ZERO DISCHARGE OF WASTE WATER FROM JUICE MAKING INDUSTRY USING VERMI-BIO-FILTRATION TECHNOLOGY

Ghatnekar, S.D., Ghalsala-Dighe, D.S. and Ghatnekar, S.S.,
Biotechnology Resource Centre, India
Email: brc_suvash@hotmail.com

The paper describes the novel vermi-bio-filtration technology developed by BRC to treat the liquid effluents produced by Gujrat based juice making industry into bio-clean and bio-safe water. The treated bio-clean water can be used to clean floors and vessels as well as for any secondary purpose except for drinking.

Around 80-85 sq. m area is required to set-up this novel plant having capacity to treat 12,000 liters of effluents everyday. The multi-stage plant consists of four vermi-bio-filters. The principle of trickling filter is used in the system. Each vermi-bio-filter is accompanied by a sump and upper layer consists of sterilized bedding material inclusive of selected microorganisms, enzymes and worms. This layer has to be replaced after 6-8 months and the resultant biomass with specific pre-treatment could be used as pro-biotic nutrient for the crops. The COD of wastewater was reduced from 12,000 ppm to less than 200 ppm. The total recurring cost to treat 12,000 liters effluents everyday works out to be Rs. 50-60 (£ 0.75-85) whereas, in the conventional ETP plant, the running costs will be Rs. 5000-6000 (£ 7.5-10). The capital cost of the plant is also 6-7 times less than the conventional ETP plant.

In fine, the implementation of this innovative technology results not only into pollution abatement but into zero discharge as well.

Keywords

Earthworms, enzymes, microorganisms, pollution abatement, vermi-bio-filter, wastewater, zero discharge.

Introduction

In the recent past, developing countries like India have changed their approach towards the treatment of liquid effluents. The research has been intensively directed towards simpler, energy saving, environmentally bio-safe and cost-effective technological solutions. In addition, the environmental regulations by Pollution Control Boards have undergone vast changes. As a result, conventional treatment technologies have been further refined and new technologies for wastewater treatment are being implemented and/or are in the development stage to meet increasingly more stringent water quality criteria (Kumar *et al*. 2008). Today, most of the wastewater treatment plants have started looking for biotechnological alternatives in their systems. Apart from the benefits of improved capacity, efficiency and lowered operative costs, microorganisms, enzymes and earthworms also keep the treatment process as natural as possible.

Amongst the varied biotechnological methods of wastewater treatment adopted, vermiculture biotechnology and microbial wastewater treatments are gaining wide popularity. Earthworms have proved to be master bio-processing agents for the management of organic effluents from diverse sources ranging from domestic sewage to industrial refuse (Ghatnekar *et al.* 2000). Startlingly, they convert effluents that are an undesirable nuisance into coveted plant probiotics in the form of soil-conditioners. The use of microorganisms is also considered as an integral part of the wastewater treatment process. Higher concentration of microorganisms is able to remove the organic matter from the water at a faster rate, particularly in the case of lagoon systems where it can take several months for the complete degradation process. In this context, Biotechnology Resource Centre, India has developed a novel technology using multi-stage vermi-bio-filters with the key objective of converting industrial liquid effluents into 'bio-safe' and 'bio-clean' water.

Since last 30 years, Biotechnology Resource Centre, India has contributed towards uniting the environment and economy by developing innovative, 'bio-safe' waste treatment technologies of global importance (Ghatnekar and Kavian 1992; Ghatnekar *et al.* 2009a). BRC has successfully commissioned vermiculture-based effluent treatment plant (ETP) in diverse industrial units (Ghatnekar *et al.* 1995; Kavian and Ghatnekar 1999). The developed "three-tier vermiculture biotechnology" involves the synergistic action of selected enzymes, microorganisms and earthworms for degradation of complex organic wastes in both the solid and liquid forms and convert them into useful plant probiotics (Ghatnekar *et al.* 2009a,b).

