Treatment of Pre-Treated Textile Waste Water Using Moving Bed Bio-Film Reactor

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Abstract—*The article emphasizes the study on the efficiency of Moving Bed Bio-film Reactor with carriers inoculated with bacteria isolated from textile sludge in the treatment of textile wastewater. This study is also intended to determine the effectiveness of Fluidized bed Fenton pre-treatment process in the COD removal and BOD to COD ratio enhancement. Biological processes are a cost-effective and environmentally sound alternative to the chemical treatment of textile wastewater. Moreover Bio- film processes have proved to be reliable for organic carbon and nutrients removal. The Moving Bed Bio-film Reactor (MBBR) is a highly effective biological treatment process that was developed on the basis of conventional activated sludge process and bio filter process. It is a completely mixed and continuously operated bio-film reactor, where the biomass is grown on small carrier elements that have a little lighter density than water and are kept in movement along with a water stream inside the reactor.*

Keywords—Moving Bed Bio-film Reactor (MBBR); Moving Bed Biological Treatment (MBBT)

1. INTRODUCTION

Water pollution is a state of deviation from pure conditions partially, wholly or largely as a by-product of human activity. Major industrial contributors to the pollution are the pulp and paper, chemical, petrochemical, refining, metalworking, food processing and textile industries. The effluent generated by the textile industry is one of the most polluting among all industrial effluents and it is an important issue to be able to treat these waste waters.

Due to changes in the consumer’s demand the content of the effluents has changed rapidly, today there is a great usage of synthetic reactive dyes. The dye effluents generated by textile, paper and printing industries affect the visibility and the photosynthesis in the water bodies and it may also be toxic to the aquatic life. The production processes in textile industry not only consume large amounts of energy and water, but they also produce substantial waste products. Several countries including India, have introduced strict ecological standards for textile industries, to minimize effluent problems.

An important environmental issue related to textile industry is the production and discharge of large volumes of highly polluted wastewater, due to the consumption of about 100 to 200l of water per kg of textile product and the use of an immense range of materials and chemicals in the production chain.

A. Need For The Study

Textile industry requires a large volume of water for their processes and the waste water discharged from the mill is equally large in volume and of polluting nature. The effluent from textile is an important source of dye pollution. Many dyes and their break down products may be toxic for living organism. Decolourisation of dyes is an important aspect of wastewater treatment before discharge.

Dyes with striking visibility in recipients may significantly affect photosynthetic activity in aquatic environment due to the reduced light penetration. Therefore, it is necessary to remove dyes from wastewater before it is being discharged into the environment.

Dye removal from wastewater with traditional physicochemical methods, such as coagulation, adsorption and oxidation with ozone is expensive, can generate large volumes of sludge. A secondary pollution problem can also arise because of excessive chemicals used in treatment processes.

MBBR is a continuously operating system with more advantages. The moving bed bio-film reactor utilises the whole tank volume for biomass growth. Contrary to the activated sludge process, it does not need any sludge recycle. This is achieved by having the biomass grow on carriers that move freely in the water volume of the reactor.

The present study evaluated the performance of MBBR with carriers inoculated with bacteria isolated from textile sludge for treating textile wastewater. Fluidized bed Fenton treatment is provided as pre-treatment to reduce COD of the textile wastewater. The enhancement of treatment efficiency with the increased quantity of carrier materials was also studied.

B. Objectives And Scope Of The Study

The main objective is to study the effectiveness of fluidized bed Fenton pre-treatment process in the COD removal and BOD to COD ratio enhancement. Moreover to evaluate the efficiency of MBBR with carriers inoculated with bacteria isolated from textile sludge in the treatment of textile wastewater.

The removal of dye from textile effluent by using various physical and chemical methods such as coagulation, adsorption and also oxidation with ozone is very costly. Besides that they can generate large amount of sludge and usually require the addition of environmental hazardous chemical additives. Considering drawbacks of such treatments, microbial remediation techniques have gained much attention in the last few decades. Microbial decolourization and degradation is an environment friendly and cost-competitive substitute to different conventional treatment technologies.

MBBR process is based on the bio-film principle and utilizes the advantages of activated sludges and other bio-film systems. They are operated similarly to the activated sludge process with the addition of freely moving carrier media. Instead of being suspended in the liquid, bio-film biomass is attached to a surface that is submerged in the liquid. Therefore, there is no need for settling and sludge recirculation.

