Poll Res. 40 (2) : 457-460 (2021)

ISSN 0257–8050

VERMI-BIOFILTRATION FOR REMOVAL OF CHEMICAL AND BIOLOGICAL POLLUTANTS FROM MUNICIPAL WASTEWATER FOR AGRICULTURE – A REVIEW

BISWAS, AMIT*[A]

*[a]*Agricultural & Food Engineering Department, IIT Kharagpur, India*
[a] Assistant Professor, School of Agriculture & Bio-Engineering, CUTM, Paralakhemundi, Odisha, India
[a] Corresponding author at: Agricultural & Food Engineering Department, IIT Kharagpur, Kharagpur 721 302, West Bengal, India
School of Agriculture & Bio-Engineering, CUTM, Paralakhemundi, Odisha 761211, India

(Received 15 August, 2020; accepted 30 September, 2020)

ABSTRACT

Direct application of raw municipal wastewater in irrigation may create many undesirable harmful consequences. Therefore, the treated effluent through different technologies is generally preferred for reuse. In the present study, the performance of vermi-biofiltration (VBF) for removal of chemical and biological impurities from municipal wastewater was reviewed. The study revealed that the treated water quality varied depending on the hydraulic retention time (HRT). The removal efficiency of BOD, COD, fecal coliforms, *E. coli* and other biological impurities by VBF was found to be more than 90% in some cases. Simultaneously, VBF was also capable to eliminate all undesirable substances with minimum cost by preserving all essential plant nutrients. The low operational and maintenance costs may make VBF viable for developing countries.

KEY WORDS : BOD, COD, Coliforms, Municipal wastewater, Vermi-biofiltration.

INTRODUCTION

Water is an invaluable resource on the earth. The total volume of available water on the earth is about 1.39×10^9 km^3 with 97.50% salty and 2.50% fresh ones. Rapid population growth, rapid urbanization, industrialisation and advanced lifestyles will lead to an unprecedented increase in freshwater demand in the future. Therefore, alternative water resources will be very much essential to satisfy the unparalleled freshwater demand (AbdEL-rahman *et al*., 2015). Agriculture is the largest water user worldwide and it is expected that its share would decrease in future to meet the water demands of other sectors. In such a critical situation, treated municipal wastewater can play an important role as an alternative source of water particularly for irrigation. The use of properly treated water may be economically feasible for the poor farmers also.

Municipal wastewater contains different types of harmful chemical and biological contaminants. These impurities affect agricultural crops as well as our environment. The concentrations of these elements in raw wastewater beyond certain standard quantity cause harmful effects to human bodies. Therefore, the raw wastewater must be purified effectively before application. For the treatment of municipal wastewater, different technologies are practiced in the different parts of the world. These different technologies are waste stabilisation pond (Naddafi *et al*., 2009), vermi-filtration (Manyuchi *et al*., 2013), membrane bio-reactor (Zhang *et al*., 2010), up-flow anaerobic sludge blanket reactor (Kasaudhan *et al.,* 2013), constructed wetlands (Abou-Elela *et al.,* 2012) etc. The performances and intricacies of these technologies in removing different contaminants vary from one to another.

With this background, the present study aims to review the performance of vermi-biofiltration

method for making municipal wastewater suitable for irrigation purpose.

MATERIALS AND METHODS

Chemical and Biological parameters

The vital chemical contaminants are: hydrogen ion activity (pH), total dissolved solids (TDS), biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (TN), total phosphorus (TP), calcium (Ca), sodium (Na), iron (Fe), heavy metals like cadmium (Cd), chromium (Cr), lead (Pb), arsenic (As) etc., chloride, sodium adsorption ratio (SAR), electrical conductivity (EC) etc. (Alobaidy *et al.*, 2010). The principal biological impurities of wastewater include fecal coliform (FC), total coliform (TC), helminth egg (HE) etc. (Kadam *et al.*, 2009).

Irrigation Standard Quality for chemical and biological parameters

The allowable limits of different chemical and biological properties of wastewater for irrigation purpose are discussed in this section. The standard level of different chemical and biological impurities provided by United States Environmental Protection Agency (USEPA; United States) and Food and Agricultural Organisation (FAO; Italy) are presented in Table 1.

Vermi-biofiltration (VBF) method

General Information

The usage of worms in wastewater or sewage treatment is called vermi-biofiltration (Tomar and Suthar, 2011). Earthworm's body acts as a biofilter in wastewater treatment. The VBF is a sort of new innovation that gives a reasonable answer for the treatment of wastewater with synchronous sewage lessening and treatment (Krishnasamy *et al.*, 2013).

Working Principle

This treatment method (Fig. 1) is the combination of traditional filtration mechanisms and vermi-composting systems. Raw wastewater is treated by this method through the earthworms. Earthworms disintegrate organic particles into small particles and increase hydraulic conductivity and aeration of those organic substances. Earthworms increase total specific surface area of media particles by grinding them and increase the contaminant adsorption capability of the filter. Biodegradation, microbial simulation and enzymatic degradation of waste solids were brought about by earthworms in this filter.

