J. Appl. Environ. Biol. Sci., 7(12)81-90, 2017

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Performance of Activated Sludge Biofilms Fluidized Process in The Biotreatment of Real Textile Wastewater

Arsalan Ahmed[1,2,*], Jianzhong Shao[1,2,*], Nazakat Ali[1], Pirah Ayaz[1],S Salvia Binte Touhid[1], Sajad Ali[3], Sumera Nazish[4], Ayaz Ahmad[5]

[1] College of Materials and Textile, Zhejiang Sci-Tech University, Hangzhou, Zhejiang 310018, P.R. China
[2] Key Laboratory of advanced Textile Materials & Manufacturing Technology, Ministry of Education, Zhejiang Sci-Tech University, Hangzhou, Zhejiang 310018, P.R. China
[3]College of Material Science and Engineering, Donghua University, Shanghai 200051, P.R. China
[4]Govt: Shah Latif Girls College, University of Sindh, Jamshoro-Sindh, Pakistan
[5]Department of Biotechnology, Abdul Wali Khan University Mardan 23200, Pakistan

Received: June 22, 2017
Accepted: September 13, 2017

ABSTRACT

This study is based on cow dung as biomass with fluidized supporting media for the removal of color and content of organic compounds from socks processing industry real effluent. This study was carried out on pilot effluent treatment plant in laboratory-scale, activated sludge (AS) aeration zone under stable state condition, changing (MLVSS) -mixed liquor volatile suspended solids and different (HRT) -hydraulic retention time with and without using hexahedron supporting media as biofilm fluidized process. The results demonstrated that the removal of color and COD percentage were ascended around 94.5 % and 96.7 %, respectively, accomplished over 20 hours. Moreover, during the whole biofilm fluidizing process in the aeration reactor, the MLSS was around 29%, using hexahedron SM in a suspended condition. The overall performance of the system was improved by means of HRT and MLVSS concentration without using SM in the fluidized process. Both color removal and reduction in COD level were enhanced with the increase of HRT and MLVSS. Maximum percentage of color removal was determined to be 93%, 90%, 85%, and 76 % in 5500, 4500, 3700, and 2700 mg/l MLVSS, respectively, at 38 h HRT. And the best reduction of COD was noticed to be 81%, 87%, 91%, and 95 % in 2700, 3700, 4500 and 5500 mg/l MLVSS, respectively, at 38 h HRT.

KEYWORDS: Bleaching, Biofilms, Fluidized Process, Activated Sludge, Mixed Liquor Suspended Solids, Decolorization.

1. INTRODUCTION

The massive amount of wastewater is disposed-off from textile (spinning, weaving, knitting, and processing) industries is considered as problematic, containing higher chemical and biological oxygen demands, surfactant, toxic compound, suspended solids (SS) and color, even with very less concentration [1-4]. Textile processing effluent or wastewater contains different pollutants, resulting to increase the level of COD, BOD, and pH[5-8]. The anaerobic digestion created due to the depletion of dissolved oxygen into receiving streams and increase in COD/BOD level of waste water. Furthermore, in an anaerobic condition, hydrogen sulfide is produced, which causes spoil egg-like smell. This will subsequently trouble the biological activity in the receiving stream. Different chemical, physiochemical and biological methods have been used for the removal of dyes are considered as an inadequate, expensive and not efficient as producing massive sludge [6, 9-11]. On the other hand, the biological treatment is a simple and cost-effective way to remove dyes from the textile wastewater. Bioprocess for decolorization is a green and alternative method over other processes. The normal activated sludge method is not able to treat the wastewater produced from socks manufacturing [12-16]. Recently, more consideration is being given to combined processes [17, 18]. As a replacement for of single cultures, usage of mixed bio-cultures appears to be a more promising for the big scale application on field level. The systematic interaction exists inside of the mixed biomass communities, which leads to complete mineralization of dyes[4, 19]. Various parameters affect the performance of the activated sludge process (ASP), like MLVSS and HRT and also by means of supporting media in the fluidized process.

***Corresponding Authors:** Jianzhong Shao, College of Materials and Textile, Zhejiang Sci-Tech University, Hangzhou, Zhejiang 310018, P.R. China, Phone # 008613588113600, E-mails: arsalanahmed_s@yahoo.com (AA) and jshao@zstu.edu.com (JS)

Therefore, the current study was done on treatment of actual socks manufacturing dye effluent at a variety of MLVSS, HRTS, with/without supporting media.

2. MATERIALS AND METHODS

2.1. Textile Industry Effluent

To treat real basis socks manufacturing industrial wastewater (SMIW) or effluent (untreated wastewater) was getting from a local socks manufacturing (Textile-knitting) industry situated in the North Karachi industrial area, Karachi, the biggest City of Pakistan. The SMIWor effluent samples, which was stored at 4 °C in a cold room. The samples were examined with reference to standard methods. The untreated (wastewater) or effluent characteristics are given in Table 1.

Table 1: The Characteristics of Sock Manufacturing (Textile-Knitting) Industry wastewater (SMIW) or Effluent.

Parameters	Unit	Value
pH at 25 °C		10-12
Temperature	°C	40-45
COD	mg/l	1550-1750
TSS	mg/l	250-350
TDS	mg/l	3800-4000
Bicarbonate, mg/l	mg/l	110-119
Trace Elements (Fe, Cr, Cu, Zn, Ni, Pb)	mg/l	0.3-0.8

Table 2: The chemical and dyes, or materials are used in Sock Manufacturing (Textile-knitting) Industry wastewater (SMIW).

