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EXPERIMENTAL INVESTIGATION AND ITS ANALYSIS IN TANNERY WASTEWATER USING MOVING BED BIOFILM REACTOR AND ACTIVATED SLUDGE PROCESS

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ABSTRACT

The Tannery Industry produces a massive amount of toxic effluent which needs to be treated properly. It contains high organic matter, suspended solids, and chromium which in turn can cause environmental problems. This study provides valuable insights into the potential of Moving Bed Biofilm Reactor (MBBR) and Activated Sludge Process (ASP) for treating tannery wastewater. It also highlights the importance of proper wastewater treatment in the tannery industry to mitigate environmental impacts. The batch analysis was conducted to find out removal efficiencies for Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD_5), Sulphide (S^{2-}), Ammonia (NH_4), Nitrate (NO_3). Kaldness K1 bio-media was used with a 50% filling ratio in the laboratory setup of the MBBR and aeration was provided to both setups. The results for the MBBR system showed chromium removal of 95.4% with the obtained reduction of biochemical oxygen demand (BOD), chemical oxygen demand (COD), sulfide (S^{2-}), and nitrate (NO_3) 93.5%, 88.8%, 93.7%, and 97.09%, respectively. It indicates significant removal efficiencies for various pollutants in the tannery wastewater, suggesting the effectiveness of the MBBR system.

Keywords: Moving Bed Biofilm Reactor, Activated Sludge Process, Tannery Effluent, BOD, COD

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INTRODUCTION

Over the last few decades, there have been designs on the treatment of various types of wastewater emanating from leather, textile, wool, paper, food, and silk industries based on primary treatment to remove suspended solids and the secondary conventional biological treatment to separate organic matters and suspended solids such as Activated sludge Process[1,2], Sequencing Batch Biofilm Reactor[3,4], trickling filters[5], rotating biological contactors[6], Membrane Bio-reactor[7], Up-flow anaerobic sludge blanket[8], submerged aerobic fixed film[9], fluidized bed reactors[10], Constructed Wetlands[11], granular media bio filters[12], etc.[1-12] These treatment processes have both the benefits and inconveniences.[13] Mechanical failures are often experienced with the rotating biological contactors whereas the trickling filter needs a large land area. The MBBR process was developed with the help of Norwegian company Kaldnes Miljøteknologi (now Anox Kaldnes AS) at the Norwegian University of Science and Technology in Norway in the late 1980s and early 1990s.[12,14] The Biofilm carriers are the fundamental aspects of MBBR.[15] In the MBBR, active surface area can be increased by providing media with a high specific surface area or by adding more carriers to a reactor. Maurer et al. have installed a full-scale pilot plant for denitrification based on a moving-bed biological treatment process using foam cubes and plastic tubes as carriers.[16] In the other experiment, the removal of two simultaneous drugs (Ibuprofen and Ofloxacin) from hospital wastewater has been investigated in a series of processes with a photo-Fenton reagent using Manganese oxide (MnO_2), MBBR treatment followed by ozonation process.[17] Mahmoudkhani *et al.* has studied in a pilot scale MBBR for the treatment of refinery wastewater containing formaldehyde, phenol and total petroleum hydrocarbon.[18] Also, various domestic and industrial wastewaters have been studied using Moving Bed Biofilm Reactors.[19] To investigate the performances of an anaerobic moving bed reactor using dairy wastewater, an experiment has been performed using Polyethylene support called BioFlow 9 as bio-carrier at 65 % media volume.[20] The feasibility of the MBBR reactors has been reported for a wide range of treatment purposes: municipal

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and industrial wastewater, aquaculture, secondary and tertiary treatment, and side stream applications.[21] In the other study, oxygen dispersion was analysed to make the outer layers of the biofilms aerobic by the aeration system. It results in comparatively better biodegradation.[22] The carriers are usually made of polyethylene with a density close to 1 g/cm^3, which allows them to move freely in the reactor.[23] The tanning industry is one of the most polluting industries worldwide especially in India where there is a severe lack of proper wastewater treatment infrastructure. Work on tannery wastewater treatment using MBBR is scanty. Therefore, work on this research area is essential. The objective of this work is to proceed further on previous single-published work, with the different types of bio-carriers. So the present study aims to analyze the performance of the Moving Bed Biofilm Reactor (MBBR) in the treatment of pretreated tannery effluent using Kaldness K1 bio-media.

