A Review Paper on Study of Recirculation & Aeration in the Treatment of Wastewater Using Vertical Flow Constructed Wetland

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Abstract - *This study has been undertaken to understand factors like recirculation and aeration influencing VFCW and how the efficiency of wetland can be improved by implementing these factors. Partially effluent water is mixed with the influent wastewater, hence the effect of recirculation is studied on various parameters and working of wetland similarly VFCW with and without aeration are studied and how aeration will impact in removal of pollutants is studied. This review is intended how recirculation and aeration is beneficial for improving the performance of conventional VFCW*

***Key Words*: Wastewater, Vertical Flow Constructed Wetland, Recirculation, Aeration.**

1. INTRODUCTION

Discharge of majority of raw wastewater directly into rivers has become a common practice due to lack of suitable and effective technologies, operational failures of larger treatment plants, and higher cost involved in setting new treatment units. The constructed wetlands (CWs) are engineered systems that have evolved as an inventive approach to tackle wastewater from domestic sources mainly because of their reliable efficiency, ecological benefits, easy operation, and less maintenance cost. They use natural functions of macrophytes, soil, and microorganisms to treat different water streams. CWs are being used to treat almost all types of wastewater such as domestic sewage, stormwater runoff, agricultural runoff, industrial drainage, and polluted rivers water. There are many co-benefits of CWs together with wastewater treatment and recycling as they also provide important ecological services such as valuable wildlife habitat, aquaculture, groundwater recharge, carbon sequestration, fisheries, flood control, silt capture, recreational uses, and add aesthetic values to the surroundings. In a vertical subsurface-flow constructed wetland (VSSF–CW), the wastewater is subjected to treatment as it passes through a porous medium or substrate, such as gravel or sand with an appropriate diameter, planted with one or more species of common macrophytes. During the passage through the bed, the pollutants which are suspended or dissolved in the feed water are subjected to a variety of physical, chemical and biological processes, which can reduce substantially their concentrations. Treatment in CW includes processes such as sedimentation, filtration, sorption, precipitation, plant uptake and microbial degradation. The treatment occurs when wastewater flows through the wetland filter media and plants. Within the wetland filter medium, wastewater interacts with plant roots. This interaction leads to rhizofiltration and sedimentation. Interaction between microbes and pollutants results in biological degradation of organic pollutants. Root hairs of the plants provide aerobic conditions that support microbial activities. Degradation of organic and inorganic matter occurs due to presence of aerobic and anaerobic microorganisms

1. Recirculation in CW-

Among the different design up gradations of vertical flow CW systems, partial recirculation of treated water to the inlet has been adopted by most of the researchers as it improves the nitrogen elimination efficiency and increases the removal of organics and suspended solids in a classical VSSF CW system and helps in achieving higher purification rates especially for Nitrogen and Phosphorus. Along with this, recirculation arrangement helps in diluting the high strength influent wastewater before it enters the wetland cells and provides organic substrate for denitrification. Some studies, reported that on applying recirculation in treatment procedures, transferring of a portion of nitrified VSSF effluent to the primary inlet tank promotes denitrification process as a result of organic matter (BOD and COD) biodegradation. Also partial effluent recirculation back to the inlet primary tanks increases the activities of aerobic microbes and provides better removal of organic matter from wastewater.

2. Aeration in CW-

CWs are usually efficient in removing chemical oxygen demand (COD) and suspended solids (SS), but removals of nitrogen (N) and phosphorus(P)are relatively low. The poor performance in ammonium-nitrogen (NH_4-N) transformation is usually caused by low oxygen (O_2) content in CW systems, since O_2 supply is insufficient as it is provided only by surface air exchange and the presence of plants leading to diffusion of O_2 via the rhizomes. Moreover, poor O_2 transport might lead to partially oxidized SS, which is a main contributor to substrate clogging problems. One alternative for improving oxygen transfer on CW is to, introduce oxygen to the system through frequent water level fluctuation, passive air pumps, or direct mechanical aeration of the water in the gravel bed. The high availability of oxygen in VFCW allows efficient degradation of biological oxygen demand (BOD) through bacterial oxidation of carbonaceous compounds and high ammonia transformation by nitrifying bacteria.

