VERMIFILTRATION: AN EFFICIENT METHOD OF WASTEWATER TREATMENT

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Abstract—Vermifiltration is a well-known biotechnological aerobic process of treatment of wastewater which is carried out with the use of epigenic earthworms as a means of treating wastewater and it has been increasingly regarded as an environmental friendly wastewater treatment technique. In the present work, treatment of domestic wastewater was performed using the species of Eisenia fetida earthworm to achieve the requisite quality of the effluent. The study included evaluation of performance efficiencies of vermicomposting system based on various parameters like pH, temperature, EC, DO, salinity, BOD, COD, phosphate, sulphate, nitrate and also the pathogen removal efficiencies for total coliform and faecal coliform. The study of five month study revealed that the presence of earthworm in the vermicompost bed can efficiently remove BOD and COD by 83.51% and 83.33% respectively. About 90-99% pathogen removal efficiency was observed for total coliform and faecal coliform which shows that vermicompost water can be reused for non-potable purposes like irrigation, gardening, industrial etc.

Keywords—Vermifiltration, wastewater, BOD, COD, pathogens, total coliform, faecal coliform

I. INTRODUCTION

Nowadays scarcity of water is one of the major issues of the present world due to growing demands of water. It has been reported that about 80% of the water supply used by the society returns as domestic wastewater in the sewer system. In most cases, huge amount of diverse nature of effluents released from varied industries are disposed in open environment causing pollution of soil and water resources. Individual wastewater treatment through physical, chemical or biological method is often very costly and results in a large amount of sludge. Thus there is a need to look for an alternative treatment processes.

Efforts are ongoing in order to develop new sustainable, low cost technologies for the treatment of wastewater. Various technologies for wastewater treatments have been extensively investigated. Many onsite treatment technologies such as the septic tanks, aerobic biological treatment units, fixed activated sludge treatments, constructed wetlands, soil infiltration trenches, vegetation based wastewater treatment, bioremediation through plants etc. are functioning and effective in removing the pollutants. Even though most of the wastewater treatment plants are designed efficiently to remove organic pollutants and nutrients but rarely have designed specifically to remove pathogenic microorganisms from wastewater. However, these technologies are restricted to use because at times these are prone to failure due to high capital, operational and maintenance costs that are not affordable for developing countries and needs large capital investments. The operational and maintenance problems in wastewater treatment may be due to mechanical failures or system failures from inappropriate design. Biological inhibition is a common type of failure.

Therefore an alternative onsite wastewater treatment process is needed to seek that is economically affordable, environmentally sustainable and socially acceptable. Wastewater recycling is an attractive option. Wastewater treatment can be tailored to meet the water quality requirements for a planned reuse which includes the treatment of wastewater in an environmentally sound manner and economical effective manner. The reuse of wastewater for non-portable water application is a potential solution for water deprived regions of the world.
Even though numerous solutions were adopted for the treatment of wastewater but among all the technologies it has been found that vermifiltration is more effective and a newly confined novel technology. Vermifiltration is a low cost, odourless and non-laborious intensive method of wastewater treatment and do not occupy large area for the treatment facility to set up.

II. RELATED WORKS

According to earlier reports, vermifiltration technology have been extensively studied due to its effectiveness in removing pollutants from wastewater and its positive effects on the environment (Natarajan et al., 2015). Vermifiltration is a relatively new technology which can process organically polluted wastewater using earthworms. In this technology the microbes play an important role in vermifiltration system and they also provide some extracellular enzymes to facilitate the earthworm for rapid degradation of organic substances in vermifilter bed (Tomar and Suthar, 2011).

With its increasing removal efficiency in treatment of wastewater, vermifiltration is also finding application in treatment of dairy industry liquid wastes. Dairy industry generates large amount of white turbid liquid waste products which contain high organic matter which cannot be processed further in the industry and hence has to be discarded (Sinha et al., 2006).

In a study by Arora and Kazmi (2015), they explored the effects of seasonal temperature on the treatment efficiency and pathogen removal efficiency. Higher BOD & COD removal was reported to accomplish during summer and autumn period with mean temperature of 25-27˚C.

In another study by Arora et al., 2016 (a), they investigated the performance of the reactor and pathogen removal efficiency during wastewater treatment by vermifiltration. Vermifiltration showed a greater potential for chemical pollutants and pathogen removal from wastewater. Higher percentage of BOD, COD, TSS, FC, FS, Salmonella and Escherichia coli removal was observed to the accepted level for reuse in irrigation purpose.

