Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 15	No. 4	pp. 1311-1316	2016

Original Research Paper

Techno-Economic Assessment of Full Scale MBBRs Treating Municipal Wastewater Followed by Different Tertiary Treatment Strategies: A Case Study from India

Nitin Kumar Singh*, Pankaj Banyal* and Absar Ahmad Kazmi**
*Environmental Engineering Group, Deptt. of Civil Engineering, Indian Institute of Technology, Roorkee-247 667, India
**Deptt. of Civil Engineering, Indian Institute of Technology, Roorkee, India

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 03-01-2016
Accepted: 04-02-2016

Key Words:
Moving bed bioreactor
Tertiary treatment
Techno-economic analysis
Wastewater treatment

ABSTRACT

The moving bed bioreactors (MBBRs) systems have been reported as sustainable treatment systems for municipal as well as industrial wastewaters in developing countries. However, the inability of the MBBR process to meet the current disposal standards has given enough stimulation for ensuing appropriate tertiary treatment. This study was aimed to techno-economic evaluation of different tertiary treatment strategies (physico-chemical processes) of three full-scale moving bed bioreactor (MBBR) systems to make it justifiable for environmental protection, resource preservation and recovering maximum resources. The combination of the MBBR and tertiary treatment enhanced the performance of the overall treatment process and the COD removal efficacy of the whole treatment system reached upto 96%. The approximate cost of the treatment and specific power consumption was analyzed as Rs. 12.50 (± 20%) and 0.6 (±20%) kWh/m^3 respectively, as depending on the terrain, drive, electricity cost and area classification. Average land requirement was estimated as ~180 m^2 (±20%) and pollutant removal efficiencies were noted as ~95% (±3%). This conceptual approach allows a direct up scaling of small scale wastewater treatment plants and explores the reusability potential of treated effluent of this kind of system.

INTRODUCTION

Stringent discharge legislations for sewage treatment plants (STPs) and pressure of reuse practices across the world is increasing day by day. However, prospects to reuse treated wastewater and directive of its treatment vary, conferring to where you live. To avert the pollution of receiving water bodies and make it up to reuse standards, stringent discharge legislations must be followed (Chernicharo 2006, Oliveira & Von Sperling 2009). In the last two decades, moving bed biofilm reactor (MBBR) systems have been used to treat a wide range of wastewater (WW) under various operational conditions and temperatures. The advantages of MBBR systems include low construction cost, minimal space requirement, simple operation combined with effective biochemical oxygen demand (BOD), suspended solids and faecal coliform removal (Almomani et al. 2014, Piculell et al. 2014, Germain et al. 2007, Bassin et al. 2012, Villamar et al. 2009, Daude & Stephenson 2004, Duan et al. 2013). Due to these advantages, MBBR systems are also one of the most popular treatment systems currently used in developing countries such as India (CPCB 2012). In spite of their great advantages, full scale MBBRs still have difficulty in producing effluents that comply with discharge standards established by most environmental agencies in India. Despite the differences in guideline of States and Union, these standards are hardly attained through lone aerobic processes (Almomani et al. 2014, Schneider et al. 2011). To improve the removal efficiencies of organics and solids within WWTPs, discussion has focused on upgrading the overall treatment process with additional treatment steps (Schneider et al. 2011). Therefore, the effluents from MBBR reactors may adapt additional treatment practices to meet the requirements of the environmental legislation and to protect the receiving water bodies. In this sense, a combination of a biological process and chemical treatment is usually required for an effective treatment, since biological systems are not adequate as the sole treatment of wastewater (Vázquez-Padín et al. 2009, Chernicharo 2006). The main role of the tertiary treatment is to enhance the removal of organic matter, as well as to reconnoitre the possibility of reuse practices. Till date, limited tertiary treatment configurations are investigated in the literature, especially at full scale for MBBR based wastewater treatment systems. Physico-chemical treatment methods provide remarkable removal of organic as well as inorganic compounds in wastewater (Ghosh et al. 1999, Lefebvre et al. 2006, Van Der Steen et al. 1999). For this reason, current tertiary treatment practices have been assessed in three MBBR plants with respect to techno-economic assessment.