The movement inside a reactor can be caused by aeration in an aerobic reactor and by a mechanical stirrer in an anaerobic or anoxic reactor. This action creates a scrubbing effect that prevents clogging. The reactor volume is totally mixed and consequently there is no dead or unused space in the reactor.

C. Fluidized Bed Fenton process

A fluidized bed is a bed of solid particles with a stream of gas or liquid passing upward through the particles at a rate great enough to set them in motion. As the liquid or gas travels through the particle bed, it imparts unique properties to the bed. For example, the bed behaves as a liquid. It is possible to propagate wave motion, which creates the potential for improved mixing. The carriers in fluidized-bed Fenton reactor can initiate the iron precipitation or crystallization process, therefore, the production of sludge is reduced.

When a liquid or a gas is passed upward at very low velocity through a bed of solid particles, the particles do not move. If the fluid velocity is steadily increased, the pressure drop and the drag on individual particles increase, and eventually the particles start to move and become suspended in the fluid. The terms fluidization and fluidized bed‖ are used to describe the condition of fully suspended particles, since the suspension behaves like a dense fluid.

Fluidized Bed reactor is a process which is now widely applied in many industrial applications. In recent studies it is evident that, fluidized bed reactors can also be an attractive procedure for treating polluted water. Fenton process is more productive when the reaction gets an efficient reaction platform which is Fluidized bed reactor.

D. Moving Bed Biofilm Reactor

The Moving Bed Bio-film Reactor (MBBR) is an efficient and cost effective biological treatment process that was developed on the basis of activated sludge process and other bio filter process. It is a completely mixed and continuously operated bio-film reactor.

The fundamental characteristic of the MBBR is the specially designed bio-film carriers, for which the geometry, sizing and materials of construction have been considered carefully to maximize performance. One of the most important features of MBBR carriers is that they contain a large protected surface area for bio-film colonization. This is one of the advantages of this treatment process.

In the MBBR, surface area can be increased by designing carriers with a higher specific surface area or by adding a greater quantity of carriers to a reactor volume. This offers flexibility for future treatment capacity without requiring the construction of additional reactors. Fig.1 shows the biological media used in MBBR.

Fig.1 MBBR Biological Media

2. REVIEW OF LITERATURE

Investigations carried out by various researchers in the area of Moving Bed Bio-film Reactor are described below.

A. Moving-bed biological treatment system

An investigation was carried out on “Moving-bed biological treatment (MBBT) system.” It is performed in a bio-film system with relatively large carriers. These are mixed with the wastewater and suspended in the reactor by turbulence. The system is located somewhere between an activated sludge and a fixed bed bio-film system. It does not have to rely on a sludge recycle, as slow-growing microorganisms can be maintained independently of the overall solid-retention time and the danger of clogging is relatively small. By selecting appropriate carriers, conventional reactors for activated-sludge systems could be converted to bio-film systems.

B. Non clogging bio-film reactor

This is achieved by having the bio-film grow on both small carrier elements that move along with the water in the reactor (attached growth) as well as in the water itself (suspended growth). The bio-film carrier elements are made of polyethylene, having a density slightly less than water, and are shaped like small cylinders with a cross inside the cylinder and longitudinal fins on the outside.

C. Carriers used in MBBR.

The carriers used were sponge cubes made from Poly-Urethane foam. They were suspended in conventional reactors without activated sludge. The advantages claimed were the removal of excess sludge by squeezing the carriers off-line (no need for clarifiers), higher volumetric COD turnover and increased oxygen transfer of the aerators.

D. Application of MMBR in various industries for the treatment of effluents.

These include treatment of pulp and paper industry waste, poultry processing wastewater, cheese factory wastes, refinery and slaughter house wastes, phenolic wastewater, dairy wastewater, municipal wastewater etc.

E. Application of aerobic moving bed biofilm process as post-treatment of anaerobically degraded azo dye “Acid Red 18”.

The main objective of this work was to enhance removal of anaerobically formed the dye aromatic metabolites. Three separate sequential treatment systems were operated with different initial dye concentrations of 100, 500 and 1000 mg/L. Each treatment system consisted of an anaerobic sequencing batch reactor followed by an aerobic moving bed sequencing batch bio-film reactor. Up to 98% of the dye decolourization and more than 80% of the COD removal occurred anaerobically.

