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Feasibility Study of Vermi-filtration for the Treatment of Dairy Wastewater

Divya Shree K M¹, M Mahadevaswamy²

P.G.Student, Department of Environmental Engineering, S. J. College of Engineering, JSS Technical Institution
Campus, Manasagangothri, Mysuru, Karnataka, India¹

Professor, Department of Environmental Engineering, S. J. College of Engineering, JSS Technical Institution Campus,
Manasagangothri, Mysuru, Karnataka, India²

ABSTRACT: The wastewater generated in dairy industry contains very high organic loading and total solids and is mostly treated in ETP (Effluent Treatment Plant), where the sludge is formed increasing the expenditure for processing and disposal along with the operation cost. Earthworms body act as a 'biofilter' and they were found to increase the removal efficiency of BOD₅ – 89.3 %, 86.5 %, 91.6 %, COD – 81.6 %, 80.3 %, 85.4 %, TS – 82.3 %, 73.9 %, 85.5 %, TDS – 85.6 %, 82.9 %, 87.1 % and OIL and GREASE content by 97.2 %, 97.2 %, 99 % for single earthworm species of reactor 1 and reactor 3 and mixed earthworm species for reactor 2 using black cotton soil for about 98 days and for varied bed depths using garden soil of 10 cm, 15 cm and 20 cm for mixed earthworm species of reactor 1, reactor 2 and reactor 3 for about 40 days were found to be of BOD₅ – 78.45 %, 68.35 %, 54.52 %, COD – 55.56 %, 46.42 %, 23.37 %, TS – 55.32 %, 42.02 %, 23.37 %, TDS – 60.67 %, 50.15 %, 25.38 % and OIL and GREASE – 29.9 %, 16.82 %, 9.34 %. The height of vermibed is considered as an important factor in vermi-filtration method. Earthworm treat the wastewater by the mechanism in the process include: 'feeding' and 'biodegradation'. Also increase the hydraulic conductivity and natural aeration by grinding the soil particle. In the present study three vermi-filters and one non-vermi - filter was designed. The effluent passed through top layer of the filter and found out the removal efficiency of physicochemical parameter. The suspended solids trapped on top of the vermi-filter and processed by earthworms. There is no sludge formation in this process which requires additional expenditure on landfill and disposal. The process is odour - free, ecofriendly and cost effective. The final vermi-filtered water was clean enough to be used for irrigation, in parks and garden.

KEYWORDS: Vermi-filtration(VF), Non-vermifiltration(NVF), Vermibed height, *Eisenia fetida*, *Eudrilus eugeniae*, Garden soil, Black cotton soil, Odor - free process.

I. INTRODUCTION

The wastewater generated in dairy industry contains high organic loading referred as BOD (Biological Oxygen Demand), COD (Chemical Oxygen Demand), and total solids that may be in dissolved or colloidal form. Dairy wastewater is highly turbid and is mostly treated by ASP. The wastewater treatment means the removal of the contaminants from any form of wastewater, includes physical, chemical and biological processes so that water can be reused. Typical process wastewater generated in dairy industry has BOD about 345 mg/L, COD - 1280 mg/L, TDS - 1500 mg/L, TS - 1963 mg/L and oil and grease concentration of 20 mg/L. Hence, the wastewater has to be treated to reduce the organic loads before discharging into the natural eco - system (rivers or oceans). Release of untreated dairy industrial wastewaters into the river leads to depletion of dissolved oxygen (DO). Conventional treatment techniques of wastewater are expensive, since they have large requirements of land and continuous supply of electricity, both of which can be premiums in developing nations across the world. Vermi-filtration is cost effective and odor free treatment for wastewater. Earthworm's body act as 'biofilter' and they have been found to remove the BOD₅ by over 90 %, COD by 80 – 90 %, total dissolved solid (TDS) by 90 – 92 %, and total solids (TS) by 90 – 95 % from wastewater by the general mechanism in the process include: 'ingestion' and biodegradation of organic waste [4].

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

Earthworms increase the hydraulic conductivity and natural aeration of the organic particle by granulating the organic particles into small particles [1]. Suspended solids were trapped on top of the vermifilter and were processed by earthworms and to soil microbes immobilized in the vermifilter. There is no sludge formation in the process as the worms consumes all the solids. This is also odor – free process. Worms also removes chemicals including heavy metal and pathogens from treated wastewater and the treated water becomes fit for non-potable purposes [5].