Vermi-bio-filtration is a relatively new technology to process organically polluted water using earthworms as biofilters (Ghatnekar and Kavian, 2000, Sinha *et al.* 2007; Li *et. al.* 2009). Biotechnology Resource Centre (BRC) has developed a new treatment technology incorporating the use of microorganisms, earthworms and enzymes to convert the redundant waste water into bio- safe and bio-clean water which can be used for various secondary purposes except for drinking. The vermi-bio-filtration-based wastewater treatment plant has been successfully commissioned by BRC at Orient Vegetexpo Ltd., Dindori, Nashik (Ghatnekar *et al.* 2000) and in gelatine manufacturing company at Gujarat (Ghatnekar *et al.* 2010). In fact in the last four years this technology is implemented in many chemical industrial set ups in Vadodara, Gujarat resulting into zero discharge of wastewater.

This paper illustrates the use of state-of-the-art vermi-bio-filtration technology to treat the redundant wastewater from Gujarat based juice industry into "bio-clean" and "bio-safe" water. This water is successfully used by the industry for secondary purpose like vessel and floor washing, toilet-flushing, gardening and irrigation etc. except for human consumption.

The scenario: Wastewater from juice making industry

The juice making industry in Gujarat produces around 12,000 litres of liquid effluent everyday. This effluent mainly contains traces of fruit pulp, sugars and chemical preservatives used for juice processing and also some organic solvents used for the washing the vessels after juice production. Due to these additives, COD of the wastewater is as high as 12,000-14,000 ppm. In addition, the sugar content is around 1,800-2,000 ppm. The organic solvents (approximately 2% of the wastewater) also make the situation worse for the treatment of this wastewater. Due to this and the stringent norms put forth by Gujarat Pollution Control Board, discharge of this wastewater was a major challenge for the company. The treatment of this enormous quantity of wastewater was a big financial burden for the concerned industry.

The major setback in the juice industry effluent treatment is low pH values, imbalance of nutrients and considerable fluctuation in the quantity of effluent and waste matter produced (Austerman-Haun *et. al.,* 1997). Ozbas *et. al.* (2006) tried reducing the high COD levels of raw effluents from juice industry with the help of aerobic and anaerobic biological effluent treatments. Similar studies were carried out by El-Kamah *et. al.* (2010) using batch activated sludge (AS) system and two-stage up-flow anaerobic sponge reactors (UASRs).

BRC, India developed tailor-made treatment technology for the concerned industry with the idea of 'zero-discharge' of the wastewater. This treatment includes the application of vermi-bio-filtration technology to convert the liquid effluent using synergistic action of the selected microorganisms, enzymes and earthworms into bio-clean and bio-safe crystal clear water. This water can be used for secondary purpose within the industry like cleaning, washing of plant reactors and floor, gardening and toilet use etc. Application of this treatment technology has not only helped the industry but protecting the environment too.

Vermi-bio-filter Treatment Technology

The vermi-bio-filtration technology involves use of synergistic activity of the selected microorganisms, enzymes and earthworms for the degradation of toxins from the waste water converting it into "bio-clean" and "bio-safe" crystal clear water. This technology has proved to be the best environment -friendly and cost-effective solution for this industry.

Treatment Set up

Around 80-85 sq. m area is required to set-up this novel plant having capacity to treat 12,000 Liters of effluents every day. The four-stage vermi-bio-filter plant consists of four 'Sintex' tanks each of 10,000 liters capacity (Figure 1 & 2). All the four tanks are connected together. The principle of trickling filter is used in the system. The lower most layer of each tank consists of coarse rubble. This is followed by layer of semi-crushed bricks and double layer of gravel and fine sand. The upper most layer consists of semi-sterilized bedding material inoculated with selected and effective microorganisms, enzymes and earthworms. The topmost layer however, needs to be replaced after six-eight months of operation. All four tanks have been planted with 25 seedlings of Canna. The roots of these plants absorb and degrade the pollutants by osmotic filtration apart from giving aesthetic and ornamental appearance to the vermi-bio-filtration system.

Figure 1: Vermi-bio-filter tank set up

Figure 2: Vermi-bio-filters with buffer tank

The treatment plant is designed for perpetual operations. Every day, 12,000 liters of raw effluent is allowed to pass through all the 4 tanks in succession. The total process completion time is more or less instant. The discharged vermi-filtered water from fourth tank is collected in another storage tank with the capacity of 25,000 liters. This water is crystal clear and bio-safe to use for secondary purposes except drinking.

