ABSTRACT

Chrome tannery wastewater causes several environmental problems due to high COD of mostly non-biodegradable in nature, BOD$_5$, Nitrogen and TSS together with significant amount of chromium (Cr$^{3+}$ and Cr$^{6+}$) and objectionable color. There are several biological methods like ASP, SBR, UASB, Biofilm reactor etc, for the treatment of composite chrome tannery wastewater. Activated sludge process is a well-accepted treatment technology for removal of biodegradable organic constituents, nitrogen, and phosphorus in most treatment plants. However, there is certain limitations still exist for direct application of the activated sludge process for treatment of industrial wastewater containing various inhibitory substances. As a result, quality of the final effluent is found to be unsatisfactory to meet the permissible discharge standard as laid down by different regulatory bodies. This difficulty is traditionally overcome by physico-chemical pre-treatment step resulting in high overall cost of treatment.

In view of above background, a Moving Bed Hybrid bioreactor appears to be a good and viable treatment option for chrome tannery wastewater, which has recently emerged as a new technology in the field of advance wastewater treatment. In this reactor system aerobic, anoxic and also anaerobic environment can be maintained by employing suspended and attached growth biomass simultaneously. As a result, carbonaceous oxidation, nitrification, denitrification as well as bio-sorption of chromium can take place in the moving carrier media supporting biofilm. Looking into this matter, a research project has been carrying out in laboratory scale Moving bed Hybrid bioreactor for treating composite chrome tannery effluent. The present research study highlighted on the scope of Moving bed Hybrid bioreactor for a comprehensive treatment solution towards pollution abatement form chrome tannery industry. It also focused on development of a simplified mathematical model and its solution based on computer program along with validation of the same using experimental data.

A detailed review on literatures is carried out mainly on biological treatment of chrome tannery wastewater, their important research findings along with principles and methodology applied. A brief overview on different conventional treatment technologies adopted for biological treatment of composite chrome tannery
wastewater is presented in tabular form. In this regard, the performance of moving bed hybrid reactor for treatment of various municipal and industrial waste streams including chrome tannery wastewater is also explored. Apart from that, the availability of mathematical models in the context of moving bed bioreactor has also been investigated. The criteria, applications and limitations of these models are thoroughly compared to facilitate development of a new simplified model for the MBHBR system. The issue of process design has also been addressed in the light of a simplified mathematical model developed in the present research study.

A laboratory scale Moving Bed hybrid reactor has been developed to evaluate its performance in terms of organic removal in presence of chromium of composite chrome tannery wastewater. The hydraulic study conducted on this reactor system revealed that it belonged to a hydraulic regime very close a completely mixed reactor. The bio-carrier particle was made of polypropylene having specific surface area 1340 m²/m³ and specific gravity about 0.9. The performance results were compared with respect to suspended growth reactor for removal of carbonaceous organic matter from composite chrome tannery wastewater. Various experimental studies suggest that more than 90% COD removal is possible with initial COD concentration in the range of (250±50) to (1000±50) mg/L in MBHBR system as compared to suspended growth reactor under batch mode of operation. Optimum results have been obtained at MLSS concentration (2500±50) mg/L and reaction period 7.5-8 hrs corresponding to bio-carrier concentration of 50 g/L. It was also observed from the batch experiments that total Chromium concentration as Cr³⁺ enhanced the rate of biodegradation of organic carbon and removal of ammonium nitrogen, when the initial COD/Cr ratio is 5:1. Cr³⁺ has very positive influence on COD removal. Maximum 95 % of COD removal occurred under an initial COD concentration 1500 mg/L, MLSS concentration (2500±50) mg/L, COD/N ratio 5 and initial Cr³⁺ concentration 200 mg/L, after 9 hrs reaction period and bio-carrier concentration of 50 g/L. However, a reverse consequence was observed when chromium concentration (Cr⁶⁺) was increased from 150 to 250 mg/L.