II. SCOPE OF THE WORK

Vermi-filtration method is an alternate wastewater treatment system, which is a low energy dependent and has distinct advantage overall the conventional biological wastewater treatment systems. Earthworms mineralize the nitrogen and phosphorus in sludge to make it bio-available to plants as nutrients. They also grind the silt and sand particles, thus giving high total specific surface area. Prevent choking of the medium and maintain a culture. Prior to my study one-layer of garden soil and black cotton soil and specific species have been used. But, in the present study two layers of black cotton soil has been used using single and mixed earthworms species (*Eudrilus euginae* and *Eisenia fetida*) and garden soil using mixed earthworms species for varied bed depths such as 10 cm, 15 cm and 20 cm respectively. To compare the efficiency of vermifiltration process, non – vermifiltration process has been adopted in this study. Investigation has been carried out by increasing the population of worms in order to achieve more efficiency in the values of BOD₃, COD, TDS, TS and OIL and GREASE. Top most layer of soil mixed with cow dung in 1:3 proportion were placed at the top of sand in which the earthworms are released.

III. MATERIALS AND METHODOLOGY

The dairy wastewater sample was collected from a KMF Dairy Industry, The Mysore – Chamarajanagar District Milk Union Limited (MYMUL), Siddarth Nagar, Mysuru, Karnataka. In this study, *Eisiena Fetida* and *Eudrilus eugeniae*, commonly known as Tiger worm and African Night Crawler earthworms species are used and was collected from Vishweshwaraiah canal farm (V.C. Farm) of Mandya in Karnataka.

4.1 Experimental setup of Vermi-filtration Using Single and Mixed Earthworm Species

The study was carried out using three different vermifiltration unit named as Rector 1, Reactor 2 and Reactor 3 having dimensions of 30 cm x 30 cm x 65 cm, 30 cm x 30 cm x 80 cm and 30 cm x 30 cm x 95 cm. The vermifiltration unit was filled with a layer of sand and gravel and a layers of black cotton soil sandwiched between the sand layer. Provision has been made to collect the filtered water at the bottom of the filtration unit. At top of the chamber a set of net wire mesh has been provided which allows only water to trickle down the reactor. The bottom most layer is made up of gravel aggregates of size 20 mm above which a layer of gravel of size 10 mm and top layer consists of gravel of size less than 10 mm was provided. Gravel layer was filled up - to a depth of 30 cm and on the top of gravel layer, sand layer of 10 cm depth was laid. Black cotton soil of depth 10 cm each which is sandwiched between a layers of sand in which earthworms are being released. Cow dung has been added to the vermifilter bed. In Reactor 1, *Eisenia fetida* earthworm species has been used, In Reactor 2, mixed earthworm species (*Eisenia fetida* and *Eudrilus eugenia*) has been used and in Reactor 3 *Eudrilus Eugenia* earthworm species has been used. The dairy wastewater passed through the pipe network by gravity to attain uniform distribution of wastewater on vermifiltration bed. Wastewater percolated down through different layers of bed and the final effluent was collected from the bottom of the filtration unit at an interval of 7 days. The schematic diagram of fabricated vermifiltration units with single and mixed vermicultures used is shown in Figure (a).

Raw wastewater storage tank was kept at an elevated platform just above the vermifiltration unit. The bottom of the storage tank was provided with 0.5 inch pipe with holes for trickling the wastewater uniformly over the entire soil surface in the reactor. Dairy wastewater flows through the vermifilter bed by gravity. The wastewater percolated down through various layers in the vermifiltration bed i.e., it flows through two layers of soil inhabited by earthworms, sandy

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

layer and the gravels. The water is collected at the bottom of the unit. This treated effluent from the vermifiltration unit was collected and analyzed for pH, TDS, TS, BOD₃, COD and OIL and GREASE.

4.2 Experimental setup of Vermi-filtration for Varied Bed Depth Using Mixed Earthworms Species

Laboratory experiments were carried out for three different vermin-filtration unit i.e., Reactor 1, Reactor 2 and Reactor 3 having dimensions of 30 cm x 30 cm x 65 cm, 30 cm x 30 cm x 80 cm and 30 cm x 30 cm x 95 cm, for varied bed depth of garden soil for 10 cm, 15 cm and 20 cm. The vermifiltration unit contains a layer of sand and gravel with two layers of garden soil sandwiched between sand layers. Provision has been made to collect the filtered water samples at the bottom of the vermifilter unit. At the top of the chamber lies the net of wire mesh which allow only water to trickle down. The bottom layer was filled with gravel aggregates of size 20 mm and above which a layer of gravel of size 10 mm and top layer consists of gravel of size less than 10 mm was provided. Gravel