EXPERIMENTAL

Sources and Characterization of Tannery Wastewater

The industrial wastewater used for this study was obtained from the effluent treatment plant in Calcutta Leather Complex. A 10 L volume of raw wastewater emanating from the composite chrome tannery unit was collected. In the investigated period, the physicochemical properties of the wastewater were characterized for the parameters viz. pH, TS, TSS, BOD_5 at 27ºC, COD, S^{2-}, NH_4-N, NO_3-N, etc. by the Standard Method.[24] The pH of the wastewater was measured by pH meter and the dissolved oxygen (DO) was measured by using the dissolved oxygen meter (DO-5509, Lutron). Single Beam Visible Spectrophotometer BSSBV-401 was used for the measurement of NO_3, Cr (III), and Cr (VI). [25] A five-day BOD was measured using the Winkler's azide modification method. The results of the characterization are reported in Table-1. It can be found that wastewater contains high organic matter, high Total solids, Nitrogen, and total chromium. In addition, tannery wastewater contains a high amount of sulfide and the pH is slightly alkaline in the range of 7.5 -8.5. COD concentration was found 28,622 mg/L, Nitrate content was 1250 mg/L, and chromium concentration (Cr^{3+}) was 87 mg/L. Analytical procedures used for COD, BOD_5, NO_3, Cr (III), and Cr (VI) determinations were those outlined in Standard Methods.

Table-1 Investigated Tannery Wastewater Average Composition

Parameters	COD	BOD	TS	TDS	Sulphide	Chromium (III)	Chromium(VI)	Nitrate
Values in mg/L	28622	4230	13254	12575	2547	87	0.015	1250

Batch Experimental Setup

The laboratory scale experimental system involves two 2 L capacity buckets, 2 no's of aquarium pumps for oxygen supply and mixing, and a seeding process using activated sludge from a municipal sewage treatment plant. The Kaldnes biomedia K1 has been chosen as the moving carrier in the MBBR, and the carrier's characteristics have been outlined in Table-2.

Table-2: Description of the Carrier Media used in this Experiment

Characteristics	Length (mm)	Diameter (mm)	Specific surface area (m^2/ m^3)	Density (Kg/ m^3)
Values	8	10.5	500	950

Carrier media is made of polyethylene. The MBBR reactor was filled to operate with a bed/reactor volume ratio of 0.5. The system was operated by a batch method to support the formation of a biofilm layer. During the seeding process, conditions such as dissolved oxygen (DO) concentration above 2 mg/L, pH between 6.5 and 8.5, and a temperature range of 25 - 35°C were maintained to support bacterial growth. The startup period lasted about a month to allow for the formation of a biofilm layer on the media. The schematic diagram of the Moving bed bioreactor and the bio-carrier are shown in Fig.-1. The removal efficiencies were studied before and after the operation period, and the removal efficiencies were calculated using the provided equation (Eq.1).

Removal efficiency = (Initial Concentration –Final Concentration)/ Initial Concentration (1)

RESULTS AND DISCUSSION

In this present study, the focus of the investigation was on evaluating the performance of the MBBR and ASP reactors using a wastewater sample with specific initial concentrations. The wastewater sample used in the study had an average initial COD concentration of 28600 ± 50 mg/L and an initial S^{2-} concentration in the range of 2500 ± 50 mg/L.