RESULTS AND DISCUSSIONS

Performance of VBF

The utilization of earthworms for purification of wastewater is called vermi-filtration (Tomar and Suthar, 2011). This method has capability to produce odourless, disinfected and highly nutritive treated water (Xing *et al.*, 2011; Arora *et al.*, 2014). Therefore, it is an environment friendly treatment method (Manyuchi *et al.*, 2013). Xing (2008) did research on municipal wastewater treatment using this vermifilter with two filter medium like quartz sand and ceramisite grain. The performance of the ceramisite grain was 15.07%, 7.39% and 49.70% better in terms of COD, BOD and NH_4-N removal than the quartz sand medium. On the other hand, no obvious removal of TN and TP was observed during this experiment. More organics were used by the earthworms for their movement in ceramisite grain media. The results of the study indicated that the ceramisite grain medium was less damaged than the quartz sand under identical experimental situations. The study concluded that this VBF technique was more appropriate than the conventional activated sludge method for small towns in Southern China. The total cost involved in this method was found to be 36% lower than that of CAS. Tomar and Suthar (2011) compared the performance of vermi-biofilter and vertical subsurface-flow constructed wetlands. VBF was found to be more effective in this study for removal of impurities from wastewater. Kumar *et al.* (2015) used different types of natural ingredients like river bed material, glass ball, wood coal and mud balls as filter media in vermi-filter for wastewater treatment. Among those four types of filter media, river bed materials performed the best in terms of BOD (81.20%) and COD (72.30%)

Fig. 1. Flow diagram of VBF process

removal. This media also performed excellent in removal of FC, total coliform, fecal streptococci and *E. coli*. This study suggested that the produced vermi-compost was suitable for sewage farming as it was rich in phosphate and nitrate. The vermi-filtration for wastewater treatment is economically feasible (Arora *et al.*, 2014). Jiang *et al.* (2016) reviewed and reported the possibility of 98% BOD and 81% COD removal efficiency from raw wastewater by this method. The chemical quality of treated effluent was also found as comparable with that of other methods like MBR, WSPs and batch reactor. The study emphasized on proper earthworm species, different types of filter materials (like agricultural wastes and industrial by-products) and integration with some traditional methods for better performance of this technique. Lourenco and Nunes (2017) recommended multistage VBFs (98.50% BOD, 74-91% COD removal efficacy) as compared to single stage for gaining better quality effluents. Singh *et al.* (2017) documented 78-98% BOD and 64-95% COD removal efficiency by this method with HRT of 2-9 h. Addy *et al.* (2019) exposed that this VBF technique had the capability to remove the different types of bacteria (like *E. Coli*) and fungi (like *Aspergillus*) by 68-98% from raw influent.

Advantages and limitations of VBF

The principal advantages as well as limitations of the VBF method were provided in Table 2.

Table 1. Water quality standard according to USEPA and FAO guidelines

Serial No.	Chemical and Biological Parameters	Unit	Guidelines	
			USEPA	FAO
1.	pH	*	6.50-8.40	6.50-8.50
2.	Total dissolved solid (TDS)	mg/l	<450	2000
3.	Biochemical oxygen demand (BOD)	mg/l	10	**
4.	Chemical oxygen demand (COD)	mg/l	**	**
5.	Total Nitrogen (TN)	mg/l	**	30
6.	Total Phosphorus (TP)	mg/l	**	**
7.	Potassium (K)	mg/l	**	0-2
8.	Calcium (Ca)	mg/l	**	400
9.	Magnesium (Mg)	mg/l	**	60
10.	Sodium (Na)	mg/l	<69	900
11.	Iron (Fe)	mg/l	5.00	5.00
12.	Cadmium (Cd)	mg/l	0.01	0.01
13.	Cromium (Cr)	mg/l	0.10	0.10
14.	Zinc (Zn)	mg/l	2.00	**
15.	Lead (Pb)	mg/l	5.00	2.00
16.	Nickel (Ni)	mg/l	0.20	5.00
17.	Boron (B)	mg/l	0.75	0-2
18.	Chloride (Cl)	mg/l	<70	1100
19.	Sodium adsorption ratio (SAR)	*	<3	15
20.	Electrical Conductivity (EC)	dS/m	<0.70	3.00
21.	Copper (Cu)	mg/l	0.20	0.10
22.	Cobalt (Co)	mg/l	0.05	0.05
23.	Fluoride (F)	mg/l	1.00	**
24.	Arsenic (As)	mg/l	0.10	**
25.	Fecal Coliform (FC)	Count per 100 Ml	23	< 200

Table 2. Advantages and Limitations of VBF

Name of Technology	Advantages	Limitations
VBF	Environment friendly, non-labour intensive and low cost wastewater treatment method. There is also no sludge formation in this reclamation technology.	Sufficient healthy appetite and suitable environment are essential for earthworms' living and growth. Otherwise, they will die.

