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EFFICIENCY OF VERMIFILTRATION TECHNOLOGY (VFT) IN GREY WASTEWATER BIOREMEDIATION WITH RESPECT TO CHANGE IN SOIL BEDDING MATERIAL PROPERTIES

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ABSTRACT

The present study was carried out to check the efficiency of vermifiltration technology (VFT) in grey water treatment collected from the nearby hostel of Sambalpur University and its effect on the bedding material properties of the vermibed. The study was carried out for 30 days analysing the physico-chemical properties of grey water and bedding material before and after the experiment. The result showed a significant reduction in pH, EC, TDS, TSS, BOD and COD of waste water by 16.88 %, 72.22%, 91.41%, 77.50%, 89.55%, and 76.13% respectively by the 30th day of the experiment concerning duration and retention time of the wastewater in TVB. The filtered effluent was clear and odour free as compared to sample water. The bedding material properties show significant increase in pH by 8.22%, EC by 26.05%, available phosphorous by 58.30% and potash content by 60.33% by the 30th day of study whereas significant decrease in OC content by 18.95% in TVB. Additionally, the process was odour free and sludge free.

INTRODUCTION

The amount of people currently living under water stress is 700 million and it is projected to be 3 billion people in 2035 (World Bank, 2005). The ever-increasing demand leads to water scarcity even in places that were traditionally conceived as water ample region such as Europe and Japan. Hence, people need to start using water consciously without wastage; new and alternative methods of production of water needed to be developed. A promising way of alternative water production is reuse of waste water. As per study, the domestic in-house specific water demand in industrialised countries approximates 100-150 l/c/d (litre/*capita*/day), of which 60-70% is turned into grey water (Friedler, 2004). Grey water is a type of domestic waste water without any input from toilets (Eriksson et al., 2002). The quality of grey wastewater depends on three key point, quality of the water supply, type of distribution network for both drinking water and the grey water, and the activities in the household (Errikson *et al.*, 2002). Grey water can be reused for toilet flushing which can reduce the in-house net water consumption by 10-20% of the urban water consumption. Additionally, it can be used for gardening and irrigation (Friedler, 2004). The World Health Organization's (WHO) Guidelines for Safe Use of Wastewater, Excreta and Grey water emphasize the importance of grey water as an alternative water resource due to its stillness, largest volume of production from households, nutrient content that, although low, can be beneficially used for crop irrigation, low pathogen content and it can reduce the demand for first use water (WHO, 2006). Therefore, treatment is required (Eriksson *et al*., 2002) and the treatment level depends on the reuse options (Pidou *et al*., 2007) of the waste water.

Wastewater treatment is the removal of contaminants from any form of wastewater. It includes physical, chemical and biological processes. A desired method for this purpose is the one that performs well, easy to manage and cost effective (Wang et al., 2013). Among the wide range of available technologies, vermifiltration represents the most efficient technology (Kumar *et al*., 2014). It is a combination of traditional vermicomposting an filtration process, which adopts the modern concept of ecological design and extends the existing chain of microbial metabolism by introducing earthworms (Yang et al., 2013; Arora *et al*., 2014) and their ecological functions to improve soil permeability and promote organic matter (OM) decomposition (Wang *et al*., 2013). Vermifiltration technology has been conducted on the small to pilot scale level studies which shows a high efficiency for domestic wastewater and industrial wastewater with high removal rates of chemical oxygen demand (COD), biochemical oxygen demand (BOD) and suspended solid (SS), as well as the ability to reduce nitrogen and phosphorus (Sinha et al. 2008). Hence, the present study was undertaken to study the efficacy of the vermifiltration technique in bioremediation of grey water and its effect on bedding material properties.

MATERIALS AND METHODS

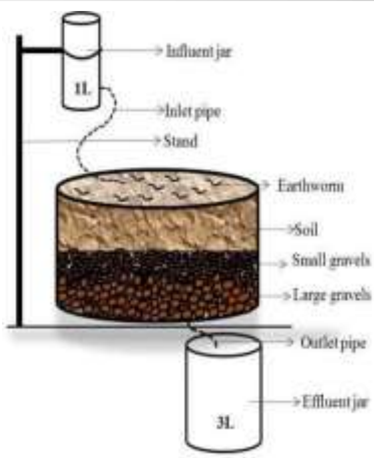

Figure 1 Laboratory design of VFT kit.

