RESEARCH ARTICLE OPEN ACCESS

Effect of Earthworms on Distillery Effluent Treatment through Vermifiltration

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ABSTRACT
Distillery is an important sub-unit of sugar production industry. Distillery wastewater generated from different stages of sugar and ethanol production contains huge amount of pollutants that are very harmful to the environment if released without proper treatment. The present paper describes the application of vermiculture based wastewater technology with the primary objective of converting liquid effluent into eco-friendly safe water. Vermifiltration of wastewater using waste eater earthworms is a newly conceived novel technology. The BOD, COD, TSS and TDS decreased by 90%, 94%, 88% and 82% respectively through vermifiltration.
Keywords: Earthworms, Distillery Effluent (DE), Vermifiltration (VF), Hydraulic Retention Time (HRT).

I. INTRODUCTION

Water pollution is one of the main concerns of the world today. The government of numerous countries have striven to find solutions to reduce this problem. Sugarcane is one of the most common raw materials used in sugar industry and ethanol production. Distillery units in India are in a considerable number, where molasses and impure alcohol are still being used as raw materials for production of liquor. The wastewater or spillage products from such distilleries contain huge quantity of dissolved organic matter, heavy metals, dyes, etc., along with other pollutants.

The aqueous distillery effluent stream known as “spent wash” is a dark brown highly organic effluent and is approximately 12-15 times by volume of product alcohol. More than 30 billion liters of spent wash are generated annually by 254 cane molasses-based distilleries in India alone 0.2-1.8 m^3 of wastewater per ton of sugarcane produced [1]. As per the Ministry of Environment & Forests (MoEF), Government of India, alcohol distilleries are listed at the top of “Red Category” industries having a high polluting potential. The industry generates large volumes 8-15 kL/kL alcohol [2], [3] of dark brown colour wastewater (spent wash) with high BOD 45,000-60,000 mg/L and COD 80,000-1,20,000 mg/L [4].

Physical, chemical and biological treatment approaches have been employed for the treatment of distillery wastewater. This work focuses mainly on lab scale biological approaches. Vermifiltration (VF) has been studied extensively due to its effectiveness for removing pollutants in wastewater and its positive effects on the environment [5]. VF is a relatively new technology to process organically polluted water using earthworms. It was first advocated by the late professor Jose Toha at the University of Chile in 1992 [6]. Vermifiltration is a treatment method that combines the conventional filtration process with the vermicomposting techniques. This technique is used in developing countries due to its low cast and eco-friendly nature.

II. MATERIALS AND METHODS

2.1. Collection and Culturing of Worms

Earthworms *Eudrilus eugeniae* were used for the study. *Eudrilus eugeniae* were purchased from Periyar Research Organization for Bio-Technique and Eco-System (PROBE), Periyar Maniyammai University, Vallam, Tanjore District, Tamil Nadu and cultured in cement tanks for further studies. The earthworms were reared in garden soil and garden waste vermibed of dimension 4 x 2 x 4/4 feet (length x breadth x height) sufficient for 2,000-3,000 worms with controlled moisture 35-45% and temperature 26-28ºC. Nylon net was used to cover the bed to prevent the entry of predators. Adequate watering was done daily to maintain optimum moisture conditions in the bed.

2.2. Collection of Samples

Distillery Effluent (DE) was collected from Trichy Distilleries, Senthaneerpuram, Tiruchirappalli District. The samples were used for the experiment after proper dilution. Physico-chemical properties of wastewater from distillery industry were analyzed in the Environmental Biotechnology Unit at P.G. and Research Department of Zoology, Periyar E.V.R College, Tiruchirappalli before starting the experiment. The results are recorded in table 1 and 2.

2.3. Non-Vermifilter (NVF) and Vermifilter (VF)

The size of the both the units are 36 cm (long) x 36 cm (wide) x 36 cm (height). It has an upper perforated filtering unit and lower collection unit. Filtering units were filled with gravel, sand and garden soil. The bottom most layers was filled up to 7 cm with gravel aggregated of size 10-20 mm, followed by gravel of size 2-4 mm size up to 7 cm, sand of size 1-2 mm up to 7 cm and the top most layer with garden soil up to 7 cm. VF unit was same as that of NVF unit except for the presence of earthworms.

