soil, and water in the Lihe River Watershed of the Taihu Region and their potential health risks when ingested. Science of the Total Environment. 2018; 615:141-149.
7. Dhulap VP, Patil SS. Seasonal Study and its Impact on Sewage Treatment in the Angular Horizontal Subsurface Flow Constructed Wetland using Aquatic Macrophytes. International Journal of Research in Engineering & Technology (IJRET). 2014; 2(5):213-22.
8. Duruibe JO, Ogwuegbu MC, Egwurugwu JN. Heavy Metals Pollution and Human biotoxic effects. International journal of Physical Sciences. 2007; 2(5):112-118
9. Morrison G, Fatoki OS, Persson L, Ekberg A. Assessment of the impact of point source pollution from the Keiskammahoek sewage treatment plant on the Keiskamma River pH, EC, COD and Nutrients. Water SA. 2001; 27(4):475-480.
10. Patel PA, Dharaiya NA. Manmade wetland for wastewater treatment with special emphasis on design criteria. Scientific Reviews and Chemical Communications. 2013; 3(3):150-160.
11. Vymazal J. Constructed wetlands for wastewater treatment : Five decades of experience. Environmental Science & Technology. 2011; 45(1):61-69.
12. Garbisu C. Phytoremediation: A Technology Using Green Plants to Remove Contaminants from Polluted Areas. Reviews on Environmental Health. 2002; 17(3):173-188.
13. Truong P, Van TT, Pinners E. Vetiver System Applications: A Technical Reference Manual. The Vetiver Network International, 2008.
14. Koul KK, Agarwal S, Lone R. Diversity of arbuscular mycorrhizal fungi associated with the medicinal plants from Gwalior-Chambal region of Madhya Pradesh-India. American-Eurasian J. Agric. & Environ. Sci. 2012; 12(8):1004-1011.
15. Central Pollution Control Board The Environment (Protection) Rules 1986, Schedule-VI, 2012.
16. Gentili R, Ambrosini R, Montagnani C, Caronni S, Citterio S. Effect of soil pH on the growth, reproductive investment and pollen allergenicity of Ambrosia artemisiifolia L. Frontiers in plant science. 2018; 9:1335.
17. Kaseva ME. Performance of a sub-surface flow constructed wetland in polishing pre-treated wastewater—a tropical case study. Water Research. 2004; 38:681-687.
18. Sonune NA, Mungal NA, Kamble SP. Study of physico-chemical characteristics of domestic wastewater in Vishnupuri, Nanded, India. International. Journal of Current Microbiology and Applied Sciences. 2015; 4(1):533-536.
19. Sudarsan JS, Roy RL, Baskar G, Deeptha VT, Nithiyanantham S. Domestic wastewater treatment performance using constructed wetland. Sustainable Water Resources Management. 2015; 1:89-96.
20. Zurita F, Anda DJ, Belmont M. Treatment of domestic wastewater and production of commercial flowers in vertical and horizontal subsurface-flow constructed wetlands. Ecological Engineering. 2009; 35:861-869.
21. Patel PA, Dharaiya NA. Constructed Wetland with Vertical Flow: A Sustainable Approach to Treat Dairy Effluent by Phytoremedeation. International Journal of Engineering Science and Innovative Technology (IJESIT). 2014; 3(1):509-512.
22. Raju AR, Anitha CT, Sidhimol PD, Rosna KJ. Phytoremediation of Domestic Wastewater by Using a Free Floating Aquatic Angiosperm, Lemna minor. Nature Environment and Pollution Technology. An International Quarterly Scientific Journal. 2010; 9(1):83-88.
23. Sarparastzadeh H, Saeidi M, Naeimpour F, Aminzadeh B. Pretreatment of municipal wastewater by enhanced chemical coagulation, 2007.
24. Hussain G, Abdullah IA, Alquwaizany AS. Role of Typha (Cattail) and Phragmites austrailes (Reed Plant) in Domestic Wastewater Treatments Research journal of Environmental Toxicology. 2014; 8(1):25-30.