3. METHODOLOGY

A. *Sampling of real textile wastewater*

Three samples of untreated real textile wastewater were collected from Augustan Textile Colours Pvt. Ltd., Kanjikode, Palakkad in three days. They were stored at $4^{o}C$ and analysis was done for all the samples collected. The characteristics of untreated textile wastewater are shown in the Table 1.

TABLE 1.CHARACTERISTICS OF UNTREATED TEXTILE WASTEWATER

Parameter	Unit	Concentration
COD	mg/l	600-800
BOD	mg/l	180-240
pH	-	10-11
TSS	mg/l	40-100
TDS	mg/l	2000-3000
Alkalinity	mg/l	700-1200
Turbidity	NTU	70-120
Sulphide	mg/l	100-140
Chloride	mg/l	1200-1600
Hardness	mg/l	250-420

B. *Synthetic wastewater*

The synthetic wastewater was prepared by considering the characteristics of a real textile dying effluent. The composition of this wastewater is given in Table 2 and it includes dyes, levelling agent, lubricants, bicarbonate remover, salt solution, caustic soda and softener.

TABLE 2.COMPOSITION OF SYNTHETIC TEXTILE WASTEWATER

Chemicals	Quantity
Chemistar turq blue(Dye)	100mg/l
Sorbecol (Levelling agent)	3 ml/l
Nylube C (Lubricant)	4 ml/l
Salt	1g/l
20 % Caustic soda	2 ml/l

Fig.2 Chemistar turq blue dye

The quantities of these chemicals were fixed by trial and error procedure. Levelling agent is used to remove dye patches present in the fabric. Lubricant facilitates the attachment of dye in the fabric. In finishing process softeners are used to provide required softness to the product.

TABLE 3.CHARACTERISTICS OF SYNTHETIC TEXTILE WASTEWATER

Parameter	Unit	Concentration
COD	mg/l	780
BOD	mg/l	197
pH	-	10.75
TSS	mg/l	49
TDS	mg/l	2604
Alkalinity	mg/l	700
Turbidity	NTU	71
Sulphide	mg/l	110
Chloride	mg/l	1575
Hardness	mg/l	298

C. *Analytical methods*

The parameters like pH, COD, BOD, TSS, TDS, Alkalinity, Turbidity, Sulphides, Chlorides, Hardness and Colour were analyzed as per procedures in standard methods.

D. *Pre-treatment of wastewater*

Sludge produced will be less in the case of Fluidized bed Fenton process so it was chosen for the pre-treatment of textile waste water. By this pre-treatment COD is reduced and the biodegradability of textile wastewater is enhanced for the subsequent biological treatment.

Fluidized bed fenton experiment

In this experiment, the glass beads of 2 mm diameters are first added to the acrylic tube reactor. It is followed by the addition of 100 g/l of SiO_2 carriers. About 1 litre of the synthetic sample whose pH is adjusted by adding H_2SO_4 or NaOH is then introduced into the reactor. The pump was turned on to suspend the carriers and mix the solution. Carriers were fluidized by adjusting the internal circulation at 50% bed expansion. The reaction began when the H_2O_2 and ferrous sulphate (Fe^2+) solution was added.

Experimental Set-Up of Fluidized Bed Fenton Process

The fluidized bed Fenton process is carried out in a 1.35L acrylic tube of 5.2 cm diameter and 133 cm height. The reactor consists of inlet, outlet, and recirculation compartments. Glass beads of size 2 mm are used to support the carrier material. Quartz (SiO_2), with diameters in the range of 1mm was used as carrier.

Fig.3 Experimental set-up of Fluidized bed Fenton process

The various characteristics of textile wastewater after pre-treatment are given in Table 4.

TABLE 4.CHARACTERISTICS OF TEXTILE WASTEWATER AFTER PRE-TREATMENT

Parameter	Unit	Concentration
COD	mg/l	335
BOD	mg/l	175
pH	-	6
TSS	mg/l	21
TDS	mg/l	1800
Alkalinity	mg/l	60
Turbidity	NTU	19
Sulphide	mg/l	4
Chloride	mg/l	74

Carrier materials and microorganism

Moving bed bio-film carriers (MBBC) were prepared using Poly Vinyl Chloride (PVC). Corrugated cylinders with internal diameter D1 of 1.5 cm, external diameter D2 of 2 cm and height of 1.4 cm was prepared. These carriers were used for attaching microorganisms. Fig.5 shows the carrier materials used for study.

