ZIBELINE INTERNATIONAL™ PUBLISHING
ISSN: 2773-6202 (Online)
CODEN: JTIOCC

Journal of Technology & Innovation (JTIN)

DOI: http://doi.org/10.26480/jtin.02.2021.40.43

CrossMark

RESEARCH ARTICLE

OPTIMIZATION OF COAGULATION-FLOCCULATION PROCESS FOR TREATMENT OF INDUSTRIAL TEXTILE WASTEWATER USING *NOPAL CACTUS* POWDER

Tran Thanh Đat[a], Trinh Trong Nguyen[b], Thai Van Nam[b*]

[a]HCMC Industry and Trade College (HITC)
[b]HUTECH Institute of Applied Sciences – Ho Chi Minh University of Technology (HUTECH)
**Corresponding Author Email: tv.nam@hutech.edu.vn*

ARTICLE DETAILS

Article History:

Received 25 September 2021
Accepted 27 October 2021
Available online 01 November 2021

ABSTRACT

Using natural coagulants derived from available and popular plants ensures the quality of wastewater discharged, saving costs for businesses, environmentally friendly. SEM results show that surface of the material is rough with the multi-layered structure that increases the contact areas, deep holes with undefined shapes on materials will increase diffusion and absorption of dirty residues of different sizes. To investigate the effectiveness of textile wastewater treatment by dried *Nopal Cactus* powder, the Jartest model was used to identify the best parameters for handling color levels and chemical oxygen demand (COD) treatment of artificial wastewater sources. Jartest experiment identified the best values for removing color levels and COD: pH = 3, dried *Nopal Cactus* powder amount of 100mg/L, stirring velocity of 40 rpm; stirring time of 10 minutes. The efficiency of processing color levels and COD with the best parameters are 87.85% and 60.21%, respectively. Regarding the efficiency of processing textile wastewater, there shows an average color reduction efficiency (52.89%), low-level COD treatment (25.56%). Optimal result: with dyeing textile wastewater sample, the input COD value is 260 mg/L, the color level is 470Pt-Co. The experiment with 36 test modes is run by STAGRAPHIC XV software and analyzed by ANOVA combination of 2 variables COD and color levels, the results with the highest performance for the color level and COD are 77.07% and 59.11% respectively. The optimal pH value is 2.6, the amount of dried *Nopal Cactus* powder is 80 mg/L, stirring velocity is 40.0 rpm, the time is 8.2 minutes

KEYWORDS

Chemical Oxygen Demand (COD), color levels, Nopal Cactus powder, optimization, textile wastewater treatment

1. INTRODUCTION

The textile industries use a large amount of water supply and dyeing chemicals. Therefore, textile wastewater has an exceedingly high color level, turbidity, and COD. The constituents of textile wastewater are polluted, which pevents the diffusion of oxygen into the environment. The excess dyeing chemicals are absorbing light, preventing the absorption of light into the water, greatly affecting the environment and ecosystem. Besides, there is also direct harm to the residential areas nearby. The level of pollution far exceeds the limits allowed to be discharged into the environment according to effluent standards, the textile wastewater has high toxicity for aquatic animals and plants, has a dark color that is difficult to be accepted by the community.

Some current wastewater treatments include coagulation-flocculation, charcoal adsorption, zeolite use, membrane filtration, reverse osmosis, chemical precipitation, ion exchange, electrochemical treatment, solvent extraction, and flotation to remove inorganic pollutants (François Renault, 2009; Mittal et al., 2010). These treatments arise a series of difficulties such as creating toxic sludge, fairly high cost, restrictions in the removal of pollutants in low concentrations, high initial costs, complex treatment processes, dirty membranes, high chemical consumption, high maintenance, and other operating costs (Fu and Wang, 2011). Recently, there is a trend of developing coagulation methods towards the use of natural organic polymers and precipitated multi-electrolyte/support coagulation in river water and wastewater treatment (Aygun and Yilmaz, 2010).