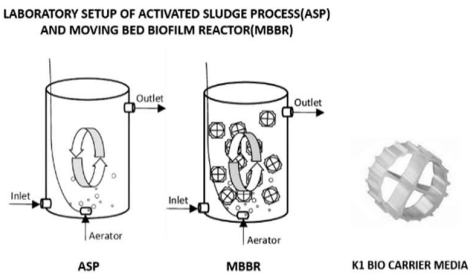

Fig.-1: Experimental Setup

COD and BOD_5 Analysis

In the present experimental work, results of batch studies have been plotted for both reactors, as shown in Fig.-2 and Fig.-3 respectively. The sample contains an average COD of 28,622 mg/l. After treatment by MBBR and ASP, the final average COD values become 3,195 mg/l and 4,580 mg/l respectively, resulting in efficiencies of 88.8% and 84% respectively. In the case of BOD, removal efficiencies are 95% and 88% respectively. Here, it has been found that the percentage removal of COD and BOD for MBBR treatment is higher than that of ASP, which in turn indicates MBBR performance is better than ASP. This is due to the enhancement of total biomass concentration as extra bio carrier Kaldnes bio-media K1 are added in MBBR. Extra biomass concentration increases biodegradation as BOD and COD removal efficiency. These findings are in agreement with previous investigations conducted in MBBR treatment for composite tannery wastewater.[26]

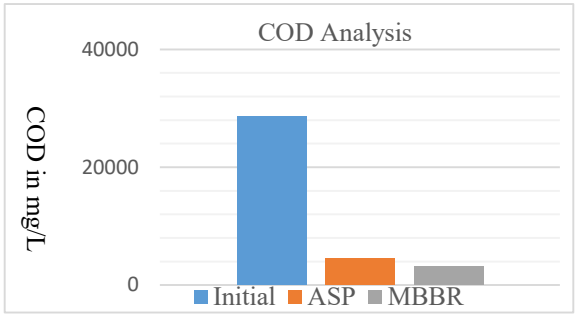

Fig.-2: COD Values for MBBR and ASP after and before Operation

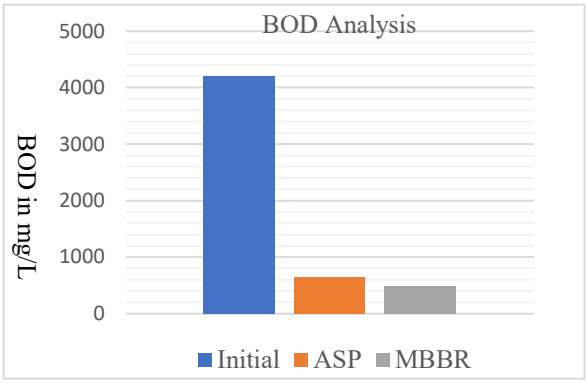

Fig.-3: BOD Values for MBBR and ASP after and before Operation

Sulphide (S^{2-}) Analysis

Sulfide in the composite tannery wastewater originates from Na_2S used during the liming procedure. In water, sulfide exists easily in the form of hydrogen sulfide which not only smells bad but it is also a strong nerve gas. The original sample had a concentration of 2,547 mg/l of S^{2-}, and after treatment with MBBR and ASP, the concentrations were reduced to 160 mg/l and 274 mg/l, respectively (Fig.-4). This corresponds to removal efficiencies of 93.7% for MBBR and 89.2% for ASP, indicating a significant reduction in sulfide concentrations. The suggested mechanism for this reduction involves sulfide-oxidizing bacteria (SOB) oxidizing sulfide into sulfur under aerobic conditions.[27]

