Environmental Health Engineering and Management Journal 2024, 11(1), 9-14
http://ehemj.com
doi 10.34172/EHEM.2024.02
Environmental Health Engineering and Management Journal

Original Article

Open Access Publish Free

Combination of pozzolan and sawdust as biofilter for textile wastewater treatment

Sri Slamet Mulyati, Nia Yuniarti Hasan, Ade Kamaludin, Redi Yudha Irianto, Salma Aripin*

Environmental Health Department, Bandung Health Polytechnic, Babakan Loa St. Number 10A, North Cimahi, Indonesia

Abstract

Background: Inappropriate management of textile wastewater results in environmental pollution. To counter this, biofilters or biofilm systems serve as alternatives. Biofilters work like a filter, with a media stack that aids in the filtration process. In this study, pozzolan and sawdust were used as media. The present study aimed to identify the difference in average color content, chemical oxygen demand (COD), and chromium of textile wastewater after passing through a single biofilter versus a combination biofilter.

Methods: This study employs a post-test with a control design experimental research design. The research population is the total textile wastewater produced by the X industry located in Cimahi city, Indonesia. The grab sampling technique was employed to collect 30 L of textile wastewater for each treatment using both the single biofilter (composed solely of sawdust) and the combination biofilter (mixture of sawdust and pozzolan).

Results: There are significant differences in color, COD, and chromium content averages between single and combined biofilter treatments, supported by *P* values of 0.012, 0.004, and 0.010. The single biofilter exhibited higher percentage reductions in color and chromium (14.25% and 90.83%, respectively) compared to the combination biofilter. In contrast, the combination biofilter achieved a remarkable COD reduction of up to 79.45%compared to the single biofilter.

Conclusion: The results of the present study showed that the single biofilter had a higher capacity to remove color and chromium compared to the combination biofilter. Meanwhile, the combination biofilter was found to be more effective in removing COD compared to the single biofilter.

Keywords: Wastewater, Chromium, Water purification, Textiles, Biofilms

Citation: Mulyati SS, Hasan NY, Kamaludin A, Irianto RY, Aripin S. Combination of pozzolan and sawdust as biofilter for textile wastewater treatment. Environmental Health Engineering and Management Journal 2024; 11(1): 9-14. doi: 10.34172/EHEM.2024.02.

Article History:
Received: 16 February 2023
Accepted: 23 September 2023
ePublished: 2 February 2024

***Correspondence to:**
Salma Aripin,
Email: salma.aripin@gmail.com

Introduction

The textile industry has wastewater quality standards that cover a range of parameters, including biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), phenol, chromium, ammonia, sulfide, oils and fats, and pH (1). Due to the large volume of wastewater generated by the textile industry, it can create environmental problems if not treated before disposal (2). Moreover, untreated wastewater can pose risks to human health, such as causing fever, skin irritation, dermatitis, and other health issues (3). The urgency of reducing color content, COD levels, and chromium content within textile wastewater have far-reaching impacts across environmental, health, and economic domains. Increased color content, originating from textile dyes, disturbs aquatic ecosystems by obstructing light penetration and impeding photosynthesis, ultimately putting aquatic life at risk. Elevated COD concentrations in textile wastewater indicate the presence of organic pollutants that consume oxygen, resulting in oxygen depletion upon discharge. This leads to the formation of aquatic "dead zones" and disrupts the delicate equilibrium of water quality. Additionally, the release of textile wastewater contaminated with chromium poses significant health hazards to humans and contaminates water sources, thereby jeopardizing public health. Beyond ecological and health concerns, industries must adhere to stringent wastewater regulations to avoid penalties and reputational damage. This highlights the need for sustainable and responsible practices. By reducing these pollutants with technologies such as biofilters or even a combination of biofilters, it can become an alternative for industries that not only contribute to resource conservation but also demonstrate their commitment to a cleaner, healthier future while potentially realizing economic benefits through cost savings and recovered resources.