The experiment was carried out in ecology laboratory of School of Life Science, Sambalpur University. Waste water sample was collected in 10 jars each of 5L capacity from a drain in the vicinity of Indravati Ladies Hostel of Sambalpur University (21.28⁰ N and 83.52⁰ E in Burla town of Sambalpur district). Two local species of earthworm were collected, namely *Perionix excavatus* and *Lampito mauritii* from the University campus by hand sorting and digging method (Anderson and Ingram). For bedding material, soil sample was collected from a bare land of nearby village of university which is located at 20.47⁰ North 85.89⁰ East in the Burla town. Vermibeds were prepared following Patnaik and Bidkar, 2017, ten plastic tubs each of 25 Litre capacities were taken to prepare vermifiltration beds. The beds were prepared using soil on the top layer, sand on the middle layer and gravels on the bottom layer. 25% of moisture was added to the bed using the collected water sample and kept undisturbed for 5 days. 1L jars were prepared as influent tank for the daily input of wastewater to the prepared bed. Beds were pierced at bottom and joined with pipe which flows to a 3L jar in the bottom meant for effluent collection (Fig. 01). After 5days, mix cultures of earthworms were inoculated in five beds, named as treatment vermibed (TVB1, TVB2, TVB3, TVB4, TVB5). The remaining five beds were kept as control beds (CB1, CB2, CB3, CB4, CB5), without earthworm inoculation. 500ml of influent was allowed into the vermibeds on daily basis. The effluents were collected from the effluent jar in sterile plastic bottles of 1L capacity in 10 days interval for 30 days and analysed within 24hr following Standard method for examination of water and wastewater (APHA, 2005). The bedding material soil with cast was collected after the completion of experiment and processed for further analysis.

The data and results were processed and analysed using Microsoft Excel 2010. To analyse the differences, one-way analysis of variance (ANOVA) for grey water was performed for each parameter with a p-value of <0.05 and chi-square test was used to study the change in bedding material with p-value of <0.05.

RESULT AND DISCUSSION

The influent was cloudy and pale white in colour. Towards the end of experiment, the TVB effluent changed to clear form whereas the CB effluent still has slight pale white colouration. It may be because of reduction in amount of dissolved solids and suspended solids in TVB effluent due to earthworms action, which helped in digestion of organic and inorganic matter in the grey water that lead to production of clear effluent as it percolates through different layer of vermibed with certain HRT (Hydraulic Retention Time). The influent odour was unpleasant which turned to an odour free effluent towards the end of the study in both TVB and CB. The change in odour was may be due to earthworm action, as they arrest all odours by killing anaerobes and pathogen that create the foul odour (Sinha *et al*., 2008), whereas the odour vanished in CB due to filtration of grey water through different layer of the vermibed.

The influent was alkaline in nature with a mean pH 8.65. In both TVB and CB, effluent pH has reduced by the 10th, 20th and 30th day of study reaching out to the neutral range of 7.19 and 7.41 in TVB and CB (Table 01, Fig. 02) which satisfies the water quality guidelines for irrigation water in India (CPCB, 2024) . Although the average pH reduction was significant in both beds, it is more efficient in TVB (14.18%) in comparison to CB (11.60%) by the end of the study. This is due to presence of earthworms and their inherent ability to act as a buffer and help in neutralizing pH in TVB (Arora et al, 2014).

The total salt concentration of water is expressed as EC. The mean EC of influent was 1.26 mho/ cm. In both TVB and CB, EC has significantly decreased by the 10th, 20th and 30th day of study (Table 01, Fig. 03). The conductivity of ions depends on the concentration of ions, their nutrient status, and the variation in the dissolved solids content. The reduction in EC was may be due to decrease in ion concentration and dissolved solids content in the effluent because of earthworm action. The average reduction in EC was higher in TVB (47.84%) than CB (35.80%).