2.4. Experimental Design

Plastic drums of 10 L capacity with a tap were filled with 6 L of distillery effluent. These drums were kept on an elevated platform just near the VF unit. One end of the flexible rubber tube was fitted to the tap of the plastic drum and the other end was placed over the VF unit. The wastewater distribution system consisted of simple 0.5 inch flexible rubber pipe with hole for trickling wastewater on the soil surface of vermibed. Wastewater from the drums flowed through the perforated rubber pipe by gravity. The wastewater percolated down through various layers in the VF bed passing through the soil layer inhabited by earthworms, the sandy layer and the gravels and at the end was collected in a collection unit at the bottom of the kit. To find the efficiency of VF and NVF units at 25%, 50% and 75% diluted distillery effluent was used. The hydraulic retention time in the vermifilter bed was kept uniformly for 8-10 hours in all experiments.

2.5. Hydraulic Retention Time (HRT)

HRT is the time taken by the wastewater to flow through the soil profile in which earthworms inhabits. HRT is the actual time spent by earthworms with wastewater to retrieve organic matter from it as food. Maximum HRT can results from slow percolation into the bed.

2.6. Physico-chemical parameters

VF and NVF filter water were collected at the collection unit and analysis the physico-chemical parameter like pH, Electrical Conductivity (EC), Biological Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Total Solids (TS), Total Suspended Solids (TSS) and Total Dissolved Solids (TDS). All the parameter was analyzed according to the standard methods for the examination of water and wastewater [7]. All the samples were analyzed in triplicate and the results were averaged during a working condition.

2.7. Statistical Analysis

The data entry and Analysis of Variance (ANOVA) were analyzed using SPSS version-16.0. One-way ANOVA was used to test differences in the related physico-parameters of wastewater using of VF systems under similar influent conditions. Duncan’s multiple range tests was used to further assess differences among VF systems that were significant in ANOVA. The probability levels used for statistical significance were $p < 0.05$ for the tests.

III. RESULTS AND DISCUSSION

3.1. pH

The quality of wastewater (Distillery Effluent) in terms of physico-chemical characteristics were described in table 1 and 2. The change in pH during different treatment dilution is illustrated in table 1 and 2. The pH value of raw DE was acidic in nature 4.5. The raw spent wash is acidic in nature and the pH values of distillery wastewater range from 3.5-5.0. But when it was diluted with different dilution 75%, 50% and 25%, it changed neutral to alkaline. The pH values of raw, diluted and filtered wastewater from VF and NVF units were observed. The average pH of the diluted (75%, 50% and 25%) raw DE was 5.56 ± 0.02^a, 5.54 ± 0.01^a and 5.54 ± 0.02^a. The pH recorded at different concentrations after experiments were 6.12 ± 0.02^a, 7.07 ± 0.01^b, 7.36 ± 0.01^c in NVF and 7.02 ± 0.02^a, 7.51 ± 0.01^b, 7.61 ± 0.01^c, in VF unit. From ANOVA test, it showed significant different values of pH measured when worm density is varied but no significant different when concentration is varied throughout the VF process ($p < 0.05$).

The pH value difference between NVF and VF unit for pH may be related to earthworm mediated rapid mineralization of organic fractions in wastewater [8]. The pH of effluent from all the VFs increased initially during the treatment and then settled in the neutral range signifying the inherent capability of earthworms to act as buffering agent and neutralize pH [9].

3.2. EC

The Electrical Conductivity (EC) of DE showed significant changes after treatment through filtration system in both NVF and VF processes. The EC of the raw, diluted (75%, 50% and 25%) DE was 18.86 (mS/cm) and 15.47 ± 0.35^c, 12.34 ± 0.03^b, 7.52 ± 0.02^a (mS/cm) respectively. The EC of treated DE was 6.53 ± 0.01^c, 5.41 ± 0.01^b, 4.73 ± 0.03^a (mS/cm) in NVF and 3.95 ± 0.03^c, 2.03 ± 0.04^b, 1.74 ± 0.01^a (mS/cm) in VFs. The difference between NVF and VF unit was statistically significant. The increase in EC during the process might have been due to the loss of weight of organic matter and release of different mineral salts in available forms (such as phosphate, ammonium and potassium) as reported by other researchers [10], [11].