3. LITREATURE REVIEW

VFCW is recommended for wastewater treatment because of its smaller size, high quality of treated effluent and less evapotranspiration rate. Moreover, VFCW proved to be very promising technique for wastewater treatment not only for COD, BOD and TSS reductions, but also for nitrification and pathogenic removal. The COD, BOD and TSS removal rates reached 92.9%, 93.6% and 94%, respectively. A wide range of pollutants such as BOD, COD, TSS, Total Kjeldahl Nitrogen (TKN), Total Phosphorous (TP), coliform, metals can be removed effectively using VFCW. (Sohair I.Abou-Elela)

3.1Recirculation-

Studied carried out on three VFCW systems, equipped with different recirculation arrangements was fixed as 25%, 50% and 75% resulted into a decrease in pollutant concentrations from inlet to outlet. Average outlet concentrations in all CW systems i.e., BOD (8.9–20.4mgL−1), TN (60.4–72.1mgL−1), NH4-N (34.2–38.2mgL−1) and TP (1.0–2.3mgL−1) reflects that performance of VF CW systems vary at different recirculation rates. Recirculation resulted into an increase of 10.0 to 19.3% TN removal from all CW systems. Maximum average purification rates of TSS (99.3%), BOD (97.8%), TP (97%), TN (50.5%) and NH4-N (50.7%) were achieved in VF CW system with an arrangement of 75% recirculation of treated water from outlet to inlet. The results of the present study suggests that arrangement of recirculation of treated water in a VF CW system could help in achieving higher removal of pollutants.(P.K. Sharma et al)

The influence of recirculation in a lab-scale vertical flow constructed wetland on the treatment efficiency of landfill leachate at different flow rates was studied. It was established that the higher flow rate leads to longer period needed for treatment. The recirculation ratios also influence the purification process. The VF-CW was operated continuously in a recirculation regime. The experiments with three different flow rates (40, 60 and 82 m lmin-1, respectively) were carried out. Experiments with three different recirculation ratios at every flow rate were conducted (the time of water running through the wetland to the time of quiet water in it–1:1;1:2;1:3). Thus the water was running for 1 hour and then was left quiet for 1, 2 or 3 h, respectively.

For COD removal, the efficiency at recirculation ration 1:1 was 67%, 81% and 90%. With recirculation ratio 1:2 was 78%, 86% and 90%, respectively, and at recirculation ratio 1:3 it was 78%, 90% and 96%. COD decreased slower when the flow rate was higher. The elimination of BOD5 occurs fast in most cases during the initial 5 days. The efficiency of BOD5 removal at a recirculation ratio of 1:1 was 72%, 85% and 92% for flow rate 82, 60 and 40 mlmin-1, respectively. At recirculation ratio 1:2 it was 83%, 92% and 93% for the corresponding flow rates. The efficiency was 91% at flow rate 82 mlmin1 and recirculation ratio 1:3. The TP removal was 41.8%, 60% and 67.3% for 1:1, 1:2 and 1:3 recirculation ratios during 8, 6 and 4 days, correspondingly. It was established that during the experiments pH slightly decreased from 7.9 to 7.5 and the salinity also decreased from 2.5‰ to 1.9‰. TDS gradually decreased from 2460 to 1778mg dm3. The values of TSS varied from 1.91 to 3.96 g/l. (silviya lavrova, Bogdana Kovmanova)

Different effluent RRs of 25%, 50%, 100%, 150% were adopted in series. Accordingly, hydraulic loading rates imposed on the VFCW wetland were 6.25, 7.5, 10, 15cm/d, respectively. And for each RR the experiment lasted for 45d except that with the RR of 100% the experiment lasted for 3 months. Between every two different RR experiments there was an adaptation period of one week. Effluent recirculation clearly improved the removal of NH4-N, whose percent removal was increased from 35.6% to 61.7% (RR-150%). With the increase of recirculation rate, the BOD5 removal varied from 56.8% to 81.3%, whereas the average percentage reduction was only 50.2% before recirculation was employed. Without recirculation the SS was reduced by 49.3%, whereas with recirculation the reduction increased from 55.1% to 77.7%. The improvement of TP removal is only from 42.3% to 48.9%. Exponential relationships with excellent correlation coefficients (R>0.93) were found between the removal rates of NH4-N and BOD5 and the recirculation rates. With the effluent recirculation, the concentrations of oxide nitrogen and DO in inflow and outflow increased, indicating that this operation benefited the formation of an oxide environment in wetland. With effluent recirculation, the pH value of the outflow decreased as the alkalinity was consumed by gradually enhanced nitrification process. (He Lian-sheng, Liu Hong-liang, Xi Bei-dou and Zhu Ying-bo)