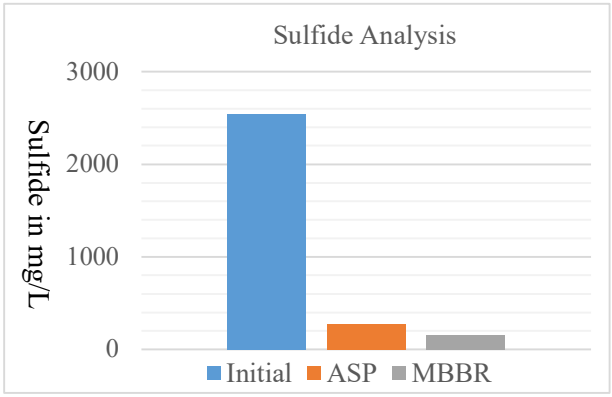

Fig.-4: Sulphide Values for MBBR and ASP after and before Operation

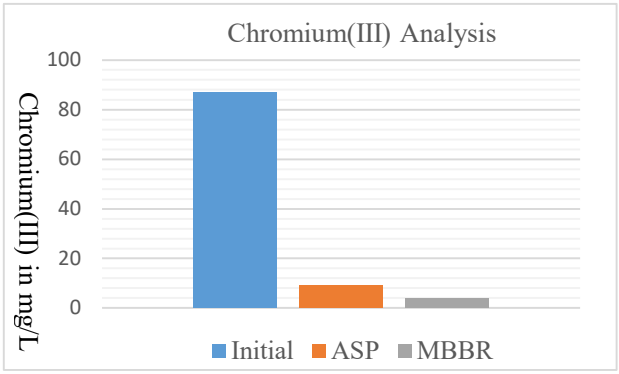

Fig.-5: Cr(III) Values for MBBR and ASP after and before Operation

Chromium (III) Analysis

The tannery effluent contains a significant amount of chromium (III) due to the tanning process involving Basic Chrome Sulphate (BCS) powder. The presented data in Fig.-5 indicates that the average chromium (III) concentration in wastewater decreases from 87 mg/l to 9 mg/l in the ASP and further to 4 mg/l in the MBBR. This signifies removal efficiencies of 89.7% in the ASP and 95.4% in the MBBR. A substantial reduction in chromium (III) concentration has been achieved by these treatment processes. Therefore, it is suggested to recover the residual chromium (III) using environmentally friendly and sustainable methods.[28] These findings align with previous research conducted in MBBR treatment for composite tannery wastewater, suggesting consistency in the efficacy of this method for chromium (III) removal in similar contexts. [31]

Chromium (VI) Analysis

Chromium (VI) is a hazardous component and a significant pollutant in the tannery industry. In Figure-6, the results of experiments conducted in this study show that the initial concentration of Cr (VI) in the sample was 0.015 mg/l. After treatment with MBBR and ASP under similar conditions, the final concentrations were reduced to 0.007846 mg/l in the MBBR, representing a 48% reduction, and 0.009964 mg/l in the ASP, representing a 34% reduction.

Nitrate (NO_3^-) Analysis

In the tanning process, the total nitrogen generated primarily originates from two sources: (i) the conversion of a large amount of skin collagen into organic nitrogen (protein, peptide, and amino acid) after hydrolysis, and (ii) the addition of various ammonium salts during the tanning process.[28, 29] Excessive nitrogen in water can lead to eutrophication. The study focuses on wastewater with a Nitrate concentration of 1250.57 mg/l, and the treatment was carried out using MBBR and ASP. The results presented in Fig.-7 show that the final nitrate concentrations after treatment are 36.36 mg/l in the MBBR and 32.11 mg/l in the ASP. The nitrification efficiency of ASP is reported to be 97.40%, which is slightly higher than the efficiency of MBBR at 97.09%. This indicates that both treatment methods are highly effective in reducing Nitrate concentrations, with ASP marginally outperforming MBBR in this specific case.