Results and Discussion

The analysis of wastewater during vermi-bio-filtration treatment is given in Table 1. The filtered water collected from fourth vermi-bio-filter tank is crystal clear with no offensive odour whatsoever and 100% "bio-safe" and "bio-clean" to use for secondary purposes except drinking.

The pH was observed to be almost neutral (7-7.3 ± 0.06) at the end of the treatment. The COD of wastewater is reduced from 12000-14000 ± 11.45 ppm to less than 200-185 ± 12.66 ppm. Also significant reduction was observed in the BOD of the waste water i.e., 95-80 ± 11.05 ppm at the end of the treatment. The total recurring cost to treat 12,000 liters effluents everyday works out to be Rs. 50-60 (£ 0.75-85) whereas, in the conventional ETP plant, the running costs will be Rs. 5000-6000 (£ 7.5-10). The capital cost of the plant is also 6-7 times less than the conventional ETP plant. In addition the said juice making Company saves the water bills; since the treated water is re-used and re-circulated for secondary purposes.

Table 1: Analysis of wastewater from juice making industry during vermi-bio-filtration treatment

Parameters	Before treatment	Vermi-bio-filter 1	Vermi-bio-filter 2	Vermi-bio-filter 3	Vermi-bio-filter 4
pH	5.5-6.1 ± 0.07	6.4-6.8 ± 0.11	6.6-6.8 ± 0.13	7.1-7.5 ± 0.04	7-7.3 ± 0.06
BOD (ppm)	550-475 ± 13.23	330-290 ± 8.78	225-160 ± 11.48	130-110 ± 9.85	95-80 ± 11.05
COD (ppm)	12000-14000 ± 11.45	7500-6000 ± 15.22	3400-2100 ± 14.32	1200-750 ± 11.09	200-185 ± 12.66

COD, chemical oxygen demand; BOD, biological oxygen demand.
Each value is average of 5 observations ± Standard Error of the mean, Values significant at P value < 0.0005

The growth of Canna plants was also satisfactory in I tank and progressively excellent in second, third and fourth tanks. The biomass harvested after 6-8 months from the uppermost layer of all the tanks was used as 'Probiotic biofertilizer' after specific pre-treatment. The schematic representation of vermi-bio-filtration treatment technology for zero discharge of industrial wastewater is given in Figure 3.