Table – 1 Physico-Chemical Characteristics of the Raw and Diluted DE before Treatment

Parameters	Raw Wastewater	Diluted Distillery Effluent		
		75%	50%	25%
pH	4.5	5.56 ± 0.02[a]	5.54 ± 0.01[a]	5.54 ± 0.02[a]
EC (mS/cm)	18.86	15.47 ± 0.35[c]	12.34 ± 0.03[b]	7.52 ± 0.02[a]
BOD_5 (mg/L)	32533.00	18100.00 ± 3.60[c]	11700.00 ± 21.36[b]	5863.67 ± 3.21[a]
COD (mg/L)	97600.00	54400.00 ± 50.00[c]	35200.00 ± 50.00[b]	17600.00 ± 17.55[a]
TS (mg/L)	70000.00	57200.00 ± 200.00[c]	35100.00 ± 100.00[b]	23200.00 ± 251.66[a]
TSS (mg/L)	8000.00	7116.67 ± 104.08[c]	5073.33 ± 87.36[b]	4143.33 ± 128.97[a]
TDS (mg/L)	62000.00	50100.00 ± 104.08[c]	32000.00 ± 25.16[b]	19100.00 ± 138.92[a]

Results are the mean value in triplicates ± SD with significant difference at p < 0.05.

Table – 2 Physico-Chemical Characteristics of the DE at Different Concentration after Treatment

Parameters	Non-Vermifilter (NVF)			Vermifilter (VF)		
	75%	50%	25%	75%	50%	25%
pH	6.12 ± 0.02[a]	7.07±0.01[b]	7.36±0.01[c]	7.02±0.02[a]	7.51±0.01[b]	7.61±0.01[c]
EC (mS/cm)	6.53 ± 0.01[c]	5.41±0.01[b]	4.73±0.03[a]	3.95±0.03[c]	2.03±0.04[b]	1.74±0.01[a]
BOD_5 (mg/L)	3092.67 ± 2.51[c]	2027.00±2.64[b]	1066.00±4.00[a]	929.33±27.68[c]	527.67±25.42[b]	425.00±3.60[a]
COD (mg/L)	9265.00 ± 15.00[c]	6058.33±20.20[b]	2809.33±9.01[a]	3174.00±22.71[c]	1615.00±20.22[b]	1250.67±25.71[a]
TS (mg/L)	23100.00±152.75[c]	14100.00±76.37[b]	11000.00±36.05[a]	7016.67±20.81[c]	6036.67±55.07[b]	3016.67±15.27[a]
TSS (mg/L)	6080.00±75.49[c]	4026.67±25.16[b]	3011.67±10.40[a]	3011.00±16.52[c]	2254.33±437.92[b]	1011.67±10.40[a]
TDS (mg/L)	17100.00±83.86[c]	12100.00±51.31[b]	8028.33±25.65[a]	5005.67±5.13[c]	4115.67±194.31[b]	2005.00±5.00[a]

Results are the mean value in triplicates ± SD with significant difference at p < 0.05.

3.3. Status of BOD

Biochemical Oxygen Demand (BOD_5) is the most important parameters used to determine degree of pollution of aquatic life. Table 1 and 2 indicates the BOD of the raw DE was 32533.00 mg/L. The BOD of 75%, 50% and 25% of raw diluted DE were 18100.00 ± 3.60[c], 11700.00 ± 21.36[b] and 5863.67 ± 3.21[a] mg/L respectively. The level of BOD_5 removal from the DE in VF, it was 929.33 ± 27.68[c], 527.67 ± 25.42[b] and 425.00 ± 3.60[a] mg/L while for NVF it was 3092.67 ± 2.51[c], 2027.00 ± 2.64[b] and 1066.00 ± 4.00[a] mg/L respectively. The average BOD_5 removal from the DE by earthworm is over 90% while that without earthworms is over 82% for NVF. Earthworms significantly degraded the wastewater organics by enzymatic actions whereby the earthworms worked as biological catalysts resulting in faster biochemical reactions hence high BOD removal in the VF [12], [13] and [14]. This has been indicated as the major difference between microbial degradation and vermidegradation [15].