Chemicals & Dyes / Materials used	Unit	Concentration	Charge
Detergent	g/L	1-2	Anionic
Sequestering agent	g/L	4	Anionic
Caustic Soda (NaOH)	g/L	4	
Hydrogen peroxide (H_2O_2)	g/L	28-30	
Optical Brightening agent-1	%	0.65-0.70	Anionic
Optical Brightening agent-2	%	0.15-0.20	Anionic
Buffering agent	g/L	0.8-0.9	
Softening agent	g/L	0.34-6	Cationic
Salts (NaCl)	g/L	160-175	
Reactive dyes (GOLDEN YELLOW 2 GR 150%)	%	0.3	
Reactive dyes (RED 6 BN 150%)	%	0.3	
Reactive dyes (BLACK RWR 150%)	%	12.5	
Soda ash ($NaCO_3$)	g/l	40-50	

2.2. Experimental Detail

In this current study, to reduce chemical oxygen demand COD and removal of color from the SMIW, we used a pilot plant for bench scale, continuous flow activated sludge bio-reactor with and without fluidized biofilm (S.M supporting media) as moving media were also used.

The biotic supporting media which is made of polyurethane(PU), hexahedron type (1.3cm x1.3cm x1.3 cm), had a volume(V) of (2.2 cm^3), with a density of (0.21g/cm^3) and 8.51 m^3/g of (S.A) surface area. The hexahedron type support media (fluidized biofilm) were added at 11.5% (V.R) volume ratio all over the study and were kept in a state of dispersed by aeration. The chamber of aeration or reactor volume was 100liters was used for investigational work. In this section, very first biomass or bacterial culture procures for the purpose to get dense activated sludge with aerated several days. Continuously sufficient amount of incorporation of air through the diffuser to keep the desired oxygen concentration in aeration chamber or the reactor. Biomass reactor was functioning at room temperature (25-30 °C). The Lamella clarifier volume was 28 liters. Lemelle plate is installed inside clarifier. To recirculation of activated sludge from this section, to aeration chamber submersible pump mechanism mounted. Figure 1. demonstrates the entire investigational set-up. Specifics of the investigational set-up are given in Tables 3.

In this pilot-scale plant, it was begun in batch mode with 1.75%(w/v) synthetic Glucose media. The medium was inoculated by means of adjusted aerobic culture. Appropriate continuous feeding of a component of glucose was begun afterward, the bioreactor was stabilized. Untreated SMIW fed as influent to the biomass cultured aerated reactor was taken from a sock manufacturing industry, which is situated in a north Karachi industrial area, Karachi,

Pakistan. The process was started with untreated SMIW, combined with 1.75% (w/v) glucose media component was delivered into the aeration tank via a pump of adjustable capacity, which was already measured/calibrated at earlier when the startup of the investigative work as well as occasionally through outrun-up of the bioreactor. Table 4. Reveals, the arrangement of synthetic made glucosemedia. The aeration tank or zone was run for several days to get the desired amount of activated sludge after that aeration tank was run on the variable concentration of MLVSS and hydraulic retention time (HRT) with and without fluidized biofilm process. If needed, the settled activated sludge which is sediment inside or bottom of the Lamella clarifier was recirculated into aeration tank or zone via pumps. If it no needed, the settled activated sludge was removed in a beaker daily from the Lamella clarifier and required concentration of the MLSS was kept inside manually in the aeration tank. All over the study filtered air was provided via diffusers to keep the DO-(dissolved oxygen) level about 2-3 mg/L inside the aeration tank. The other control parameters for experiments were run under the same conditions for each experiment. pH and temperature in the aeration tank throughout each operation were pH = 7 ± 0.3. T= 25 ± 1 °C, respectively.

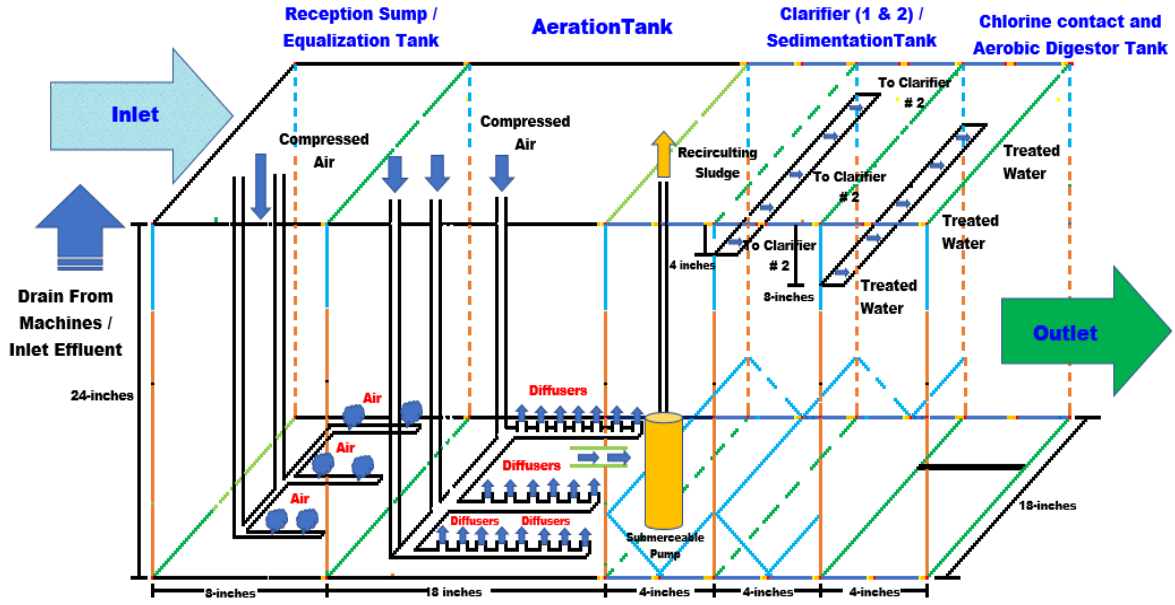

Figure 1: Schematic diagrams of Pilot Scale Effluent Treatment Plant.