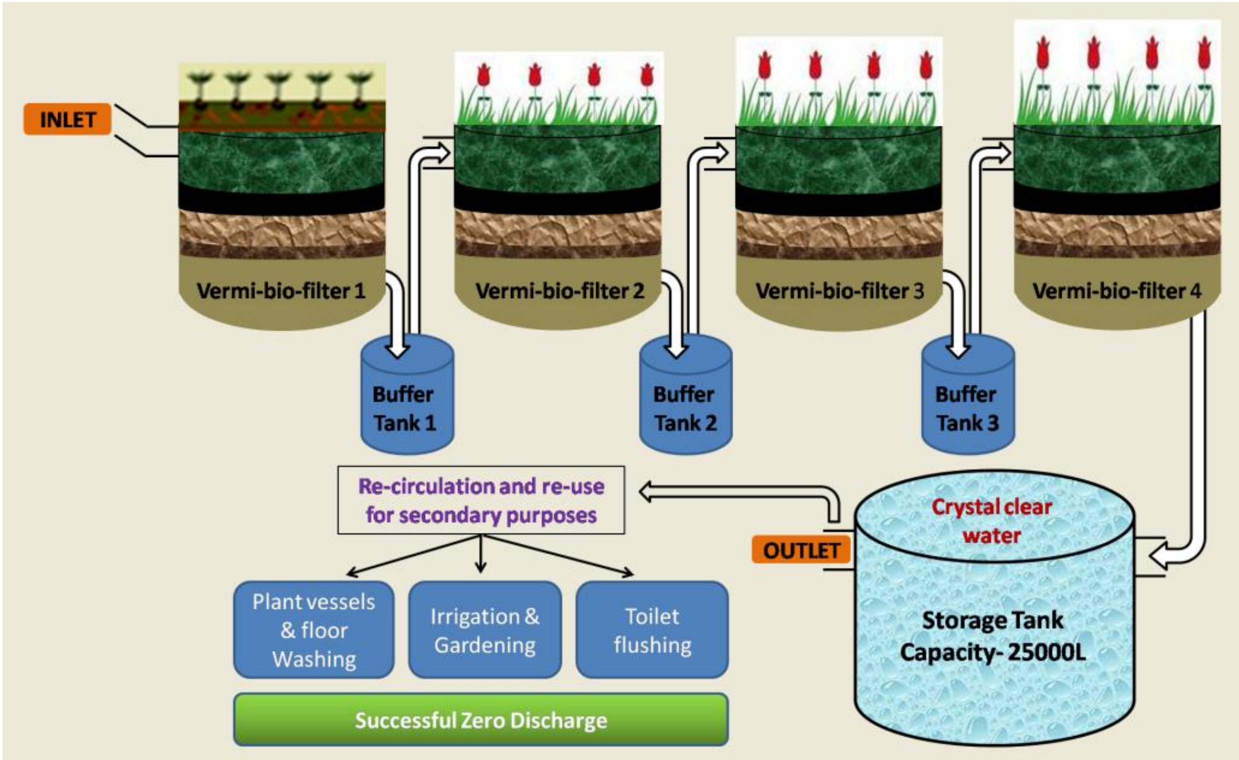

Figure 3: Vermi-bio-filtration treatment technology for successful zero discharge of wastewater

Synergistic action of enzymes, microorganisms and earthworms in vermi- bio-filtration

The role of different types of enzymes, microorganisms, and earthworms for effluent treatments has been previously reported. However, their potential exploitation in effluent degradation in the most optimal way can be attained by their synergistic action in three-tier vermiculture biotechnology (Ghatnekar *et al*. 2009a,b) that was applied in the bedding material layer of the vermi-bio-filter system used in the present study.

Kavian and Ghatnekar (1999) carried out extensive studies on cellulases from *L. rubellus.* Their studies confirmed that enzymes can act on specific recalcitrant pollutants to remove them by precipitation or transformation to other products. They can also change the characteristics of a given effluent to render it more amenable to treatment or aid in converting effluent material to value-added products.

Kavian and Ghatnekar (1991) also conducted studies on the bio-management of dairy effluents using an *L. rubellus* culture and concluded that sludge cake could support the growth of earthworms without processing. Kavian *et al.* (1996) studied the bio-management of paper mill sludge using vermiculture biotechnology. *L. rubellus* were used to treat approximately 1.5 tonnes of the sludge coming out of the mill daily. The sludge was successfully converted into biofertilizer and plant tonics.

The studies of Hamdi *et al.* (1991) indicated the use of *Aspergillus niger* as an efficient means of protein waste bio-conversion while working on waste-water from an olive mill. Kavian and Ghatnekar (1998) demonstrated the utility of fungal species viz., *A. flavus* and *A. niger* in the treatment of pharmaceutical waste. In a separate study, Ghatnekar et al. (2009c) reported bio-management of liquid effluents discharged after secondary treatment from the gelatine manufacturing industry using a combination of *A. flavus* and *A. niger.*

In the present study, the liquid effluents discharged in each vermi-bio-filter tank were subjected to degradation by selected enzymes, microorganisms and earthworms in each of the tank. These three components synergistically degraded the organic and inorganic contents of the liquid effluents, thereby initiating a series of alternate aerobic and anaerobic microbial reactions, causing an exponential increase in the population of selected microorganisms.

Significance of earthworms and microorganisms in vermi-bio-filtration

Organic matter degraded by the selected microorganisms was further digested by colonies of earthworms living in bedding material. Various actinomycetes inhabiting the earthworms' guts also triggered degradation of solid contents. According to Sinha *et al.* (2008), earthworms' body works as a 'biofilter' and they have been found to remove BOD by over 90%, COD by 80–90%, total dissolved solids (TDS) by 90–92%, and the total suspended solids (TSS) by 90–95% from wastewater by the general mechanism of 'ingestion' and biodegradation of organic wastes, heavy metals, and solids from wastewater and also by their 'absorption' through body walls. Zhao *et al*. (2010) reported an intensified bacterial diversity in the vermi-filtration due to the presence of earthworms (*Eisenia foetida*), especially in response to nutrients in their casts. Earthworms and microorganisms cooperate in vermi-bio-filter to ingest and biodegrade organic wastes and other contaminants in wastewater. This extends the food chain in normal bio-processes and thus greatly improves sewage treatment efficiency (Li *et al.* 2009).