III. MECHANISM INVOLVED

Earthworms act as an aerator, grinder, crusher, chemical degrader and a biological stimulator and degrade waste by multiple actions. Vermifiltration is a natural engineered system in which the wastewater is treated by using the potential of earthworms which are capable of degrading the organic fraction of waste present in wastewater. Usually this technology is a modified version of the traditional method of water treatment which finds application in improvement of water quality in bore wells in ancient times. The conventional wastewater treatment can be achieved by three stages primary, secondary and tertiary. In comparison with the conventional treatment system, vermifiltration technology serves as a better alternative as it operates in a single process instead of using three different units in vermifilter and due to its cost effectiveness, vermifiltration technology is an eco-friendly and sustainable technology. Also during vermifiltration, there is no sludge formation and it is an odour-free process and the resulting vermifiltered water was clean enough to be reused for farm irrigation and gardens. Hence vermifiltration is overall a very advantageous technology in comparison to the other conventional technologies.

It is a technology to treat wastewater by the great waste manager-the earthworm’s species. Earthworms are known as versatile waste eater and decomposers. Their body works as a biofilter which widens the metabolism by increasing their population. There is a symbiotic and synergistic effect between the earthworms and microorganisms which play a crucial role in wastewater treatment. There are millions of microorganisms that are present inside the earthworm which helps in biochemical degradation of organic matter present in wastewater. Earthworms degrade and homogenise the organic waste through muscular actions of their foregut and add mucus to the ingested material and make it available for microbial diversity present inside. Inside the gut they show their enzymatic activity in order to degrade the organic waste. These microbial activities will be stimulated and accelerated by earthworms through developed aeration and also by improving the soil microbe population (Sinha et al., 2008). The vermifilter media provide a high specific area for the earthworms to process and stabilise the dissolved, inorganics and suspended solids trapped on the
top of vermifilter through complex biodegradation process and is fed to the small microbes that are immobilised on vermifilter bed material. This enables the soil stabilization and filtration system to become effective.

IV. METHODOLOGY

Wastewater contains large fractions of organic as well as inorganic components which must be treated before it is dispose of in order to protect the environment as well as health of living organisms. Keeping this concern in mind, a wastewater treatment plant was setup at the institute campus. A large storage tank of 500 L capacity was installed which finds its way to overhead tank of 300 L capacity with continuous agitation. The wastewater gets collected and stored first in the 500 L capacity large storage tank. Then it is pumped in to overhead tank of 300 L tank, where a continuous agitation was provided for proper mixing of wastewater which avoids the settling of organic waste at the bottom of the tank.

Figure 1: Vermifilter plant at the campus of Dr. B. Lal Institute of Biotechnology, Jaipur

The treatment of the wastewater was accomplished with the different layers in the vermifilter reactor. The vermifilter bed comprises of 5 layers (total depth-100cm) of packed filter media of different sizes of gravels and vermicompost layer. At the top, an empty space of 10 cm is provided for aeration. Also at bottom, an empty space of 10 cm is provided for collection of the effluent samples. The first layer comprises of mature vermigratings (earthworm & vermicompost) of 30 cm depth in which the earthworm species of *Eisenia fetida* were inoculated with stocking density of 10,000 worms/m$^2$. The second layer comprises of 2-4 mm fine gravel size with 15 cm depth followed by third layer of 6-8 mm medium gravel size with 15cm depth. The fourth layer comprises of large gravel with 20 cm depth. The wastewater was collected from the institution campus itself. The wastewater was introduced in to the vermifilter system through perforated PVC pipes of 1.5 mm diameter with hydraulic loading rate of 1m$^3$/m$^3$/day.

The experiments were performed during the month of March 2017 through June 2017. Initially, 15 days were considered as acclimatization period for earthworms to adjust to the new surrounding environment. The starting of the vermifiltration process was initiated by seeding wastewater in batch mode for 3 hrs/day and later after acclimation and configuration the hydraulic retention time was found to be 8 hrs/day at room temperature. After the designing and construction of the vermifilter, the performance efficiency of vermifilter was evaluated for treatment of domestic wastewater. Grab sampling technique was adopted throughout the research study continuously. The sampling was done once in a week. The samples were taken directly for analysis of physico-chemical parameters. Later microbiological work was also carried out as soon as possible within 24 hrs. The samples were stored in refrigeration at 4$^\circ$C to avoid any changes in its properties during the
experiment. The concentration of BOD, COD, TDS, EC, DO, pH, temperature, Salinity, Phosphate, Sulphate, Nitrates in the wastewater before and after were determined.