3.4. Status of COD

The variation of Chemical Oxygen Demand (COD) in filter having different VF and NVF is illustrated in Table (1 and 2). The data showed that the COD of effluent was significantly low ($p < 0.05$) in VF and NVF units as compared to influent as mentioned in table ($p < 0.05$). COD is an important indicator of organic load of industrial and domestic wastewater. The COD of the raw DE was 97600.00 mg/L. The COD of 75%, 50% and 25% of raw diluted raw diluted DE were 54400.00 ± 50.00[c], 35200.00 ± 50.00[b], and 17600.00 ± 17.55[a] mg/L respectively. COD removal of the treated DE different dilution in VF was 3174.00 ± 22.71[c], 1615.00 ± 20.22[b] and 1250.67 ± 25.71[a] mg/L while for NVF it was 9265.00 ± 15.00[c], 6058.33 ± 20.20[b] and 2809.33 ± 9.01[a] mg/L respectively. In case of VF unit, the average removal efficiency of DE was recorded as 94% while in NVF the COD reduction was represented as 80% respectively. Sinha *et al.*, [12] studied the VF of wastewater originated from dairy industry under a pilot-scale project. They claimed the average COD reduction in the ranges of 80-90%. Earlier worker have also reported significant reduction in the COD load during NVF and VF processes [16].

3.5. TS, TSS and TDS

Total Solids (TS) reduced during VF significantly ($p < 0.05$) as shown in table (1 and 2). The raw DE had 70000.00 mg/L. These values decreases after dilutions (75%, 50% and 25%) DE were 57200.00 ± 200.00[c], 35100.00 ± 100.00[b], 23200.00 ± 251.66[a] mg/L. DE filtered from VF was 7016.67 ± 20.81[c], 6036.67 ± 55.07[b], and 3016.67 ± 15.27[a] mg/L while in NVF it was 23100.00 ± 152.75[c], 14100.00 ± 76.37[b] and 11000.00 ± 36.05[a] mg/L. TS reduced during VF significantly as shown in table – 1 and 2. TS removal efficiencies of the overall both experimental plant VF and NVF were 80% and 60% respectively.

Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) showed drastic reduction during NVF and VF (Table 1 and 2). The concentration of both TSS and TDS were reduced during VF significantly ($p < 0.05$). The raw DE had 8000.00 mg/L, TSS and 62000.00 mg/L of TDS. The TSS of the diluted (75%, 50% and 25%) DE was 7116.67 ± 104.08[c], 5073.33 ± 87.36[b] and 4143.33 ± 128.97[a] mg/L. TDS of the diluted (75%, 50% and 25%) DE was 50100.00 ± 104.08[c], 32000.00 ± 25.16[b], and 19100.00 ± 138.92[a] mg/L. Results thus clearly suggested the capability of earthworms to remove solid fractions of wastewater during VF processes. Similarly TSS and TDS were reduced significantly in DE obtained from both experimental units (NVF and VF). The removal rate was high in VF unit (3011.00 ± 16.52[c], 2254.33 ± 437.92[b], 1011.67 ± 10.40[a] mg/L and 5005.67 ± 5.13[c], 4115.67 ± 194.31[b], 2005.00 ± 5.00[a] mg/L) than NVF system (6080.00 ± 75.49[c], 4026.67 ± 25.16[b], 3011.67 ± 10.40[a] mg/L and 17100.00 ± 83.86[c], 12100.00 ± 51.31[b], 8028.33 ± 25.65[a] mg/L).

The TSS and TDS of DE were significantly reduced by VF unit and the mean TSS removal in VF was observed 63% and 88%, and in NVF was 82% and 60%. This could be attributed to the ingestion of organic and inorganic solid particles in wastewater through earthworm, which excrete them as finer particles [17]. The various physical, chemical and biological reactions take place in VF process including the adsorption of molecules and ions, oxidation–reduction of organic matter, the behavior of earthworms and their synergetic effects with microorganisms [18]. During VF process, a tortuous behavior for TSS concentration was also observed. This unfavorable performance might be due to turbulence, which led to washing out of the influent solids and settled biomass [19].

IV. Conclusion

Conventional treatment results into formation of sludge which requires safe disposal in secured landfills at additional cast. Vermifiltration is an alternative, sustainable technology for wastewater treatment. Further, the economic optimization of these processes must be worked out for treating voluminous amount of wastewater by vermifiltration. In addition, the refuge of such techniques might be easily used in agriculture and environmental decontamination.

V. Acknowledgements

The authors are grateful to the University Grants Commission (UGC), New Delhi, India for funding their project (F.No. 41-126/2012 (SR) Dated: 10 July 2012). The authors are also thankful to the Principal, Periyar E.V.R. College (Auto), Tiruchirappalli, Tamil Nadu, India for the encouragement and providing facilities for the study.