The two-selected functioning parameters, i.e. concentration of MLVSS and HRT were changed throughout the development of the investigation work keeping into attention and also evaluate the effect of fluidized biofilm (S.M) process in biological treatment. The commonly applied assortment into activated sludge method for industrial effluent treatment. The biological process in aeration tank or reactor were run for concentration of MLVSS range of 2700, 3700, 4500, and5500 mg/L and HRT value of 20, 30, and 38, respectively, and also using with and without hexahedron type (1.3 cm x 1.3 cm x 1.3 cm), biotic supporting media for (fluidized biofilm process) were added at 11.5% (V.R) volume ratio all over the study and were kept in a state of dispersed by aeration. All the Connected pipes are made of PVC.

Table 3: Specification of Pilot Scale Process Tanks.

Specification	Equalization Tank	Aeration Zone or Chamber	Clarifier 1 & 2	Treated water Tank
Tank Vol.	8" x 24" x 18"	8" x 24" x 18"	4"x 24"x 18"	4"x 24"x 18"
Total Vol.	3456 cubic in	7776 cubic in	2160 cubic in	2160 cubic in
Total Capacity	57 L	127 L	28 L	28 L
Working Vol.	45 L	100 L	26 L	24 L
Material of Construction	Stainless Steel	Stainless Steel	Stainless Steel	Stainless Steel
Quantity:	01	01	02	01
Diffuser:	Pipe type Diffusers	Pipe type Diffusers		
Lamella Clarifier	-	-	Lamella plate installed	-
Inlet	1 no.	1 no.	2 no.	1 no.
Outlet	1 no.	2 no.	1 no.	1 no.

Table 4: The composition of Glucose Media.

Component	Concentration (g/L)
Jaggery	16
Cow manure/dung(fresh)	153
Urea 46 % (Nitrogen)	0.835
DAP (18% Nitrogen,46% Phosphate-P_2O_4)	0.370

2.3. Analytical Methods

For wastewater analyzation of SMIW was withdrawn at different period of time from Aeration zone or reactor. Centrifuged at 6000 rpm for 25 min to precipitates suspended biomass using a Hitech Model centrifuge. The removal of color was determined using UV-Vis spectrophotometer (Model 7800). The pH measurements were conducted using Hach session 378 pH-conductivity meters. Chemical oxygen demand (COD), Total Suspended Solids (TSS), Total Dissolved Solid and Trace Metals (Cr, Fe, Ni, Cu, Co, Zn, Cd, and Pb) were performed according to the standard Method[20].

3. RESULTS AND DISCUSSION

This current research study was completed on real SMIW in continuous mode at Pilot scale plant, using biomass or activated sludge at using an activated sludge process (ASP) at dissimilar HRTs (20, 30 and 38 hrs.) and (MLVSS) mixed liquor volatile suspended solids concentrations of 2700, 3700, 4500 and 5500 (mg/l) with and without (PU made hexahedron type) supporting media for fluidized biofilm process in biological treatment. The color reduction/removal and COD were studied at dissimilar MLVSS concentrations, HRT, and biofilm fluidized process.

3.1. Effect of MLVSS concentration on color and COD removal at 20 hrs. HRT.

The result reveals, the effects of different concentrations of MLVSS (2700,3700,4500, and 5500 mg/l) on the removal of COD and also on decolorization of SMIW or effluent under steady state conditions with the time interval at 20 h HRT is demonstrated in figure 2 & 3. The outcomes of the studies exhibited that proportion of color and reduction of COD improved with the rise of MLVSS, at 20 hrs. HRT, color removal was found to be 48, 52, 61 and 68 % in 2700, 3700, 4500 and 5500 mg/l MLVSS respectively under stable/steady state condition. In the case of COD removal, increasing trend was also observed with the rise in MLVSS concentration. At 20 h HRT the removal in COD was found to be 66%, 71%, 75%, and 79 % in2700, 3700, 4500, and 5500 mg/l MLVSS respectively under steady state condition. The causes of higher reduction of color and removal of COD at higher MLVSS are due to the existing or present of biomass/microorganisms in the aeration zone. Alike type of the outcomes has also been reported already[21].

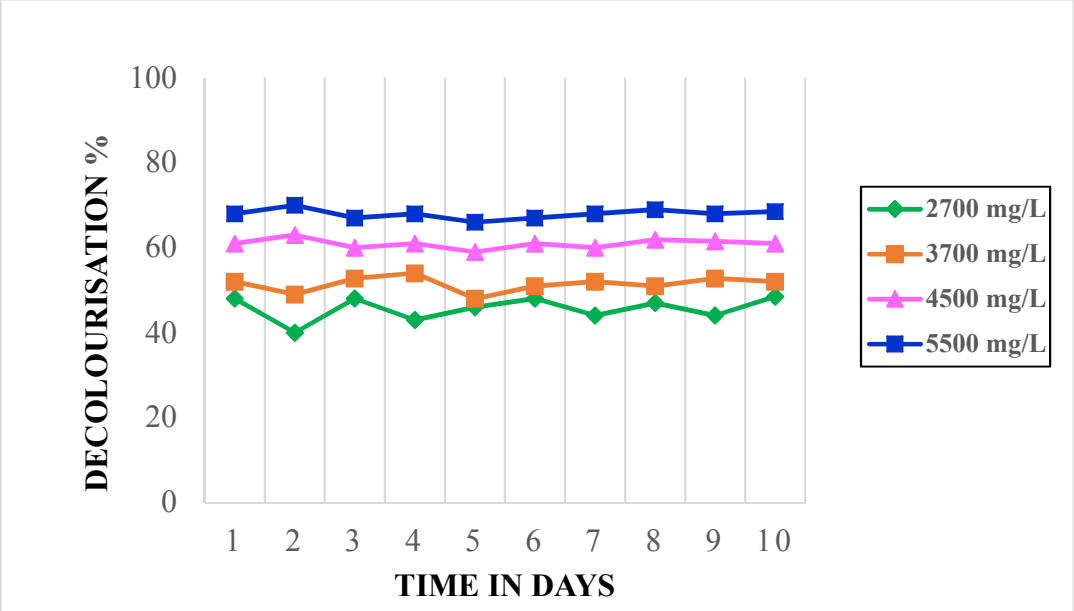

Figure 2: Effect of MLVSS concentrations on decolorization of Sock Manufacturing (textile-knitting) industry wastewater with the time interval at 20 hrs. HRT.