The advantages of natural polymer precipitation such as: ease of treatment, high solubility in water, reducing sludge volume, availability, and self-decomposition. Nopal Cactus is one of the plants that has received much research attention and has been extensively studied in the treatment of turbidity, color level as well as COD of some surface water and wastewater (Nam and Ba 2017). Antioxidants in Nopal Cactus can remove organic substances as well as the color of wastewater, dried Nopal Cactus powder has been shown to be capable of eliminating opaque toxins and color levels in the extracts used in coagulation wastewater treatment (Nam and Ba, 2017). Nopal Cactus originating in the Americas were planted around the 17th century, now become wild and common on the deserted sandy soil along the Central Coast of Vietnam, they have intense vitality and are easy to find. Therefore, the research "Optimization of coagulation-flocculation process for treatment of industrial textile

Quick Response Code	Access this article online	
	Website: www.jtin.com.my	**DOI:** 10.26480/jtin.02.2021.40.43

Cite The Article: Tran Thanh Đat, Trinh Trong Nguyen, Thai Van Nam (2021). Optimization of Coagulation-Flocculation Process For Treatment of Industrial Textile Wastewater Using Nopal Cactus Powder. *Journal of Technology & Innovation, 1(2): 40-43.*

wastewater using Nopal Cactus powder" was carried out to research and evaluate the effectiveness of the application of available natural coagulants, ensuring safety but cost-effective and environmental friendliness to replace the current coagulants.

2. Materials and Reseearch Methods

2.1 Materials

Natural coagulants (dried *Nopal Cactus* powder): Collected from Binh Thuan province, washed several times with distilled water to remove dirt particles and use pliers to remove thorns, removed crusts and sun-expose for 3 hours and cut into small pieces. The raw material is dried at 60°C for 24h, and then all finely ground into powder to the appropriate size used for the experiment. Dyeing and weaving wastewater: the researcher created active dyeing and weaving wastewater with a certain color level and conducted a Jartest experiment to determine the best parameters. After experimenting to determine the best parameters and optimizing the experiment to the most optimal value, the researcher conducts surveys and experiment which the optimal value on specific factory wastewater samples. Wastewater used is the wastewater of the dyeing factory systems in Cu Chi, HCMC. The factory is under the management of Ms. Bao Ngoc Huong.

2.2 Research methods

Experimental method: Preparing dried *Nopal Cactus* powder; creating artificial textile wastewater; running Jartest to determine the best values for the parameters of the experiment (pH; high content of dried *Nopal Cactus* powder; stirring velocity; stirring time)

Data processing methods & material structure determination: using Excel software, STATGRAPHIC XV, ANOVA analysis to process the data of the experiment; SEM photos of dried *Nopal Cactus* powder were taken to assess the ability to remove color levels and COD in wastewater.

Sample analysis method: determine the color levels and turbidity by the photometric method. COD is determined by the closed reflux boiling method with an oxidant which is $K_2Cr_2O_7$.

3. Results and Discussions

3.1 The surface structure of Nopal Cactus powder

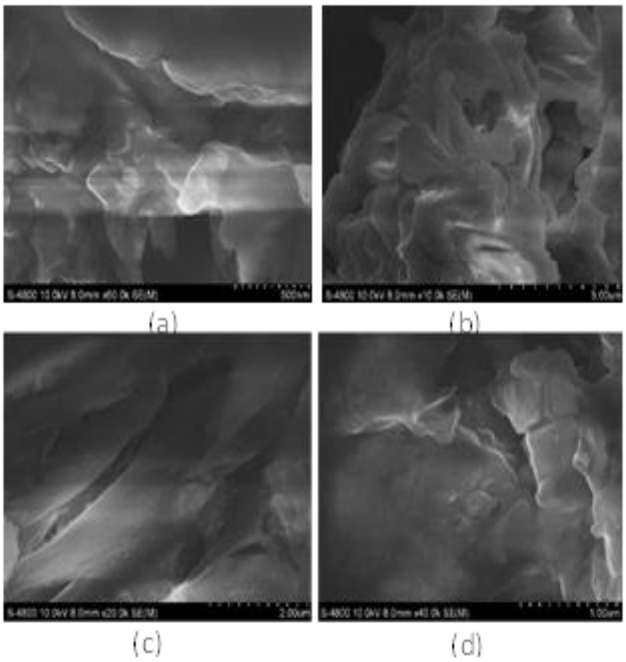

Figure 1: The surface structure of Nopal Cactus

SEM images taken at amplifications of 500nm (a), 5µm (b), 2µm (c) and 1µm (d) show the rough material surfaces with multiple-layer structures that increase the contact areas, the deep holes with undefined shapes will increase the ability to diffuse and absorb dirt residues at different sizes.