Table 1Change in physico-chemical properties of water sample during the study period.

Parameters	Time in days						
	Influent	10th day effluent		20th day effluent		30th day effluent	
		CB	TVB	CB	TVB	CB	TVB
pH	8.65±0.07	7.95±0.07 (8.09)	7.70±0.14 (10.98)	7.58±0.03 (12.37)	7.38±0.03 (14.68)	7.41±0.01 (14.34)	7.19±0.01 (16.88)
EC (mho/cm)	1.26±0.01	1.13±0.02 (10.32)	0.95±0.01 (24.60)	0.84±0.03 (33.33)	0.66±0.03 (47.62)	0.46±0.02 (63.49)	0.35±0.06 (72.22)
TDS in ppm	3.26±0.37	2.40±0.14 (26.38)	2.05±0.07 (37.12)	1.89±0.08 (42.02)	1.19±0.02 (63.50)	1.22±0.03 (62.58)	0.28±0.04 (91.41)
TSS in ppm	10±0	8.5±0.71 (15.00)	6.5±0.7 (35.00)	4.9±1.27 (51.00)	3.25±0.35 (67.50)	0.75±0.07 (92.50)	0.25±0.07 (97.50)
BOD ppm	36.93±0.25	24.78±1.39 (32.89)	21.35±1.48 (42.18)	20.79±0.69 (43.70)	14.67±1.44 (60.28)	14.96±1.61 (59.49)	3.86±0.87 (89.55)
COD ppm	79.6±1.69	72.4±1.7 (9.05)	64±3.39 (19.60)	62.44±1.19 (21.56)	46.96±0.34 (41.01)	50.8±1.70 (36.18)	19±2.55 (76.13)

Note: Mean ± Standard Deviation, (X): % reduction in CB and TVB in respective days over 0 day.

Total Suspended Solids (TSS) and Total dissolved solid (TDS) are water quality parameter used to assess the quality of wastewater. They are listed as conventional pollutants in the U.S. Clean Water Act (APHA, 2005). The mean TSS of influent was 10 ppm. The TSS in TVB and CB has significantly reduced by the 10th, 20th and 30th day of study (Table 01, Fig. 05). This is probably due to percolation and retention of influent through different layer of CB and TVB where the suspended solids are trapped. However, the average reduction was comparatively higher and efficient in TVB (97.50%) than in CB (92.50%); which was due to presence of earthworm which enhanced the filtration process by ingesting of organic and inorganic solid particles in wastewater and excretes them as finer particles (Kumar *et al*.,2014). Total dissolved solid (TDS) acts as a pollution indicator in water. The mean TDS of the influent was 3.26 ppm which greatly reduced in both TVB and CB effluent by the 10th, 20th and 30th day of study period (Table 01, Fig. 04). The average reduction in TVB (91.41%) is higher than CB (62.58%). This is primarily due to the retention of dissolved solids in different layers of the bed during percolation. Secondarily, the earthworm acted as the major factor for enhanced and efficient reduction in TVB than CB. The reduction in TDS was significant in both TVB and CB.

The mean BOD concentration of influent was 11.07 ppm, which significantly decreased in the TVB and CB effluent by the 10th, 20th and 30th day of study period (Table 01, Fig. 06). The average reduction in TVB (64%) was higher than CB (45.36%). This was due to presence of earthworm in TVB as they significantly degraded the wastewater organics by enzymatic action whereby the earthworms worked as a biological catalyst resulting in a faster biochemical reaction, hence higher BOD removal (Manyuchi *et al.,* 2013). Kumar *et al.,* (2014) reported that BOD removal in vermifilter is attributed to the activity of earthworm and its associated microorganism that degrades the wastewater organics by its enzymatic activity. The reduction in BOD of effluent in both TVB and CB was significant. Water with a higher concentration of COD indicates high pollution. In present study, the mean COD content of influent was 80.78ppm. During the study period, a significant reduction in COD level was observed by the 10th, 20th and 30th day of treatment in TVB and CB effluent (Table 01, Fig. 07). The average COD removal in TVB (45.58%) was more efficient than CB (22.26%). Manyuchi *et al.,* 2013 and Natarajan et al., 2014 also found the same result where the average COD removal from the sewage wastewater by earthworm in the vermifilter was higher while that without earthworm. The reduction in COD of effluent in both TVB and CB was significant.