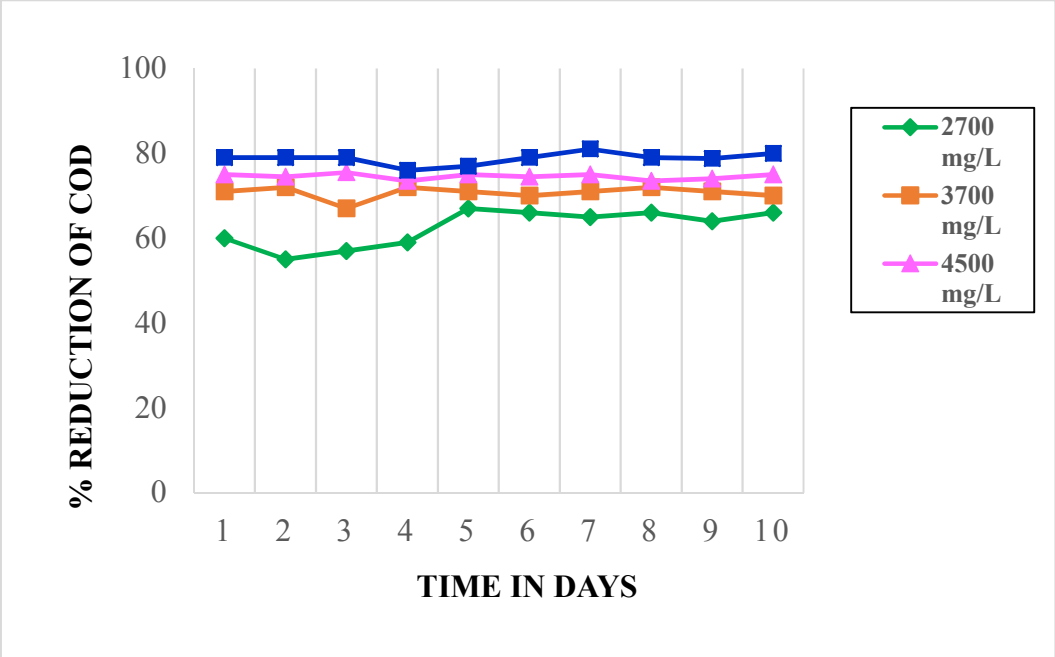

Figure 3: Effect of MLVSS concentrations on COD reduction of Sock Manufacturing (textile-knitting) industry wastewater with the time interval at 20 hrs. HRT.

3.2. Effect of MLVSS concentration on color and COD removal at 30 hrs. HRT.

Figure 4 and 5. Shows the effect of different concentration of MLVSS on decolorization and reduction of COD with time at 30 h HRT. It is observed from statistics gets from the figures proportion of decolorization and reduction of COD proportionally increases, with rises of the retention time of hydraulics (20 h -30 h). The Supreme decolorization was 92 % at 5500 mg/l MLVSS which reduced to 86%,77%, and 65 % in 4500, 3700 and 2700 mg/l MLVSS respectively. Reduction of COD also improved, with raised in HRT and MLVSS. The removal of COD was detected to be 79,85,88, and 93 % at 2700, 3700, 4500 and 5500 mg/l MLVSS. Figure 6. Illustrations the proportion of decolorization and reduction of COD with different time intervals of HRT at 2700 mg/l concentration of MLVSS at different HRT, it easily could be realized from figure statistics or the fact that the percentage of the decolorization and reduction of COD are higher in comparison to outcomes collected at 20 h and 30 h HRT utilizing same concentration of MLVSS (2700 mg/l) under same experimental parameters and conditions.

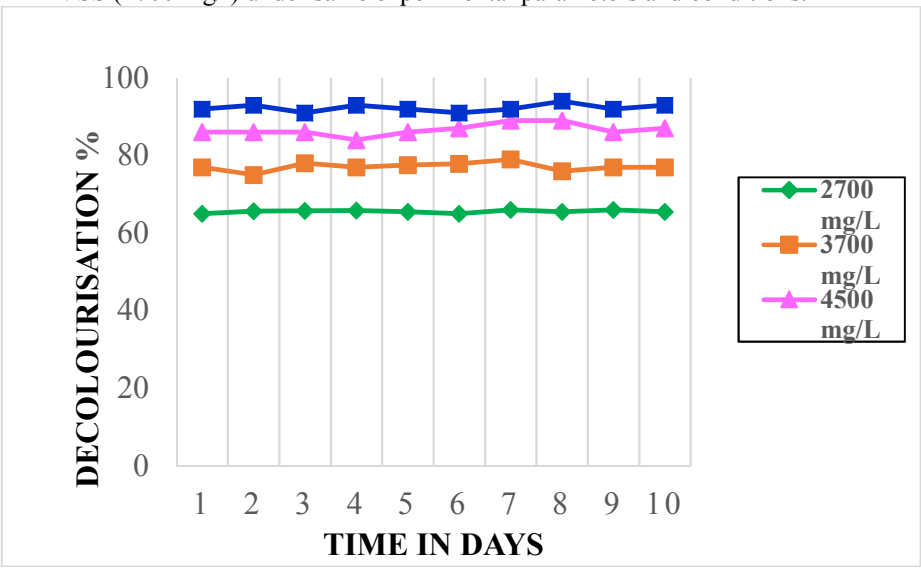

Figure 4: Effect of MLVSS concentrations on decolorization of Socks Manufacturing (textile-knitting) industry wastewater with time at 30 hrs. HRT.

