Process parametric study for COD removal of electroplating industry effluent

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Abstract

This paper investigated the effects of parameters, like inoculum size (15, 10 and 5% of the working volume of the reactor), gas velocities (0.0027, 0.00342 and 0.0068 m/s), bed heights (0.3, 0.6 and 0.9 m), static bed heights (4.85 and 2.43 cm), sizes of solid media particles (12, 4 mm), and the height to diameter ratio (H/D : 0.25 and 0.5) onto COD reduction process for electroplating effluent (initial COD values: 1140 ppm) using *Pseudomonas aeruginosa* and *Pseudomonas putida*. The authors derived simple mathematical correlations representing the entire COD reduction process. The correlation between the inoculum volume and gas velocities was in the form of an equation $Y = ax^2 + bx + c$, as deduced from nonlinear regressions. The correlations were validated, and percentage errors were found out to infer the effects of all parameters in the COD reduction process. The maximum COD reduction was achieved to 28.30 ppm (97.52%), in a batch mode, at 10% inoculum size, 0.0027 m/s low gas velocity and a static bed height of 2.43 cm.

Keywords Electroplating effluent · COD · Modeling · Inoculum volume · Gas velocity

Introduction

The industrial, agricultural or domestic activities intensify water pollution problem. The wastewater streams like electroplating, in particular, contain poisonous and toxic substances which are discharged into environments (Sezgin and Balkaya 2016). Electroplating effluent contains heavy metals which are toxic even at low concentrations, and they tend to accumulate in nature affecting the ecosystem. These heavy metals (such as copper, nickel, chromium, zinc, cadmium, and mercury) cause an adverse effect on the human health (Fu and Wang 2011). The electroplating effluents exhibit high chemical oxygen demand (COD) due to the presence

of compounds such as electroplating additives (Zhao and Cao 2012), metal precipitates (Gallegos-Gareia et al. 2009) and metal-cyanide complex (Naim et al. 2010). Therefore, removal of these compounds, containing heavy metals, is necessary to bring down COD of electroplating effluent in a permissible discharge limit of 250 mg/l (Singh et al. 2016) and thereby controlling pollution and its effect on the environment.

The methods for heavy metal removal like chemical precipitation, sulfide precipitation, chelating precipitation, coagulation and flocculation, adsorption, ion exchange, membrane filtration, flotation and electrochemical treatments are well reviewed by Fu and Wang (2011). The ion exchange, membrane filtration, and flotation processes require high initial capital cost and high maintenance cost. The problem of sludge generation and its disposal in the case of chemical precipitation and coagulation/flocculation limit its use, whereas electrochemical methods treat heavy metal wastewater with high initial capital cost (O'Connell et al. 2008). Despite low-cost and widely applied technique, adsorption incurs the question of selection of the suitable adsorbent for the treatment (Barakat 2011). Electrocoagulation also seeks attention to problems like long residence time (Al-Shannag et al. 2015), high operating cost (Bazrafshan et al. 2015), slow abatement of COD

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due to insufficient quantity of adsorption matrix (Lekhlif et al. 2014) and selection of electrodes (Dermentzis et al. 2011). The biosorption process also lacks the regeneration of biosorptive capacity of the biomass (Park et al. 2006). UV–Fenton oxidation process involves the use of Fenton reagent which has the higher cost, if used alone, without combining it with other techniques (Zhao and Cao 2012). These limitations motivated many studies in the past for treating electroplating effluent for the removal of COD, and still, there is a need for simple, easy and economical method.

Inverse three-phase fluidization is more efficient when applied for biological aerobic treatment (Sur and Mukhopadhyay 2017b; Nikolov and Karamanev 1987). When the fluidized bed expands downwards—against the net buoyancy force of the particles—it is termed as the inverse fluidized bed. A three-phase inverse fluidized bed bioreactor (TPIFB) is successfully employed in all aerobic biological treatment of wastewater due to its low energy concerns, low-pressure drop, better gas holdup and high rates of mass and heat transfer rates (Sabarunisha Begum and Radha 2014). Recent developments in three-phase inverse fluidized beds have encouraged its applications in various industries, viz. biotechnological (Sur and Mukhopadhyay 2017a) and environmental (Haribabu and Sivasubramanian 2014) and chemical (Rajasimman and Karthikeyan 2007).

