A Research Paper on Treatment of Nallah Wastewater using Vertical Flow Constructed Wetland (VFCW)

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Abstract - *One of the most trusted and low in maintenance and low in operation cost of the wastewater treatment is the setup of and operation of Vertical Flow Constructed Wetland. These wetlands system have a very good ability to handle sudden increase in amount of domestic wastewater and sudden increase in the load of various contents of the wastewater. The plants here used in this wetland setup are Cypres Rotundus & Canna Indica. These plants were specifically chosen for their growth of roots and development of rootzone in the soil providing more contact area and substrate for the microorganisms for their processing and playing an important role in the treatment of wastewater. The solids removal was seen to be remarkable in this case whereas the COD and BOD_3 removal where seen at 85% & 75% each. The VFCW was operated using the domestic wastewater from the outlet near to the hotels and restaurants in the city which had a high amount of organic matter present in there pre treated wastewater.*

***Key Words*: Vertical Flow Constructed Wetland, VFCW, COD, BOD, treated wastewater, Cypres Rotundas, Canna Indica, Wetland.**

1. INTRODUCTION

In India major sources of water pollution are domestic wastewater, industrial effluent and run-off from agriculture. The biggest and most important environmental problem and danger to human health is generation of wastewater and its contamination in the surrounding as well as the penetration in the fresh and potable water. With the increase in population the domestic-wastewater generation rate is getting higher and is growing exponentially. There is a need to treat the wastewater before its discharge in to the environment where the flora and fauna thrives. The treatment of wastewater is a growing problem as the population grows. Collection as well as the treatment and discharge of domestic wastewater can be done in centralized or decentralized systems. There are many centralized treatment plants available to treat the wastewater, but they require large scale infrastructure, there is a high amount of consumption of energy, it is very expensive to operate and require highly trained and highly qualified individual's along with its heavy maintenance. Hence Decentralized Wastewater Treatment System (DCWWTS) is a best alternative to treat the wastewater near its sources. DCWWTS provides primary, secondary and tertiary treatment for wastewater.

The constructed wetlands (CW) can be a part of DCWWTS and widely used to treat wastewater. CW can be defined as a wetland specifically constructed for the purpose of wastewater treatment at a selected site. The media used for wetland can consist of locally & easily available materials like gravel, sand, charcoal, aggregate, cupola slag or other coarser materials. Plant species used for wetland normally grow locally and are able to withstand wetland conditions. The plant roots also act as a substrate for the microorganisms. Roots increase the surface area for the attached growth process. The contaminant removal involves many processes including microbial degradation, plant uptake, sorption, sedimentation, filtration. Various CWs such as Horizontal Flow Constructed Wetland (HFCW), Vertical Flow Constructed Wetland (VFCW) have been used to treat polluted surface water, domestic, agricultural and industrial wastewaters. VFCW is normally a secondary treatment and efficient in removing organic matter, also it is a cost-effective technique with low maintenance.

Vertical Flow Constructed Wetlands require smaller area results in higher oxygen transfer capability, and have simple hydraulics. The main advantage of Vertical Flow Constructed Wetland systems has the ability to transfer high amounts of oxygen inside the bed. Oxygen transfer is more important in VFCWs for the removal of organic material.

2 Literature Review-

Z.M. Chen, et al., (2008) Presented in this paper is an integrated cost and efficiency analysis of a pilot vertical subsurface flow constructed wetland (CW) built up near the Longdao River in Beijing, China. The CW has been monitored over one year and proved to be a good solution to treat the polluted water and restored the ecosystem health of the Longdao River. The modified CW system in accordance with local conditions costs less in construction, operation and maintenance than traditional wastewater treatment system and occupies less land than conventional CW. Also, derived from the efficiency analysis, the Longdao River CW provides better elimination effects for nutrient substances in the polluted river water and has stable performances in cold seasons.

