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# Study on Effectiveness of Intervention of a Vertical Flow Constructed Wetland in between Septic Tank and Soak Pit for the Treatment of Septic Tank Effluent

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## ABSTRACT

Septage comprises the solid and liquid constituents of any primary treatment system, including a Septic Tank. In this study, the wastewater collected from a septic tank is passed through a partially converted anaerobic filter, and a vertical flow constructed wetland (VFCW) before being sent to a soak pit. The main objective of this case study was to check the effectiveness of incorporating a VFCW between a septic tank and a soak pit to bring down the consequences created due to effluent seepage from soak pits to the groundwater. Conventionally, the effluent gets directly passed to soak pits after primary onsite treatment in the septic tank. The soak pit walls made of porous materials allow the gradual seepage of final effluent into the ground, polluting the groundwater reserves. We analyzed the septic tank effluent from 60 households wherein the effluent was let off into the soak pits. The various parameters analyzed with their averages were 393.83 ± 293.41 $mg.L^{-1}$ for COD, 151.48 ± 94.37 $mg.L^{-1}$ for BOD, 30.81 ± 13.05 $mg.L^{-1}$ for $NO_3^-$, 23.35 ± 13.54 $mg.L^{-1}$ for $PO_4^{3-}$, 7.35 ± 0.31 for pH, 184.05 ± 163.20 $mg.L^{-1}$ for TSS, 3.05 x $10^7$± ٢،٠٤ x $10^8$ $CFU.100mL^{-1}$ for TC. Therefore, it is certain that the final effluent being sent into soak pits after primary treatment does not meet the Central Pollution Control Board (CPCB) discharge standards. In this case study, we were able to obtain final effluent values after VFCW treatment as 55.72 $mg.L^{-1}$ for COD, 12.12 $mg.L^{-1}$ for BOD, 10.2 $mg.L^{-1}$ for $NO_3^-$, 3.74 $mg.L^{-1}$ for $PO_4^{3-}$, 7.41 for pH, 8.37 $mg.L^{-1}$ for TSS, 379.27 $mg.L^{-1}$ for TS and 51.9 $CFU.100mL^{-1}$ for TC. With this case study, we were able to resolve this impediment by bringing down the values of all the parameters considered while analyzing under the limits of discharge standards set by CPCB. The removal efficiency of COD, BOD, $NO_3^-$, $PO_4^{3-}$, pH, TSS, and TC after wetland was found to be 89.46%, 88.051, 63.484, 44.37%, 3.41%, 98.47%, 97.71%, 97.19% respectively. The study has proven that with the introduction of another decentralized treatment system between a septic tank and soak pit, it is safe to dispose of the effluent into soak pits, thereby reducing the chances of groundwater pollution considerably.

## INTRODUCTION

The concept of sanitation remits the idea of being clean for oneself and considering their immediate surroundings (Nurudeen & Toyin 2020). With the object of providing this and various other goals, the United Nations introduced 8 Millennium Development Goals (MDG) in 2000 to be achieved by 2015 and later replaced it with Sustainable Development Goals in 2015 (SDG) with 17 agendas to be fulfilled by 2030 which had a clear targeted goal for sanitation and especially hygiene. Joint Monitoring Programme (JMP) by World Health Organization (WHO)/ United Nations Children's Fund (UNICEF) was established to provide guidelines and to compare the progress of MDGs across countries and later revised to WHO/UNICEF Joint Programme for Water Supply, Sanitation, and Hygiene by 2017 with regards to 2030 agenda (Jong & Vijge 2021).

