South African Journal of Chemical Engineering 25 (2018) 74–78

Contents lists available at ScienceDirect

South African Journal of Chemical Engineering

journal homepage: http://www.journals.elsevier.com/south-african-journal-of-chemical-engineering

Biological treatment of distillery wastewater by application of the vermifiltration technology

M.M. Manyuchi [a, b, *], C. Mbohwa [a], E. Muzenda [a, c]

[a] BioEnergy and Environmental Technology Centre, University of Johannesburg, South Africa
[b] Department of Chemical and Process Systems Engineering, Harare Institute of Technology, Zimbabwe
[c] Department of Chemical, Materials and Metallurgical Engineering, Faculty of Engineering and Technology, Botswana International University of Science and Technology, P Bag 16, Palapye, Botswana

A R T I C L E I N F O

Article history:
Received 29 August 2017
Received in revised form
14 December 2017
Accepted 16 December 2017

Keywords:
Distillery effluent
Eisenia fetida
BOD
COD
TDS
TSS
Vermifiltration
Vermicompost

A B S T R A C T

In this study distillery wastewater was treated using the vermifiltration technology in a bid to reduce downstream contamination by the effluent. 10 kg of *Eisenia fetida* earthworms were used as the vermifiltration media in a 0.5 m × 0.5 m x 0.3 m vermifiltration bed over a 40 h period cycle. The distillery effluent physicochemical parameters which included pH, total Kjeldahl nitrogen (TKN), biological oxygen demand (BOD), total dissolved solids (TDS), total suspended solids (TSS) and the chemical oxygen demand (COD) were measured every 5 days. The vermicompost which was produced as a result of the vermifiltration process's nitrogen, phosphorous and potassium composition was also determined. The distillery effluent pH changed from acidic to neutral whilst a decrease of 94.9% was observed for the TKN, 91.1% for the BOD, 91.9% for the TDS, 92.4% for the TSS and 89.4% for the COD upon treatment with vermifiltration. The vermicompost, a by-product of the vermifiltration process had a nitrogen, phosphorous and potassium composition of 1.87%, 0.87% and 0.66% respectively.

1. Introduction

The distillery industry generates a lot of wastewater from its processing and most distilleries end up disposing their untreated effluent into water bodies causing environmental threats to aquatic life due to high levels of biological contaminants (Shivajirao, 2012). Several low cost technologies have been investigated for potential use in distillery effluent treatment which includes biological, chemical and thermal treatment methods and these technologies have a shortfall one way or the other. There is need to look onto affordable and easy to use technologies such as the vermifiltration process, a low cost and easy to use technology. During vermifiltration, earthworms are used as the biological filtration media for removal of bio contaminants in wastewater that result in high total Kjeldahl nitrogen (TKN), biological oxygen demand (BOD), total dissolved solids (TDS), total suspended solids (TSS) and the chemical oxygen demand (COD). Studies conducted on the application of the vermifiltration technology in wastewater treatment has reported a noted decline in the TKN, BOD, TDS, TSS and COD concentrations over given periods of time with reductions ranging between 70 and 90% (Anusha and Sundar, 2015). Popular earthworms that have been applied in the vermifiltration technology include *Eisenia Fetida* and *Perionyx Excavates* (Rajpal et al., 2011). Fig. 1 shows a summary of how the vermifiltration technology is implemented in wastewater treatment as well as the end products such as a clean effluent and vermicompost, a bio fertilizer that can be realized from the process. During the vermifiltration process, the earthworms also act as a biological filter enhancing the biological treatment of wastewater (Sinha et al., 2008).

This study investigated the potential of applying the vermifiltration technology in the treatment of distillery wastewater in a bid to ease downstream contamination from the distillery industries.