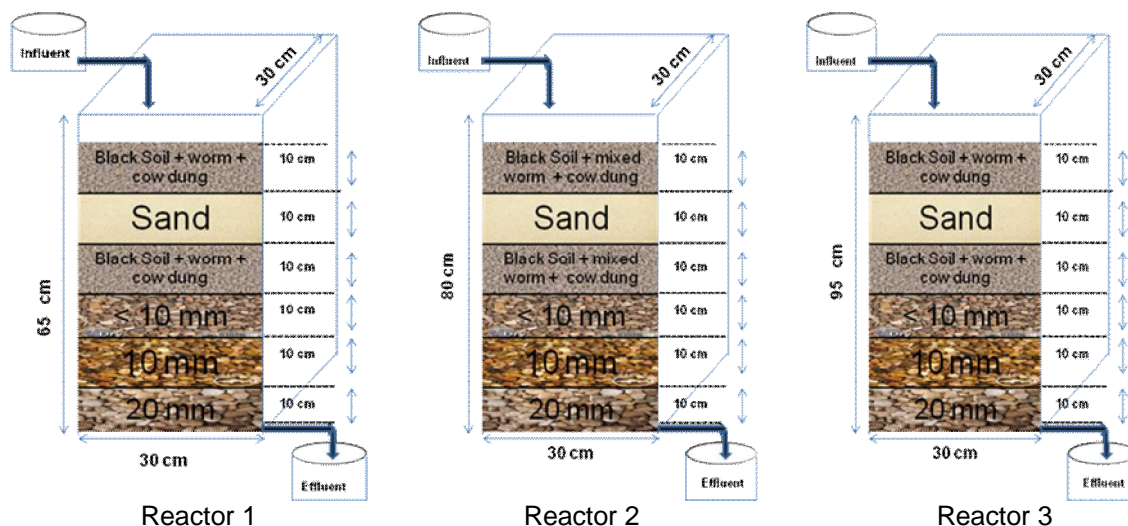


Fig (a): Schematic diagram of Vermi - filtration Unit for Single and Mixed Earthworm Species

layer was filled up-to a depth of 30 cm and on the top of gravel layer, sand layer of 10 cm depth was laid. Garden soil of depth 10 cm, 15 cm and 20 cm each which is sandwiched between a layers of sand in which earthworms are being released. Cow dung has been added to the vermifilter bed. In Reactor 1, Reactor 2, and in Reactor 3 mixed earthworm species (*Eisenia fetida* and *Eudrilus eugenia*) has been used. The dairy wastewater flowed through the pipe network by gravity with uniform distribution over the vermifiltration bed. The wastewater percolated down through the different layers of bed and at the end effluent was collected in a chamber placed at the bottom of the filter unit. The treated wastewater was collected at an interval of 5 days. Figure (b) shows Schematic diagram used for the experiment diagram of Reactor (1), Reactor (2) and Reactor (3). Wastewater was stored in a storage tank placed above the vermifiltration unit. The arrangement of influent to the vermifilter unit was made similar to the arrangement as discussed in sub-section 4.1.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

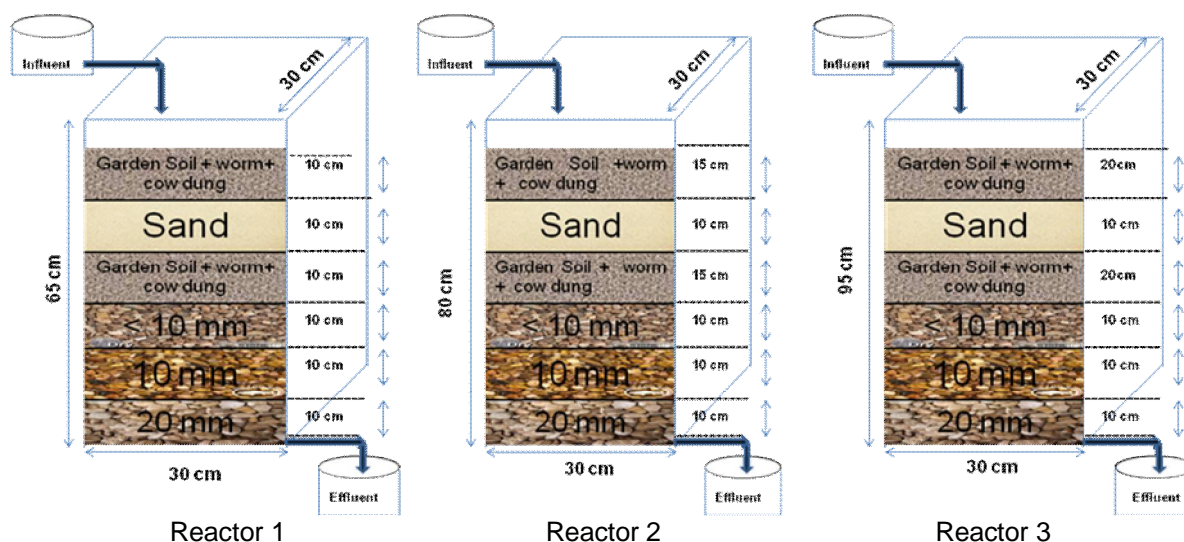


Fig (b): Schematic diagram of Vermin - filtration Unit for Varied Bed Depth Using Mixed Earthworm Species