According to Central Pollution Control Board (CPCB), India will need 1.5 trillion cubic meters of water to meet the water demand by 2030 (CPCB ENVIS Letters 2021). Based on Niti Aayog's report in 2018, the per capita water availability is disputed to deplete to 1465 cubic meters by 2025 from 1544 cubic meters, which was available in 2011 and 1816 cubic meters in 2001. To meet the water demand, Recycling and Reusing wastewater can be beneficial alternatives to reduce the stress on the water reserve that is available today (Matto et al. 2019). Sanitation and water availability being a merit good, the Indian government has brought forward specific key policy initiatives and programs in accordance with that, like the Flagship program Namami Gange Program in 2014, Jawaharlal Nehru National Urban Renewal Mission (JNNURM) in 2005, National Urban Sanitation Policy (NUSP) in 2008, Swachh Bharat Mission (SBM) in 2014 and National Policy on Fecal Sludge and Septage Management (NPFSSM) in 2017 for Urban Sanitation (Kapur 2021). Out of all the policies, the policy that garnered the maximum attention among the public was SBM. SBM consists of Phase 1 with significant objectives of making India Open Defecation Free (ODF), uprooting Manual Scavenging, and bringing about specific behavioral changes regarding some already existing sanitary practices, whereas Phase 2 gave importance to maintaining the ODF status achieved in phase 1 and to improve the lives of sanitation workers and the management of solid and liquid waste (Bhattacharya et al. 2018).

Even though in phase 1 access to safe sanitation was provided, it is also required to make sure that safe and proper Containment, Collection, Transportation (If on-site treatment is not possible), Treatment, and Resource recovery or Safe disposal is made systematically to maintain sanitation (Peal et al. 2020, Schrecongost et al. 2020). In developing countries like India and other countries, certain complications can arise due to the transportation of waste collected to a far-off treatment facility either through sewers or vacuum trucks or manually if there is no provision for a treatment plant present nearby. There are chances of waste getting dumped elsewhere into the environment rather than being taken to the treatment facility (Mehta et al. 2019). Thereby untreated waste will lead to more trouble if left unattended. If treatment is not done effectively, the usage or disposal of the end product will also be unhygienic and can create disorders in humans (Reymond et al. 2020). As a solution to all of this inconvenience, onsite treatment of waste can be considered. One such treatment technology is the usage of septic tanks and soak pits and the sanitary facility available (Strande 2014).

A septic tank acts as a sedimentation tank where settling settleable solids happens and a digestion tank where some magnitude of anaerobic digestion happens (Ergas et al. 2021). Thereby, there is a slight destruction in solids occurring along with a reduction in sludge concentration, little pathogen reduction, and release of Carbon dioxide ($CO_2$), Methane ($CH_4$), and Hydrogen sulfide ($H_2S$) gases. A septic tank usually comprises two chambers with a sludge layer, a clear zone with effluent, and a scum layer found inside (Adegoke & Stenstrom, 2019). From these chambers, effluent will be passed onto soak pits, typically in circular dimensions provided with inner linings and filled with brick ballasts and loose stones. The effluent in soak pits will gradually leach out through the porous walls of the soak pits in time. Since proper and complete treatment is not done inside the septic tanks, the effluent leached out from the soak pit pores will join the groundwater reserves or any other drinking water source present in the proximity to contaminate the water body (Ergas et al. 2021). There are a lot of disadvantages due to the percolation of the effluent from soak pits. Besides cross-contamination, leachate can also affect the soil properties that it comes in contact with without treatment. The leachate is unhygienic, and since total oxidation of organic matter is not completed properly, upon introduction to air, it will become offensive and produce a foul smell (Mahajan n.d). Since countries like India largely depend upon septic tanks and soak pits for onsite treatment technologies, it is vital to have a treatment system between the septic tank stage and soak pit in highly congested areas to avoid this condition (Forbis-Stokes et al. 2021).