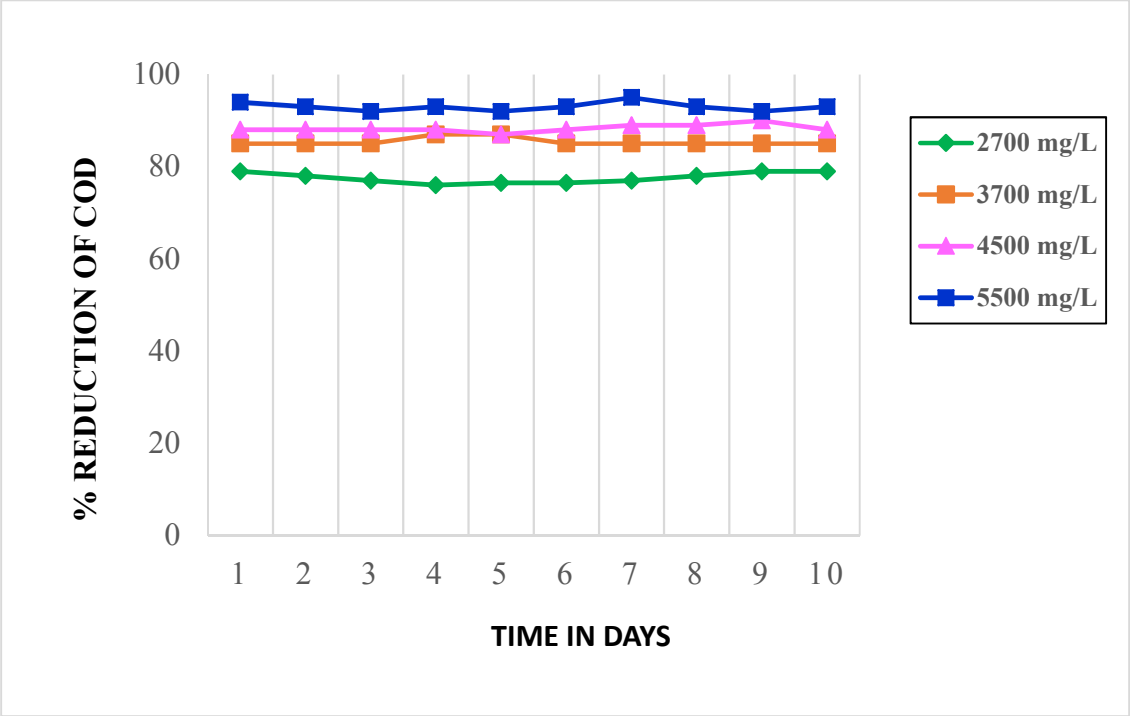

Figure 5: Effect of MLVSS concentrations on COD removal from Socks Manufacturing (textile-knitting) industry waste water with time at 30 hrs. HRT.

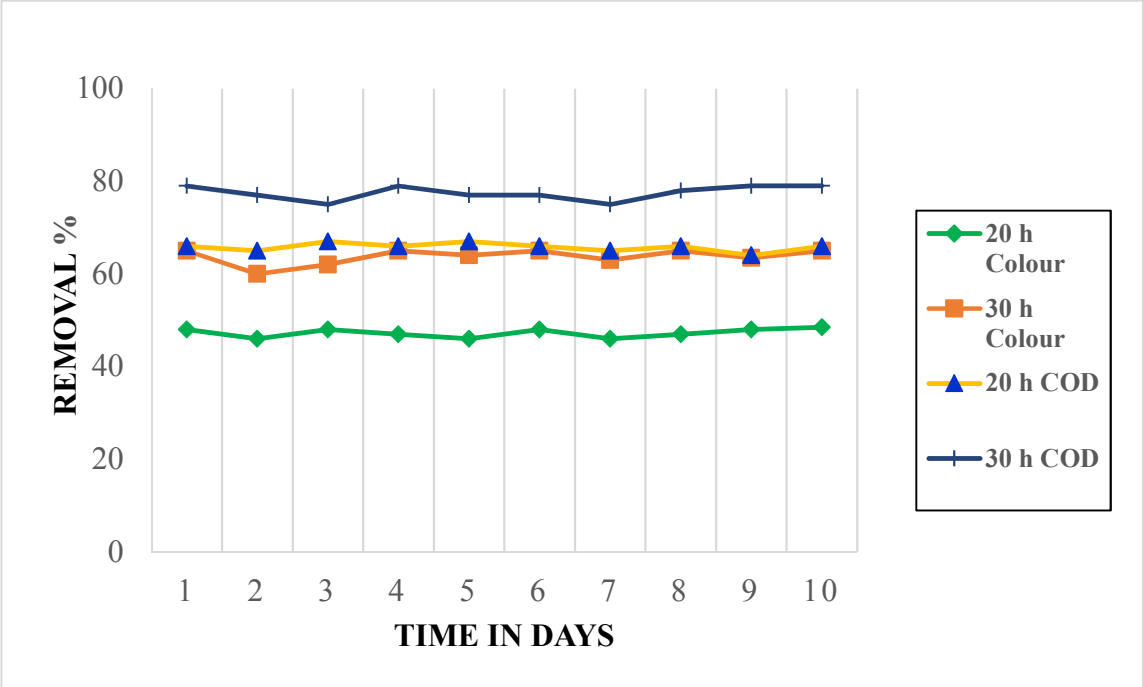

Figure 6: Removal of color and COD from Socks Manufacturing (textile-knitting) industry wastewater with 2700 mg/L MLVSS and at different HRT.

3.3. Effect of MLVSS concentration on color and COD removal at 38 hrs. HRT.

The result of the effect of different concentration of MLVSS at 38 h HRT on decolorization and reduction of COD under stable state condition is given in figure 7 and 8, respectively. The results demonstrate improved percentage of removal of color and reduced of COD, with increases of hydraulic retention time in the aeration zone at all the mentioned concentration of MLVSS (2700, 3700, 4500, and 5500 mg/l) at 5500 mg/l MLVSS gives 93%, which is maximum decolorization of SMIW, which is declined to 90%, 85%, and 76% in 4500,3700, and 2700 mg/l of MLVSS respectively. With increases in the concentration of MLVSS as well as HRT, the reduction percentage of COD is also increased. The observation of a reduction of COD was 81%, 87%, 91%, and 95%, which is too maximum of 2700, 3700, 4500 and 5500 mg/l MLVSS respectively.