The color of textile wastewater changed from dark brown to light brown, and the COD of the wastewater decreased by 76% when treated with sawdust as an adsorbent (4). In laboratory tests, the addition of activated sawdust resulted in a 77%-84% reduction in chromium waste content at a concentration of 20 mg/L (5). With a dose of 0.2-1.6 g/100 ml sample, sawdust adsorbent was able to remove 57.7%-82.3% of chromium waste content in laboratory-scale experiments (5). Both sawdust and pozzolan are porous materials that have the potential to be used as filter media.

The treatment of wastewater can be done by utilizing a biofilter or biofilm system. An efficient biofilter operates on the principle of biofiltration, which is structured like a filter and contains a stack of media (6). In this study, pozzolan and sawdust were utilized as the buffering media. Pozzolans refer to materials that comprise silica and alumina compounds. An instance of an artificial pozzolan is the outcome of burning clay and coal or fly ash. Sawdust, on the other hand, is a byproduct of either softwood, hardwood, or a mixture of both.

Considering the aforementioned introduction, the present study aimed to investigate the differences in the mean values of color, COD, and chromium content of textile wastewater after passing through a single biofilter and a combination biofilter. The novelty of the study is the utilization of sawdust and pozzolan as a media for biofilters in reducing color, COD, and chromium content of textile wastewater.

Materials and Methods

The research design used is a field experiment with a post-test control design. The population for the study included all untreated wastewater from the Textile X Industry in Cimahi city in Indonesia, which served as the control. The employed sampling technique utilizes a grab sampling technique to collect textile wastewater from the industry. Meanwhile, the samples comprise a volume of wastewater, precisely 30 L, from a total volume of 180 liters, the sample is subjected to treatment using a combined biofilter system, while another volume undergoes treatment using a single biofilter system. The research's independent variables include the use of a single biofilter (composed solely of sawdust) and a combined biofilter (consisting of a mixture of pozzolan and sawdust). Meanwhile, the dependent variables encompass the reductions in color, COD, and chromium content within textile wastewater.

Pozzolans refer to materials that comprise silica and alumina compounds. An instance of an artificial pozzolan is the outcome of burning clay and coal or fly ash. Sawdust, on the other hand, is a byproduct of either softwood, hardwood, or a mixture of both. Although each kind of wood has a distinct structure, they generally share a fundamental composition, which involves elements like cellulose, lignin, hemicellulose, and holocellulose. The filter media, composed of pozzolans and sawdust, was obtained from a reliable local supplier in Cimahi, Indonesia. The media that was ordered adhered to the required research specifications and was also activated by the researcher before its utilization.

The activation process of both filter media (pozzolan and sawdust) is done by heating them in an oven at 100 °C for 5 minutes. In a previous study by Filliazati, the media was dried in an oven at 103 °C for 24 hours. The seeding process in this study is conducted for 3 days using a batch system with a flow rate of 0.2 L/s. In previous studies, the process was conducted for two weeks or less until a biofilm was formed using a flow rate of 0.34 mL/s (7).

The research procedure begins with the preparation and activation of the biofilter media. The media for the single biofilter consists of sawdust alone, while the media for the combination biofilter includes both sawdust and pozzolan. The next step involves the seeding process. The goal of this process within a biofilter is to introduce specific and effective microorganisms into the system. These microorganisms play a crucial role in initiating or accelerating the biological processes occurring within the biofilter. Through their introduction, the objective is to establish a thriving and active microbial community capable of efficiently degrading and transforming organic pollutants present in wastewater. Ultimately, this process enhances the biofilter's efficacy in treating wastewater by leveraging the natural degradation abilities of these microorganisms.

Potassium permanganate ($KMnO_4$), a chemical compound used as a strong oxidizing agent, is employed in the seeding process within the biofilter for distinct purposes linked to evaluating the efficiency of the biological treatment of wastewater.

The statistical analysis in the research includes univariate analysis and bivariate analysis. Univariate analysis is employed to determine the mean value and percentage reduction of color, COD, and chromium content in textile wastewater. On the other hand, bivariate analysis is utilized to ascertain differences between the treatment using a single biofilter and a combined biofilter in terms of reducing color, COD, and chromium content in textile wastewater.