The objective of this research paper is to summarize, highlight and evaluate the different tertiary treatment options for the effluent of MBBR reactors treating domestic wastewater, in an attempt to fulfil the 'Indian discharge standards' as well as reuse guidelines. The following types of tertiary treatment strategies were analyzed: multigrade filter, activated carbon filter, pressure sand filter, and ultra violet disinfection. The main objectives of the present study were (a) techno-economic assessment of different tertiary treatment strategies for secondary effluent at the scale of a municipal WWTP, (b) assessment of land usage, cost of treatment and c) specific energy consumption for this enhanced wastewater treatment.

DATA COLLECTION AND ASSESSMENT METHODOLOGY

Study area: In the present study, three existing small scale sewage treatment plants (STPs) were selected for investigation to gain insight and to bring out actual facts and figures of existing treatment practices. The description and schematic of STPs is presented in Table 1 and Fig. 1, respectively.

Analysis and methodology: During the field drive, grab samples were collected. Analysis of influent and effluent samples was conducted by essential water quality parameters, viz., chemical oxygen demand (COD), biochemical oxygen demand (BOD; 3 days), and total suspended solids (TSS) according to the standard methods (APHA 2005). The data were assorted and evaluation methodology was formulated according to our previous study (Banyal et al. 2015) for consolidation and analysis of data with this MBBR technology based treatment systems. The complete methodology was formulated and worked with the under mentioned broad spectrum of consolidation of data and to assess the financial aspects of the DEWATS (Fig. 2).

RESULTS AND DISCUSSION

Performance evaluation: The treatment efficiencies in terms of BOD, COD and TSS of M1, M2 and M3 plants are graphically depicted in Fig. 3. All the three plants have shown treatment efficiency for the above three performance parameters in the range of 94 to 96 % and out of which M2 plant has been the best among the rest one. This is totally credited to the treatment technology being augmented with the tertiary treatment. The performance results of these plants are by and large in the range, which gets matched within ±2%. The quality of effluent being treated in all the three plants has been good enough due to the good staff being administered and the administration being accounted for the successively running of the STPs.

Area and cost analysis: The land requirement is one of the major key issues for planning and implementation of the project, if the land is there, then only the respective treatment system can be executed. With this perspective, the next major parameter for assessment will be the capital cost which has been adequately estimated by the qualitative inputs and seeing the year of construction of the plant. The land requirement will surely be dependent on the units installed with that technology and funds availability with the setup in which it is required to be installed. Having these majors points, the area and cost parameters were taken into account. Fig. 4 depicts the area and cost requirement with a comparison based on the actual year of installation. Both area and capital cost are correlated because both are interlinked and dependent on each other.

The land requirement varied from 180 m^2 to 270 m^2 and the valves best suited for < 0.4 MLD capacity. It is here clearly indicative that the MBBR can be planted within space constraints with the tertiary treatment. The design arrangement of MBBR plant can be modified with the space availability and the type of installation. The M1 plant is basically being planted in the basement of the mall, whereas the M2 plant is as per best managed space and M3 plant has used space more due to free availability of space of the P3 plant.

Cost of treatment and power consumption analysis: The strategy as enumerated in the above section was espoused to verify the facts of the three MBBR technology + tertiary treatment, to derive a sound result, reflecting the cost of treatment for MBBR technology for 0.4 MLD capacities. The treatment cost varied from Rs 10.10 to 14.30 and has shown that the treatment cost will surely depend on the

Table 1 Description of MBBR STPs (<5 MLD) evaluated in the present study

S. No.	Plant Code	Technology + Tertiary Treatment	Capacity (MLD)	Year of Commissioning
1	M1	MBBR + MGF + ACF + Softener	0.4	2013
2	M2	MBBR + PSF + ACF + UV	0.35	2008
3	M3	MBBR + PSF + ACF	0.4	2014

MBBR, moving bed bioreactor; MGF, multigrade filter; ACF, activated carbon filter; PSF, pressure sand filter; UV, ultra violet disinfection