At HRT 38 h the reduction of COD was higher in comparison to the results of the other got at 20 h, and 30 h HRT at 20 h HRT, the COD reduction was 66%, 71%, 75%, and 79 % in 2700, 3700, 4500, and 5500 mg/l MLVSS. Which is improved to 79%, 85%,88%, and 93% at a same concentration of MLVSS and at an HRT of 30h.Due to the higher concentration of biomass/microbes, the higher decolorization and reduction of COD was achieved at higher HRT. Previously study reported that "if the growth of the biomass or microbes in the activated sludge step was limited by means of carbon source" remarking that the MLSS decreased from around 6000 to1000 mg/L, when the concentration of starch feeding was reduced from 3.9 to 1.9 mg/L;MLSS then increased after the feeding of starch concentration was again increased to 3.9 mg/L [22].

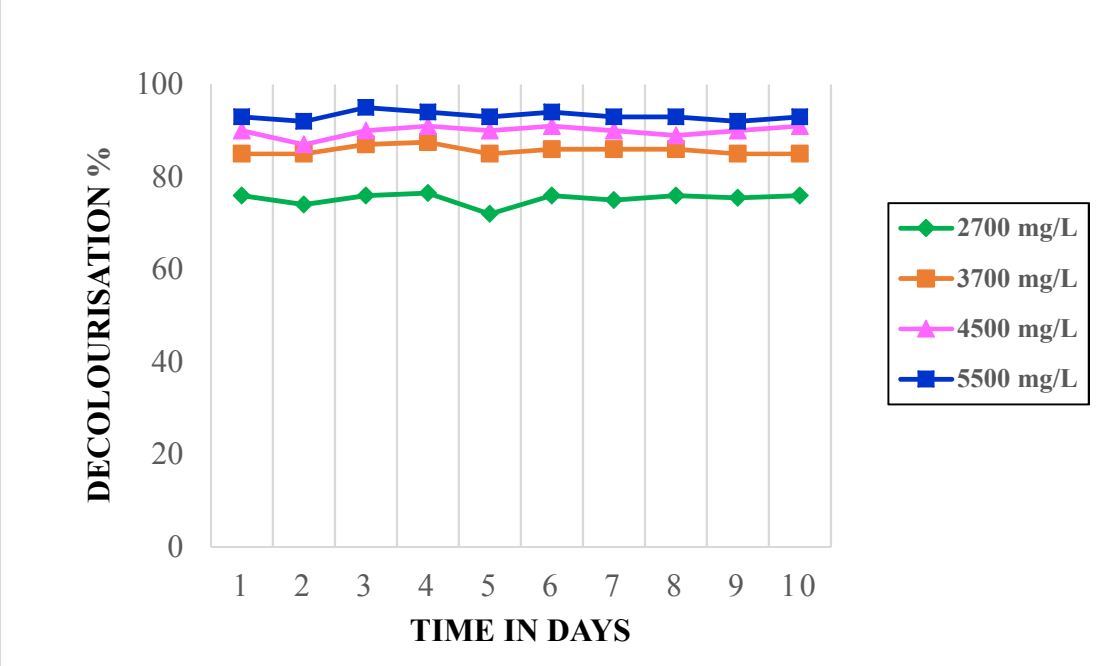

Figure 7: Effect of MLVSS concentrations on decolorization of Socks Manufacturing (textile-knitting) industry waste water with time at 38 hrs. HRT.

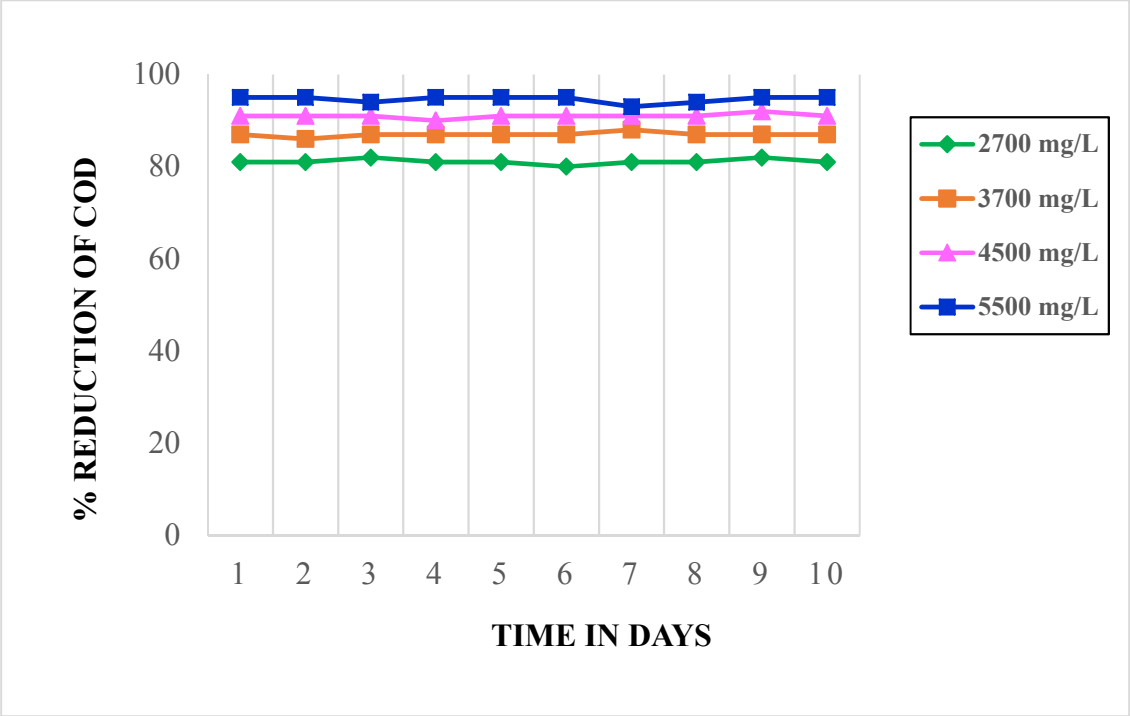

Figure 8: Effect of MLVSS concentrations on COD removal from Socks Manufacturing (textile-knitting) industry waste water with time at 38 hrs. HRT.