Results

The $KMnO_4$ number, which indicates the growth of microorganisms, was used as an indicator of organic substance presence. $KMnO_4$ was chosen due to its powerful oxidizing properties, which are necessary for breaking down organic matter. The seeding process was conducted on one of the biofilters, specifically the combination one. The organic matter values tested through the determination of KMnO4 after the seeding process in the combination biofilter are higher than before the seeding process. High organic matter values indicate the presence of a larger number of microorganisms. Microorganisms, including organic-degrading bacteria, are its primary constituents. The results of the seeding process for $KMnO_4$ number are presented in Table 1.

The color content of textile industry wastewater in raw water (wastewater condition before treatment) and after treatment with both single and combined biofilters is presented in Table 2.

The test of difference in mean color content between single and combination biofilter treatments showed a significant difference. Statistical test results obtained a P value of 0.012 (<0.05). The COD content of textile industry wastewater in raw water and after treatment with both single and combined biofilters is presented in Table 3.

The mean difference test in the COD content between the single and combination biofilter treatments showed a significant difference. Statistical test results obtained a P value of 0.004 (<0.05).

The chromium content of textile industry wastewater in raw water and after treatment with both single and combined biofilters is presented in Table 4.

The mean difference test in chromium content between single and combination biofilter treatments showed a significant difference. Statistical test results obtained a P value of 0.010 (<0.05).

The temperature and pH measurements of textile industrial wastewater in raw water and after treatment, both single and combined biofilters are presented in Table 5.

Discussion

The research results indicate a decrease in color content by 14.25% when using the single biofilter and by 6.27% when using the combined biofilter. The use of sawdust adsorbent resulted in better removal compared to the pozzolan combination. Previous studies have shown that the use of physically and chemically activated sawdust can significantly reduce the color intensity of wastewater, from 600 to 40 mg/L. In the present study, the reduction of color intensity reached 93.33% by treating the wastewater with activated sawdust at a dose of 5 g in 200-1000 mg/L of wastewater and stirring the mixture (8). It was found that the use of physically and chemically activated sawdust with an adhesive is even more effective in eliminating the color of textile wastewater (8).

Optimal color removal results can be achieved by carrying out two stages of activation and obtaining a smoother shape. Activated carbon that is free from impurities has a high adsorption surface area, which makes it effective in absorbing color content.

Another research employed bio-adsorbents derived

Table 1. The $KMnO_4$ seeding process of textile wastewater

Treatment	$KMnO_4$ Number (mg/L)
Before the seeding process	178.80
After the seeding process	231.31

Table 2. Color content of textile wastewater

Repetition	Raw water (PtCo)	Single biofilter (PtCo)	Combination biofilter (PtCo)
1		74	84
2		70	82
3		69	81
4		65	79
5	85	64	75
6		78	75
7		79	78
8		80	81
9		77	82
Mean		72.89	79.67
Reduction		14.25%	6.27%

Table 3. COD content of textile wastewater

Repetition	Raw Water (mg/L)	Single biofilter (mg/L)	Combination biofilter (mg/L)
1		388.57	400.00
2		560.00	560.00
3		857.14	560.00
4		822.86	285.71
5	2125.7	617.14	674.29
6		571.43	514.29
7		891.43	240.00
8		822.86	240.00
9		777.14	457.14
Average		700.95	436.83
Reduction		67.02%	79.45%

Table 4. The chromium content in textile wastewater

Repetition	Raw water (mg/L)	Single biofilter (mg/L)	Combination biofilter (mg/L)
1		0.89	2.67
2		0.44	1.67
3		0.33	1.56
4		0.22	1.33
5	5.67	0.11	1.22
6		0.56	0.33
7		0.78	0.67
8		1.00	0.78
9		0.33	1.00
Average		0.52	1.25
Reduction		90.83	77.95%

Table 5. Textile wastewater temperature

Parameters	Raw water	Single biofilter	Combination biofilter
Temperature	27.4°C	25.7°C	25.7°C
pH	9.48	8.11	8.18

from neem leaves, orange peel, peanut skin, and coconut husk to remove the color of textile waste. The study found that the highest color removal of 82.3% was achieved at an optimal stirring speed of 600 rpm. Unlike our team's research, this study only carried out physical activation of the material, but the bio-adsorbent material was crushed into a finer mesh size (9).