REFERENCES

[1] D. Mukesh, and K. Anil, *Bio treatment of industrial effluents*, (e-book, Elsevier, U.S.A, 2005).
[2] CPCB, *Central Pollution Control Board* (2002), Annual report; 2002–2003.
[3] M. Rais, and A. Sheoran, Treatment of Sugarcane Industry Effluents: Science & Technology issues, *International Journal of Engineering Research and Applications, 5(1)*, 2015, 11-19.
[4] TERI, *The Energy and Resources Institute* (2003), Background paper on water efficiency status in Indian distilleries and agro-based pulp and paper mills [SPF ref: 75].
[5] L. Wang, Z. Zheng, X. Luo, and J. Zhang, Performance and mechanisms of a microbial earthworm ecofilter for removing organic matter and nitrogen from synthetic domestic wastewater, *Journal of Hazardous Materials, 195*, 2011, 245-253.
[6] S. Wang, Y. Yang, S. Lou, and J. Yang, Wastewater treatment performance of a vermifilter enhancement by converter slag-coal cinder filter, *Ecological Engineering, 36*, 2010, 489-494.
[7] APHA, Standard Methods for the Examination of Water and Wastewater, 19th edition; Washington, DC, 1999, USA.
[8] A. Rajpal, R. Bhargava, S.K. Sasi, and A.K. Chopra, On site domestic organic waste treatment through vermitechnology using indigenous earthworm species, *Waste Management and Research*, *30(3)*, 2012, 266-275.
[9] S. Arora, A. Rajpal, R. Bhargava, V. Pruthi, A. Bhatia, and A.A. Kazmi, Antibacterial and enzymatic activity of microbial community during wastewater treatment by pilot scale vermifiltration system, *Bioresource Technology*, *166*, 2014, 132-141.
[10] J.M.C. Wong, M. Fang, G.X. Li, and M.H. Wong, Feasibility of using coal ash residue as co-composting materials for sewage sludge, *Environmental Technology*, *18*, 1997, 563-568.
[11] P. Garg, A. Gupta, and S. Satya, Vermicomposting of different types of waste using *Eisenia fetida*: a comparative study, *Bioresource Technology*, *97*, 2006, 391-395.
[12] R.K. Sinha, G. Bharambe, and P. Bapat, Removal of high BOD and COD loadings of primary liquid waste products from dairy industry by vermifiltration technology using earthworms, *Indian Journal of*

Environmental Protection, *27(6)*, 2007, 486-501.

[13] S.D. Ghatnekar, M.F. Kavin, S.M. Sharma, S.S. Ghatnekar, and A.V.Ghatnekar, Application of vermifilter based effluent treatment plant (Pilot scale) for biomanagement of liquid effluents from the gelatine industry, *Dynamic soil, Dynamic plant*, *4(1)*, 2010, 83-88.

[14] A.M. Kharwade, and I.P. Khedikar, Laboratory scale studies on domestic grey water through vermifilter and non-vermifilter, *Journal of Engineering Research and Studies*, *2(4)*, 2011, 35-39.

[15] S.A. Azuar, and M.H. Ibrahim, Comparison of sand and oil palm fibre vermibeds in filtration of palm oil mill effluent (POME), *UMT 11th International Annual Symposium on Sustainability Science and Management, 09th-11th July 2012, Terengganu, Malaysia*, 1414-1419.

[16] M. Xing, X. Li, and J. Yang, Treatment performance of small-scale vermifilter for domestic wastewater and its relationship to earthworm growth, reproduction and enzymatic activity, *African Journal of Biotechnology*, *9(44)*, 2010, 7513-7520.

[17] T. Kumar, A. Rajpal, R. Bhargava, and K.S. Prasad, Performance evaluation of vermifilter at different hydraulic loading rate using riverbed material, *Ecological Engineering*, *62*, 2014, 77-82.

[18] M.B. Bouche, and P. Soto, An industrial use of soil animals for environment: the treatment of organically polluted water by lumbrifiltration. *Proceedings of the 14th International Colloquium on Soil Zoology and Ecology, University of Rouen, Mont Saint Aignan*, France Aug-30th , Sep-3rd , 2004, 1-13.

[19] M.K.. Sharma, A. Khursheed, and A.A. Kazmi, Modified septic tank-anaerobic filter unit as a two-stage onsite domestic wastewater treatment system, *Environmental Technology*, *35*, 2014, 2183-2193.