M.Y. Sklarz, et al., (2009) Here a recirculating vertical flow constructed wetland (RVFCW) was developed for the treatment of grey water. The overall aim of this research was to apply the RVFCW, a decentralized, small-scale system, to the treatment of domestic wastewater (DWW), modifying it, where necessary, to produce effluents that conform to Israeli regulations for urban landscape irrigation. Two RVFCWs were operated with and without a soil-plant component and with various recirculation flow rates (RFR) and treatment times. Without plants, at a RFR of 4.5 $m^3\ h^{-1}$ and 12 h treatment time, the average biological oxygen demand (BOD5) and total suspended solids concentrations of the treated effluent were 5 and 10 mg l^{-1}, respectively. A kinetic analysis showed that even 6 h were sufficient to achieve the required effluent quality. Addition of the soil-plant component, which necessitated a reduction in the RFR, caused no changes in effluent quality, and its role in the treatment remained undetermined. In conclusion, the RVFCW produces high quality effluents, and can treat DWW at a potential organic load of over 120 g $BOD_5\ m^{-2}\ d^{-1}$.

Huiyu Dong, et al., (2011) Three lab-scale vertical-flow constructed wetlands (VFCWs), including the non-aerated (NA), intermittently aerated (IA) and continuously aerated (CA) ones, were operated at different hydraulic loading rates (HLRs) to evaluate the effect of artificial aeration on the treatment efficiency of heavily polluted river water. Results indicated that artificial aeration increased the dissolved oxygen (DO) concentrations in (IA) and (CA), which significantly favored the removal of organic matter. The DO grads caused by intermittent aeration formed aerobic and anoxic regions in (IA)and thus promoted the removal of total nitrogen (TN). The removal COD removal efficiency of all three models decreased due to increase in HLR. The artificial aeration enhanced the reactor resistance to the fluctuations of pollutant loadings. At 19 cm/day HLR in CA the COD removal 6 efficiency was observed at around 81%. This study has demonstrated the feasibility of applying artificial aeration to VFCWs treating polluted river water, particularly at a high HLR.

Jun-Jun Chang, et al., (2012) Two pilot-scale integrated vertical-flow constructed wetlands (IVCWs) in parallel were employed to evaluate domestic wastewater treatment performance at a loading rate of 250 mm/d, and each was planted with two different plant species: Typha orientalis and Arundo donax var. versicolor (Plot 1), and Canna Indica and Pontederia cordata (Plot 2). The results showed that different plant combinations offered no significant improvement in pollutant removal efficiencies). The mean removal efficiencies associated with Plot 1 and Plot 2 were 59.9% vs. 62.8% for COD. Dissolved oxygen (DO) in the wetland beds was a dependence factor for the removals of organic matter and nitrogen, and it could be used to predict removal rates of chemical oxygen demand (COD). Low temperatures had a negative impact on nutrient removals.

Satish S. Patel, et al., (2012) Present study was carried out to determine the high COD of GIDC (Gujarat Industrial Development Corporation) areas. One of the burning problems of Industrial society is the high consumption of water and the high demand for clean drinking water. Numerous approaches have been taken to reduce water consumption, but in the long run it seems only possible to recycle wastewater into high quality water. In this study, an attempt was made to compare the efficiency of grass lend plants like Cyperus rotundus Linn. The Cyperus Rotundus. based treatment system was the most efficient in removing the pollutants from the effluent. So, in conclusion, Cyperus species were more efficient than the constructed wetland technology. For dilution of 10:90 (effluent: fresh water) the COD removal was around 50 % whereas for effluent of 100% no dilution of fresh water the COD removal of the reactor was around 55.55%. But when the dilution was decreased up to 85:15 the COD removal efficiency was around 20% whereas for 90:10 and above dilution the COD removal efficiency rose to 50%

Gargi Sharma, et al., (2014) In this article it was found that the vertical flow constructed wetlands provide more oxygenated environment and significantly reduce the organic matter as well as microbial species from wastewater. In this study vertical up-flow constructed wetlands were constructed and used as bio-filter to improve the water quality of secondary treated effluent. The reduction pattern is studied in this research and correlated with plant species and presence of plant. The plant species used in the constructed wetlands were canna and phragmitis. The fibrous rooting system of canna species causes the high aerobic conditions throughout the treatment bed which in turn facilitates higher removal in comparison to phragmitis planted wetland. COD removal was ranges from 38 to 47% while treating domestic wastewater through vertical flow system. The author also observed lower COD removal in one case of non-planted wetland than planted one. Size and distribution of gravel in all units were same as 8-12mm gravel were placed at the top and 16-20mm gravel at the bottom. A total of 20 water samples were collected on weekly basis for constructed wetland units which are planted with canna (with and without sand layer incorporation). pH values range from 8.19 to 8.38 in influent and effluents of all the units.