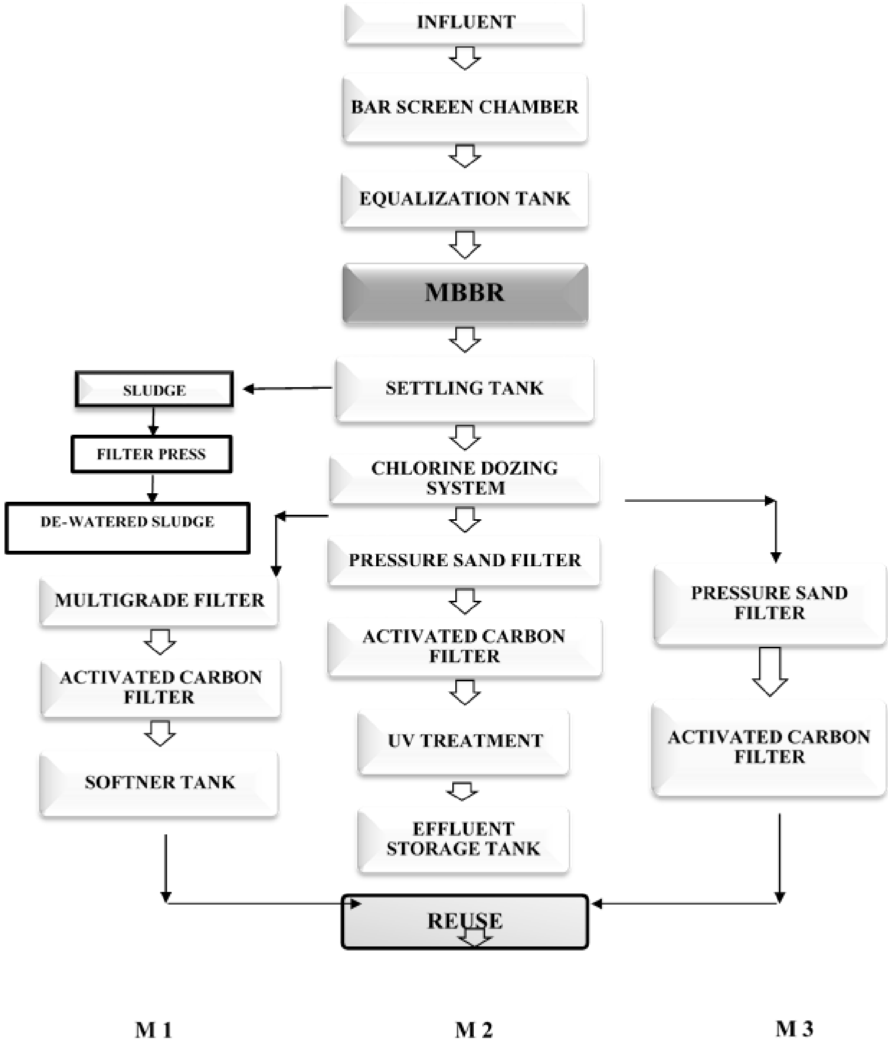

Fig. 1: Schematic layout of MBBR STPs.

integral institution and management practices of the operational agency. The M1 plant has a laborious kind of setup, whereas M2 plant has a mixed type of setup arrangement for manning STPs and M3 plant has common type of arrangements as this institution has many STPs. Here, one thing is strongly endorsed that no plant has the independent type of setup for management for manning these STPs, but they have been as part of mixed, with the institutional arrangement, so that is why during the study more time has involved in segregation of data inputs. The study was carried out to find out the cost imperative as these data are not clearly available in the market as of now and surely the authorities are always hiding facts and figures from the users. In Fig. 5, the decreasing trend line was observed as per the treatment cost and can be correlated with the technology + tertiary treatment cost.

Further to this, the cost Rs/kg of BOD removed was found out to be three to five times of the cost of treatment and gets re-verified with the figurative assessment. The range for values found out to be Rs. 33.70 to 45.0 and these plants have shown good treatment efficiencies. The power consumption accounts upto 75% of the total operation and maintenance (O & M) cost and depends on the state/area where the plants are installed. The cost of electricity has been varying in Northern India from Rs. 2.0~Rs 5.0 in hills to Rs 6.0~Rs 8.0 in habitat areas and in metros. The cost of electricity is tremendously increasing from the last few years and especially in metros the cost was at Rs 13.0/unit in