3.4. Biofilm Fluidized Process

The laboratory scale results reveal that the reduction of color, as well as COD, decreases by biological SMIW treatment with cow dung/manure microbes and was ended generally among in few (2-3)days.if we couldn't recirculation of activated sludge appropriately. To get enhancement in the rate of COD/color removal and increases the percentage of the (SRT) retention time of sludge was successfully accomplished by using hexahedron biofilm supporting media and with cow dung microbe's w.r.t higher concentration of active biomass [23].

It was proposed to prove, the decreases of pollutant load by the effect of the biofilm fluidized process. Figure 9. Demonstrates the removal percentage of COD/color with and without hexahedron S.M at the biofilm fluidized process. In this research, figure 9. Demonstrates that without using of hexahedron S.M.it is perceived that color and COD reduction were declined, around to 48 % and 66 %,respectively, if couldn't recirculation properly of activated sludge in without hexahedron S.M and steady removal of color and COD were accomplished after more than 4-5 days. In contrast, figure 9. Shows by using of hexahedron S.M, it is perceived that color and COD removal percentage were ascended, around 94.5 % and 96.7 %, respectively. It was also observed that with using of hexahedron S.M and steady removal of color and COD were accomplished over 20 hours.

In this case, the enhancement in the 46.5% of color and 30.7 % of COD reduction is accomplished by utilizing hexahedron S.M and DO was kept in 2-3 mg/l. During whole biofilm fluidizing process. By means of hexahedron S.M, up to 7290 mg/l MLSS was raised, which was around thrice times bigger than that in control 2700 mg/l, without hexahedron S.M. Furthermore, in the aerated reactor, the whole MLSS is only around 29%, using hexahedron S.M, which was found to be suspended condition. It might be concluded or inferred that the boosts of removals of color and COD were ascribed to not only the rise of the constancy of the inoculated microscopic organismbut also in the rise of the entire biomass holding generation of inoculated microscopic organisms in the biofilm fluidized process. Usually, in conventional treatment with activated sludge process involves 2700 mg/l to 5500 mg/l of MLVSS.

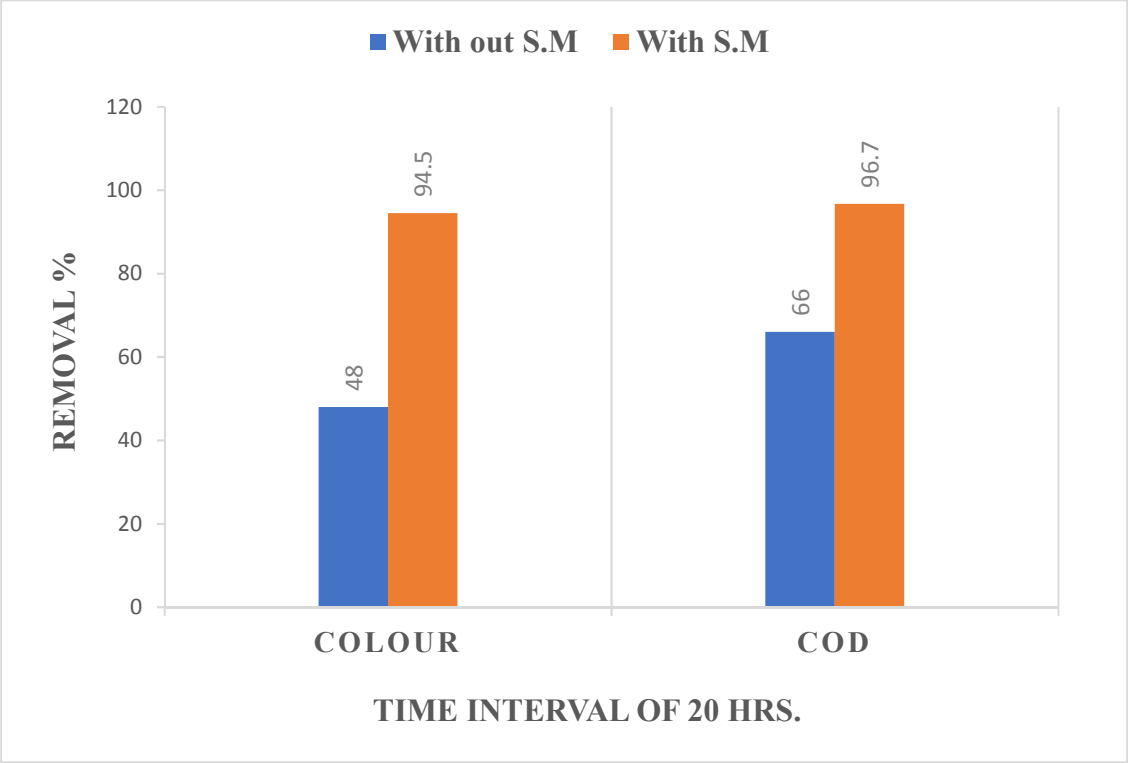

Figure 9: Effect on removal of color and COD with or without using of hexahedron S.M in biological or biofilm fluidized process.