4.3 Experimental setup of Non-vermifiltration

In order to treat the dairy wastewater on the removal of TDS, TS, BOD₃, COD and OIL and GREASE experiments was carried using a non vermifiltration unit i.e., Reactor 4 of size 30 cm x 30 cm x 65 cm. The non-vermifiltration unit contains a layer of sand and gravel with two layers of garden soil sandwiched between sand layers. Provision has been made to collect the filtered water samples at the bottom of the Non-vermifilter unit. The bottom layer was filled with gravel aggregates of size 20 mm above which a layer of gravel of size 10 mm and top layer consists of gravel of size less than 10 mm was provided. Gravel layer was filled up-to a depth of 30 cm and on the top of gravel layer, sand layer of 10 cm depth was laid. Garden soil of depth 10 cm each which is sandwiched between a layers of sand. The dairy wastewater flowed through the pipe network by gravity to attain uniform distribution over the Non-vermifiltration bed. Wastewater percolated down through different layers of bed and the final effluent was collected in a chamber placed at the bottom of the filter unit. The treated wastewater was collected at an interval of 7 days. Figure (c) shows Schematic diagram of Reactor (4). Wastewater was stored in a storage tank placed above the non-vermifiltration unit. The arrangement of influent to the Non-vermifilter unit was made similar to the arrangement as discussed in sub-section 4.1.

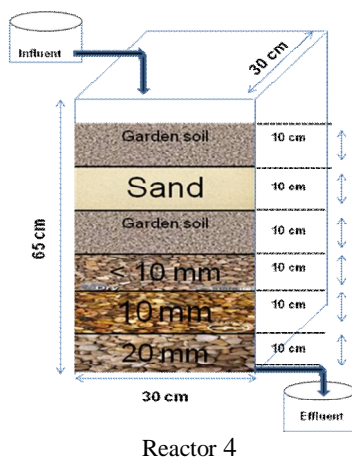


Fig (c): Schematic diagram of Non-Vermifiltration unit

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

IV. RESULTS AND DISCUSSIONS

The different types of experimental work done to determine the performance evaluation of vermi-filtration method and non-vermifiltration method. In Vermi-filtration method different earthworms species and mixed earthworm species has been used and work was carried out for varied bed depths using mixed earthworms species and non-vermifiltration method has also been analysed for Dairy wastewater. The results of the test conducted to know the removal efficiency of the various parameters such as pH, COD, BOD₃, TS, TDS and OIL and GREASE have been discussed in this chapter.

pH

pH measures the hydrogen ion concentration in a liquid. The average pH value (6.97) of the raw dairy wastewater was neutralized by the earthworms in the vermifilter bed to a pH of around 7.91, 7.77 and 7.91 from three reactors (see Fig. d). However, pH value of treated dairy wastewater without earthworms also improved to 6.98 but not as high as those in the vermifiltration method. It can be noted that the same trend when they applied to the vermifiltration technology for varied bed depths in treating the dairy wastewater found to be around 7.85, 7.91 and 7.83 (see Fig. e). Earthworm activity caused an in-built pH buffering ability by increasing the pH, hence neutralizing the wastewater pH. The pH value of vermifiltration and non-vermifiltration improved throughout the experimental study.

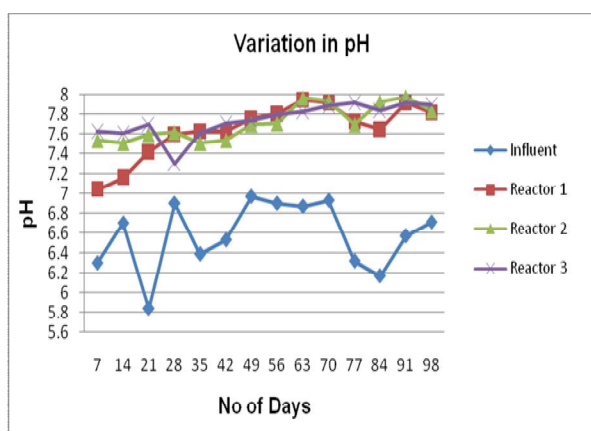


Fig (d): Variation in pH of Influent And Effluent Sample Using Single and Mixed Earthworms Species