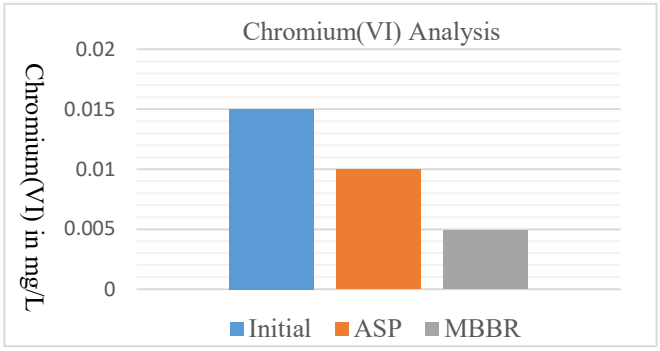

Fig.-6: Cr(VI) Values for MBBR and ASP after and before Operation

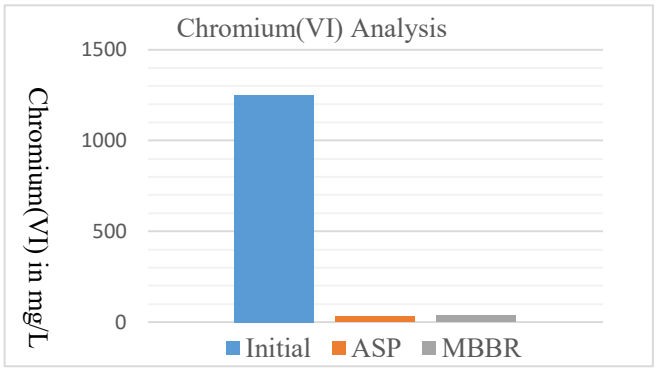

Fig.-7: Nitrate Values for MBBR and ASP after and before Operation

CONCLUSION

The present research study aims to assess the performance of the MBBR in comparison to the conventional ASP for the removal of carbonaceous organic matter from tannery wastewater. The treatment was conducted using a batch-wise technique with tannery wastewater. The results indicate that the MBBR demonstrated significant effectiveness in the removal of pollutants. The reductions in BOD, COD, and sulfide were reported as 93.5%, 88.8%, and 93.7%, respectively. Notably, MBBR shows better performance than ASP in terms of COD removal. However, the biodegradation of tannery wastewater inherently exhibited a slow rate due to toxicity. To address this issue, it can be suggested that increasing the concentration of bio-carriers in MBBR could enhance the rate of biodegradation. This insight can contribute to optimizing wastewater treatment processes for the tannery industry, considering both efficiency and environmental sustainability.

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CONFLICT OF INTERESTS

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

All the authors contributed significantly to this manuscript, participated in reviewing/editing, and approved the final draft for publication. The research profile of the authors can be verified from their ORCID IDs, given below:

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REFERENCES

1. B.P.K. Ram, P.K. Bajpai, and H.K. Parwana, *Process Biochemistry*. **35(3-4)**, 255(1999), https://doi.org/10.1016/S0032-9592(99)00062-X
2. D. Mazumder, S. Mukherjee, and P. K. Ray, *International Journal Environment and Pollution*, **34(1–4)**, 43(2008), https://doi.org/10.1504/IJEP.2008.020781
3. C.D. Iaconia, A. Lopeza, R. Ramadoria, A.C.D. Pintob, and R. Passino, *Water Research,* **36(9)**, 2205(2002), https://doi.org/10.1016/S0043-1354(01)00445-6
4. C.D. Iaconi, A. Lopez, R. Ramadori, and R. Passino, *Environmental Science Technology*, **37(14)**, 3199(2003), https://doi.org/10.1021/es030002u
5. M.M.A. Aslam, Z.M. Khan, M. Sultan, and E. Niaz, *Polish Journal of Environmental Studies,* **26(5)**, 1(2007), https://doi.org/10.15244/pjoes/69443
6. F. Hassard, J. Biddle, E. Cartmell, B. Jefferson, S. Tyrrel, and T. Stephenson, *Process Safety and Environmental Protection*, **94**, 285(2015), https://doi.org/10.1016/j.psep.2014.07.003
7. Y.J. Chung, H.N. Choi, S.E. Lee, and J.B. Cho, *Journal of Environmental Science and Health*, **39(7)**, 881(2004), https://doi.org/10.1081/ESE-120037885
8. O. Lefebvre, N. Vasudevan, M. Torrijosa, K. Thanasekaran, and R. Moletta, *Water Research*, **40(7)**, 1492(2006), https://doi.org/10.1016/j.watres.2006.02.004
9. R. Gurjar, A.D. Shende, and G.R. Pophali, *Water Science and Technology*, **80 (4)**, 737(2019), https://doi.org/10.2166/wst.2019.316
10. J. M. Nelson, G. Nakhla, and J. Zhu, *Engineering*, **3(3)**, 330(2017), https://doi.org/10.1016/J.ENG.2017.03.021
11. A. Alemu, N. Gabbiye, and B. Lemma, *Frontiers in Environmental Science,* **9**, 1(2021), https://doi.org/10.3389/fenvs.2021.721014
12. N. Moona, K.R. Murphy, M. Bondelind, O. Bergstedt, and T.J.R. Pettersson, *Environmental Science: Water Research and Technology*, **4**, 529(2018), https://doi.org/10.1039/C7EW00413C
13. B. Saha, and F.A.B. Azam, *Textile & Leather Review,* **4(2)**, 76*(*2021), https://doi.org/10.31881/TLR.2020.11
14. H. Ødegaard, B. Rusten, and T. Westrum, *Water Science and Technology,* **29,** 157(1994), https://doi.org/10.2166/wst.1994.0757
15. H. Ødegaard, *Water Science and Technology,* **42(12)**, 33(2000), https://doi.org/10.2166/wst.2000.0235
16. M. Maurer, C. Fux, M. Graff, and H. Siegrist, *Water Science and Technology*, **43(11)**, 337(2001), https://doi.org/10.2166/wst.2001.0700
17. A.H. Khan, H.A. Aziz, N.A. Khan, S. Ahmed, M.S. Mehtab, S. Vambol, V. Vambol, F. Changani, and S. Islam, *International Journal of Environmental Analytical Chemistry,* **103(1)**, 140(2023), https://doi.org/10.1080/03067319.2020.1855333
18. R. Mahmoudkhani, A.M. Azar, A. Dehghani, and H. Ghoreishi, *International Conference on Life Science and Engineering*, **45**, 3(2012), https://doi.org/10.7763/IPCBEE
19. A.H. Javid, A.H. Hassani, B. Ghanbari, and K. Yaghmaeian, *International Journal of Environmental Research,* **7(4),** 963(2013).
20. S. Wang, N.C. Rao, R. Qiu, and R. Moletta, *Bioresource Technology,* **100(23)**, 5641(2009), https://doi.org/10.1016/j.biortech.2009.06.028
21. J.P. McQuarrie, and J.P. Boltz, *Water Environment Research*, **83(6)**, 560(2011), https://doi.org/10.2175/106143010X12851009156286
22. R.M. Ahl, T. Leiknes, and H. Odegaard, *Water Science and Technology*, **53 (7)**, 33(2006), https://doi.org/10.2166/wst.2006.205
23. H. Ødegaard, *Water Environmental Engineering and Reuse of Water*, 205(1999).
24. APHA (2005) Standard methods for the examination of water and waste water, 21st edn. American Public Health Association, Washington, DC
25. E. Sotirakou, G. Kladitis, N. Diamantis, and H. Grigoropoulou, *Global NEST Journal,* **1**, 47(1999).
26. Goswami S, D. Mazumder, *Materials Today: Proceedings*, **3(10)**, 3337(2015), https://doi.org/10.1016/j.matpr.2016.10.015
27. T.J. Hurse, U. Kappler, and J. Keller, *Sulfur metabolism in phototrophic organisms, Springer Press, Dordrecht*, p. 437(2008), https://doi.org/10.1007/978-1-4020-6863-8_22
28. R. Selvaraj, M. Santhanam, V. Selvamani, S. Sundaramoorthy, and M. Sundaram, *Journal of Hazardous Materials*, **346**, 133(2018), https://doi.org/10.1016/j.jhazmat.2017.11.052
29. S. Payel, A. Hashem, M. Sarker, and S. Nur-A-Tomal, Textile *& Leather Review,* **3(3)**, 118(2020), https://doi.org/10.31881/T

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