2. Materials and methods

Vermifiltration of the distillery effluent was conducted in a 0.5 m × 0.5 m x 0.3 m vermifiltration bed which was prevented from direct exposure to the sun. A sample of 100 L for the distillery wastewater was obtained from a local distillery in Harare,

* Corresponding author. BioEnergy and Environmental Technology Centre, University of Johannesburg, South Africa.
E-mail address: mmanyuchi@uj.ac.za (M.M. Manyuchi).

https://doi.org/10.1016/j.sajce.2017.12.002
1026-9185/

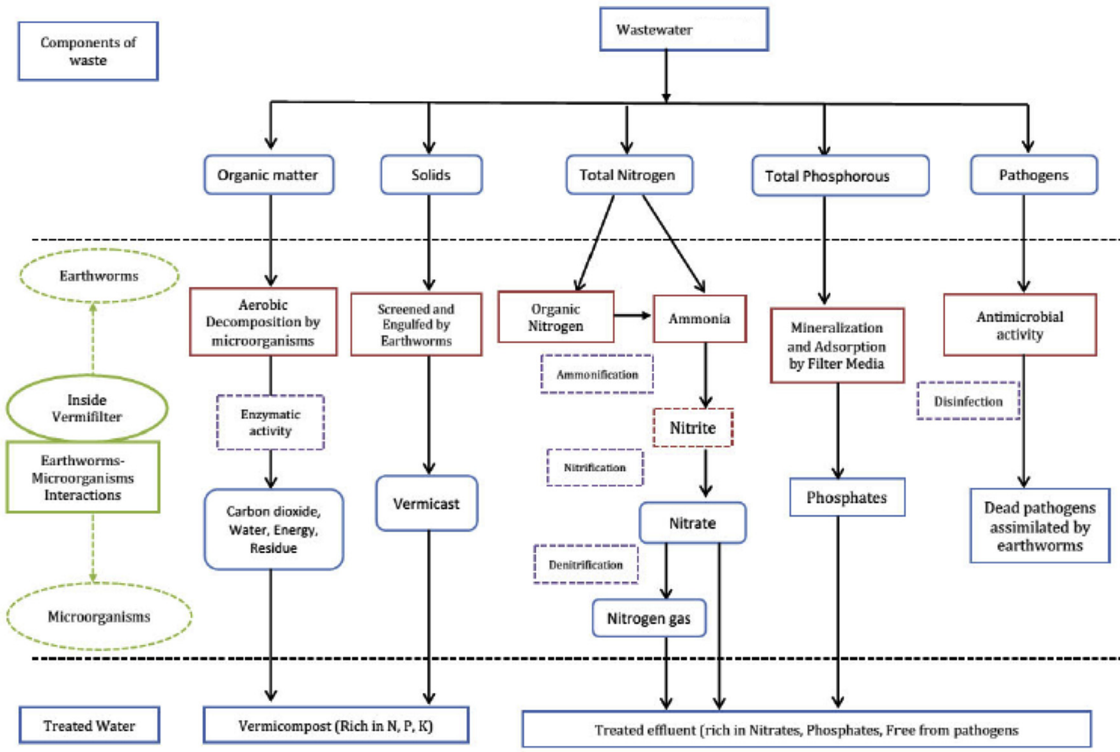

Fig. 1. Application of the vermifiltration technology in wastewater treatment (Gupta, 2016).

Zimbabwe. The gravel and sand for the vermifiltration bed were obtained locally and set up in accordance to Gupta (2016) as shown in Fig. 2.

Eisenia fetida earthworms were used as the earthworm of choice for the vermifiltration process and were obtained from the local fishermen. The earthworms were loaded at a rate of 10 kg/m^3 in accordance to Komarowski (2001). Temperature in the vermifiltration bed was operated under standard conditions with temperature assuming to be ranging between 25 ± 1 °C. The vermifiltration process was allowed to take place over a period of 40 h and the changes in the distillery effluent physicochemical parameters were noted after every 5 h. The working principle of the vermifilter is shown in Fig. 2 in accordance to the methodology described by Gupta (2016). The physicochemical properties of the distillery wastewater were measured using standard methods in accordance to APHA (2005). The pH was determined by a HI Hanna