To detect the impact of soak pits on the environment, a survey was conducted by collecting Septic tank effluent from 60 different locations in Goa, and inlet characteristics of the wastewater were done. After screening this data, we were able to arrive at the conclusion that an immense amount of pollution is directly passed onto the soak pits and, from there, eventually, to the ground. Since Laterite is the major soil type in Goa with very little retention capacity, the leachate from the soak pits will seep into the groundwater reserve and pollute the groundwater table, unfitting for the environment's well-being. So, it was essential to find an alternative to this condition by introducing a treatment system between the septic tank and the soak pit. VFCW was selected as the intermediate treatment system as it is cheap and would require significantly less operation as it is a passive system. The main objective of the case study was to find the effectiveness of introducing a partial anaerobic filter inside the septic tank chamber and a VFCW before disposing of the effluent from the septic tank chamber into soak pits. The case study aimed to bring down the values of physico-chemical parameters used for analyzing wastewater samples to the standard limits set forward for Sewage Treatment Plants of India by CPCB (Central Pollution Control Board 2008) and globally by the US EPA (Environmental Protection Agency) (US-EPA 1994).

## MATERIALS AND METHODS

### Characterization of Wastewater from Septic Tank

With regards to the characterization of wastewater in septic tanks, 60 different locations in Goa were selected, and surveys were conducted. From the locations, septic tank wastewater samples were collected. The samples obtained in this survey were analyzed for all the physico-chemical parameters of wastewater in the Water Sanitation and Hygiene Lab in BITS Pilani K K Birla Goa Campus, Goa. The supplementary file contains data regarding the locations of sample collection and parameter values obtained after analysis.

### Construction of the Setup

The system consists of a septic tank comprising three chambers. The third chamber is partially converted into an anaerobic filter, a vertical flow constructed wetland (VFCW), a disinfection tank, and a soak pit. Cement Concrete walls were used to construct all the chambers in the setup. The septic tank was constructed with dimensions 5×2×2 m, and the length of the three compartments was provided as 2 m, 2 m, and 1m, respectively. In the Anaerobic filter in the third compartment of the Septic tank, 20-40 mm gravel was added up to a height of 1m from the bottom of the chamber. VFCW was constructed as a second-stage wetland with the dimensions 2×2×2 m, comprising three layers of sand and gravel. From the top, 0- 40 mm sand was provided to a height of 40 cm, followed by 4-10 mm sized gravel for a height of 15-20 cm, and finally, for the third layer, 10-20 mm sized gravel was given for the height of 20 cm (Yadav et al. 2018). Aeration pipes were provided at the bottom of the wetland to maintain passive ventilation. Out of the 2m depth provided for VFCW, 20 cm at the top is utilized by plants in the wetland, and the bottom 20 cm is occupied by the aeration pipes leaving 1.6 m of the anaerobic zone. Dimensions for the Disinfection tank were designated as 1x2x2 m. The soak pit was filled with loose stones of size 20-40 mm for a height of 2 m. the pictorial representation of the setup is shown in Fig. 1.

### Working of the Setup

The system was constructed and implemented in July 2021 and was left operational till January 2022 so that the system gets acclimatized to the treatment conditions. From January 2022, monitoring of the system was initiated; collection and