3.2 The best pH results

The pH value from 2 to 3 has an increased COD processing efficiency (from 56.15% to 60.21%); with pH from 3 to 13, the COD processing efficiency decreases (from 60.21% down to 30.83%); The processing efficiency of COD at pH= 3 is the highest (60.21%). The pH value from 2 to 3 gives a high-efficiency treatment of color levels but tends to decrease slightly (from 92.89% ÷ 87.85%). Compared to decolorization, the effect of pH on COD processing is less effective.

This can be explained as follows: *Nopal Cactus* powder has a composition of polymers such as L - arabinose, D - galactose, L – rhamnose, D - xylose, and galacturonic acid which contain many COOH groups. When the pH value is low (creating acidic environment), hydrolytic processes take place strongly to create empty positions with a negative electric charge (-) which will bind to the sediment particles with the positive electric charge (+); the increasing pH value creates a neutral environment, and the base reduces the ability to hydrolyze and processing efficiency. Based on the results of the above analysis, it is found that at the value of pH = 3, the processing efficiency of both color levels and COD is the best.

3.3 The best amount of *Nopal Cactus* powder

With the content of dried *Nopal Cactus* powder from 80 to 90 mg/L, the processing efficiency of the color levels is quite high but there is a slight decrease (from 72.47% to 70.33%); From 90 to 100 mg/L, the performance increases sharply (from 70.33% to 87.85%); with the dried *Nopal Cactus* powder content from 80 to 100 mg/L, COD processing efficiency also tends to decrease slightly (from 47.08% to 37.4%) and increases sharply to 60.21% in 100mg/L content of *Nopal Cactus* powder.

The amount of dried *Nopal Cactus* powder used in this study is higher than that of on the use of dried *Nopal Cactus* powder in color levels treatment and COD in surface water (40 mg/L) (Nam and Ba, 2017). This is reasonable because, with textile wastewater, COD, color, and pollution levels are higher than surface water, the higher content of dried *Nopal Cactus* powder is suitable. From the above analysis, the best value at 100mg/L brings the best processing efficiency.

3.4 The best stirring velocity

The color processing capacity is quite high and does not change much at stirring speeds from 10 rpm to 60 rpm, processing efficiency is relatively high (87.93%, 87.68%, 87.85%, 86.59%, 85.12%, 84.67%). Regarding COD, it shows overall average processing efficiency. The highest values are 60.21% and 62.38% for stirring speeds of 10 and 40 rpm, respectively.

Based on the above analysis, the researcher chooses the best value with a stirring speed of 40 rpm. Compared to previous research on the use of dried *Nopal Cactus* powder for surface water treatment of 30 rpm, it is higher than 10 rpm (Nam and Ba, 2017).

3.5 The best stirring time

The color processing capacity is quite high and does not change much at stirring times from 6 rpm to 16 rpm, the processing efficiency is relatively high (86.38%, 87.24%, 87.85%, 86.87%, 86.59%, 86.22%). Regarding COD, overall, the processing efficiency is below average (<50%). When the stirring period is from 8 to 10 minutes, the processing efficiency is highest at 60.21% with the stirring time of 10 minutes. Based on the above analysis, the researcher chooses the best value with a stirring time of 10 minutes, in line with the results of previous studies which is 10 minutes stirring on dried *Nopal Cactus* powder (Bouatay and Mhenni, 2014; Bustillos et al., 2013). This result is also consistent with study which is 10 minutes stirring (Nam and Ba, 2017).