Hans Brix, et al., (2015) Official guidelines for the on-site treatment of domestic sewage have been published by the Danish Ministry of Environment as a consequence of new treatment requirements for single houses and dwellings in rural areas. This paper summarizes the guidelines for vertical constructed wetland systems (planted filter beds) that has capacity to fulfil demands of 95% removal of BOD and 90% nitrification. The system can be extended with chemical precipitation of phosphorus with aluminum polychloride in the sedimentation tank to meet requirements of 90% phosphorus removal. The sewage is, after sedimentation, pulse-loaded onto the surface of the bed using pumping and a network of distribution pipes. The drainage layer in the bottom of the bed is passively aerated through vertical pipes extending into the atmosphere in order to improve oxygen transfer to the bed medium. Half of the nitrified effluent from the filter is recirculated to the first chamber of the sedimentation tank or to the pumping well in order to enhance denitrification and to stabilize the treatment performance of the system. A phosphorus removal system is installed in the sedimentation tank using a small dosing pump. The mixing of chemicals is obtained by a simple airlift pump, which also circulates water in the sedimentation tank. The vertical flow constructed wetland system is an attractive alternative to the common practice of soil infiltration and provides efficient treatment of sewage for discharge into the aquatic environment.

Manoj Kumar, et al., (2017) In this research article it was demonstrated that the understating of municipal wastewater treatment in five types of CWs operated under semi continuous vertical flow mode. All CWs treatment conditions show the significantly lower pollutants concentrations. The plant Eichhornia crassipes commonly known as Water Hyacinth was planted in the iron scrapes of the CW. The iron scrape's filtration barrier created in the constructed wetlands was sufficient enough to remove all the pollutants. Prior to use the plants were maintained/propagated for a one-week acclimation in 10% modified Hoagland's solution (Hoagland and Arnon, 1950) in a tray. After 1week of adaptation, healthy Eichhornia crassipes, plants of similar size in root length 10-12 cm and having fresh weight of 22 - 25 g were selected. 4-5 plants having root hair rhizome length 4-6 cm were transplanted in respective CWs.

Iyad Al-Zreiqata, et al., (2018) The primary goal here was to allow increase in denitrification by circulating the nitrified effluent back into a recirculation tank, where it is mixed with primary treated wastewater. Therefore, the recirculating vertical flow constructed wetland was created here. It was operated under a hydraulic loading of $108L/m^2d$. Weekly sampling was performed for a period of 11months. The ratio of the average chemical oxygen demand (COD) to biological oxygen demand (BOD5) of the feed wastewater was found to be approximately 1.8, similar to domestic wastewater. Because of this recirculation mechanism the removal of TSS, COD, BOD_5 removal percentage was 96.1%, 95.5%, 93.7% respectively.

Tang, Ping, et al., (2018) An enzyme treatment was developed and evaluated for its effectiveness in decreasing severity of bio clogging through a laboratory-scale vertical-flow constructed wetland (VFCW) experiment in this study. The enzyme preparation was a combination of α-glucoamylase and β-glucanase. The results show that the enzyme treatment greatly reduced bio clogging, and the peak hydraulic conductivity after treatment increased by a factor of 16, mainly because polysaccharides in the clogging matter were decomposed and the gelatinous clogging matter was dissolved and dispersed. The results also show that the abundance of Proteobacteria microbes increased by 89.4% after the enzyme treatment, although the diversity of the microbial community within the substrate decreased slightly.