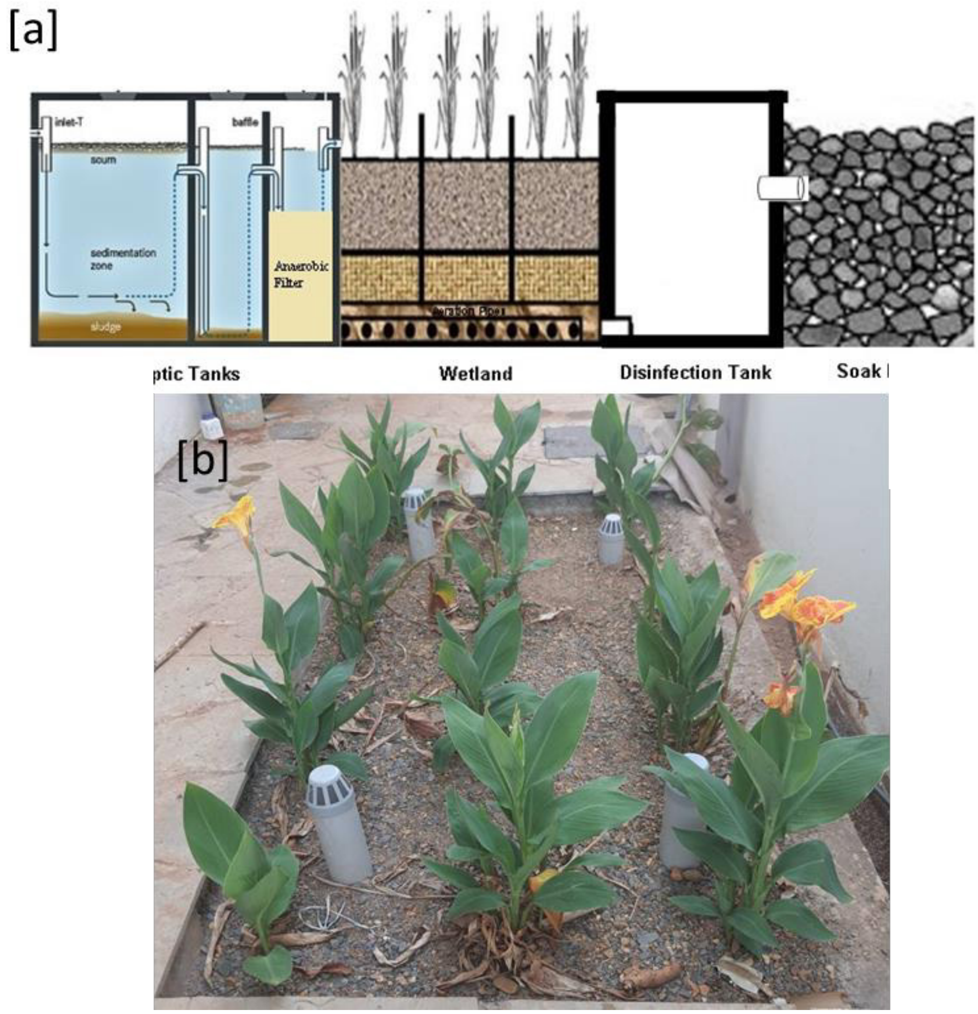


Fig. 1: [a] Design of the treatment system after the septic tank and [b] Real-time picture of the setup.

analysis of samples were started along with it. The system was operated manually and treated 1m$^3$ of raw wastewater per day. Wastewater enters the first chamber of the septic tank system, where the inlet pipe is placed to the bottom and moves towards the rest of the chambers by the up flow. In the third chamber of the septic tank, wastewater will flow through an anaerobic filter placed at the center of the chamber, extending up to the bottom. From this chamber, wastewater will move onto the VFCW from the bottom to the top by vertical flow at 1.8 m and pass onto the disinfection tank where chlorination was done. Once the residual total coliform was removed, treated effluent was circulated for gardening, and the leftover effluent was then deposited into the soak pit.

### Analytical Methodology

Samples were collected from three collection points; the initial model was the raw wastewater before providing any treatment, the second sample was generated after anaerobic filtration, and the third sample was collected after the wetland treatment. Once collected, all three sampling points were analyzed for Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Turbidity, pH, Nitrates ($NO_3^-$), Ortho-Phosphate ($PO_4^{3-}$), Total Solids (TS), Total Suspended Solids (TSS) and Total Coliforms (TC). For COD and $PO_4^{3-}$, analysis was done using Standard Operating Procedures mentioned in APHA (APHA, WEF 2005). For the analysis of $NO_3^-$, Spectroquant® Prove 100 Spectrophotometer was used with the Spectroquant® cell test kits. Oakton-PC 450 pH meter was used for the study of pH. For calculating TSS and TS, a Hot air oven and weighing balance were used, and for TSS, filter paper of pore size 1.45 microns was used.

### Location of the Setup

This work was carried out near Bogmallo, South Goa, Goa, India, and the location coordinates are 15.3556314°, 73.8490873°.