V. RESULTS AND DISCUSSION

For the evaluation of performance efficiency for domestic wastewater, important physico-chemical parameters were performed and analyzed. Table 1 shows the variations in pH, temperature, electrical conductivity and total dissolved solids for domestic wastewater during the treatment.

Table 1: Variations in pH, Temperature, EC & TDS in domestic wastewater treatment

| Days | pH Influent | pH Effluent | Temperature (°C) Influent | Temperature (°C) Effluent | Electrical Conductivity (µs/cm) Influent | Electrical Conductivity (µs/cm) Effluent | Total Dissolved Solids (mg/l) Influent | Total Dissolved Solids (mg/l) Effluent |
|------|-------------|-------------|---------------------------|---------------------------|----------------------------------------|----------------------------------------|---------------------------------------|---------------------------------------|
| 1    | 8.08        | 7.08        | 24.8                      | 24.7                      | 2469                                   | 2522                                   | 1232                                  | 1248.5                                |
| 7    | 7.76        | 7.8         | 24.8                      | 25.3                      | 2446                                   | 2587                                   | 1220                                  | 1292                                  |
| 14   | 7.62        | 7.52        | 24.5                      | 24.4                      | 3110                                   | 2440                                   | 1550                                  | 1216                                  |
| 21   | 7.2         | 6.6         | 23.1                      | 24.2                      | 3170                                   | 2563                                   | 1850                                  | 1453                                  |
| 28   | 7.77        | 6.71        | 32.3                      | 34.2                      | 2967                                   | 2150                                   | 1478                                  | 1072                                  |
| 35   | 6.45        | 7.07        | 31.5                      | 31.5                      | 2694                                   | 2925                                   | 1344                                  | 1462                                  |
| 42   | 7.79        | 7.1         | 33.4                      | 33                        | 2844                                   | 2574                                   | 1421                                  | 1287                                  |
| 49   | 7.94        | 7.3         | 31.6                      | 31.4                      | 2764                                   | 2617                                   | 1382                                  | 1308                                  |
| 56   | 8.13        | 7.2         | 32                        | 31.8                      | 2539                                   | 2422                                   | 1269                                  | 1211                                  |
| 63   | 8.13        | 7.14        | 31.3                      | 31.1                      | 2463                                   | 1550                                   | 1231                                  | 775                                   |
| 70   | 8.13        | 7.14        | 31.3                      | 31.1                      | 2463                                   | 1550                                   | 1231                                  | 775                                   |
| Average | 7.7        | 7.2         | 29.1                      | 29.3                      | 2720.8                                 | 2354.5                                 | 1382.5                                | 1190.9                                |
| SD   | 0.5         | 0.3         | 3.9                       | 3.8                       | 271.4                                  | 437.8                                  | 191.5                                 | 232.3                                 |

The average pH of the influent and effluent was found as 7.7 ± 0.5 and 7.2 ± 0.3 which shows that the pH of the influent and effluent remains almost same throughout the study period. Similarly a slight increase in pH was observed in the effluent which signifies earthworms act as a buffering agent and neutralize the pH. Throughout the study period, the average temperature of the domestic wastewater influent and effluent of the vermifilter was found as 29.1 ± 3.9 and 29.3 ± 3.8 respectively. There was minimal difference in the temperature as shown in graph 2. However a sudden reduction in effluent temperature was observed in between the 35-42 days which is due to the change in climate. The average EC value for the influent and effluent was found as 2720.8 ± 271.4 µs/cm and 2354.5 ± 437.8 µs/cm as shown in graph 3. An average decrease in EC was observed. During the domestic wastewater treatment the influent average TDS was observed as 1382.5 ± 191.5 ppm which decrease slightly in the effluent as 1190.9 ± 232.3 ppm as shown in graph 4.