These microbes can increase the capability of the constructed wetland to purify influent water, and thus the rate of reduction of COD improved. It offers a solution to the problem of bio clogging in constructed wetlands. Within the first 20 days of this treatment the COD reduction rate for bed 1 increased from 20.0% to 41.1%, indicating a significant increase in water purification capacity. From day 20 onward, the COD reduction rate decreased to 23.5% on day 35 and then stabilized between 22.0% and 26.0%, slightly higher than the initial reduction rate. In bed 2, as bio clogging increased, the COD reduction rate slowly decreased from 24% to 15%. The cumulative COD removed amount of bed1 and bed2 is 20.2g and 13.2g respectively over the course of the second phase experiments.

Fernando García-Ávila, et al., (2019) Here the use of VFCW was to treat municipal wastewater reduces energy consumption and therefore economic costs, as well as reduces environmental pollution. The purpose of this study was to compare the purification capacity of domestic wastewater using two species of plants sown in subsurface constructed wetlands with vertical flow built on a small scale that received municipal wastewater with primary treatment. The species used were Phragmites Australis and Cyperus Papyrus. For this purpose, a constant flow of 0.6 m^3 day^{-1} was fed from the primary lagoon to each of the two wetlands built on a pilot scale with continuous flow. Each unit was filled with granite gravel in the lower part and with silicic sand in the upper part of different granulometry, the porosity of the medium was 0.34, with a retention time of 1.12 days and a hydraulic load rate of 0.2 m day^{-1}. To analyze the purification capacity of wastewater, physical, chemical and biological parameters were monitored during three months. Samples were taken at the entrance and exit in each experimental unit. The results obtained in the experimental tests for the two species of plants, indicated that the Cyperus Papyrus presented a greater capacity of pollutants removal as biochemical oxygen demand (80.69%), chemical oxygen demand (69.87%). In the case of Phragmites Australis retains more solids. The species with greater efficiency in the treatment of municipal wastewater for this study was Cyperus Papyrus.

Anant Yadav, et al., (2019) In this research article the main aim of the study was to construct a two-stage vertical flow constructed wetland (VFCW)system to treat single household raw sewage water in India under tropical climate. For selecting the plant species different sets of lab experiments were carried out. Two different plant species (Typha angustata and Canna Indica) were considered for their nutrient removal efficiency. The overall nutrient removal efficiency was the same in case of both the plant species that were tested. Typha angustata had been selected for planting in the single household wetland system as it is found in the natural wetlands of Goa. The nutrient removal of pilot scale VFCW was monitored at two hydraulic loadings at 0.150m/day and at 0.225m/day. The removal of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Dissolved Solid (TDS) and Total Volatile Solids (TVS) at 1st stage was 64%,65%,34% and 54% and respectively and for the 2nd stage reactor it is 90%, 88%, 58% and 71% respectively on an average. After changing HLR (hydraulic loading rate) to 0.225m/day the removal of COD, BOD, TDS, TVS at 1st stage was 61%, 62%,33%, 40%. There was a marginal decrease in the treatment efficiency of COD and BOD of the system was observed.

Arun Kumar Thalla, et al, (2019) In the present study, a comparison is made between horizontal subsurface flow (HSSF-CW) and vertical flow (VFCW) constructed wetland in effectively post-treating the effluents from the secondary biological treatment system. Locally available plants, viz. Pennisetum pedicellatum and Cyperus rotundus, which are abundantly available in the Western Ghats, were used in the wetland. A pilot-scale study was undertaken in National Institute of Technology, Karnataka Campus. The experiments were conducted at two hydraulic retention times, i.e., 12 h and 24 h. The experimental study was carried out in February 2018 to May 2018. Concentration-based average removal efficiencies for HSSFCW and VFCW were BOD, 77% and 83%; COD, 60% and 65%. VFCW showed a better overall removal efficiency than HSSF-CW by 7.14%.Thus, constructed wetland can be considered as a sustainable alternative to the tertiary conventional treatment of domestic wastewater, thus making it possible for reuse.