3.6 Decolorization and COD removal efficiency with Kaolin content at the best parameters

Beside the color from the dye dissolution, the real textile wastewater has an apparent color from the TSS. Therefore, the purpose of adding kaolin is to make the hypothetical wastewater almost the same to the actual wastewater. The additional amount of Kaolin is 500mg so that when examining the treatment with *Nopal Cactus* powder, the coagulation-flocculation process creates cotton from TSS and then absorbs the real color (from the solubleness of the dye product) onto the floc.

The color is well-processed in accordance with the amount of Kaolin surveyed above. Color removal efficiency increases when Kaolin content increases from 300 to 1300 mg/L. The COD removal efficiency is highest (60.21% ÷ 62.4%) when Kaolin content is between 500 – 700 mg/L.

3.7 Examining the capabilities of treating real textile wastewater by *Nopal Cactus* powder

With color treatment performance for 3 types of wastewaters with dark, medium, and light color, the efficiency is average (from 39.56% to 52.89%), COD treatment efficiency is low (from 15.38 % to 25.56%). Both cases (dried *Nopal Cactus* powder; dried *Nopal Cactus* powder + Kaolin) are compared to QCVN 13 – MT:2015, the researcher found that with medium color processing efficiency, the value of color levels in post-processing output is still higher than QCVN for all MNT1,2,3 models (Torres et al., 2012).

Regarding the COD content, only MNT3 sample has higher input values than QCVN 13 – MT:2015 (260mg/L) and post-treatment value of 213 mg/L (efficiency 18.07%) is still not reached. Although dried *Nopal Cactus* powder treatment has not yet met the standards of discharge into the environment, it is clear that the real wastewater treatment performance is acceptable (highest color level 48.14%; COD 25.56%), the use of natural coagulation in combination with further processing methods increases processing efficiency while reducing the amount of sludge generated.

3.8 Optimizing the experiment with the use of *Nopal Cactus* powder in treating real textile wastewater

To identify the optimal value and evaluate the effectiveness of textile wastewater treatment with dried *Nopal Cactus* powder, the Jartest experiment need be arranged to examine the influence factors based on the best values surveyed earlier. To reduce the numbers of experiments and learn from practical research, the researcher chooses the amount (80 & 100 mg/L) and stirring rate at 2 levels (20 & 40 rpm) while pH (2; 3; 4) and stirring time at 3 levels (8; 10; 12 minutes) with the best value between min and max values.

3.8.1 Running variables independently

Data process using STATGRAPHIC XV software shows that the test results are meaningful for each coefficient regression. The components involved in the model all show high meaningful levels (all four factors have a value of $p < 0.05$). The pH value, the amount of dried *Nopal Cactus* powder, stirring velocity and stirring time all clearly show the significance at 95% reliability level, except for some interactions between factors (Jadhav and Mahajan, 2014). The conformity of the model is tested through the R^2 correlation determination factors.

For color processing efficiency, the R^2 correlation determination factor is 84.16%, R^2 (adj) = 75.90 % and the four main factors all have a value of $p < 0.05$ except for some interactions. This can be said that the model is suitable and reliable (Pichler et al., 2012). For COD processing efficiency, the R^2 correlation determination factor is 81.82 %, R^2 (adj) = 72.33 % and there are three main factors: the amount of dried *Nopal Cactus* powder, stirring velocity, stirring time, they all have a value of $p < 0.05$.

The final regression equation shows the relationship between the color treatment efficiency and COD with 12 independent variables (according to all the coded factors) for the quadratic response surface model described in equations 1 and 2.