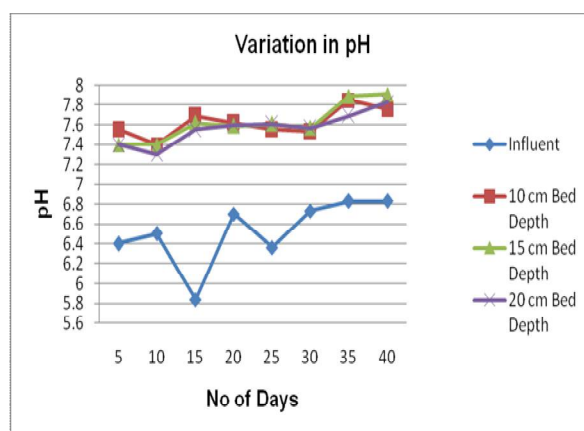


Fig (e): Variation in pH of Influent And Effluent Samples for varied bed depth using Mixed Earthworm species

Total Solids (TS)

Total solids (TS) refer to the organic and inorganic contaminants which are either suspended or dissolved in the wastewater. The average TS value of the raw dairy wastewater is about 1890 mg/L. The earthworms in the vermifiltration method significantly removed the TS from the dairy water by 82.3 %, 85.5 % and 73.9 % (see Fig. f) for the interval of 98 days using single and mixed earthworms species and for varied bed depths around 55.32 %, 42.02 % and 29.20 % (see Fig. g) for the interval of 40 days using mixed earthworms species and from Non-vermifiltration method the removal efficiency is about 23.95 % for about 70 days. Earthworms ingest solid particles of wastewater and excrete them as finer particles. These finer particles trapped in the voids vermifilter and caused high removal efficiency of TS from wastewater. These solids which were removed accumulate over time as sludge in a normal bio-filter and choke the system which then ceases to work properly. However, in the vermifilter bed these bio-solids were constantly ingested by the earthworms and expelled as vermicompost. This explained why there was no choking and interrupted

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

functioning of the vermifilter bed. The TS values (494 - 273 mg/L) remaining after vermifiltration method using single and mixed earthworms species the treated dairy water were acceptable for use of irrigation purposes and for varied bed depths the TS values (1309 - 826 mg/L) respectively. The height of vermibed is considered as an important factor in vermi-filtration method. For earthworm, the vermibed height of 15 cm and 20 cm had bad effect on the growth of organism. The TS values (1397 mg/L) in the Non- vermifiltration method were unacceptable in water to be used for irrigation.

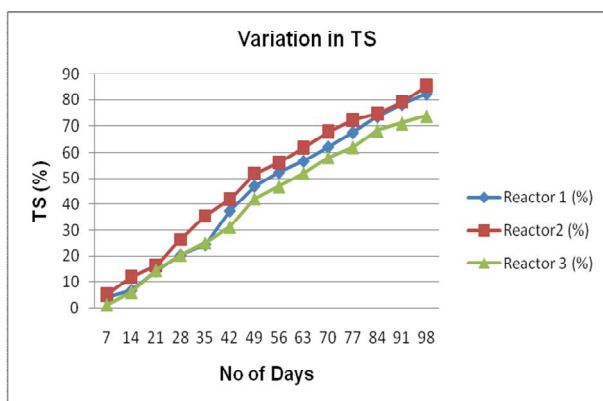


Fig (f): Removal Efficiency of TS by Vermin-filtration method using single and mixed earthworm species

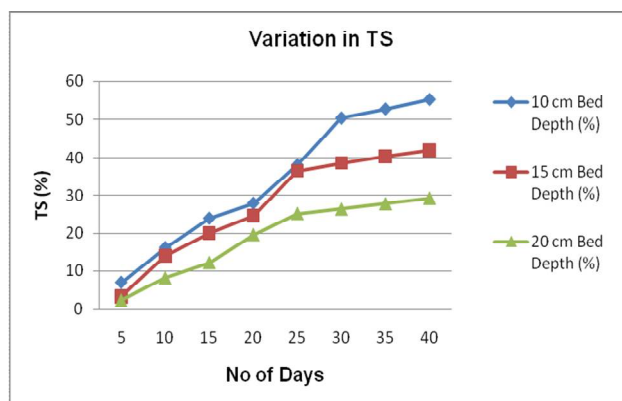


Fig (g): Removal Efficiency of TS by Vermin-filtration method for varied bed depth using mixed earthworm species

Total Dissolved Solids (TDS)