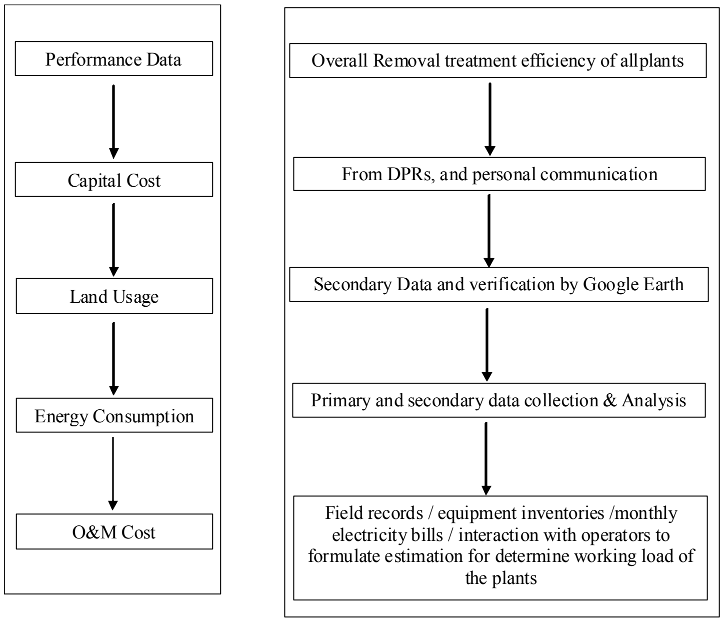

Fig. 2(a): Factors shortlisted for study (b) What & how factors are listed.

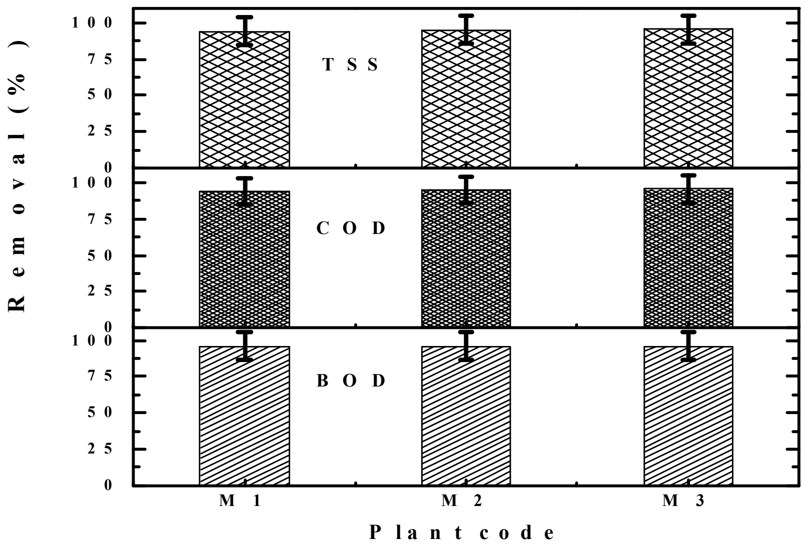

Fig. 3: Treatment efficiency of selected MBBR plants (0.35-0.40 MLD).

April 2015, whereas earlier it was Rs 10.0 which is itself very alarming. The power consumption depends on the make and the efficiency of the motor, and seeing the present scenario, the recommended options would be to use VFDs with the plant and further auto atomization is highly endorsed for increasing the efficiency of the STPs and in turn will decrease the other input cost like manpower cost and further the plant can be suitably monitored for its efficiency and performance. As per Fig. 5, the M1 and M2 plant has shown similar SPC (0.8 kWh/m^3 of WW treated) whereas M3 plant has shown 0.6. The difference can be attributed to the utilization of more power because of the tertiary treatment being used in M1 and M2 plant as this differs from M3 Plant. The average value for MBBR plant for 0.4 MLD could