In a separate study conducted by researchers in India, the bioadsorbent employed was made from temple waste flowers. The flower was subjected to physical and chemical activation processes to remove impurities. The results of the test showed that the removal of color from textile waste was 98.17% when treated with 200 mg of active carbon derived from temple waste flowers (10).

In general, carbon activation aims to enhance the filtering or filtration performance of the filter media. Activated carbon has been widely utilized to eliminate contaminants in water. Activated carbon A with a granule size of 1.5 mm and a surface area of 791.56 m^2/g was more effective in reducing the parameters of turbidity, TSS, COD, and BOD compared to activated carbon B with a granule size of 2.3 mm and a surface area of 781 495 m^2/g, which had a smaller surface area (11).

Activated biofilters converted into finely-sized activated carbon play a more significant role in the adsorption process and demonstrate an enhanced capacity for color removal compared to biofilters composed of larger aggregates, which support the growth of microorganisms for organic matter degradation even after activation. The removal of color content can be enhanced through the addition of temperature and prolonged activation time of the adsorbent. In a previous study, utilizing an activation temperature of 103 °C for 24 hours qualitatively demonstrated the capability to transform the intense green color into a light brown hue.

The average COD content from the combination biofilter treatment yielded lower results compared to the single biofilter treatment. The difference between the two treatments was quite significant at 264.12 mg/L, and the results were statistically significant. The COD removal rate for the combination biofilter treatment reached 79.45%. Another study also showed effective COD removal after passing through the combination filter media, achieving a removal rate of 96.6%. In that study, the combined filter media consisted of a activated carbon filter with a thickness of 20 cm from coconut shells and 60 cm from plastic waste. The sample wastewater used in this study is of medical origin. Although the activation process was not specified, the two types of media were immersed in the wastewater sample for 14 days to allow for the growth of microorganisms (12). Our team's study involved submerging the biofilter media in the wastewater sample for only three days, while the residence time was 24 hours. In contrast, the previous study did not involve any variation in residence time, and the media were soaked in the wastewater sample for 14 days. It is known that the growth of microorganisms in the biofilter media increases with the duration of submergence, leading to more efficient degradation of organic waste.

Other studies have shown ineffective results in COD removal, only reaching 31.73%, which may be due to the use of only plastic waste as the filter media. In these studies, biofilm growth was carried out for 30 days and the residence time was 36 hours (13). Compared to our research team, who also used a single biofilter media, we achieved a higher COD removal rate of 67.02%. Another study on COD removal was conducted on wastewater from the rubber industry, using gravel as pretreatment and followed by a Dielectric Barrier Discharge (DBD) plasma reactor. In this study, the COD removal rate was only 27.12% after passing through the gravel biofilter as pretreatment. However, after passing through the plasma reactor, the COD removal rate increased significantly to 76.44% (14). Compared to our team's research, the COD removal using a single biofilter alone was already quite high, reaching 67.02%, and the combined biofilter reached 79.45%. These percentage reductions were significant, especially considering that no additional treatment was employed. The fundamental concept behind using a biofilter for treating organic waste is to have a sufficient number of microorganisms grow on the media surface to form a biofilm layer. This biofilm layer consists of microorganisms, particularly bacteria, that aid in the oxidation and degradation of organic waste. To achieve this, microorganisms must be seeded or cultured in the media. The natural way to culture microorganisms is by allowing wastewater to flow into the reactor containing the media. The time required to reach steady-state conditions during breeding is usually not more than 2 weeks.

The biofilter and DHD plasma reactor studies conducted a seeding process for 7 days at a flow rate of 0.0005 L/s. In contrast, our research team only seeded the biofilter media for 3 days at a discharge of 0.2 L/s. However, the duration of the seeding process did not affect the efficiency of COD removal. Other factors such as the molecular structure of the organic contaminants also play a role in their reaction and degradation when in contact with the biofilter media. If the number of microorganisms resulting from the seeding is sufficient to degrade the organic waste, but the structure of the degraded organic waste is too complex to decompose, it can lead to suboptimal removal of organic waste, including COD. The solubility of contaminants also plays a role in how they interact with biofilter media. Typically, soluble organic substances do not bond well to the surface of particles. So, even if a biofilm layer has formed and is ready to degrade organic waste, the high solubility of the substances can cause them to remain in the wastewater, resulting in incomplete removal of COD. Density is another factor that affects the degradation of organic substances. If the organic matter in the wastewater has a lower density than water, it will float and follow the flow of water in the reactor to the outlet, passing through without making contact with the biofilm layer. Consequently, the COD content remains high or is only reduced to a suboptimal level (15).