Biological effluent treatment involves the use of aerobic or anaerobic microorganisms to decrease organic loads. The aerobic process ensures total oxidation of organic compound unlike anaerobic process, wherein oxygen acts as the main electron acceptor and converts complex molecules to simple compounds. These metabolic reactions release energy required for the growth of microbial cells, and these microbial cells digest organic pollutants. Most of the literature has reported the treatment of effluent with the low organic load which has initial chemical oxygen demand (COD) less than 350 mg/l (Souza et al. 2004). So far, none of the researchers have investigated the efficiency of biological methods for effluent treatment generated from electroplating wastes, economically at high loading. It is important to understand the effects of different parameters taking part in this biological degradation process with their interrelations. Their correlations reveal some vital facts necessary to understand the operation and process design of TPIFB for electroplating effluent. No correlations for the electroplating effluent are available in the literature. This fact encourages the present work. Moreover, the quantum of research for effluent treatment in the batch mode, using TPIFB, is limited (Sur and Mukhopadhyay 2017a). Therefore, the current research specifically investigates the parameters and their correlations responsible for the reduction in COD of the electroplating effluent through a single representation for the full TPIFB operation, carried out in the batch mode.

Materials and methods

Reactor setup

The raw untreated electroplating effluent (initial COD of 1140 mg/l) was collected from a nearby area of Rajkot city. It was treated in a bioreactor fabricated from acrylic (Sur and Mukhopadhyay 2017a), and solid media particles were made up of polypropylene (Online resources: ESM: Table S1). Electroplating effluent (composition: Cr = 19.4 ppm; Ni = 9.4 ppm; Fe = 0.9 ppm; conductivity = 68 mS/cm; pH 4.1) was treated to investigate the performance of gas sparger in a batch mode i.e., zero liquid velocity. A gas sparger (numbers of holes: 271, diameter: 2.5 mm each, pitch: triangular) was used to allow entry of gas for the purpose to reduce the COD. The solid media particles (polypropylene) were added from the top to the bioreactor column, filled with an electroplating effluent. The air entered the reactor column from its bottom. The air connection to bioreactor had an air filter before its entry from the compressor. The steady state was found to reach in maximum 25 min. After this condition, COD removal was observed at a zero liquid velocity and definite gas velocities. Having ensured ‘inverse’ mode (solid media particles in downward motion) of bioreactor operation, the experiments were accomplished with the combination of all the parameters including gas velocities (0.0027, 0.00342 and 0.0068 m/s), bed heights (0.3, 0.6 and 0.9 m), static bed heights (4.85 and 2.43 cm) and sizes of solid media particles (12, 4 mm). After each batch, the reactor was washed with 10% concentrated solution of hydrochloric acid to ensure no contamination.

Microorganisms

Initially, COD degradation capabilities of various cultures were determined for the electroplating effluent, those included: *Pseudomonas putida*, *Pseudomonas aeruginosa* (purchased from IMTECH, Chandigarh, India), *Pseudomonas fluorescens* and *Bacillus subtilis* (purchased from NCL, Pune, India). These microbial cultures were used for the three different sizes of inoculums: 5, 10 and 15% of the working volume of the reactor.

Results and discussions

Various parameters affected the overall performance of TPIFB for COD reduction. Only gas flow kept the solid media particles in a fluidized condition. The stationary bed of solid media particles (polypropylene particles) started fluidizing at 0.8 LPM (0.0027 m/s) showing inversion (Fig. 1).

Fig. 1 Bed at minimum fluidization showing inversion

Fig. 2 Onset of expanded bed regime

As the gas velocity increased, the remaining fixed bed also moved progressively until the full fluidization was achieved (incipient fluidization). For maintaining inversion mode, the value of the minimum gas velocity (0.0027 m/s in the present case) represented the beginning of expanded bed

regime (Fig. 2). This gas velocity was much lower due to induced liquid circulations promoted by gas bubbles. The complete movement inside the TPIFB comprised the larger and smaller bubbles making a homogeneous pattern.

The media particles were distributed along the total height of the reactor column non-uniformly with further increase in the gas velocity. The concentration of media particles was still higher at the top and progressively decreased downward. This concentration was maintained uniform with a slight increase in gas velocity. Bed showed no more inverse flow beyond 0.0068 m/s gas velocity, and slugs also formed at 0.0068 m/s. The requirement of inversion was maintained with good liquid circulations dragging the media particles upward. Most of the time inverse three-phase fluidized bed exhibited dispersed bubble flow regime wherein the bubble size was almost uniform. In this regime, the bed expansion was also uniform with downward movement. The gas velocity ensured that the TPIFB was operated an inverse mode. Apart from gas velocities, the other parameters affected the COD; those include—inoculum size, total bed height, static bed height and the size of the particles—as discussed in the next section. The mixed cultures of *Pseudomonas aeruginosa* and *Pseudomonas putida* were finally selected to treat electroplating effluent, as they exhibited the higher reduction in COD.