## RESULTS AND DISCUSSION

### Wastewater Characteristics

Table 1 represents the results obtained after performing various analyses on the septic tank wastewater samples collected from 60 locations in Goa. After treatment in the septic tank, the average values of parameters obtained with the relative standard deviation were 393.83 ± 293.41 mg.L$^{-1}$, 151.43 ± 94.37 mg.L$^{-1}$, 30.81 ± 13.05 mg.L$^{-1}$, 23.35 ± 13.54 mg.L$^{-1}$, 7.35 ± 0.31, 184.05 ± 163.20 mg.L$^{-1}$, 3.05x10$^7$ ± 2.04x10$^8$ CFU.100mL$^{-1}$ for the parameters COD, BOD, $NO_3^-$, $PO_4^{3-}$, pH, TSS, TC respectively. The standard limits set by CPCB for the safe discharge of treated wastewater for COD, BOD, $NO_3^-$, $PO_4^{3-}$, pH, TSS, and TC are less than 50 mg.L$^{-1}$, less than 10 mg.L$^{-1}$, less than 10 mg.L$^{-1}$, less than 5 mg.L$^{-1}$, 6.5 - 9.0, less than 20 mg.L$^{-1}$, less than 100 CFU.100 mL$^{-1}$ respectively (Central Pollution Control Board 2008). Based on the values obtained after analysis compared to the standard limits, it is evident that the treatment is insufficient, and all the values are well above the limits set by the CPCB. From these values, it can be concluded that a huge amount of pollution is being transferred into the soak pits without adequate treatment (Schellenberg et al. 2020). This argument clarifies the need to introduce an efficient treatment system after the septic tank before the effluent is sent to the soak pits.

Table 1: Characteristics of the septic tank wastewater collected from 60 different points in Goa.

| Parameters | Values obtained |
|---|---|
| COD [mg.L$^{-1}$] | 393.83 ± 293.41 |
| BOD [mg.L$^{-1}$] | 151.48 ± 94.37 |
| $NO^{3-}$ [mg.L$^{-1}$] | 30.81 ± 13.05 |
| $PO_4^{3-}$ [mg.L$^{-1}$] | 23.35 ± 13.54 |
| pH | 7.35 ± 0.31 |
| TSS [mg.L$^{-1}$] | 184.05 ± 163.20 |
| TC [CFU.100mL$^{-1}$] | 3.05 x 10$^7$ ± 2.04 × 10$^8$ |

As illustrated in Table 2, the values obtained after analysis of the samples collected from the constructed new setup are shown. The average COD value with its corresponding standard deviation for raw wastewater was 529.21 ± 84.83 mg.L$^{-1}$; after complete treatment, the value obtained was 55.72 ± 7.68 mg.L$^{-1}$. From this, it can be inferred that the treatment was working. With the introduction of wetland, the system brought down the COD value from 248.07 mg.L$^{-1}$ obtained after the anaerobic filter to 55.72 mg.L$^{-1}$ after wetland treatment, which is around the CPCB standard limit 50 mg.L$^{-1}$ provided for COD. BOD's value varied from 101.48 ± 11.26 mg.L$^{-1}$ to 12.126 ± 3.145 mg.L$^{-1}$ after complete treatment. Here it can be observed that in VFCW treatment, the BOD value was reduced to 12.126 mg.L$^{-1}$, which is around the limit of BOD set by CPCB. When considering the values of $NO_3^-$ it can be seen that the values reduced from 27.93 ± 2.38 mg.L$^{-1}$ for raw wastewater to 10.2 ± 1.31 mg.L$^{-1}$ after VFCW. After wetland treatment, the $NO_3^-$ value is 10.2, around the standard limit for $NO_3^-$ set by CPCB. Generally, it is found that while using VFCW, there is a hike in nitrate values (Yaragal & Mutnuri 2021). While considering the values obtained, we can infer that this system was able to overcome the drawback of an increase in nitrate with the introduction of VFCW. For the values obtained for $PO_4^{3-}$ also, we can observe a considerable

Table 2: Characteristics of the wastewater samples collected from the system constructed.