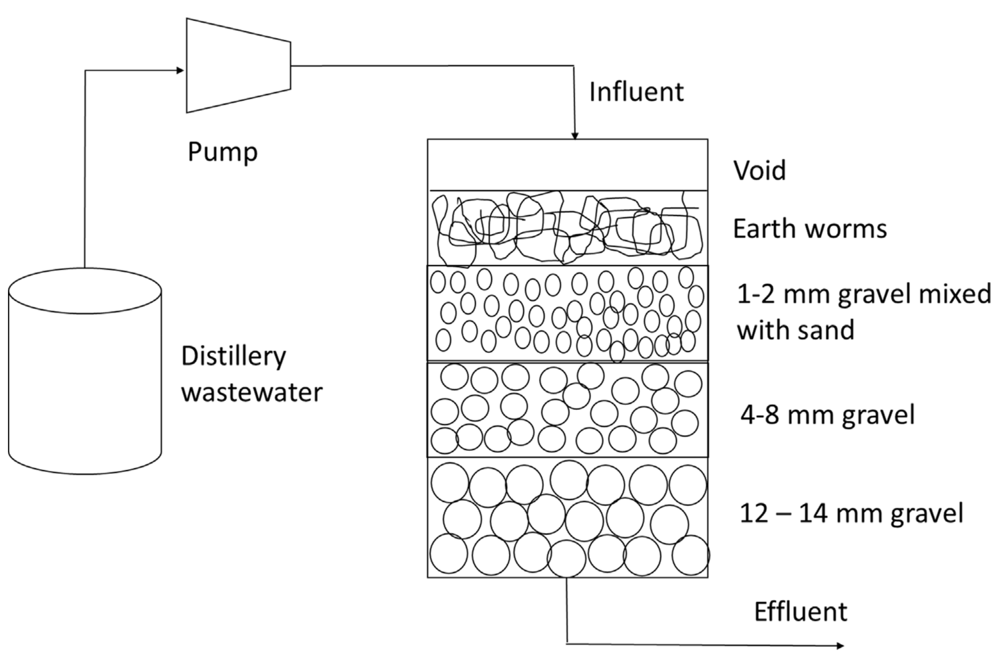

Fig. 2. Vermifiltration technology working principle.

instrument probe, the total organic carbon loading (TOC) in the vermicompost was determined by the Shimadzu TOC-V solid sample module (SSM-5000A). Vermicompost which accumulated on the vermifilter was removed and analysed for nitrogen, phosphorous and potassium (NPK) after a 30 day cycle. The NPK composition was determined using a Perkin Elmer 800 atomic absorption spectrophotometer.

3. Results and discussion

3.1. Raw distillery wastewater characteristics

The distillery effluent was characterized by high COD values (92 500.0 ± 500.0 mg/L), high BOD values (25 466.7 ± 814.5 mg/L) and high TDS (65 116.7 ± 600.7 mg/L). These characteristics made vermifiltration an interesting option for the distillery effluent treatment. A summary of the characteristics of the wastewater are shown in Table 1.

3.2. Effect of vermifiltration on distillery wastewater physicochemical parameters

3.2.1. Effect on pH

The pH of the distillery effluent changed from being acidic to neutral during the vermifiltration of distillery effluent (Fig. 3). The trend can be attributed to the removal of bio contaminants from the distillery effluent by the earthworms and their further conversion to vermicompost. Sinha et al. (2008) reported an almost similar trend in pH behaviour and this can be attributed to the removal of suspended solids in the distillery wastewater.

3.2.2. Effect on TKN

The TKN decreased by 94.9% in the distillery effluent during the vermifiltration process (Fig. 4). Xing et al. (2010) reported an almost similar result when they indicated that the TKN reduced by 62.3% when domestic wastewater was treated using *Eisenia fetida* earthworms using different types of vermifilter set up. The high decrease in this study can be attributed to the fact that high earthworm concentrations were used in this study increasing the distillery wastewater treatment efficiency.