Effect of inoculum size

Inoculums were prepared for 5, 10 and 15% concentrations, and experiments were performed for all these concentrations with its combinations to different gas velocities (0.0027, 0.00342, 0.0068 m/s). This way optimal inoculum size and gas velocities were determined initially (Fig. 3a, b, c). The best possible reduction in COD was attained at the value of 28.30 ppm (97.52%) at 0.0027 m/s and 10% volume of inoculum.

At lowest of all possible gas velocity, the COD reduced to 28.30 ppm (97.52%) with uniform and consistent gas bubbles. The flow pattern was fully in dispersed bubble regime. Size of the inoculum governed the growth of *Pseudomonas aeruginosa* and *Pseudomonas putida*, and it was responsible for the generation of turbidity based on its percentage. Due to turbidity, electroplating effluent exhibited little inconsistency in bubble flow pattern. Therefore, the gas holdup was constant and uniform for inoculum size of 5 and 10%. However, this trend was reversed as 15% inoculum exhibited inconsistent gas holdup. On the other side, the growth of a mixed culture of *Pseudomonas aeruginosa* and *Pseudomonas putida* was slow until 10 h for 5% volume of inoculum. They grew along with uniform bubble patterns between 10 and 20 h. After 20 h, poor gas holdup prevailed until the end of the process (Fig. 4). For 10% volume of inoculum, the adaptability of *Pseudomonas aeruginosa* and *Pseudomonas*

Fig. 3 Effect of inoculum: **a** at 0.0027 m/s **b** at 0.00342 m/s **c** at 0.0068 m/s gas velocity

Fig. 4 Poor gas holdup for 5% inoculum size

putida was better in the sense that there was no hindrance to microbial adaptability, because of turbidity. The growth was also uniform for all the values of gas velocities. It indicated that lower the size of the inoculum, the minimum was the turbidity. However, the size of inoculum was decided by trial and error in TPIFB.

Effect of bed height

The optimal conditions were investigated for the effect of bed heights for the reduction in COD for electroplating effluent. Three bed heights were taken as 30, 60, and 90. At lower bed height of 30 cm, gas holdup sustained in a bioreactor for comparatively lesser period than that with when bed height was 60 cm. Both the heights—30 and 60 cm exhibited the discrete bubble regime. Therefore, the pattern of reduction in COD was the same for both—30 and 60 cm bed height. However, initial adaptation period for *Pseudomonas aeruginosa* and *Pseudomonas putida* was different at both of these bed heights. The consistent gas holdup was characteristic with both the bed heights—30 and 60 cm. However, inversion sustained for all retention time with 30-cm bed height (Fig. 5) with 95.68% COD removal reaching the final COD value of 49.30 ppm. So 30-cm bed height was continued for the rest of the experiments. On the contrary, 90-cm bed height produced slugs at regular interval. This contributed the poor exposure of bioparticles (biofilm and solid media particles) to gas bubbles, so it caused the microbial cultures of *Pseudomonas aeruginosa* and *Pseudomonas putida* deficient in the growth. This resulted in slower degradation of COD and reducing it to 724.80 ppm (36.42%), much higher than the minimum permissible value of 250 ppm. Therefore, slugs must be prevented in selecting suitable bed height for better performance.

Effect of static bed height

The solid media particles rested upon one another in the upper portion of the fluidized bed. This layer of solid media

Fig. 5 Effects of bed heights: 0.0027 m/s gas velocity, 10% inoculum

Fig. 6 Effects of static bed heights: 0.0027 m/s gas velocity, 10% inoculum

particles was regarded as static bed height in a bioreactor, denoted as ' H .' The ratio represented by static bed height to column diameter (H/D) played an important role in evaluating TPIFB performance apart from considerations of gas velocity. H/D was taken as 0.5 and 0.25, but since the diameter was constant here, H equivalent to H/D of 0.5 and 0.25 was calculated to be equal to the height of 4.85 and 2.43 cm of solid media particles in a bioreactor filled with the electroplating effluent. 2.43 cm height of media particles corresponding to a volume of 30 cm (equivalent to 2.12 l) was the parameter at which maximum 95.68% (Fig. 6) COD removal achieved attaining the final value of 49.30 ppm.