The process of removing COD using a biofilter as a medium for growing microorganisms belongs to the category of biological treatment processes. In theory, several factors can affect the biological processes in soil. These factors include the microorganisms themselves as the agents of the process, the substrate and nutrients available, the electron acceptors involved, and various environmental factors that can impact the process (15). To provide a clear illustration, it can be observed that soil functions as a natural biofilter, while an artificial biofilter simulates the soil in wastewater treatment applications, highlighting the interrelation between the natural and artificial biofilter. The efficacy of the organic waste degradation process is contingent upon the presence of microorganisms in terms of both their quantity and diversity. The greater the diversity of microorganisms involved in the process, the more viable pathways for organic waste degradation are possible, leading to enhanced COD removal. For bacterial growth and multiplication, substrates and nutrients are required. Microorganisms utilize organic contaminants as substrates and nutrients in wastewater. Thus, the variance in the number of organic contaminants utilized by microorganisms between single and combination biofilters can have a consequential impact on the COD removal rate between these two types of biofilters. The number of organic substances assessed by determining the $KMnO^4$ number after the seeding process in the combination biofilter was higher than before the seeding process. The high number of organic matter indicates a greater number of microorganisms present. Microorganisms, including decomposing bacteria, are chiefly composed of organic substances.

In the context of biological treatment processes, the degradation of organic waste requires the participation of electron acceptors, such as O_2, SO_4, and CO_2 (15). These electron acceptors are essential for the oxidation of the substrates. In the case of using organic contaminants in wastewater as substrates, the presence of these electron acceptors is crucial. However, if the number and types of electron acceptors differ between single and combined biofilters, this may also affect the efficiency of COD removal between the two biofilters. It should be noted that the number and types of electrons present in organic contaminants were not studied in the research conducted.

In terms of removing heavy metals from textile wastewater, it was observed that passing through a single biofilter resulted in greater removal of chromium as a heavy metal compared to passing through a combination biofilter. This was supported by a study indicating that the content of coliform, E. *coli, Enterococcus, and Clostridium* in a single biofilter was higher than in a combination biofilter, with 9900 CFU coliform, 9900 CFU E. coli, 48 CFU *Enterococcus*, and 10 CFU *Clostridium* in a single biofilter, compared to 98 CFU coliform, 98 CFU *E. coli*, 38 CFU *Enterococcus*, and 8 CFU *Clostridium* in a combination biofilter (16). As previously noted, microorganisms play an important role in the biological process, and the more microorganisms are involved in degrading organic substances, the more effective the removal of heavy metals from textile wastewater. The heavy metal chromium can form a bond with the biofilm layer or even penetrate inside bacterial cells, which is known as the complexation process between metals and microorganisms.

In the context of biological processes in wastewater treatment, heavy metals and bacterial groups that grow as biofilms undergo various reactions, including oxidation-reduction, complexation, and methylation. One of the important processes in heavy metal removal is reduction, which can be facilitated by certain microorganisms such as *Pseudomonas* sp and *Clostridium* sp. These microorganisms are known to have the ability to reduce chromium ions to their fewer toxic forms, making them potential agents for the bioremediation of wastewater contaminated with heavy metals (15).

Conclusion

The percentage reduction of color and chromium content in textile wastewater was found higher in the single biofilter, which is 14.25% and 90.83%, respectively, compared to the combination biofilter. Meanwhile, the percentage reduction of COD content in textile wastewater was found to be higher in combination biofilters containing sawdust and pozzolan compared to single biofilter, with a result of high reduction capability achieving up to 79.45% removal. Further in-depth research is recommended to explore the greater color and chromium removal efficiency of the single biofilter in comparison to the combined biofilter.

Acknowledgments

The research is funded by Bandung Health Polytechnic in Bandung, Indonesia.