3 Materials & Methods-

In this wetland, all the materials were housed in 5 different crates made up of plastic and it was thick and durable. The 4 different crates consisted of coarse aggregates with 2cm in length and fine aggregate with maximum of 0.5 cm length. The river sand here was used with sieve size of 2 microns and the fine sand used was of 0.5 microns. Also, the cupola slag used here was having a size of 0.5 microns and was pure black in color with no pungent smell which was acquired from a small foundry industry near the site area. The soil was brown in color with sieve size of no more than 0.5 microns. The setup used for equal distribution of wastewater all over the bed of plants/soil was prepared from pvc pipes which was drilled with holes of around 1cm diameter and was connected to overhead waste-water reservoir which was situated 1m above the lab scale model of vertical flow wastewater.

3.1 Sampling-

The wastewater sampling was done by using the technique of grab sampling and was collected in the quantity of 20 liters. The sampling point was chosen strategically where there was presence of hotels and restaurants where having their sewage connected to the main stream of the municipal wastewater. The stream had a depth of 30 cm.

3.2 Diagram and working explanation of the Lab scale model of VFCW-

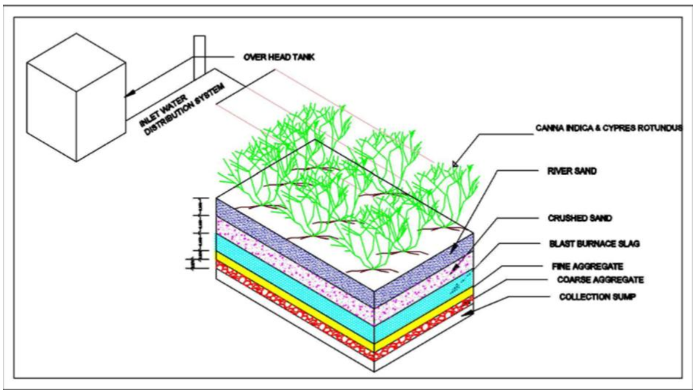
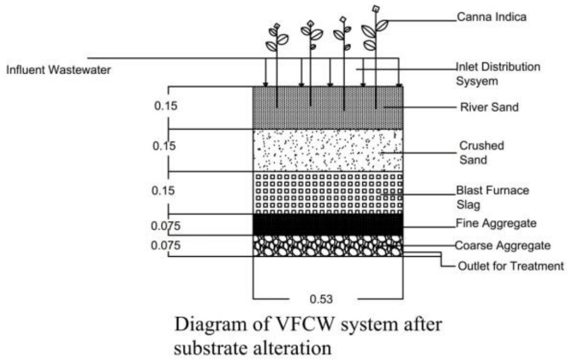


Fig – 1: Vertical Flow Constructed Wetland

The above diagram shows the clear illustrations of working model of VFCW and also the detail specifications of layers of each material.

Layer specifications are as follows

1. There is the layer of the plants which consists of Cypres Rotundus & Canna Indica with the ratio of 2:1 (5 plants of Canna Indica and 10 plants of Cypres Rotundus)
2. All the plants are very well distanced so to ensure the uniform growth of each plant.
3. The second layer after the soil in which plants are planted are fine river sand which is having a height of 15 cm. The soil layer in which plants are planted are also 15 cm in height.
4. The crushed sand layer is having a height of 15 cm which is directly under the fine sand layer.
5. Then comes the blast furnace slag layer or Cupola slag layer which we have used here and it also has a height of 15 cm.
6. Directly under the cupola slag layer we have used the layer of fine aggregate which has a height of 15 cm.
7. The fine aggregate is followed by the coarse aggregate layer which is also having a height of 15 cm.
8. All the layers are separated by a small thin layer of mesh which helps in retaining the materials in their own layers as it also prevents from mixing and outflow of the material in the treated water sump. Also, the mesh helps in preventing mixing of one layer into another.
9. The crates in which all these materials are situated are having a dimension of 30cm x 25cm x20cm.
10. There are holes drilled of 1 cm diameter with horizontally and vertically distanced at 7 cm at the bottom of each crates.



(**Fig – 2-** Diagram of VFCW after substrate alteration.

4. Physio–Chemical analysis-

The tests carried out in the analysis of the wastewater and treated wastewater were carried out on day to day basis not only the initial but also final treated wastewater was checked on day to day basis. The main element behind checking both the effluents was to determine the efficiency of the plants & materials used in the wetland itself. The tests carried out were Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD_3), pH, TSS, TDS were carried out. Here all the COD procedures are carried out by diluting the treated and non-treated wastewater at 50% dilution and all the BOD are carried out with 2% dilutions treated as well as non-treated.