4. CONCLUSIONS

The current study results are evidently demonstrated that activated sludge with biofilm or supporting media fluidized process, for treatment of SMIW or effluent is efficient to get rid of the color and COD by means of hexahedron S.M. It is perceived that color and COD removal percentage were ascended around 94.5% and 96.7%, respectively.it was also observed that with using of hexahedron S.M and steady removal of color and COD were accomplished after 20 hours. Moreover, in the aerated reactor, the whole MLSS is only around 29% using hexahedron S.M, which was found to be suspended condition. It might be concluded or inferred that the boosts of removals of color and COD were ascribed to not only the rise of the constancy of the inoculated microscopic organism but also in the rise of the entire biomass holding generation of inoculated microscopic organisms in the biofilm fluidized process. Furthermore, the performance of the activated sludge process, affected by mean of HRT and MLVSS concentration.

Acknowledgements
Mr. Abbas Naqvi, Mr. Abdul Ahad, Mr. Sajid Ahmed, Mr. Bashir Ahmed, Mr. Saqib Hassan, and Mr. Nadeem Ahmed, are acknowledged for their valuable suggestions, continuous support, and their assistance during experimental work at the Keystone Enterprise (Pvt.) Ltd., Karachi Pakistan.

5. REFERENCES

1. Siddique, K., et al., *Textile Wastewater Treatment Options: A Critical Review*, in *Enhancing Cleanup of Environmental Pollutants*. 2017, Springer. p. 183-207.
2. Siddiqua, U.H., et al., *Relationship between structures and dyeing properties of reactive dyes for cotton dyeing.* Journal of Molecular Liquids, 2017.
3. Dao, M.T., et al., *Effectiveness on color and COD of textile wastewater removing by biological material obtained from Cassia fistula seed.* Journal of Vietnamese Environment, 2016. **8**(2): p. 121-128.
4. Asthana, M., A. Kumar, and B. Sharma, *Wastewater Treatment*, in *Principles and Applications of Environmental Biotechnology for a Sustainable Future*. 2017, Springer. p. 173-232.

5. Avdičević, M.Z., S. Dobrović, and K. Košutić. *Performance evaluation of the polymeric and ceramic membranes in the treatment of textile dye processing wastewater*. in *25. HRVATSKI SKUP KEMIČARA I KEMIJSKIH INŽENJERA*. 2017.
6. Singh, H., M.S. Bhatti, and A.S. Reddy, *Decolourization of Textile Dyebath Chloride Rich Wastewater by Electrolytic Processes.* Int. J. Electrochem. Sci, 2017. **12**: p. 3662-3674.
7. Djafer, A., et al., *Reuse of waste activated sludge for textile dyeing wastewater treatment by biosorption: performance optimization and comparison.* Water and Environment Journal, 2017. **31**(1): p. 105-112.
8. Bhattacharjee, S., *Removal of Biological Organic Matter and Suspended Solid from Textile Wastewater Using Anaerobic-Aerobic Process: A Review of an Industrial Implementation.* Journal of Scientific Research, 2017. **9**(2): p. 267-275.
9. Hassanzadeh, E., et al., *An efficient wastewater treatment approach for a real woolen textile industry using a chemical assisted NF membrane process.* Environmental Nanotechnology, Monitoring & Management, 2017. **8**: p. 92-96.
10. Davies, N., *Using Bacteria to Decolorize Textile Wastewater.* AATCC Review, 2017. **17**(4): p. 32-37.
11. Yukseler, H., et al., *Analysis of the best available techniques for wastewaters from a denim manufacturing textile mill.* Journal of Environmental Management, 2017.
12. Lin, S.H. and C.F. Peng, *Continuous treatment of textile wastewater by combined coagulation, electrochemical oxidation and activated sludge.* Water research, 1996. **30**(3): p. 587-592.
13. Aquino, J.M., et al., *Combined Coagulation and Electrochemical Process to Treat and Detoxify a Real Textile Effluent.* Water, Air, & Soil Pollution, 2016. **227**(8): p. 1-12.
14. Mirbolooki, H., R. Amirnezhad, and A.R. Pendashteh, *Treatment of high saline textile wastewater by activated sludge microorganisms.* Journal of Applied Research and Technology, 2017. **15**(2): p. 167-172.
15. Abiri, F., N. Fallah, and B. Bonakdarpour, *Sequential anaerobic–aerobic biological treatment of colored wastewaters: case study of a textile dyeing factory wastewater.* Water Science and Technology, 2017. **75**(6): p. 1261-1269.
16. Atalay, S. and G. Ersöz, *Novel Catalysts in Advanced Oxidation of Organic Pollutants*. 2016: Springer.
17. Zhao, M., et al., *New trends in removing heavy metals from wastewater.* Applied microbiology and biotechnology, 2016. **100**(15): p. 6509-6518.
18. Desai, I. and I. Bhardwaj, *Recent biotechnological trends in industrial effluent treatment.* Biotech Consortium India, New Delhi, 1995.
19. Rajasimman, M., S.V. Babu, and N. Rajamohan, *Biodegradation of textile dyeing industry wastewater using modified anaerobic sequential batch reactor–Start-up, parameter optimization and performance analysis.* Journal of the Taiwan Institute of Chemical Engineers, 2017. **72**: p. 171-181.
20. Association, A.A.P.H., *Standard methods for the examination of water and wastewater. Washington, DC: American Public Health Association, 2012. On-Site Electricity Generation.* Energy & Fuels, 2016. **30**(3): p. 1849-1857.
21. Kumar, K., et al., *Effect of mixed liquor volatile suspended solids (MLVSS) and hydraulic retention time (HRT) on the performance of activated sludge process during the biotreatment of real textile wastewater.* Water Resources and Industry, 2014. **5**: p. 1-8.
22. O'neill, C., et al., *Anaerobic–aerobic biotreatment of simulated textile effluent containing varied ratios of starch and azo dye.* Water Research, 2000. **34**(8): p. 2355-2361.
23. Kim, T.-H., et al., *Pilot scale treatment of textile wastewater by combined process (fluidized biofilm process–chemical coagulation–electrochemical oxidation).* Water research, 2002. **36**(16): p. 3979-3988.