Graph 1: Variation in pH

Graph 2: Variation in Temperature
Graph 3: Variation in Electrical Conductivity

Graph 4: Variation in Total Dissolved Solids

Table 2: Variations in DO, BOD, COD and nitrate in domestic wastewater treatment

| Days | Dissolved Oxygen (mg/l) | BOD (mg/l) | COD (mg/l) | Nitrate (mg/l) |
|------|------------------------|------------|------------|----------------|
|      | Influent | Effluent | Influent | Effluent | Influent | Effluent | Influent | Effluent |
| 1    | 1.57     | 2.34     | 187      | 89       | 1664    | 330.7    | 3.0      | 6.6      |
| 7    | 2.83     | 1.92     | 199      | 76       | 504     | 257.3    | 10       | 12.1     |
| 14   | 3.396    | 3.65     | 260      | 57       | 794     | 247.3    | 20       | 19.1     |
| 21   | 1.15     | 1.96     | 250      | 75       | 564     | 117.3    | 11.8     | 19.1     |
| 28   | 0.14     | 2.19     | 300      | 36       | 587.3   | 87.3     | 19.1     | 19.1     |
| 35   | 1.33     | 1.8      | 360      | 33       | 264     | 44       | 17.8     | 12.3     |
| 42   | 0.58     | 2.15     | 200      | 32       | 634     | 47.3     | 19.1     | 19.1     |
| 49   | 0.1      | 2.92     | 189      | 30       | 530.7   | 60.7     | 16.4     | 19.1     |
| 56   | 0.49     | 2.72     | 265      | 28       | 377.3   | 64       | 5.7      | 19        |
| 63   | 0.47     | 2.02     | 189      | 27       | 224     | 97.3     | 7.2      | 19        |
| 70   | 0.47     | 2.02     | 155      | 29       | 224     | 50.7     | 7.2      | 19        |
| Average | 1.14   | 2.34     | 237      | 31       | 425.7   | 71.1     | 12.5     | 16.7     |
| SD   | 1.09     | 0.55     | 74       | 3        | 173.0   | 27.0     | 6.2      | 4.3       |

The average dissolved oxygen concentration in influent was observed as $1.14 \pm 1.09$ mg/L which increase slightly in effluent as $2.34 \pm 0.55$ mg/L as shown in graph 5. Lower DO in effluent indicate that the wastewater is not fit to dispose in the nearby water sources and also unfit for irrigation purpose.
The average biochemical oxygen demand (BOD) of influent and effluent was found as 237 ± 74 mg/L and 31 ± 3. BOD removal efficiency of vermifilter was found as 86.91 % considering few initial days of acclimation period as shown in graph 6. Similarly the concentration of COD decline from 425.7 ± 173 mg/L in influent to 71.1 ± 27 mg/L in effluent which shows that about 83.29 % get reduced by the activity of earthworms as shown in graph 7. This result indicates that microbes play an important role in enhancing the biodegradation through their burrowing action. The average concentration of nitrate in the influent and effluent was found to be increasing as 12.5 ± 6.2 mg/L and 16.7 ± 4.3 mg/L as shown in graph 8 which shows ability of earthworm to synthesize nitrate from wastewater.

Pathogen removal efficiency

The pathogen removal performance of vermifiltration for domestic wastewater treatment is given in Table 3. The average value of Total Coliform and Faecal Coliform in the influent was 4.7 ± 0.7 MPN/100 mL and 3.6 ± 0.2 MPN/100 mL. The concentration of TC and FC decreased up to 2.5 ± 0.9 MPN/100 mL and 1.1 ± 0.1 in the effluent. Therefore the results show that 99 % of TC and FC was removed respectively during treatment of domestic wastewater treatment. The possible reason for the pathogen removal may be due to antimicrobial activity of the microorganisms against other pathogens. Also Sinha et al., (2008) reported that the earthworm release coelomic fluid from its body cavity, having antibacterial properties which may inhibits the growth of other pathogens.

Table 3: Pathogen Removal

| Parameters | Influent (average ± sd) | Effluent (average ± sd) | Log removal |
|------------|-------------------------|-------------------------|-------------|
| TC (log)   | 4.7 ± 0.7               | 2.5 ± 0.9               | 2.2         |
| FC (log)   | 3.6 ± 0.2               | 1.1 ± 0.1               | 2.5         |

VI. CONCLUSION

Vermifiltration technology can be used as a cost effective and sustainable technology over the conventional technology since it is effective and extensively used technology with efficiency, economy and convenience for decentralization. This technology also led to an odour free process for the successful treatment of any type of wastewater as the system is fully aerated with plenty of oxygen available for aerobic decomposer microbes by the borrowing action of earthworms.
It has been observed that in treatment of domestic wastewater, effluent efficiency of removal of BOD, COD were 86.91 % and 83.29 % respectively. So it can be concluded that the vermifiltration system is more efficient in treating the domestic as well as clinical wastewater in our study. Also vermifiltration of wastewater should be started with higher numbers of earthworms, atlest 15,000- 20,000 worms per m³ of soil to attain good results.

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