Effect of gas velocity

Low gas velocity was sufficient to reduce the COD to a significant level for wastewater generated from electroplating industry. At the start of the operation of TPIFB, the bubbles moved to the bottom of the bed disturbing solid media particles. This was the minimum fluidization velocity. As the gas velocity increased, the gas holdup increased over a period and then remained steady resulting in improved degradation of COD across all the retention time. The gas holdup was, in turn, dependent on the rate of consumption of oxygen by the microbial cultures of *Pseudomonas aeruginosa* and *Pseudomonas putida*. Figure 7 illustrates consistent degradation in COD for 10 and 15% inoculum size. The maximum COD was achieved at a gas velocity of 0.0027 m/s at 10% size of inoculum and at 28 h of retention time. At a velocity higher than 0.0027 m/s ($= 0.00342$ m/s), the growth almost reduced between 12 and 17 h, since there was holdup contributed by bigger size gas bubbles. As such, these bigger bubbles reduced the surface area available for the growth of *Pseudomonas aeruginosa* and *Pseudomonas putida* for COD degradation. Therefore, microbial species consumed more time in degradation of organic wastes and exhibited adaptability by 18 h. Then after, the gas bubbles

Fig. 7 Effect of gas velocity on COD reduction at 10% inoculum

Fig. 8 Effect of 12 mm and 4 mm particles on COD reduction

Table 1 Properties of solid media particles

Particles	Diameter, d_p (mm)	Shape	Density kg/m ³	Surface area per particle (mm ²)
P1	12	Sphere—hollow	643.9	162.18
P2	4	Sphere—solid	722.6	12.56

were constantly formed in an uneven manner until 18 h due to the growth pattern of *Pseudomonas aeruginosa* and *Pseudomonas putida*. The maximum COD reduced up to 49.30 ppm (95.68%) from its initial value of 1140 ppm for 12-mm-diameter solid media particles.

Effect of size of particles

Two different types of solid media particles were taken for trials (Fig. 8). Table 1 displays the properties of both the particles. Once the packed bed was broken, then the bioreactor was in inverse conditions with both these particles. The gas flow rate was further reduced to a value where particles were reaggregated and thus the bed expanded. All the

Fig. 9 Solid media particles: **a** 12 mm diameter **b** 4 mm diameter

experimentations were conducted with 12-mm-diameter particles (Fig. 9a) since they had large surface area and the density lower than that of 4-mm-diameter spheres of polypropylene particles (Fig. 9b). Both these factors (density and size of particles) were important in achieving COD reduction. So higher the surface area of solid media particles, better was the reduction in COD of the electroplating effluent. This is due to the fact that *Pseudomonas aeruginosa* and *Pseudomonas putida* utilized the entire surface present on the solid media particles to grow over it and digested the organic waste present in it, lowering the COD values. After reduction, the amount of COD reached was 170.50 ppm for 4-mm-diameter particles and same was 28.30 ppm for 12-mm-diameter particles. Thus, almost six times higher COD reduction was possible with 12-mm-diameter particles. Faster reduction of COD was achieved with the higher size of solid media particles.

From the experimental trials, all the optimal parameters were found for the TPIFB. It was ensured that low gas velocities (0.0027 m/s) gave much higher COD reduction (28.30 ppm; 97.52%) through batch mode in TPIFB. This fact favored the economy of the operation also. Table 2 illustrates the comparisons of other similar work as enriched for the up-to-date literature review. The present COD reduction process resulted from only with biological treatment in TPIFB operated in aerobic mode. For successful design and operation of TPIFB, correlations between different