3.2.3. Effect on BOD

The distillery effluent decreased by 91.1% during the vermifiltration process (Fig. 5). As the vermifiltration process occurs, the earthworms feed on the bio contaminants in the wastewater effectively lowering the BOD concentration. Sinha et al. (2008) reported a BOD decrease of more than 90% when sewage effluent was treated using a mixture of *E. Fetida*, *P. Excavatus*, and *E. Euginae* earthworms. Natarajan and Kannadasan (2015) also reported a 90% decrease in distillery wastewater BOD upon applying *Eudrilus Eugeniae* as the vermifiltration media.

Table 1
Raw distillery wastewater characteristics.

Parameter	Average value
pH	3.7±0.2
TKN	1173.3±25.2
BOD	25 466.7±814.5
TDS	65 116.7±600.7
TSS	3466.7±450.9
COD	92 500.0±500.0

*All parameters are in milligrams per litre except for pH.

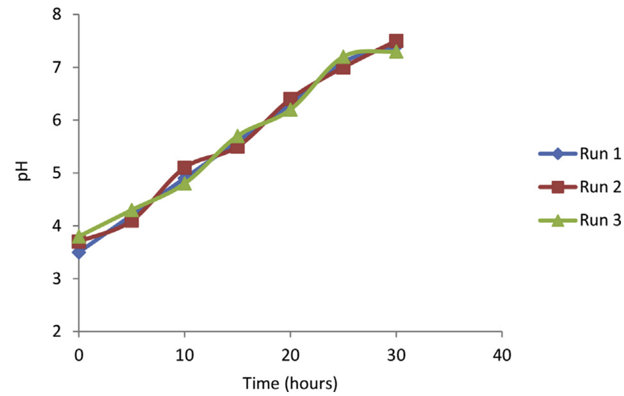

Fig. 3. Effect of vermifiltration on distillery effluent pH.

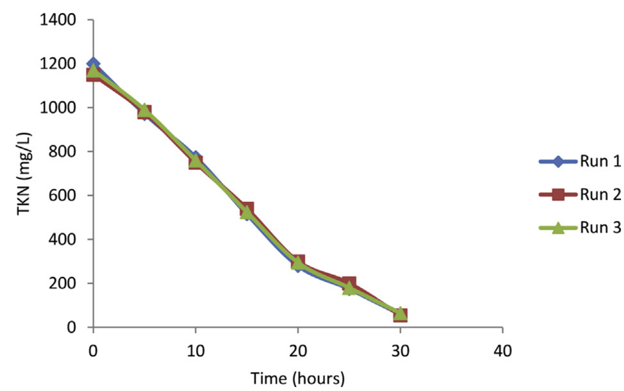

Fig. 4. Effect of vermifiltration on distillery effluent TKN.

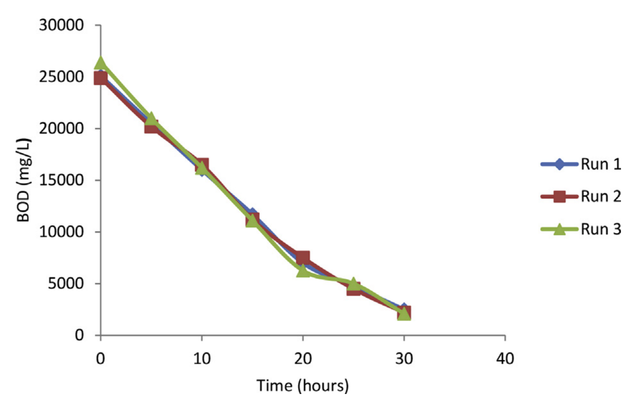

Fig. 5. Effect of vermifiltration on distillery effluent BOD.

3.2.4. Effect on TDS

The TDS in the distillery effluent decreased by 91.9% during the vermifiltration process (Fig. 6). There is potential for the TDS to accumulate in the vermifilter during the vermifiltration process resulting in decreased TDS concentrations. Previous studies by Sinha et al. (2008) reported TDS decreases of 90–92% when sewage wastewater was treated using the vermifiltration technology. This was further confirmed by Natarajan and Kannadasan (2015) who reported an 82% decrease in distillery wastewater TDS upon applying *Eudrilus Eugeniae* as the vermifiltration media.