Authors' contribution

Conceptualization: Sri Slamet Mulyati.
Data curation: Sri Slamet Mulyati.
Formal analysis: Sri Slamet Mulyati.
Funding acquisition: Sri Slamet Mulyati.
Investigation: Sri Slamet Mulyati.
Methodology: Nia Yuniarti Hasan.
Project administration: Sri Slamet Mulyati.
Resources: Sri Slamet Mulyati.
Software: Ade Kamaludin.
Supervision: Nia Yuniarti Hasan.
Validation: Redi Yudha Irianto.

Visualization: Ade Kamaludin.
Writing–original draft: Sri Slamet Mulyati.
Writing–review & editing: Salma Aripin.

Competing interests

None.

Ethical issues

The present study does not require any ethical issues.

Funding

The research is funded by Bandung Health Polytechnic in Bandung, Indonesia.

References

1. Miller R. Review essay: the third way. Polit Sci. 2000;52(2):174-80. doi: 10.1177/003231870005200207.
2. Mostafa M. Waste water treatment in textile Industries-the concept and current removal technologies. J Biodivers Environ Sci. 2015;7(1):501-25.
3. Tüfekci N, Sivri N, Toroz İ. Pollutants of textile industry wastewater and assessment of its discharge limits by water quality standards. Turk J Fish Aquat Sci. 2007;7(2):97-103.
4. Karadagi BS, Hiremath G. Removal of COD and color from textile wastewater using sawdust as an adsorbent. Int J Innov Res Sci Eng Technol. 2015;5(6):9593-7. doi: 10.15680/ijirset.2015.0506012.
5. Minakshi, Kaushik CP, Arya S. Removal of hexavalent chromium from aqueous solutions using sawdust as a low-cost adsorbent. Int J Adv Res Sci Technol. 2014;3(2):99-105.
6. Herlambang A, Marsidi R. Denitrification process with biofilter system for the treatment of wastewater containing nitrate. J Environ Technol. 2003;4(1):46-55. doi: 10.29122/jtl.v4i1.272.
7. Filliazati M. Domestic wastewater treatment with aerobic biofilter using Bioball media and water hyacinth plants. J Wetland Environ Technol. 2013;1(1):1-10. doi: 10.26418/jwet.v1i1.4028.
8. Adeyi AA, Mohammed IA, Yusuff AS, Olateju II, Popoola LT. Textile waste water treatment and colour removal using chemically activated sawdust. J Bioprocess Chem Eng. 2014;1(3):1-6.
9. Durairaj S, Durairaj S. Colour removal from textile industry wastewater using low-cost adsorbents. Int J Chem Environ Pharm Res. 2012;3(1):52-7.
10. Elango G, Govindasamy R. Removal of colour from textile dyeing effluent using temple waste flowers as ecofriendly adsorbent. IOSR J Appl Chem. 2018;11(6):19-28. doi: 10.9790/5736-1106011928.
11. Siong YK, Idris J, Atabaki M. Performance of activated carbon in water filters. Water Resour. 2013:1-9.
12. Akhmadi Z, Suharno S, Hikmah K. Biofiltration performance of coconut shell and plastic waste made from egg holders for medical wastewater treatment. J Kesehat Lingkung Indones. 2020;19(1):62-7. doi: 10.14710/jkli.19.1.62-67.
13. Juniarta PS, Suyasa WB, Sila Dharma I. Effectiveness of biofilter made from plastic waste to decrease BOD, COD and ammonia of hospital wastewater. Ecotrophic J Environ Sci. 2018;12(1):1-8. doi: 10.24843/EJES.2018.v12.i01.p01.
14. Nurjanah S, Zaman B, Syakur A. BOD and COD removal of rubber industry wastewater with aerobic biofilter system and dielectric barrier discharge (DBD) plasma. J Environ Eng. 2017;6(1):1-17.
15. Notodarmojo S. Soil and Groundwater Pollution. Bandung: Penerbit ITB; 2005.
16. Ouadi B, Bendraoua A, Boualla N, Adjdir M. Efficiency of pozzolan and sawdust as biofilter in the treatment of wastewater. Appl Water Sci. 2020;10(6):143. doi: 10.1007/s13201-020-01226-y.