Table 2 Comparisons of various research work for COD reduction

Sr. no.	Process/treatment	COD removal (%)	Dependent variables	Author
1	Inverse fluidized bed bioreactor	97.52%	Inoculum size, gas velocity	Present work
2	Electrocoagulation	52%	Working temperature, pH of electrolyte, current density, electrodes	Tran et al. (2015)
3	UV–Fenton oxidation-biological aerated filter process	88%	pH dependent, reaction activity of Fenton reagent	Zhao and Cao (2012)
4	Electrocoagulation	> 95%	Current density, pH of electrolyte, time of operation	Praveen et al. (2011)
5	Electrocoagulation	75.30%	Current density, pH of electrolyte, contact time	Dermentzis et al. (2011)
6	(1) Hydroxide precipitation (2) Sulfide precipitation	(1) 50% (2) 61.25%	pH dependent	Naim et al. (2010)
7	Fluidized bed reactor	54%	Sulfate activities of biofilm	Gallegos-Garcia et al. (2009)
8	Electrocoagulation	63.57%	Current density, pH of electrolyte, contact time	Adhoum et al. (2004)
9	Electrocoagulation	75.30%	Current density, pH of electrolyte, contact time	Dermentzis et al. (2011)
10	Electrocoagulation	100% [Fe–Fe/Fe–Al] metal removal	pH of electrolyte, time of operation, current density	Rajamahadik et al. (2013)
11	Chemical precipitation and electrodialysis	95% [Cr] metal removal	Current density	Peng et al. (2004)
12	Adsorption in activated alumina	> 90% [Cr-bronze] metal removal	Concentration of alumina, bed depth service time	Mazumder et al. (2011)

parameters helped in understanding the complexity between all parameters involved into the system. They are presented in the following sections as a single representation of the system.

Mathematical correlations

The mixed cultures of *Pseudomonas aeruginosa* and *Pseudomonas putida* reduced COD in TPIFB as evident from the experimental investigations. The correlations were developed for TPIFB in batch mode at steady state. In the present case, pollutants and oxygen were diffusing simultaneously into liquid effluent streams. Schematic diagram showing the TPIFB reactor, with corresponding correlations, is illustrated in Fig. 10. The correlations assumed the following:

- (1) There is no back mixing past the gas sparger in the bioreactor column.
- (2) The COD reduction process is strictly aerobic. Oxygen acts as the growth limiting nutrient.
- (3) The solid media particles (spherical in shape) are inert.
- (4) Size of inoculums incurs different extent of turbidity in the reactor while degrading the COD.

The reduction in COD incorporated basic process steps as: (1) Oxygen transported from the gas phase into wastewater (bulk liquid phase) and 2) organic pollutants and oxygen transported to biofilm surface over the top of solid media particles and diffusion occurred among these phases simultaneously. The overall rate of oxygen consumption (r_0) is given by the equation:

$$r_0 = Q_i(C_i - C_f) - (K_L a)(C^* - C_f)V, \quad (1)$$

where, Q_i is the volumetric flow rate of gas phase in inlet; C_i is the concentration of dissolved oxygen in inlet effluent; C_f is the concentration of dissolved oxygen in bulk effluent; C^* is the concentration of gas and liquid phase at equilibrium; $K_L a$ is the overall gas–liquid mass transfer coefficient; V is the working volume of the reactor.

Equation (1) considered the complete mixing of the effluent around the solid media particles at steady-state conditions. Further, mass balance equation over a biofilm covering solid media particles led to following equations:

$$r_0 = K_0 P_s(C_i - C_{bf})$$

$$r_0 = \frac{V \epsilon_s}{\frac{4}{3} \pi r_b^3} (4 \pi r_b^2 N_p) \frac{dc}{dr_b}, \quad (2)$$

Fig. 10 Schematic diagram showing reactor, with corresponding correlations equations necessary for TPIFB

where P_s is the particle surface area for total numbers of solid media particles; r_b is the radius of bioparticles (particles and biofilm together); K_0 is the mass transfer coefficient for biofilm; C_{bf} is the concentration of dissolved oxygen in biofilm; N_p is the number of solid media particles; ε_s is the solid holdup.

Equation (2) represented overall oxygen consumption rate, which in turn, helped in knowing COD reduction rate since *Pseudomonas aeruginosa* and *Pseudomonas putida* grew through oxygen uptake from the sparger air in the TPIFB. Their growth rate is exhibited by Monod equation in terms of oxygen concentration. So, the specific growth rate is written as,

$$\mu = \frac{\mu_{\max} C_f}{K_M + C_f}, \quad (3)$$

where $\mu_{\max}$ is the maximum specific growth rate; K_M is the constant representing growth.

However, to apply Eq. (2), oxygen concentration data pertaining to biofilm were required and given by the following equation:

$$\frac{D_{bf}}{r_b^2} \left[\frac{d}{dr_b} \left(r_b^2 \frac{dC_f}{dr_b} \right) \right] - \frac{\rho}{Y_{x0}} (\mu) = 0, \quad (4)$$

where D_{bf} is the diffusivity of oxygen within the biofilm; ρ is the biofilm dry density; Y_{x0} is the growth yield coefficient for oxygen.