5. Test Results-

Test results of Untreated vs. Treated wastewater-

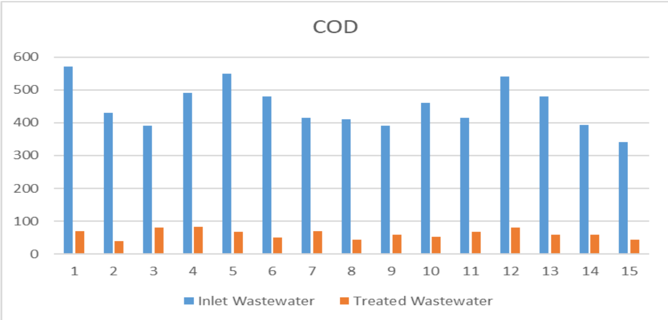


Fig – 3: Chemical Oxygen Demand

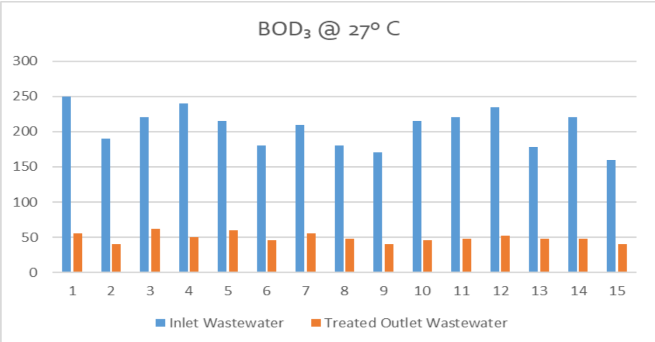


Fig- 4- Biochemical Oxygen Demand (3 days @27ºc)

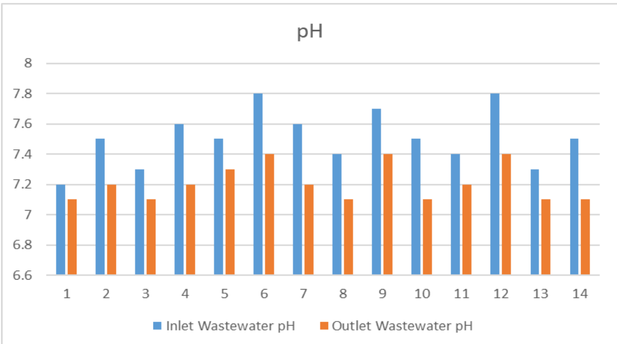


Fig- 5- pH of treated vs. untreated wastewater.

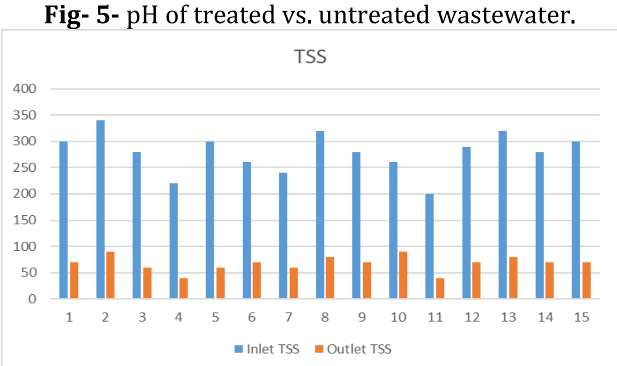


Fig-6- TSS of untreated vs. treated wastewater

6. Growth of the Plants-

Growth of the vegetation was measured here using the heights of the plants as they showed the good height during the operational phase also there were shoots developing in the canna Indica and they were used to develop the flowers of yellow color as well as the height of the plants were during the initial stage of the growth were having a registered height of 25 cm and as the operation started and wastewater added in them they had a growth of total 60cm in a time span of 1 month. The cypress Rotundus were planted in the bed and they had a height of 20cm and they hadn't developed any shoots of seeds on their top but as operation of the model started in timespan of 1 month, they started developing the seeds at the top of the plant and dispersion of the seeds began. Also, the plants (cypres rotundas) were grown in a total height of 30cm excluding seeds which made them 37cm.