Earthworms increase the hydraulic conductivity and natural aeration by granulating clay particles (Ghatnekar *et al.* 2000). They also grind silt and sand particles, increasing the total specific surface area, which enhances the ability to 'adsorb' organic and inorganic matter from wastewater. Intensification of soil processes and aeration by earthworms enable the stabilization of soil and the filtration system to become effective and smaller in size (Ghatnekar *et al.* 1995; Sinha *et al.* 2008).

Zhao *et al*. (2010) observed that the presence of earthworms in vermi-filter led to significant stabilization of sludge by enhancing the reduction of volatile suspended solids. Specifically, earthworms in the vermi-bio-filter were capable of transforming insoluble organic materials to a soluble form and then selectively digesting the sludge particles to a finer state, which facilitated further degradation of organic materials by the microorganisms in the reactor.

Applications of vermi-bio-filter technology

The growth of Canna plants in the first tank was mere satisfactory because of the heavy load of pollutants. However, progressively the growth started improving from "the satisfactory" to "the excellent" state in the successive vermi-bio-filters. The crystal clear water from the fourth tank was suitable for plant-vessels, floor washings and toilet flushing and gardening.

Since the 1990s, studies on vermi-filtration technology from small to pilot scales have been conducted. Almost all of the earlier experimental vermi-filtration processes showed a perfect efficacy on sewage treatment, with high removal rates of COD, BOD and TSS, as well as some ability to remove N and P (Sinha *et al.* 2008). Some researchers further developed vermi-filtration to treat municipal sewage with relatively low organic loads (Bouché and Soto 2004; Xing *et al.* 2005; Sinha *et al.* 2008).

Ghatnekar et al. (2000) reported the use of a vermi-filtration system for treatment of waste water from a vegetable dehydration unit at a rate of 100 million m^3 per day. The treated pure water was then used for irrigation of vegetable plots where onion (*Allium cep*a), cabbage (*Brassica ole*racea) and chilli (*Capsicum annum*) were cultivated. Ghatnekar and Kavian (2000) suggested the utilization of a 'Vermi-filtration Bio-treatment Plant' to treat wastewater from a sewage plant of a small town for irrigating agriculture. Ghatnekar *et. al.* (2010) were able to evaluate the efficacy of the vermi-bio-filtration system for the treatment of secondary liquid effluents from the gelatine manufacturing industry.

The organic content in selected liquid effluents has the expected degradation potential and is harmless to the selected earthworm population in the upper most vermi-cast layer. The vermi-compost obtained in the process may find use as plant probiotics and soil conditioners.

Conclusion

The vermi-bio-filtration technology used in the present study has provided the cost effective and eco-friendly solution to the concerned juice industry. The treated water is re-circulated and re-used for various purposes and the 'zero discharge' is achieved. All in all, this state-of-the-art technology has the potential to cope with industrial wastewater management and universal water crisis concurrently.

References

Austerman-Haun U., Sayfried C. F. and Rosenwinkel K. H. (1997) UASB reactor in the fruit jice industry. *Water Sci. and Technol.* 36: 407-414.

Bouché M. B. and Soto P. (2004) An industrial use of soil animals for environment:the treatment of organically polluted water by lombrifiltration. Proceedings of the XIVth International Colloquium on Soil Zoology and Ecology, August 30-September 3, 2004, University of Rouen, Mont Saint Aignan, France, pp 1-13

El-Kamah H., Tawfik A., Mahmoud M. and Abdel-Halim H. (2010) Treatment of high strength wastewater from fruit juice industry using integrated anaerobic/aerobic system. *Desalination* 253(1-3): 158-163.