Thereafter, the MBHBR system was run under continuous mode of operation with varying bio-carrier concentration viz., 25 g/L, 50 g/L, 75 g/L and 100 g/L under different HRT combination 6, 8,10, and 12 hrs using both the chrome bearing
synthetic carbonaceous wastewater and the real life chrome tannery wastewater. In this study, satisfactory performance was observed at bio-carrier concentration (75-100) g/L, HRT 12 hrs, Initial COD concentration of (1000-1500) mg/L and MLSS concentration of (2500-3000) mg/L. The biodegradation of composite chrome tannery wastewater inherently exhibited a slow rate of COD removal due to toxicity.

A simplified mathematical model of the moving bed hybrid bioreactor (MBHBR) under steady state has been developed to predict the various output parameters, viz. effluent substrate concentration (S), average substrate flux in the biofilm (J) and effective biofilm thickness \((L_e)\). The proposed MBHBR model assumed similar reaction kinetics for both suspended and attached growth microorganism and uniform bio-film thickness \((L_f)\). The basic assumption considered in this proposed model is competition between the suspended and attached growth microorganisms for a single electron donor molecule under moving condition as a limiting factor. Simple Monod’s kinetic expression for substrate utilization into the bio-film coupled with Fick’s second law of molecular diffusion of substrate into the bio-film from bulk liquid was used to derive the model equations. Losses of bio-film due to particle-particle collision and hydraulic shear loss contributing to suspended biomass are also considered in the biomass balance equation. The velocity of moving particle, which is an important factor in the proposed model, was derived from the principle of air-water momentum equation. An approximate numerical solution of the moving bed bioreactor model has also been proposed, which used simple Euler’s method to predict the effluent substrate concentration and the bio-film thickness. The simple excel sheet programme as well as FORTRAN programme have been employed to predict the effluent substrate concentration.

Apart from that various kinetic co-efficients for the treatment of composite chrome tannery wastewater in the MBHBR system, were determined using the mathematical model already developed. The values of the kinetic coefficients were found as \(k = 3.5 \text{ d}^{-1}\), \(K_s = 0.175 \text{ mg/cc or 175 mg/L}, Y = 0.58 \text{ mg/mg , } b_s = 0.14 \text{ d}^{-1}, b_d =0.147 \text{ d}^{-1} \text{ and } b_t = 0.29 \text{ d}^{-1} \) for synthetic chrome bearing carbonaceous wastewater. The values of the same were found as \(k = 3 \text{ d}^{-1}, K_s = 0.245 \text{ mg/cc or 245 mg/L}, Y = 0.5 \text{ mg/mg , } b_s = 0.08 \text{ d}^{-1}, b_d =0.05 \text{ d}^{-1} \text{ and } b_t = 0.13 \text{ d}^{-1} \) for composite chrome tannery wastewater. For the sake of model validation twelve (12) numbers of effluent COD
data from continuous study, each for synthetic chrome bearing carbonaceous wastewater and composite chrome tannery were employed in the mathematical model of moving bed hybrid bioreactor. The relevant kinetic coefficients (i.e. k, K_s, Y, b_s, b_t and b_d), already determined have been used for this experimental validation purpose. The COD concentrations obtained from the experimental study results are plotted with those calculated from the MBHBR model. A zero deviation line is plotted along with error bar diagram corresponding to +10 %, and –10 % deviation. It has been observed that all the experimental COD concentration data are within ±10 % deviation with respect to those predicted from the model.

The proposed solution method for MBHBR system is found an easy and accurate one, which can be used for further designing the moving bed hybrid bioreactor. In this regard, the relevant kinetic coefficients have been used for process design of the MBHBR with a rational approach. At the last, identification of predominant bacteria present in well-acclimated microbial consortia treating composite chrome tannery wastewater has been performed by 16SrDNA sequencing protocol. In this isolation cum identification study, the attached biomass was predominantly found as *Aeromonas veronii* whereas the suspended biomass was identified as *Falsibacillus pallidus*.