Equation (4) is subjected to boundary conditions as: $(dC_f/dr) = 0$. The radius of solid media particle is added with biofilm thickness as a final state while calculating

diffusivities of oxygen. The diffusion of oxygen through gas spargers controlled the COD reduction process. However, since it was a bioprocess, inoculum volume had a major role to play across the entire process.

To understand the effects of inoculums size, the theoretical relationships governing inoculum volume and gas velocities were derived here. The nonlinear regressions were performed for all the variables first. Trails and error approach confirmed the effect of these parameters. The equations of the form of $Y = ax^2 + bx + c$ describe the correlations between inoculum volume and gas velocity in TPIFB treating electroplating effluent. Table 3 illustrates all the values of coefficient to substitute in the equation $Y = ax^2 + bx + c$, for 5, 10 and 15% inoculum volume. The value of the coefficient of correlation (R^2) as 1 confirmed the strong correlation between them.

These correlations are validated. The random sets of parameters were taken to conduct the experimentations for investigating its COD reduction capacity and compared to theoretical correlations (Table 4). The percentage error was found out. Most of the percentage errors were ranged from 1.59 to 3.82%. This range of error was acceptable, since it meant that the actual value of the set of parameters including gas velocity, inoculum volume and static bed height was within the acceptable limit of $\pm 5\%$ to its theoretical values for the entire range of TPIFB operation ensuring accuracy and reliability of the results. The highest error exhibited was 8.99% with a set of parameters that had higher gas velocity, inoculum volume and static bed height with a lower diameter of solid media particles. It meant that lower gas velocity was preferred contribution to COD reduction with lower static bed height. Inoculum volume above 10% was not favorable

Table 3 Coefficient values for correlations equations, with reference to inoculum volume

Sr. no.	Inoculum volume (in percentage of working volume of reactor) (%)	Equation $y = ax^2 + bx + c$			Value of R^2
		Value of coefficient 'a'	Value of coefficient 'b'	Value of coefficient 'c'	
1	5	32871	− 3452.9	10.319	1
2	10	505891	− 5017.7	13.936	1
3	15	102782	− 981.94	4.531	1

Table 4 Percentage error with random set of parameters representing validation of correlations

Gas velocity (m/s)	Inoculum volume (%)	Bed height (cm)	Static bed height (cm)	Particle dia. (mm)	% COD reduction		% Error
					Actual	Theoretical	
0.0027	5	30	2.43	12	95.55	97.1	1.59
0.00342	15	60	2.43	4	70.22	73.00	3.80
0.0068	5	30	2.43	4	65.4	68.00	3.82
0.0027	10	60	4.85	4	62.69	64.93	3.45
0.00342	5	30	4.85	12	72.69	73.8	2.68
0.0068	15	90	4.85	4	21.22	23.31	8.99

to the bioreactor operation in inverse mode since it resulted in turbidity as well as slugs in the bioreactor. The bed height (total), static bed height and size of particles did not have more significant and direct influence on COD reduction. However, the total bed height and static bed height majorly affected the flow patterns and contributed to the gas holdup, which in turn gave an idea about mass transfer between gas bubbles and electroplating effluent. Therefore, the fact that the homogenous bubble governed the COD reduction process was the assumption for the presented correlations. The bioreactor operation further considered the entire experimentation at no slug conditions and with the maintenance of uniform gas velocity.

Conclusions

The mathematical correlations represent the entire COD reduction process in TPIFB and simplify all correlations between the parameters. The theoretical relationships governing inoculum volume and gas velocities of the form of $Y = ax^2 + bx + c$ describe the perfect correlations between inoculum volume and gas velocity for treating electroplating effluent as R^2 (coefficient of determination) value is unity. Validations of correlations exhibiting less percentage error for almost all random experiments strengthen its acceptability.

The inoculum size, gas velocities, static bed height and solid media particle diameter influence the performance of TPIFB. The electroplating effluent performed optimally at 10% inoculum size with low gas velocity 0.0027 m/s and the static bed height of 2.43 cm in TPIFB. The maximum COD removal is achieved at 97.52% in a batch mode. The low gas velocity is the major advantage to carry on the COD reduction in TPIFB.

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Compliance with ethical standards

Conflict of interest This manuscript is the authors' original work and has not been published nor has it been submitted simultaneously elsewhere. All authors have checked the manuscript and have agreed to the submission.

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