7. Results & Discussion-

1. There were no significant changes in pH of treated and untreated wastewater.
2. The pH from the treated outlet of the VFCW didn't cross the mark of 7.5.
3. The BOD_3 removal was 76.18% during the treatment of the wastewater of what the inlet BOD_3 was before treating it when sampling was done on the site.
4. The COD removal was observed at around 86.12 % of what the sample was in its untreated stage.
5. The TSS removal was observed at around 75.76% of the untreated sample of the wastewater

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9. REFERENCES

1] Brix H & Aries C. "For Danish New wastewater guidelines, the use of vertical flow constructed wetlands for onsite treatment of domestic waste water". Ecological Engineering 25 (2005) 491–500

2] Chang J, Wua S, Dai Y, Liang W, Wua Z." Treatment performance of integrated vertical Flow constructed wetland plots for domestic wastewater". Ecological Engineering 44 (2012) 152–159.

3]Chen Z, Chen B, Zhou J, Li Z, Zhou Y, Xi X, Lin C., Chen G. "A vertical subsurface-flow constructed wetland in Beijing". Communications in Nonlinear Science and Numerical Simulation 13 (2008) 1986–1997

4] García F, Patiño P, Zhinín F, Donoso-Moscoso S, Flores del Pino L, Avilés-Añazco" A Performance of

Phragmites Australis and Cyprus Papyrus in the treatment of municipal wastewater by vertical flow subsurface constructed wetlands". International Soil and Water Conservation Research ISWCR 173.

5] Huiyu D, Qiang Z, Li1 T, Jin H, Chen W "Effect of artificial aeration on the performance of vertical-flow constructed wetland treating heavily polluted river water". Journal of Environmental Sciences 2012, 24(4) 596–601.

6] Kumar M, Singh R "Performance evaluation of semi continuous vertical flow constructed wetlands (SC-VF-CWs) for municipal wastewater treatment". Bioresource Technology BITE 17589.

7] Patel S, Vediya S.D, Chavda G, Parmar D and Rathod N "The pilot study of COD Removal in Industrial complex effluent by wetland plants Cyprus rotundas Linn". Universal Journal of Environmental Research and Technology. Volume 2, Issue 5: 439442.

8] Ping T; Zeshun X; Zhou Y; Zhang," A recirculating vertical flow constructed wetland for the treatment of domestic wastewater" Bioresource Technology Journal BITE 20331.

9]Sklarz M, Gross A, Yakirevich "A. Enzyme treatment improves the performance of laboratory-scale vertical. Desalination" 246 (2009) 617–624.

10] Sharma G, Priya and Brighu U," Analysis of Vertical Up-flow Constructed Wetlands for Secondary Treated Effluent". Procedia APCBEE published by Elsevier.

11]Thalla A, Devatha C, Anagha K, Sony E "Performance evaluation of horizontal and vertical flow constructed wetlands as tertiary treatment option for secondary effluents". Applied Water Science (2019) 9:147

12] Yadav A, Chazarenc F, Mutnuri S. Ecological engineering published by Elsevier Development of the ""French system" vertical flow constructed wetland to treat raw domestic wastewater."

13]Zreiqat I, Bassim A, Headey T, Nivala J, Manfred van Afferdend, Roland "Influence of septic tank attached growth media on total nitrogen removal in a recirculating vertical flow constructed wetland for treatment of domestic wastewater." Ecological Engineering 118 (2018) 171–178.

14]Alshaal T., Elhawat N., Domokos E., Katai A., Marton L., Czako M., El-Ramady H., and Fari M.G., (2014), "Giant Reed (Arundo donax L.): A Green Technology for Clean Environment" Phytoremediation, pp 3-20.

15]Cooper P., (1999), "A review of the design and performance of vertical flow and hybrid reed bed treatment systems." Water Science Technology, 40 (3).
16]Ding Y., Wang W., Song X., Wang G. and Wang Y., (2014), "Effect of spray aeration on organics and nitrogen removal in vertical subsurface flow constructed wetland." Chemosphere, 117, 502–505.