Ghatnekar S. D. and Kavian M. F. (1992) New Spins-offs of Biotech after the Rio-Earth Summit, Proceedings of inaugural session of Biotech India '92, World Trade Review, October 28-31, 1992, pp 10-14

Ghatnekar S. D. Kavian M. F. and Ghatnekar G. S. (1995) Vermiculture-based effluent treatment plants in diverse industries. In: Ray SK (Ed) Proceedings ofBiotechnology Strategy for Development, Biotek South Asia, 1994, New Delhi, pp 167-169

Ghatnekar S. D., Kavian M. F., Ghatnekar M. S. and Ghatnekar S. S. (2000) Bio-management of wastewater from vegetable dehydration plant. *In:* Trivedy RK, Kaul SN (Eds) Advances in Wastewater Treatment Technologies (Vol 2), Global Science Publications, U.P., India, pp 19-26

Ghatnekar S. D. and Kavian M. F. (2000) Utilisation of vermi-filter biotreatment plant to treat waste water from a sewage plant of a small town for irrigating agriculture. Report on Case Studies of Ecosan Pilot Projects in India, Version 1. September 14, 2006, pp 46-47

Ghatnekar S. D., Ghalsasi D. S. and Tamhane B. M. (2009a) The novel three-tier biotechnology to convert solid waste of gelatine manufacturing unit into useful plant probiotics. *Indian Journal of Environmental Protection* 29 (9), 767-774

Ghatnekar S. D., Ghatnekar S. S. and Ghalsasi D. S. (2009b) Three-tier vermiculture biotechnology to treat bio-solid wastes into bio-clean probiotics for agriculture. Proceedings of 14th European Biosolids and Organic Resources Conference, Seminar and Exhibition, November 9-11, 2009, organized by Aqua Enviro Technology Transfer, The Royal Armouries, Leeds, UK, pp 1-13

Ghatnekar S. D, Tamhane B. M., Sawant S. A. and Sharma S. M. (2009c) Biomanagement of liquid effluents from gelatine manufacturing industry using combination of *Spirulina platensis, Aspergillus flavus* and *A. niger*. *The Journal of the Indian Botanical Society* 88 (3-4), 165-169

Ghatnekar S. D., Kaviam M. F., Sharma S., Ghatnekar S. S., Ghatnekar G. S. and Ghatnekar A. V. (2010) Application of Vermi-filter-based Effluent Treatment Plant (Pilot scale) for Biomanagement of Liquid Effluents from the Gelatine Industry. *Dynamic Soil, Dynamic Plant 4* (Special Issue 1), 83-88.

Hamdi M, Bou Hamed H and Ellouz R (1991) Optimization of the fermentation of olive mill waste water by *Aspergillus niger*. *Applied Microbiology and Biotechnology* 36 (2), 285-288

Kavian M.F. and Ghatnekar S. D. (1998) Biotechnological innovation to treat waste from pharmaceutical industry. The Sixth Congress of Pharmaceutical Sciences of Iran, August 26-27, p 28 (Abstract)

Kavian M. F. and Ghatnekar S. D. (1999) Scope of vermiculture biotechnology in agriculture. In: Bagyaraj DJ, Verma A, Khanna KK, Kehri HK (Eds) *Modern Approaches and Innovations in Soil Management*, Rastogi Publications, Meerut, pp 151-161

Li Y. S., Xiao Y. Q., Qiu J. P., Dai Y. Q and Robin P (2009) Continuous village sewage treatment by vermi-filtration and activated sludge process. *Water Science and Technology* 60 (11), 3001-3010

Ozbas E. E., Tufekci N., Gulsum Y. and Suleyman O. (2006) Aerobic and anaerobic treatment of juice industry effluents. *J. Sci. & Ind. Res.* 65: 830-837.

Sinha R. K., Bharambe G. and Bapat P. (2007) Removal of high BOD and COD loadings of primary liquid waste products from dairy industry by vermi-filtration technology using earthworms. *Indian Journal of Environmental Protection* 27 (6), 486-501

Sinha R. K., Bharambe G. and Chaudhari U. (2008) Sewage treatment by vermifiltration with synchronous treatment of sludge by earthworms: a low-cost sustainable technology over conventional systems with potential for decentralization. *Environmentalis*t 28 (4), 409-420

Xing M., Yang J. and Lu Z (2005) Available online:

http://www.docstoc.com/docs/35289495/Microorganism-earthworm-Integrated-Biological-Treatment

Zhao L., Wang Y., Yang J., Xing M., Li X., Yi D. and Deng D (2010) Earthworm-microorganism interactions: A strategy to stabilize domestic wastewater sludge. *Water Research* 44, 2572-2582.