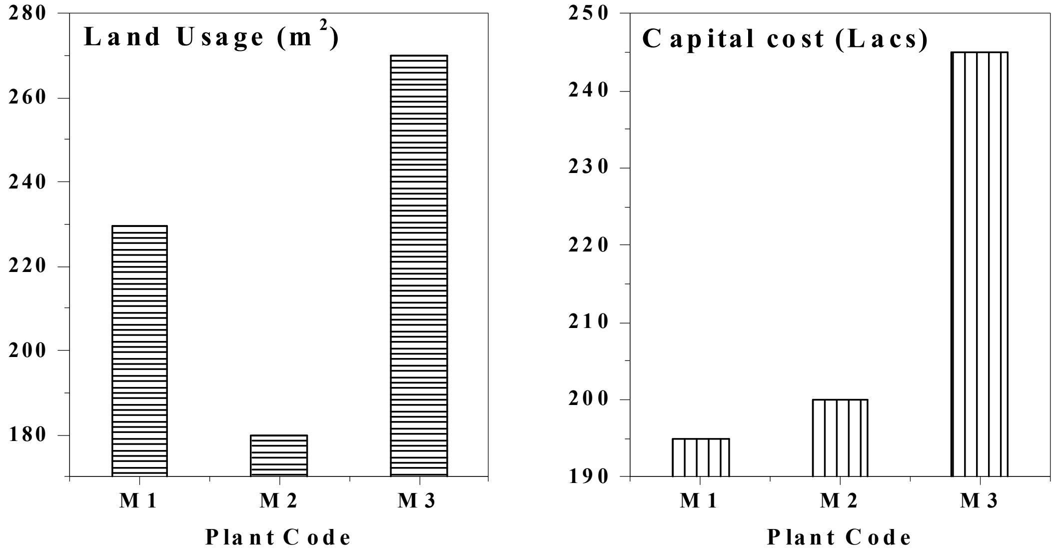

Fig. 4: Actual land usage and capital investment for selected MBBR STPs.

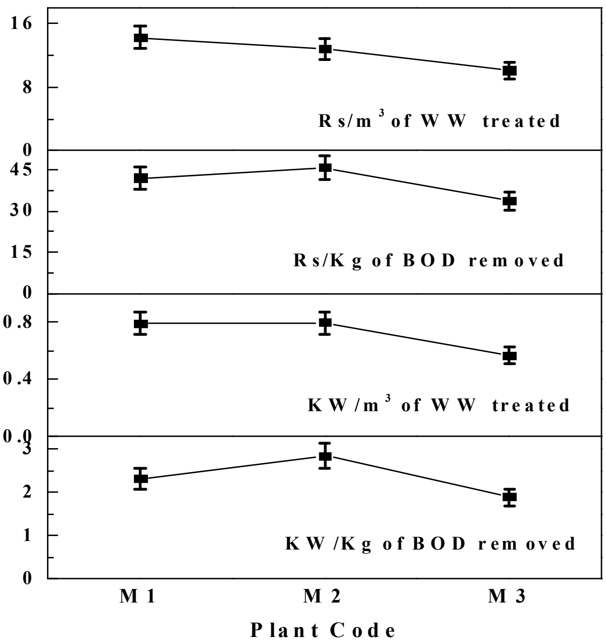

Fig. 5: Cost of treatment and specific power consumption for selected MBBR plants.

vary from 0.6~ 0.8 kWh/m^3 and further if VFD and energy efficient motors are installed, the SPC of STPs can be attained to the tune of 0.4 to 0.5 kWh/m^3 which can be at much lower side with the MBBR + tertiary treatment. Further to this, the power consumption Rs/kg of BOD removed were found out to be varying from 1.9~2.8 kWh/kg of BOD removed, which is the best amongst itself for optimization of usage of energy.

CONCLUSIONS

This present study reports comprehensive techno economic indicators, which could affect the small scale wastewater treatment plant. The results of the assessment approaches should be used in combination in order to attain an accordingly balanced solution.

Following upshots were drawn from this field campaign:

- The contrast between different arrangements of MBBR technology followed by tertiary treatment (0.35~0.4 MLD) plant ensued that the electro-mechanical cost will remain same, however, changes are only due to civil works involved. Area assessment from field review has brought out distinctive parameters that it can be accommodated in congested/restricted space availability of ~180 m^2 (±20%).
- Capital cost for MBBR + tertiary treatment was found to be fluctuating depending upon the terrain + class of city + transportation factors + labour cost and with this the highest distinctive figure of 240 Lacs/MLD (±20%) can be utilized with the increasing trend of GDP, however, benchmark can be incorporated that the technology from the market has not lost the essence of credibility. Cost of treatment was Rs 12.50 (±20%) and which will surely depend on the administration + management of the institution and the area classification.
- The specific power consumption was in the range of 0.6~0.8 kWh/m^3 which was best for MBBR+Tertiary

treatment arrangements. The overall field data assessment for 0.3~0.4 MLD STPs for MBBR+ tertiary treatment technology, has brought that energy utilization is inversely proportional to the capacity of STPs and SPC value of 0.6 (±20%) can be further utilized for any advancement in the field of economic evaluation. The values for SPC can be theoretically recommended for 0.4 (±20%) if the plants are automatically controlled + VFD (energy measure) is utilized.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of the Department of Science and Technology, India and Indian Institute of Technology, Roorkee, India for this research towards Ph.D.