Total dissolved solids (TDS) refer to the organic and inorganic contaminants which are either suspended or dissolved in the wastewater. The average TDS value of the raw dairy wastewater is about 1573 mg/L. TDS get reduced during vermin-filtration method. Results show that the earthworms can significantly remove the total dissolved solids from the dairy wastewater of about 85.6 %, 87.1 % and 82.9 % (see Fig. h) for the interval of 98 days using single and mixed earthworms species and for varied bed depths removal of TDS from the dairy wastewater by about 55.32 %, 42.02 % and 29.20 % (see Fig. i) for the interval of 40 days using mixed earthworms species and from Non - vermifiltration method the removal efficiency is around 20.74 % for the interval of 70 days. The sludge formed due to accumulation of solids in the conventional system clog the filter system. The Vermi - filtration system was protecting from the congestion due to solid biomass. Earthworms consume the solid biomass and clear the path for efficient process conditions and resulted into high removal efficiency of TDS from wastewater. Earthworms ingest solid particles of wastewater and excrete them as finer particles. These finer particles trapped in the voids vermifilter and caused high removal efficiency of TDS from wastewater. The TDS values (194 - 257 mg/L) remaining after vermi - filtration method using single and mixed earthworms species the treated dairy water were acceptable for use of irrigation purposes and for varied bed depths the TDS values (1309 - 826 mg/L) respectively. The height of vermibed is considered as an important factor in vermi-filtration method. For earthworm, the vermibed height of 15 cm and 20 cm had bad effect on the growth of organism. The TDS values (1207 mg/L) in the Non- vermifiltration method were unacceptable in water to be used for irrigation.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

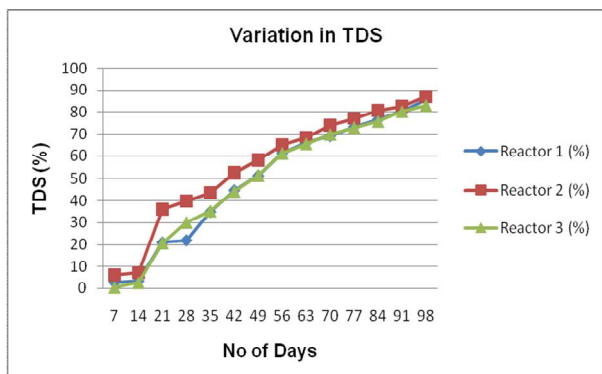


Fig (h): Removal Efficiency of TDS by Vermifiltration method using single and mixed earthworm species

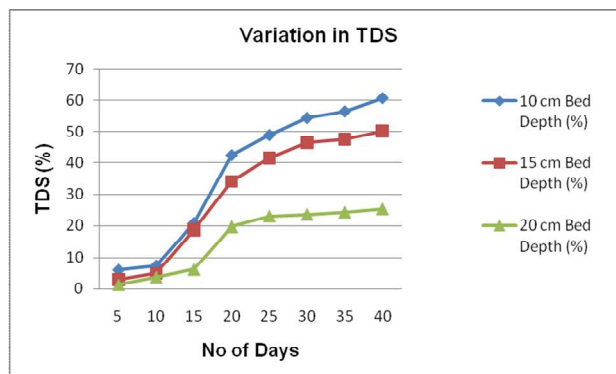


Fig (i): Removal Efficiency of TDS by Vermifiltration method for varied bed depth using mixed earthworm species

Chemical Oxygen Demand (COD)

The chemical decomposition of organic and inorganic contaminants in wastewater which cannot be biologically removed is term as COD. The average COD value of the raw dairy wastewater is about 1390 mg/L. Results indicate that the overall efficiency of COD of the treated dairy wastewater from the vermin - filtration method were found to be around 81.6 %, 85.4 % and 80.3 % (see Fig. j)for the interval of 98 days using single and mixed earthworms species and for varied bed depths removal of COD from the dairy wastewater by about 55.56 %, 46.42 % and 23.37 % (see Fig. k) for the interval of 40 days using mixed earthworms species and from Non – vermifiltration method the removal efficiency is around 24.52 % for the interval of 70 days. The COD values remaining after vermin - filtration of the dairy wastewater was acceptable for use of irrigation purpose. The enzymes in the gut of earthworms help in the degradation of several of those chemicals which cannot be decomposed by microbes. The COD values (184 - 249 mg/L) remaining after vermi - filtration method using single and mixed earthworms species the treated dairy water were acceptable for use of irrigation purposes and for varied bed depths the COD values (559 - 964 mg/L) respectively. The height of vermibed is considered as an important factor in vermi-filtration method. For earthworm, the vermibed height of 15 cm and 20 cm had bad effect on the growth of organism. The COD values (954 mg/L) in the Non-vermifiltration method were unacceptable in water to be used for irrigation.