The fundamental characteristic of the MBBR is the specially designed bio-film carriers, for which the geometry, sizing and materials of construction have been considered carefully to maximize performance. One of the most important features of MBBR carriers is that they contain a large protected surface area for bio-film colonization. In the MBBR, surface area can be increased by designing carriers with a higher specific surface area or by adding a greater quantity of carriers to the reactor volume.

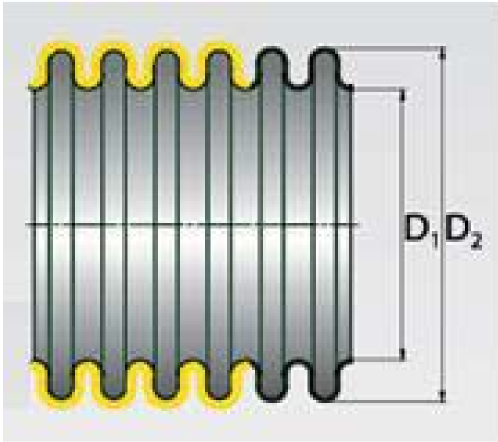

Fig.4 Cross sectional view of corrugated cylinder

Fig.5 Corrugated Cylinders

E. *Moving bed bio-film reactor (MBBR)*

Moving bed bio-film reactor was used for the treatment of synthetic waste water. Parameters like BOD, COD, TDS, TSS, Alkalinity, Hardness, Turbidity, Sulphide and Chloride were analysed after treatment with MBBR.

Various factors affecting treatment of textile wastewater in moving bed bio-film reactor are:

1. Contact time
2. pH
3. Filling ratio of carriers in empty reactor

Experimental Set-Up of MBBR

Three laboratory scale acrylic glass reactor each with a total volume of 11.25 L was used in the study. The reactor had an internal size of 15 X 15 cm and height of 50 cm. The effective depth of wastewater in the reactor was 35 cm i.e.

70% of reactor volume. The reactor was filled with various percentages of carrier elements

The schematic diagram of experimental set-up for the study is shown in Fig.6

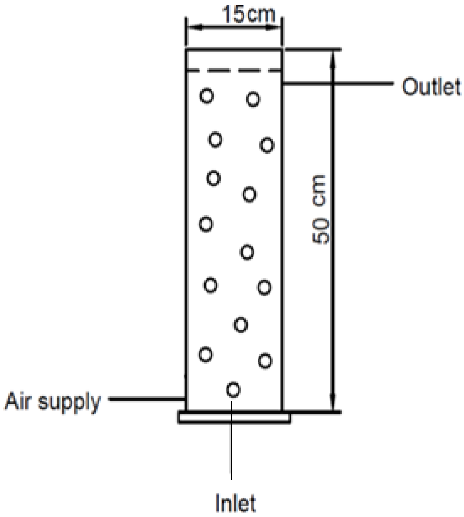

Fig.6 Schematic diagram of experimental set-up of MBBR

The reactor was filled with 7.875 l of wastewater during each testing. Mixing was given by using paddles from the top and aeration was provided by aerators from the bottom of the reactor. Aeration rate of 3 l/min was maintained to keep the media in circulation and meet the desired DO concentration. The experimental set up of MBBR is shown inFig.7

Fig.7 Experimental set up of MBBR

F. Isolation and inoculation of bacteria

Biological sludge from aeration tank of Augustan textiles was collected. This sludge was used for seeding the microorganism. Isolation, Identification and Inoculation are done in Department of Microbiology, Kerala Agriculture University, Vellanikkara.

Isolation

i) Materials required for Isolation

Sludge from textile, Nutrient agar, Conical flasks, Water blanks, Sterile petri-dishes, and Pipettes.

ii) Procedure

Nutrient Agar media was prepared. 10 ml of each sample was mixed with 90 ml sterile water blank in a conical flask (10^{-1} dilution). 1 ml was pipetted from the conical flask to 9 ml sterile water blank in the test tube (10^{-2} dilution).This process was repeated till 10^{-6} dilutions obtained. 1 ml of suspension was pipetted from 10^{-6} dilutions, to sterile, petri-dishes separately. The melted and cooled media were poured in respective plates. The suspension was mixed with media by rotating the petri-dishes in clockwise and anti-clockwise direction. The plates were allowed to solidify. Invert the plates and incubated at 28± 2ºC for 24 to 48 hour. Observed for single isolated colonies of respective microorganism.