| Parameters | Domestic wastewater | After anaerobic chamber | After VFCW |
|---|---|---|---|
| COD [$mg.L^{-1}$] | 529.21 ± 84.83 | 248.07 ± 29.54 | 55.77 ± 2.68 |
| BOD [$mg.L^{-1}$] | 101.48 ± 11.26 | 49.63 ± 4.55 | 12.12 ± 3.14 |
| $NO_3^-$ [$mg.L^{-1}$] | 27.93 ± 2.38 | 17.76 ± 0.86 | 10.2 ± 1.31 |
| $PO_4^{3-}$ [$mg.L^{-1}$] | 6.73 ± 1.62 | 4.98 ± 1.21 | 3.74 ± 0.69 |
| pH | 7.16 ± 0.10 | 7.39 ± 0.073 | 7.41 ± 0.35 |
| TSS [$mg.L^{-1}$] | 549.2 ± 109.55 | 69.48 ± 16.22 | 8.37 ± 2.30 |
| TS [$mg.L^{-1}$] | 16595.46 ± 2119.30 | 3692.37 ± 610.50 | 379.27 ± 32.96 |
| TC [$CFU.100\ mL^{-1}$] | 1852.8 ± 500.66 | 805.5 ± 95.48 | 51.90 ± 12.16 |

decrease in values after wetland treatment as 6.73 ± 1.62 $mg.L^{-1}$ to 3.74 ± 0.69 $mg.L^{-1}$ after VFCW, and we can see that the final effluent has $PO_4^{3-}$ value as 3.745 which is under the standard limit 5 $mg.L^{-1}$ for $PO_3^{4-}$ set by CPCB. In the case of pH, we can observe the values 7.165 ± 0.10 changing to 7.41±0.35 after complete treatment, and the pH value of sample 7.41 is in the limit of the effluent discharge standard for the pH ranges from 6.5-9.0. TSS values differ from 549.2 ± 109.55 $m.L^{-1}$ to 8.37 ± 2.30 $mg.L^{-1}$ after VFCW. It can be deduced that upon treatment, the system was able to cut down the concentration of TSS from 549.2 $mg.L^{-1}$ to 8.37 $mg.L^{-1}$, which is under the CPCB standard limit of 20 $mg.L^{-1}$. From the TS values observed, we can conclude that there is a substantial reduction in the values mentioned in the initial raw sample, which is 16595.46 ± 2119.30 $mg.L^{-1}$ to the final effluent after VFCW with 379.27 ± 32.96 $mg.L^{-1}$. Even if good quality treatment happens after VFCW, the final value obtained for TS is still higher. It can also be noticed that there is a good quality treatment for pathogen reduction with TC varying from 1852.8 ± 500.66 $CFU.100\ mL^{-1}$ to 51.90 ± 12.16 $CFU.100\ mL^{-1}$ after VFCW which is well under the CPCB standard limit of 100 $CFU.100\ mL^{-1}$ (Central Pollution Control Board 2008). After all the analysis, it can be concluded that the introduction of wetlands has a positive impact in lowering the values of the wastewater sample to the standard limits set forth by the CPCB. Accordingly, we can assume that the values of all the parameters around the CPCB limit after wetland treatment, and the final effluent can be reused after disinfection and sent to soak pits. Even if there is a percolation of leachate from the soak pits in time, there won't be any groundwater pollution since the physicochemical parameters remaining after disinfection will be under the limits.

Table 3 shows the removal efficiency of the system after the series of treatments. It can be seen that there is a considerable reduction of 89.469% (+), 88.051% (+), 63.484% (+), 44.378% (+), 3.419% (-), 98.475% (+), 97.714% (+), 97.198% (+) for COD, BOD, $NO_3^-$, $PO_4^{3-}$, pH, TSS, TC respectively in which positive sign (+) represents the reduction in parameter values after wetland treatment and negative sign (-) represents the increase in the parameter values. Fig. 2 explains the weekly variation in physicochemical parameters.