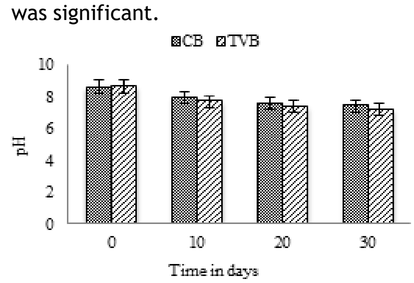

Fig. 02 Change in pH of grey water.

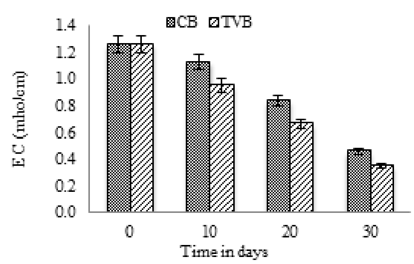

Fig. 03 Change in EC of grey water.

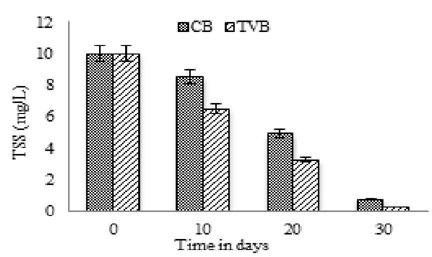

Fig. 04 Change in TSS of grey water.

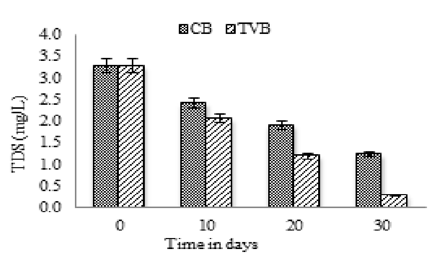

Fig. 05 Change in TDS of grey water.

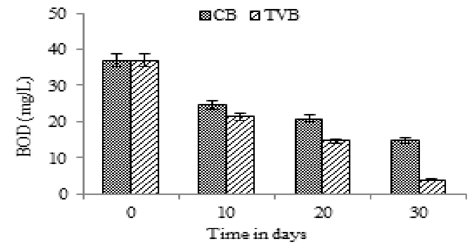

Fig. 06 Change in BOD of grey water.

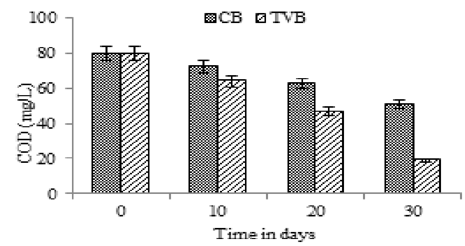

Fig. 06 Change in COD of grey water.

Effect on bedding material properties

Physical changes such as change in soil texture and water filtration capacity were observed during the study period in TVB whereas no change was observed in bedding material of CB. Small and continuous grain like castings was observed in TVB after 4 to 5 days of study. There was significant change in soil texture and water filtration capacity of the TVB soil that of the initial day. The bedding material became more porous, aerated and light. These changes are due to the action of earthworms as influence the supply of nutrients through their tissues but largely through their burrowing activities; they produce aggregates and pores (i.e., biostructures) in the soil and/or on the soil surface, thus affecting its physical properties (Bhadauria and Saxena, 2010). They hosts millions of decomposer microbes in their gut and excrete then in soil along with nutrients in their excreta known as "vermicast" (Sinha et al., 2007). Adhikary, S., 2012 in his review reported that the end product soil has excellent structure, porosity, and aeration and water retention capabilities; castings can hold 2 - 3 times more water than their weight in soil.