CONCLUSION

The chief chemical properties of municipal wastewater are pH, TDS, BOD, COD, TN, TP, Ca, Na, K, different types of heavy metals, SAR and EC. The principal biological impurities include FC, total bacteria and *E. coli*. On the basis of review, the following conclusions can be derived.

- The treated water quality in terms of concentrations of different chemical and biological impurities varies depending on the HRT.
- The BOD, COD and *E. Coli* removal efficiency of VBF was found to be more than 90%.

The study recommended this low cost and eco-friendly single stage as well as multistage VBF for developing countries to remove undesirable substances from municipal wastewater by preserving essential plant nutrients.

ACKNOWLEDGEMENT

The author wishes to thank the Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur for providing facilities for carrying out this research in related area.

REFERENCES

AbdEL-rahman, A. M., AbdEL-halim, A., A. M. Gad, A., Hashem, M. 2015. Assessment of waste stabilization ponds for the treatment of municipal wastewater in Upper Egypt. *Assessment.* 5(1).

Abou-Elela, S. I. and Hellal, M. S. 2012. Municipal wastewater treatment using vertical flow constructed wetlands planted with Canna, *Phragmites and Cyprus. Ecol. Eng.* 47 : 209-213.

Addy, J. V., Aguoru, C. U., Imandeh, N. G., Azua, E. T. and Olasan, J. 2019. Studies on Vermifiltration of Restaurant Effluent and Reuse in Benue State, North Central, Nigeria. *IJEAB.* 4(2).

Alobaidy, A. H. M. J., Al-Sameraiy, M. A., Kadhem, A. J. and Majeed, A. A. 2010. Evaluation of treated municipal wastewater quality for irrigation. *J. Environ. Prot.* 1(3) : 216.

Arora, S., Rajpal, A., Bhargava, R., Pruthi, V., Bhatia, A. and Kazmi, A. A. 2014. Antibacterial and enzymatic activity of microbial community during wastewater treatment by pilot scale vermifiltration system. *Bioresour. Technol.* 166 : 132-141.

Jiang, L., Liu, Y., Hu, X., Zeng, G., Wang, H., Zhou, L., and Liu, S. 2016. The use of microbial-earthworm ecofilters for wastewater treatment with special attention to influencing factors in performance: a review. *Bioresour. Technol.* 200 : 999-1007.

Kadam, A. M., Nemade, P. D., Oza, G. H., Shankar, H. S. 2009. Treatment of municipal wastewater using laterite-based constructed soil filter. *Ecol. Eng.* 35(7) : 1051-1061.

Kasaudhan, G. K., Mumtaz, N. and Raj, V. 2013. Optimization of municipal wastewater treatment by UASB reactor and polising pond. *Biolife.* 1(4) : 200-207.

Krishnasamy, K., Nair, J., Hughes, R. J. 2013. Vermifiltration systems for liquid waste management: a review. *Int. J. Environ. Waste Manage.* 12 (4) : 382-396.

Kumar, T., Bhargava, R., Prasad, K. S. H., Pruthi, V. 2015. Evaluation of vermifiltration process using natural ingredients for effective wastewater treatment. *Ecol. Eng.* 75 : 370-377.

Lourenço, N. and Nunes, L. M. 2017. Optimization of a vermifiltration process for treating urban wastewater. *Ecol. Eng.* 100 : 138-146.

Manyuchi, M. M., Kadzungura, L., Boka, S. 2013. Vermifiltration of Sewage Wastewater for Potential Use in Irrigation Purposes Using *Eisenia fetida* Earthworms. *World Academy of Science, Engineering and Technology.* 78.

Naddafi, K., Hassanvand, M. S., Dehghanifard, E., Faezi Razi, D., Mostofi, S., Kasaee, N., Nabizadeh, R. and Heidari, M. 2009. Performance evaluation of wastewater stabilization ponds in Arak-Iran. *J. Environ. Health Sci. Eng.* 6 : 41-46.

Singh, R., Bhunia, P. and Dash, R. R. 2017. A mechanistic review on vermifiltration of wastewater: design, operation and performance. *J. Environ. Manage.* 197 : 656-672.

Tomar, P. and Suthar, S. 2011. Urban wastewater treatment using vermi-biofiltration system. *Desalination.* 282 : 95-103.

Xing, M. Y. 2008. *Study on the performance of vermin-biofilter for municipal wastewater treatment.* PhD diss., Doctoral Thesis. University of Tongji, China.

Xing, M., Yang, J., Wang, Y., Liu, J. and Yu, F. 2011. A comparative study of synchronous treatment of sewage and sludge by two vermifiltrations using an epigeic earthworm *Eisenia fetida*. *J. Hazard. Mater.* 185 : 881-888.

Zhang, X., Wang, Z., Wu, Z., Lu, F., Tong, J. and Zang, L. 2010. Formation of dynamic membrane in an anaerobic membrane bioreactor for municipal wastewater treatment. *J. Chem. Eng.* 165 (1) : 175-183.