3.2.5. Effect on TSS

The TSS reduced in the distillery wastewater upon treatment

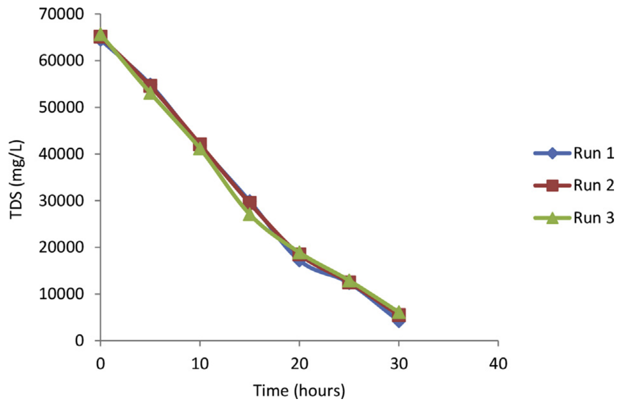

Fig. 6. Effect of vermifiltration on distillery effluent TDS.

using the vermifiltration technology by almost 92.4% (Fig. 7). The earthworms provided a bio filtration mechanism during the wastewater treatment period which allowed the total suspended solids to accumulate on the vermifilter thereby reducing the TSS concentration in the distillery wastewater and later converted to vermicompost. Sinha et al. (2008) reported a 90% decrease in sewage wastewater upon application of the vermifiltration period with a hydraulic retention period of 6–9 h. This was also confirmed by Natarajan and Kannadasan (2015) who reported an 88% decrease in distillery wastewater TSS upon applying *Eudrilus Eugeniae* as the vermifiltration media.

3.2.6. Effect on COD

The COD in the distillery wastewater decreased by 89.4% upon vermifiltration (Fig. 8). The decrease in the COD was attributed to both the decrease in the bio contaminants due to ingestion by earthworms during vermifiltration which has potential to effectively lower the COD. Previous studies reported COD decreases of between 80 and 90% when sewage wastewater was treated using a combination of *E. Fetida*, *P. Excavatus*, and *E. Euginae* earthworms (Sinha et al., 2008). In addition, Natarajan and Kannadasan (2015) also reported a 94% decrease in distillery wastewater COD upon applying *Eudrilus Eugeniae* as the vermifiltration media.

A summary of the distillery effluent after treatment with vermifiltration is given in Table 2. The treated distillery effluent can be used as irrigation water lowering the demand from other water bodies.

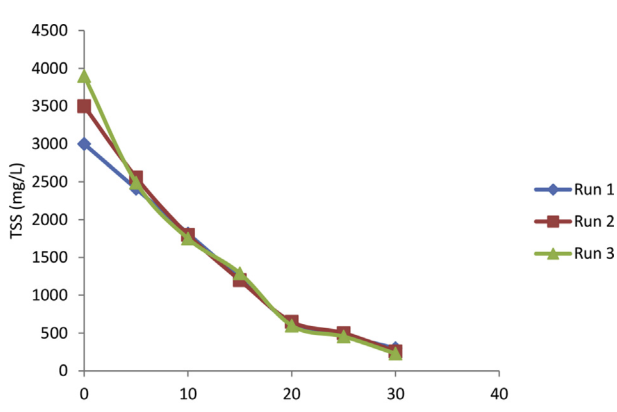

Fig. 7. Effect of vermifiltration on distillery effluent TSS.