From the graphical observation of COD, we can deduce that the raw wastewater sample produced COD values around 529.11 $mg.L^{-1}$ varying from a maximum of 677.84 $mg.L^{-1}$ to a minimum of 429.82 $mg.L^{-1}$. A higher COD level generally indicates a higher quantity of oxidizable organic matter in the sample (Burns 2021). After Septic tank treatment, the values obtained were around 248.07 $mg.L^{-1,}$ differing from 304.54 $mg.L^{-1}$ to 213.782 $mg.L^{-1}$. The reduction in COD values from raw wastewater to the final treated wastewater can be associated with anaerobic digestion and sedimentation in the septic tank (Adegoke & Stenstrom 2019). After VFCW, the COD values obtained were around an average value of 55.72 $mg.L^{-1}$ ranging from 67.89 $mg.L^{-1}$ to 42.87 $mg.L^{-1}$ and the accelerated decrease in COD value observed was also supplemented by the partial aeration provided below the wetland (Tang & Huang 2008). In accordance with the COD values, we can see a similar reduction in BOD values averaging at 101.482 $mg.L^{-1}$ without treatment ranging from 121.54 to 85.57 $mg.L^{-1}$, 49.636 $mg.L^{-1}$ after anaerobic filter varying

Table 3: Percentage reduction occurring in each parameter after complete treatment.

| Parameters | Per cent reduction |
|---|---|
| COD [$mg.L^{-1}$] | 89.46% |
| BOD [$mg.L^{-1}$] | 88.05% |
| $NO_3^-$ [$mg.L^{-1}$] | 63.48% |
| $PO_4^{3-}$ [$mg.L^{-1}$] | 44.37% |
| pH | -3.41% |
| TSS [$mg.L^{-1}$] | 98.47% |
| TS [$mg.L^{-1}$] | 97.71% |
| TC [$CFU.100mL^{-1}$] | 97.19% |


Fig. 2: Graphical representation of variation in physic-chemical parameters after each stage of treatment.
The blue line indicates the inlet wastewater, orange line indicates the wastewater after anaerobic filter and the grey line indicates the wastewater characteristics after VFCW

within 57.86 to 44.08 $mg.L^{-1}$ and 12.126 $mg.L^{-1}$ after VFCW treatment with maximum and minimum values 13.79 to 8.74 $mg.L^{-1}$. The high BOD value of raw wastewater indicates that the oxygen required to decompose biodegradable organic matter is high. The lesser value of BOD for samples after VFCW treatment shows that the oxygen required for organic matter decomposition is significantly less. This validates the fact that proper treatment of wastewater is happening in the system with the introduction of wetlands.

In the case of $NO_3^-$, average values obtained were 27.93 $mg.L^{-1}$ for raw wastewater with a minimum of 30.4 $mg.L^{-1}$ to a maximum of 24.7 $mg.L^{-1}$, 17.76 $mg.L^{-1}$ after treatment in an anaerobic filter ranging from 18.9 to 16.8 $mg.L^{-1}$, 10.2 $mg.L^{-1}$ after VFCW treatment varying from12.1 to 10 $mg.L^{-1}$. There is enough reduction in nitrate values after the septic tank and anaerobic filter, indicating that some of the nitrates got reduced in the chamber. The decrease in nitrate value after VFCW treatment is because of the larger anaerobic zone of size 1.8m provided in the VFCW and the anaerobic filter provided in the septic tank. For $PO_4^{3-}$ analysis, raw wastewater gave an average value of 6.73 $mg.L^{-1}$ with 10.39 $mg.L^{-1}$ as the maximum and 3.99 $mg.L^{-1}$ as the minimum. Sample after anaerobic treatment produced 4.98 $mg.L^{-1}$ ranging from 6.86 to 3.25 $mg.L^{-1}$, and after complete treatment, the value was reduced to 3.745 $mg.L^{-1}$ varying from 4.53 to 2.83 $mg.L^{-1}$. The reduction in $PO_4^{3-}$ after wetland can be considered as due to the uptake by plants. We can observe pH values of 7.165 with limits from 7.32 to 7.01 for raw wastewater, 7.39 ranging from 7.54 to 7.24 for the sample after the anaerobic filter, and 7.41 as average with maximum and minimum varying from 7.67 to 7.44 for the sample after VFCW.