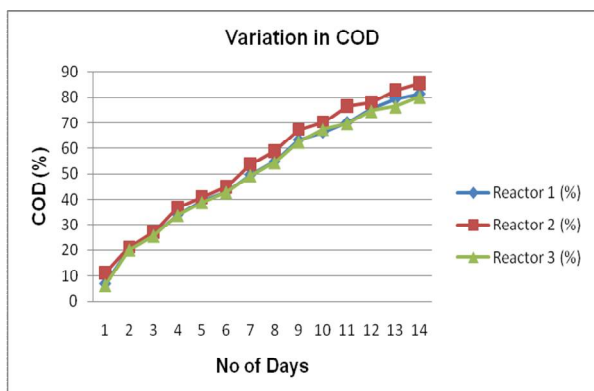


Fig (j): Removal Efficiency of COD by Vermifiltration method using single and mixed earthworm species

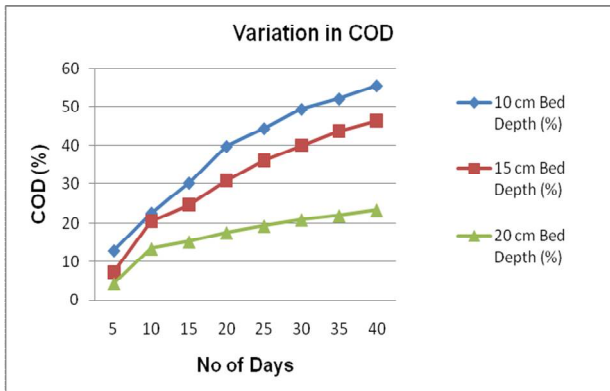


Fig (k): Removal Efficiency of COD by Vermifiltration method for varied bed depth using mixed earthworm species

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

Bio-Chemical Oxygen Demand (BOD₃)

BOD₃ describes the amount of dissolved oxygen essential to breakdown organic contaminants through aerobic bacteria. The average BOD₃ value of the raw dairy wastewater is about 399 mg/L. Results indicate that the overall efficiency of BOD₃ of the treated dairy wastewater from the vermicfilter were found to be always greater than 89.3 %, 91.6 % and 86.5 % (see Fig. l) for the interval of 98 days using single and mixed earthworms species and for varied bed depths removal of BOD₃ from the dairy wastewater by about 78.45 %, 68.35 % and 54.52 % (see Fig. m) for the interval of 40 days using mixed earthworms species and from Non – vermifiltration method the removal efficiency is around 46.01 % for the interval of 70 days . Earthworms significantly degraded the wastewater organics by enzymatic actions where by the earthworms worked as biological catalyst resulting in faster biochemical reactions hence high BOD removal in vermi – filtration. BOD₃ removal efficiency was found to be much better than that of COD removal efficiency vermifiltration method. The BOD₃ values remaining after vermin - filtration of the dairy wastewater was acceptable for use of irrigation purpose. The BOD₃ values (33 - 53 mg/L) remaining after vermi - filtration method using single and mixed earthworms species the treated dairy water were acceptable for use of irrigation purposes and for varied bed depths the BOD₃ values (81 - 171 mg/L) respectively. The height of vermibed is considered as an important factor in vermi-filtration method. For earthworm, the vermibed height of 15 cm and 20 cm had bad effect on the growth of organism. The BOD₃ values (203 mg/L) in the Non- vermifiltration method were unacceptable in water to be used for irrigation.

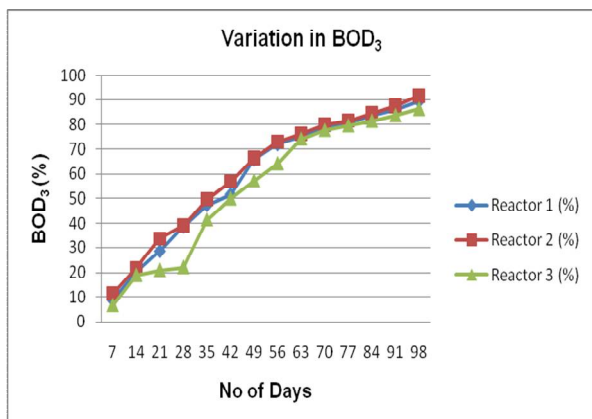


Fig (l): Removal Efficiency of BOD₃ by Vermin-filtration method using single and mixed earthworm species

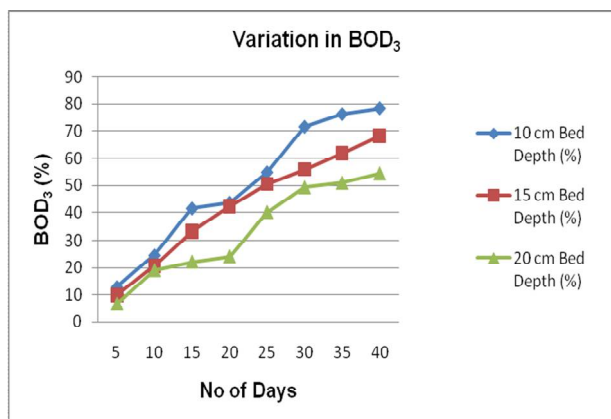


Fig (m): Removal Efficiency of BOD₃ by Vermin-filtration method for varied bed depth using mixed earthworm species