The soil sample was slightly acidic in nature with a mean pH of 6.16. A significant increase in mean soil pH was observed to 6.49 (5.09%) and 6.71(8.22%) in CB and TVB respectively (Table 02) due to influence of VFT. This is possibly because of decreased TDS of grey water leading to increased amount of mobile ions in the soil due to mixing of removed ions from of grey wastewater effluent to the soil. Vermicomposting acts as a buffer to maintain the pH of soil (Singh *et al.,* 2014). The sample soil has a mean EC of 0.256mho/cm which significantly increased to 0.31mho/cm (13.59%) and 0.36mho/cm (26.05%) in CB and TVB respectively (Table 02). This may be due release of different mineral salts in available forms during vermifiltation (Garg *et al.,* 2006) which was up taken by soil microorganisms available in vermibed soil. Jayakumar *et al.,* 2009 reported that the electrical conductivity has shown significant increase in the vermicasts over the worm un-worked composts. This shows that during vermicomposting process, the soluble salt level increases due to the mineralization activity of earthworms and microorganisms in the organic substance and as well in the gut of earthworms. High salt concentration may cause phytotoxicity problems and therefore EC is a good indicator of the suitability and safety of a cast for agricultural purposes (Villar *et al., 1993).* The sample soil has a mean OC (organic carbon) content of 0.14 gm%. Reduction was observed in OC content by 46.25% (0.09 gm%) and 18.95% (0.12 gm%) in CB and TVB respectively by the end of study (Table 02). The change in soil OC was significant from sample soil to vermicast and final soil. This may be due to mineralization of organic matter during decomposition (Singh *et al.,* 2014). The potash content of soil sample was
154.52 Kg/Ha. Under the influence of VFT, the soil showed a significant increase in the K content of soil by 44.29% and 60.33% in CB and VB respectively. The potassium level in CB and VB has changed to 277.36 Kg/Ha and 389.55 Kg/Ha in CB and TVB respectively (Table 02). The increase in K may be due to addition of mineralized organic matter from effluent to soil as it percolates through layer of soil; increase in K content was more efficient in VB than CB which was due to additional action of earthworms in VB (Singh *et al.,* 2014).

Table 2 Change in bedding material physico-chemical property.

Physico-chemical parameters	Soil (0th day)	Soil in CB (30th day)	Soil in TVB (30th day)
pH	6.16 ± 0.02	6.49 ± 0.07 (5.09%)	6.71 ± 0.09 (8.22%)
EC (mho/cm)	0.27±0.019	0.31± 0.026 (13.59%)	0.36± 0.032 (26.05%)
OC (gm %)	0.14 ± 0.01	0.09 ± 0.01 (46.25%)	0.12 ± 0.01 (18.95%)
Potash (Kg/H)	154.52±4.79	277.36± 5.97 (44.29%)	389.55±8.60 (60.33%)

CONCLUSION

Water scarcity is a bigger problem the world is going to face in near future. In general, normal household releases wastewater abundantly in the form of domestic grey wastewater. It is a potential alternative water resource as discussed by World Health Organisation. The present study focused on checking efficiency of VFT for treatment of grey water and its effect on bedding material property. Various water quality parameters were analysed such as pH, electrical conductivity, TSS, TDS, BOD, COD of the sample water and the final filtered water. The study results show a significant reduction of all the parameters in the filtered water concerning the duration of retention time of grey wastewater in TVB and CB. The removal of waste was more efficient in the vermifiltered water from TVB in comparison to CB. At the end of the study there was no foul smell from the effluent, the dissolved and suspended solids were well minimized and there was no sludge formation. This indicates that VFT is an efficient method for treatment of waste water. It shows better performance and results than any conventional method of wastewater treatment. Additionally, the result showed a positive effect of VFT on the bedding material by improving the soil quality both physically and nutritionally. The reduction in organic matter was may be due to mineralization. Hence, it can also be used to vermin-remediate and preserve wastelands. Thus, VFT can be an eco-friendly, cost- effective and sustainable technology for treatment of wastewater and remediation of land in future.

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