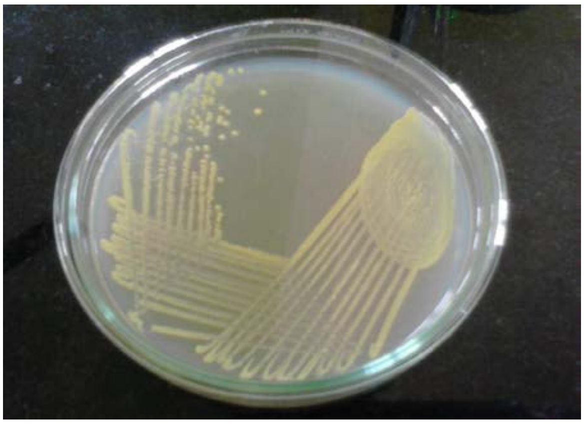

Fig.8 Culture of Microbacterium marnilacus

Inoculation

Carrier materials were dipped in the bacterial culture for 2 hours .Culture was made up by inoculating Microbacterium marnilacus to nutrient broth. After 2 hours carriers were air dried and transferred to MBBR.

4. RESULTS AND DISCUSSION

Moving bed biofilm reactor was used for the treatment of synthetic waste water. Parameters like BOD, COD, TDS, TSS, Alkalinity, Hardness, Turbidity, Sulphide and Chloride were analysed after treatment with MBBR.

Various factors affecting treatment of textile wastewater in moving bed bio-film reactor are:

1 Contact time

2 pH

3 Filling ratio of carriers in empty reactor

For pH, the range selected is from 6-9 which is based on previous study. This pH range is suitable for bacterial growth. For filling ratio (FR), the range selected is 40-80%.This is because if filling ratio is less than 40% then oxygen transfer efficiency will be poor. If filling ratio is greater than 80%, then mixing will not occur. COD of synthetic wastewater was `measured every day after setting up MBBR. Variations in COD after setting up MBBR are shown in table 5.

TABLE 5.VARIATIONS IN COD AFTER SETTING UP MBBR

Parameter	**After Pre-treatment**	**1st day after setting up MBBR**	**11nd day after setting up MBBR**	**111rd day after setting up MBBR**	**1Vth day after setting up MBBR**
COD (mg/l)	340	210	120	118	118
Dye Removal (%)	88%	88.5%	91%	99%	99%

COD was found to be decreasing and remains constant after third day. So time is fixed as three days. The levels of three factors considered in the experiment are shown in table 6.

TABLE 6.LEVELS OF THREE FACTORS

Variables	**Variable levels**	
	Low	High
pH	6	9
Filling Ratio (%)	40	80
Contact Time (days)	1	3

The optimum range of variables that should be considered in the experiment is pH between 6-9, Filling ratio 40-80% and contact time 1-3 days.

5. SUMMARY AND CONCLUSIONS

Textile industry discharge coloured wastewaters and dyes into water bodies which adversely affect aquatic environment. Therefore, it is necessary to remove dyes from wastewater before it is being discharged. Microbial decolourization and degradation is an environment friendly and cost-competitive substitute for different conventional treatment technologies.

Sludge produced is very less in fluidized bed Fenton process. So this process is used to pre-treat the textile wastewater. By this pre-treatment COD is reduced and the biodegradability of textile wastewater is enhanced for the subsequent biological treatment. During fluidized bed Fenton process significant quantities of hydroxyl radicals were produced which are capable for the oxidation of the most resistant pollutants.

In the subsequent biological treatment, Poly Vinyl Chloride (PVC) corrugated carrier materials were used in the MBBR. Carriers of MBBR are inoculated with Microbacterium marnilacus, isolated from textile sludge. Maximum COD and BOD removal were obtained after 2.25 days of treatment at pH 7.33. Filling ratio of carriers in the reactor affects the COD and BOD removal efficiency. Maximum COD and BOD removal were obtained at 67.07% filling ratio.

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