REFERENCES

Almomani, F.A., Delatolla, R. and Örmeci, B. 2014. Field study of moving bed biofilm reactor technology for tertiary-treatment of wastewater lagoon effluent at 1°C. Environ. Technol., 35: 1596-1604.

APHA 2007 2005. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, American Water Works Association, and Water Environment Federation.

Banyal, P., Singh, N. and Kazmi, A.A. 2015. Assessment of decentralized wastewater treatment systems for sanitation of small communities using a qualitative approach methodology: a case study from Northern India. Int. J. Eng. Adv. Technol., 4: 32-39.

Bassin, J.P., Kleerebezem, R., Rosado, A.S., Van Loosdrecht, M.C.M. and Dezotti, M. 2012. Effect of different operational conditions on biofilm development, nitrification, and nitrifying microbial population in moving-bed biofilm reactors. Environ. Sci. Technol., 46: 1546-1555.

Chernicharo, C.A.L. 2006. Tertiary-treatment options for the anaerobic treatment of domestic wastewater. Rev. Environ. Sci. Biotechnol., 5: 73-92.

CPCB 2011-12. Annual Report, India. http://cpcb.nic.in/annualreport.php.

Daude, D. and Stephenson, T. 2004. Moving bed biofilm reactors: a small-scale treatment solution. Water Sci. Technol., 48: 251-257.

Duan, L., Song, Y., Jiang, W. and Hermanowicz, S.W. 2013. Development of an integrated moving bed biofilm reactor-membrane bioreactor for wastewater treatment. sustain. Cities Dev. Environ. Prot. Parts 1-3, 361-363: 611–614.

Germain, E., Bancroft, L., Dawson, A., Hinrichs, C., Fricker, L. and Pearce, P. 2007. Evaluation of hybrid processes for nitrification by comparing MBBR/AS and IFAS configurations. Water Sci. Technol., 55: 43-49.

Ghosh, C., Frijns, J. and Lettinga, G. 1999. Performance of silver carp (*Hypophthalmicthys molitrix*) dominated integrated tertiary treatment system for purification of municipal waste water in a temperate climate. Bioresour. Technol., 69: 255-262.

Lefebvre, O., Vasudevan, N., Torrijos, M., Thanasekaran, K. and Moletta, R. 2006. Anaerobic digestion of tannery soak liquor with an aerobic tertiary-treatment. Water Res., 40: 1492-1500.

Oliveira, S.C. and Von Sperling, M. 2009. Performance evaluation of UASB reactor systems with and without tertiary-treatment. Water Sci. Technol., 59: 1299-1306.

Piculell, M., Welander, T. and Jonsson, K. 2014. Organic removal activity in biofilm and suspended biomass fractions of MBBR systems. Water Sci. Technol., 69: 55-61.

Schneider, E.E., Cerqueira, A.C.F.P. and Dezotti, M. 2011. MBBR evaluation for oil refinery wastewater treatment, with tertiary-ozonation and BAC, for wastewater reuse. Water Sci. Technol., 63: 143-148.

Van Der Steen, P., Brenner, A., Van Buuren, J. and Oron, G. 1999. Tertiary-treatment of UASB reactor effluent in an integrated duckweed and stabilization pond system. Water Res., 33: 615-620.

Vázquez-Padín, J.R., Figueroa, M., Fernández, I., Mosquera-Corral, A., Campos, J.L. and Méndez, R. 2009. Tertiary-treatment of effluents from anaerobic digesters by the Anammox process. Water Sci. Technol., 60: 1135-1143.

Villamar, C. A., Jarpa, M., Decap, J. and Vidal, G. 2009. Aerobic moving bed bioreactor performance: A comparative study of removal efficiencies of Kraft mill effluents from Pinus radiata and eucalyptus globulus as raw material. Water Sci. Technol., 59: 507-514.