3.2Aeration

Using activated sludge as seed sludge, two VFCW units were started up by intermittent operation after 45days.VFCW-a is aerated and VFCW-c normal operating without aeration. The VFCW-a unit had better resistance ability to organic shock loads than the VFCW-c unit, and its corresponding 3.5day removal should reach approximately 82% after organic shock loads were introduced into the system. Compared with the VFCW-c unit, the VFCW-a unit required a shorter HRT (about 6h) to reach a certain level of pollutant removal with SS 81.2%, COD 85%, TN 89.9% and TP 77.9% at 42h HRT. When the HRT reached 54h, SS, COD, TN and TP removals in both units could almost achieve an according level at 90%, 85%, 89% and 84%, respectively. Under intermittent operation with 42h HRT, the VFCW-a unit could obtain relatively stable removal efficiencies at 12h idling time, which was about 6h less than the VFCW-c unit could. In contrast, there was no evident difference in P removals between the two VFCW units under different idling timed. Overall, passive supplementary aeration in VFCW units is an innovation for treating decentralized domestic wastewater under intermittent operation, since the VFCW-a unit has better resistance to organic shock loads, as well as a shorter HRT and idling time. (Liandong Zhua)

TP removal was studied using four model having different aeration techniques first was non-aerated VFCW, the second was tidal flow i.e. (VFCW-TF), third was external recirculation i.e. (VFCW-ER) and the fourth was artificial aerator i.e. (VFCW-AA). In non-aerated VFCW, the removal of TP was 29–74% and the removal of PO43--P is not investigated in the reported studies. In VFCW, the removal of PO43--P and TP was 45–97 and 75–94%,with TF. The removal with ER was 46 and 21–67%, respectively. With AA, the removal of TP was24–92% and the removal ofPO43—P was not investigated in the reported studies using AA to improve the treatment efficiency. As expected, aerated CWs performed much better compared with non-aerated CWs. The overall TP removal efficiencies of aerated and non-aerated CWs were estimated as68±20and 48±23%, respectively, and the removal rates were 1.1±1.4 and 0.4±0.4 g m−2 day−1, respectively. (Huma Ilyas1 & Ilyas Masih)

Eight batch-operated VFCWs with and without intermittent aeration were operated in parallel for the treatment of simulated domestic wastewaters with different influent strengths in this study. The application of intermittent aeration in VFCWs not only significantly increased the DO concentration, but also successfully created alternate aerobic and anaerobic conditions. Regardless of influent strengths, excellent removal efficiencies of COD, NH4 +-N, and TN were successfully achieved in intermittent aerated VFCWs, and significantly higher than conventional VFCWs. The results suggest that the intermittent aeration could be a valuable strategy for further increasing the treatment efficiencies and thus expanding the application of VFCWs, especially for the in-situ treatment of high strength decentralized domestic wastewaters .COD removal rates for 85.49%, 73.59%, 68.08% and 62.68% for various influent strengths for non-aerated VFCW. While for intermittent aerated VFCWs, COD removal rates were 98.17%, 98.49%, 96.42% and 96.69% under the different influent strengths (A, B, C and D). The average effluent NH4 +-N concentration in non-aerated VFCWs was greatly higher than that of intermittent aerated VFCWs at the same influent strength (Himing Wu, Jinlin Fan, Jian Zang, Zhen Hu)

4. Conclusion

1. It is commonly assumed that phosphorus removal from wastewater is a result of chemical reactions between the inorganic phosphorus and the metal compounds inside the wetland matrices, and other processes such as adsorption and nutrient uptake by wetland plants may also function. Inorganic chemical reactions are normally rapid processes that are not only greatly affected by the increase of the wastewater-media contact time; but also are affected by the rates of phosphate uptake by reeds and adsorption onto the surfaces of the media. Therefore, employing effluent recirculation may have little effect on TP removal processes.
2. Limited oxygen supply always restricted organic matters degradation with the increasing of influent strength, the limitation of oxygen became more obvious, resulted in decrease of COD removal rates in non-aerated VFCWs.

3. It is widely accepted that nitrification could occur with DO concentration above 1.5 mg/L. While in non-aerated VFCWs, the DO was rapidly consumed after feeding, and then the DO concentration was normally seen below 0.35mg, hence for nitrification it is necessary to maintain the oxygen content.
4.The side effect of continuous aeration is aerobic condition which allows nitrification only but intermittent aeration provide both aerobic as well as anaerobic condition favorable for both nitrification and denitrification.

5. Poor O2 transport might lead to partially oxidized SS, which is a main contributor to substrate clogging problems. In this respect, it is crucial to provide a sufficient amount of O2 to efficiently degrade the accumulated organic particles in CWs and avoid clogging problem.

6. When the effluent is recirculated, additional oxygen for aerobic microbial activities can be transferred into wastewater that is repeatedly pumped and re-distributed.

7. Recirculation operation will also benefit to the treatment by enhancing interactions (contact time) between pollutants in wastewater and microorganisms attached to the roots of plants and surfaces of gravels.

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