Oil and Grease

The average Oil and Grease value of the raw dairy wastewater is about 16.62 mg/L. Results indicate that the overall efficiency of Oil and Grease of the treated dairy wastewater from the vermin - filtration method were found to be around 97.2 %, 99 % and 97.2 % (see Fig. n) for the interval of 91 days using single and mixed earthworms species and for varied bed depths removal of Oil and Grease from the dairy wastewater by about 29.9 %, 16.82 % and 9.34 % (see Fig. o) for the interval of 40 days using mixed earthworms species and from Non – vermifiltration method the removal efficiency is around 24.24 % for the interval of 70 days. The Oil and Grease values (0.3 mg/L) remaining after vermi - filtration method using single and mixed earthworms species the treated dairy water were acceptable for use of irrigation purposes and for varied bed depths the values Oil and Grease (9.7 mg/L) respectively. The height of vermibed is considered as an important factor in vermi-filtration method. For earthworm, the vermibed height of 15 cm and 20 cm had

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

bad effect on the growth of organism. The Oil and Grease values (7.5 mg/L) in the Non- vermifiltration method were unacceptable in water to be used for irrigation.

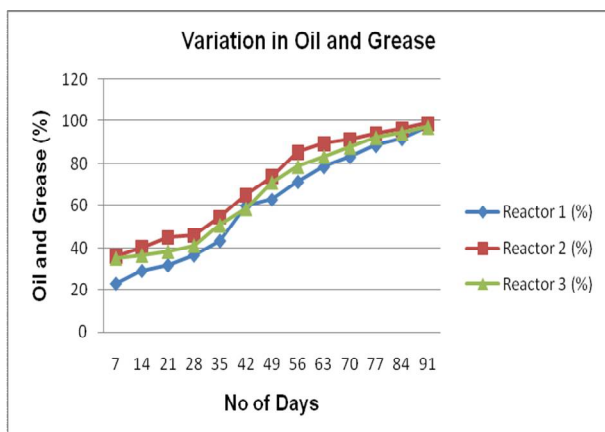


Fig (n): Removal Efficiency of Oil and Grease by Vermifiltration method using single and Mixed earthworm species

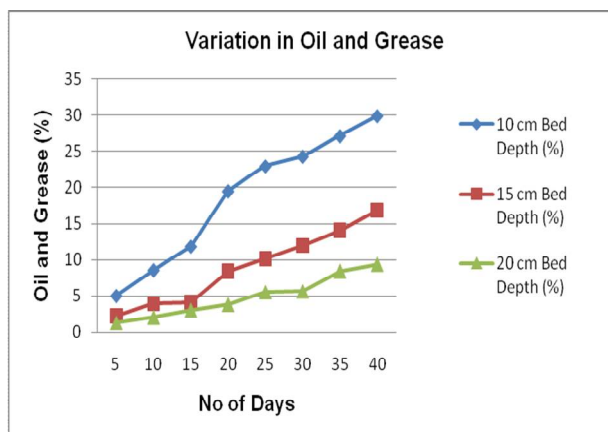


Fig (o): Removal Efficiency of Oil and Grease by Vermifiltration method for varied bed depth using mixed earthworm species

V. CONCLUSIONS

Vermifiltration is an alternative, sustainable technology for dairy wastewater treatment. There was no problem of any foul odor with vermifiltration unit throughout the experimental study. There is no sludge formation in the process in the vermifiltration process, which requires additional expenditure on landfill disposal. Variation in pH, in both vermifiltration and non vermifiltration unit was found to be nearly equal; it lies within the ISI standards of 5.5 – 9.0. Results specify that, more removal efficiency in TS, TDS, COD, BOD₃ and oil and grease. Any non-toxic wastewater from the industries can be successfully treated by the earthworms and technology can be designed to a particular wastewater. The combined effect of the *Eisena fetida* and *Eudrilus eugeniae* worms and the microbial geological system successfully treat dairy wastewater. The vermifilter water is most suitable for irrigation purpose but would require further treatment for other uses. Vermifiltration is more efficient than Non-vermifiltration in efficiency of removal of TS, TDS, COD, BOD₃ and OIL and GREASE. The height of vermibed is considered as an important factor in vermifiltration method. For earthworms, the vermibed height of 15 cm and 20 cm had bad effect on the growth of organisms.

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International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 7, July 2016

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