In the case of TSS, we can see that the maximum and minimum value ranges obtained for raw wastewater are from 723 to 310 $mg.L^{-1}$ with 549.2 $mg.L^{-1}$ as average, which is at a high. The sample after the anaerobic filter produced a TSS value of the average of 69.48 $mg.L^{-1}$ ranging from 93.33 to 43 $mg.L^{-1}$ whereas the sample after VFCW had a value of 8.37 $mg.L^{-1}$ as average with maximum and minimum varying from 6.5 to 13 $mg.L^{-1}$. The higher reduction of TSS occurring in the septic tank is due to the sedimentation of most of the settleable solids in the chambers. For the analysis of TS, we can observe that for raw wastewater, an average of 16595.46 $mg.L^{-1}$ with ranges of at19435.93 to 12765.88 $mg.L^{-1}$ was obtained. The average TS value for the sample after the anaerobic filter was 3692.37 $mg.L^{-1,}$ with maximum and minimum changing from 4665.45 to 2507.66 $mg.L^{-1}$. After complete treatment, the final effluent sample showed an average TS value of 379.27 $mg.L^{-1}$ with ranges within 430 to 323.75 $mg.L^{-1}$. There is a considerable decrease in Total coliforms after the septic tank and anaerobic filter as well as after wetland treatment with average values at 1852.8 $CFU.100\ mL^{-1}$ for raw wastewater with ranges from 2850 to 1230 $CFU.100\ mL^{-1}$, 805.5 $CFU.100\ mL^{-1}$ for sample after anaerobic filter varying from 960 to 700 $CFU.100\ mL^{-1}$ and 51.909 $CFU.100\ mL^{-1}$ for the sample collected after complete treatment in VFCW with maximum value 75 $CFU.100\ mL^{-1}$ to a minimum of 37 $CFU.100\ mL^{-1}$. Reduction of total coliforms happening in the septic tank due to the help of the bacteria present that will decompose the organic matter current once the organic matter gets settled (Holt 2011).

## CONCLUSIONS

Based on the results obtained by the physicochemical analysis of parameters at different stages of the treatment system, it can be concluded that the introduction of another on-site wastewater treatment system, such as a VFCW between the septic tank and soak pit, showed better treatment of the septic tank effluent. The final effluent obtained after VFCW met the standards set by CPCB (Central Pollution Control Board 2008). The removal efficiency of parameters COD, BOD, $NO_3^-$, $PO_4^{3-}$, pH, TSS, and TC after wetland was found to be 89.469%, 88.051%, 63.484%, 44.378%, 3.419%, 98.475%, 97.714%, 97.198% respectively. We can infer from the values obtained for removal efficiency that the treatment is positive and satisfactory. The final effluent values were 55.727 $mg.L^{-1}$ for COD, 12.126 $mg.L^{-1}$ for BOD, 10.2 $mg.L^{-1}$ for $NO_3^-$, 3.745 $mg.L^{-1}$ for $PO_4^{3-}$, 7.41 for pH, 8.373 $mg.L^{-1}$ for TSS, 379.27 $mg.L^{-1}$ for TS and 51.909 $CFU.100\ mL^{-1}$ for TC. The final effluent values being around the Effluent Discharge standards by CPCB, our study was able to show that the effluent after wetland treatment in the system was safe enough to be circulated for reuse or to be sent to a soak pit after disinfection. The aim of the case study was thus achieved by introducing an alternate treatment system like VFCW between a septic tank and a soak pit. VFCW being less expensive and requiring less maintenance, it is a better and cheap alternate treatment addition to the conventional septic tank–soak pit system used in India and does not require any skill for maintenance.

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