17]Dong H., Qiang Z., Li T., Jin H. and Chen W., (2012), "Effect of artificial aeration on the performance of vertical flow constructed wetland treating heavily polluted river water." Journal of environmental science 24(4), 596–601.

18]Foladori P., Ruaban J. and Ortigara A., (2013), "Recirculation or artificial aeration in vertical flow constructed wetlands: A comparative study for treating high load wastewater." Bioresource technology,149, 398-405.

19]JiaW., Zhang J., Wu J., Xie H., and Zhang B., (2010), "Effect of intermittent operation on contaminant removal and plant growth in vertical flow constructed wetlands: A microcosm experiment." Desalination, 262, 202–208.

20] Nivala J., Abdallat G., Aubron T., Al-Zreiqat I., Abbassi B., Wu G., Afferden M. and Müller R.A., (2019), "Vertical flow constructed wetlands for decentralized wastewater treatment in Jordan: Optimization of total nitrogen removal" Science of the total environment 671, 495-504. 19]Weedon C.M., (2003), "Compact vertical flow constructed wetland systems -first two years' performance." Water Science Technology, 48(5), 15–23.

21]C.A. Prochaska, A.I. Zouboulis." Removal of phosphates by pilot vertical-flow constructed wetlands using a mixture of sand and dolomite as substrate". Ecological Engineering 26 (2006) 293–303.

22]Shubiao Wua, David Austinb, Lin Liua, Renjie Dongc. "Performance of integrated household constructed wetland for domestic wastewater treatment in rural areas". Ecological Engineering 37 (2011) 948–954.

23] Z.M. Chen, B. Chen, J.B. Zhou, Z. Li, Y. Zhou, X.R. Xi, C. Lin, G.Q. Chen. A vertical subsurface-flow constructed wetland in Beijing. Communications in Nonlinear Science and Numerical Simulation 13 (2008) 1986–1997.

24]E. Asuman Korkusuz, Meryem Beklioglu, Goksel N. Demirer." Comparison of the treatment performances of blast furnace slag-based and gravel-based vertical flow wetlands operated identically for domestic wastewater treatment in Turkey". Ecological Engineering 24 (2005) 187–200.

25]Alexandros Stefanakis, Christos S. Akratos, Vassilios A. Tsihrintzis. Vertical Flow Constructed Wetlands. First edition 2014, Elsevier.

26] Mr. Vishwash K. Mistry, Prof. B.R. Patel, Prof. D.J. Varia. "Suitability of Concrete Using Cupola Slag as Replacement of Coarse Aggregate". International Journal of Scientific & Engineering Research, Volume 7, Issue 2, February-2016.

27]Kavya S Kallimani, Arjun S Virupakshi. "Comparison study on treatment of campus wastewater by constructed wetlands using Canna Indica & Phragmites Australis plants". International Research Journal of Engineering and Technology, Volume 2, Issue 9, Dec-2015.

28]Muhammad Masud Aslama, Murtaza Malikb, M.A. Baiga, I.A. Qazia, Javed Iqbalc. Treatment performances of compost-based and gravel-based vertical flow wetlands operated identically for refinery wastewater treatment in Pakistan. Ecological Engineering 44 (2012) 189– 198.

29]Arda Yalcuk, Nazli Baldan Pakdil, Semra Yaprak Turan. Performance evaluation on the treatment of olive mill waste water in vertical subsurface flow constructed wetlands. Desalination 262 (2010) 209–214.

30]F. Zurita, J. De Anda, M.A. Belmont. Treatment of domestic wastewater and production of commercial flowers in vertical and horizontal subsurface-flow constructed wetlands. Ecological Engineering 35 (2009) 861–869.

31]S. Juwarkar, B. Oke, A. Juwarkar and S. M. Patnaik. Domestic wastewater treatment through constructed wetland in India. Wat. Sci.Tech. Vol.32, No.3. pp. 291-294.1995.

31]Jaya S Pillai, Vijayan N. Decentralized Greywater Treatment for Nonpotable Reuse in a Vertical Flow Constructed Wetland.