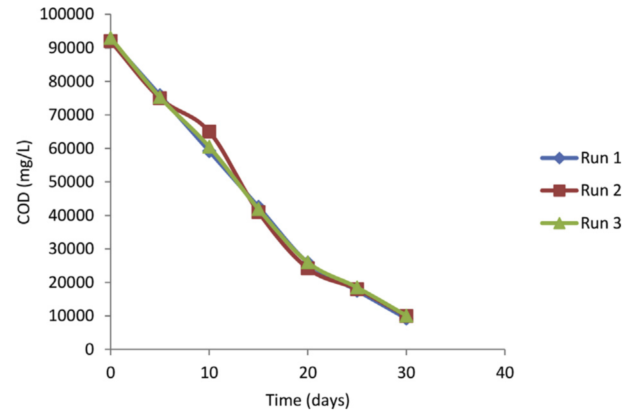

Fig. 8. Effect of vermifiltration on distillery effluent COD.

Table 2
Distillery effluent characteristics after treatment with vermifiltration.

Parameter	Average value
pH	7.3 ± 0.1
TKN	60.0 ± 5.0
BOD	2266.7 ± 208.2
TDS	52766.7 ± 971.3
TSS	263.3 ± 35.1
COD	9783.3 ± 464.6

*All parameters are in milligrams per litre except for pH.

Table 3
Vermicompost properties from the distillery effluent.

Parameter	Average value
pH	6.9 ± 0.1
TOC (%)	62.7 ± 0.2
COD (mg/L)	1785 ± 4
BOD (mg/L)	825 ± 5
TN (%)	1.87 ± 0.09
P (%)	0.87 ± 0.07
K (%)	0.66 ± 0.03

3.3. Vermicompost properties

Vermicompost, a bio fertilizer was produced during the vermifiltration process as the earthworms fed on the organic matter in the distillery effluent. The characteristics of the vermicompost obtained from the distillery sludge are given in Table 3.

4. Conclusion

The vermifiltration technology can be used to effectively treat distillery wastewater which has high solids content and is highly biodegradable. The COD, BOD, TKN, TSS and TDS were significantly reduced by more than 90% during the 40 h vermifiltration process. The treated distillery effluent can be used for irrigation purposes. In addition, vermicompost, a bio fertilizer which was rich in NPK was produced as part of the vermifiltration process.

Conflicts of interest

The authors declare no conflict of interest.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.sajce.2017.12.002.

References

Anusha, V., Sundar, K.M.S., 2015. Application of vermifiltration in domestic wastewater treatment. Int. J. Innov. Res. Sci. Eng. Technol. 4 (8), 7301–7304, 2015.

APHA, 2005. Standard Methods for the Examination of Water and Wastewater, twenty-first ed. American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC.

Gupta, S.A., 2016. Mainstreaming Citywide Sanitation-opportunities and Challenges for Excreta Management Vermi-filtration for Faecal Waste Treatment. Centre for Science and Environment, New Delhi, 4-5 April, 2016.

Komarowski, S., 2001. Vermiculture for sewage and water treatment sludge. Water, Publication of Australian Water and Wastewater Association, pp. 39–43. July 2001.

Natarajan, N., Kannadasan, N., 2015. Effect of earthworms on distillery effluent treatment through vermifiltration. Int. J. Eng. Res. Afr. 5 (12), 102–106.

Rajpal, A., Bhargava, R., Chopra, A.K., 2011. Stabilization of anaerobic digester sludge through vermicomposting. J. Appl. Nat. Sci. 3 (2), 232–237.

Shivajirao, P.A., 2012. Treatment of distillery wastewater using membrane technologies. Int. J. Adv. Eng. Res. Stud. 1 (3), 275–283.

Sinha, R.K., Bharambe, G., Chaudhari, U., 2008. Sewage treatment by vermifiltration with synchronous treatment of sludge by earthworms, with synchronous treatment of sludge by earthworms: a low-cost sustainable technology over conventional systems with potential for decentralization. Environ. Int. J. Environ. Prof. 28 (4), 49–420.

Xing, M., Li, X., Yang, J., 2010. Treatment performance of small-scale vermifilter for domestic wastewater and its relationship to earthworm growth, reproduction and enzymatic activity. Afr. J. Biotechnol. 9 (44), 7513–7520.