Equation 3.8.1:

The color processing efficiency (%) = 248,205 + 22,1179*pH - 0,306792*D - 1,07912*S - 28,2296*T - 5,135*pH^2 + 0,00641667*pH*D + 0,0756667*pH*S - 0,630625*pH*T + 0,000963889*D*S + 0,0220208*D*T + 0,0370625*S*T + 1,18219*T^2

Equation 3.8.2:

COD processing efficiency (%) = -280,421 + 91,2267*pH - 0,869389*D + 2,79783*S + 40,4412*T - 14,1462*pH^2 + 0,128792*pH*D - 0,405125*pH*S - 0,751875*pH*T + 0,00354722*D*S - 0,0034375*D*T - 0,155146*S*T - 1,52469*T^2

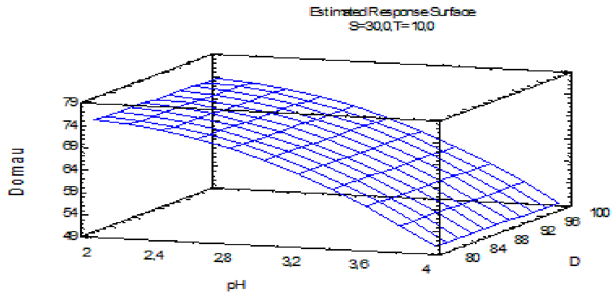

Figure 2: The response surface model for color treatment

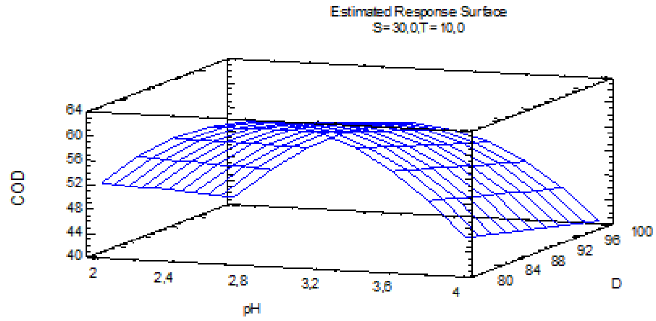

Figure 3: The response surface model for COD treatment

Color processing performance and optimal COD processing performance are 91.13% and 67.70%, respectively. Accordingly, post-treatment wastewater with the color level of 58.05 Pt-Co and COD of 83.98 mg/L reaches QCVN 13-MT: 2015/BTNMT; column B is for the facility in operation. Optimizing the experiment has brought the optimal value with higher processing performance than the value previously studied.

3.8.2 The combination of 2 variables COD and color

The optimal processing performance for color and COD variables are 77.07% and 59.10%, respectively. The researcher found that the water after treatment has color and COD value of 107.71 Pt-Co and 106.34 mg/L, respectively (Theodoro et al., 2013). This value has been met according to the regulations on discharging to the receiving source in column B according to QCVN 13 – MT: 2015 / BTNMT.

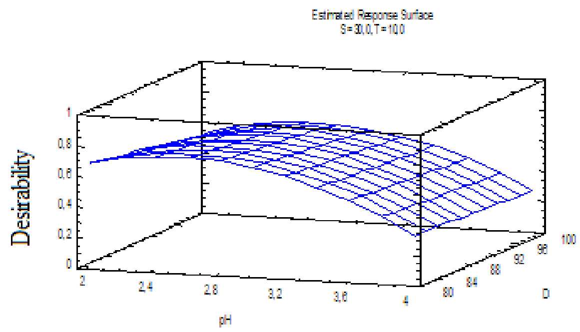

Figure 4: The response surface model for COD and color processing treatment

4. CONCLUSION

Dried *Nopal Cactus* powder through SEM imaging method shows rough surface with multiple-layer structure which increases contact areas. Deep holes with undefined shapes on this material will increase diffusion and absorption of dirty residues of different sizes. The material is the natural coagulant which is environmentally friendly.

The artificial colored water sample 410 Pt-Co + 500mg/L Kaolin has been identified the best parameters, pH=3; LL= 100mg/L; the stirring velocity of 40 rpm; the stirring time of 10 minutes. The treatment capacity of textile wastewater samples showed an average color reduction efficiency

(52.89%), low COD treatment efficiency (25.56%). The optimal result is that the real textile wastewater sample at the company at the dyeing process has an input COD value of 260 mg/L, the color level of 470Pt-Co.

The experiment with 36 tests running on STAGRAPHIC XV software and ANOVA analysis with COD and color variables, which shows the optimal processing performance with the color level and COD of 77.07% and 59.11% respectively. The optimal value of pH is 2.6, the amount of dried *Nopal Cactus* is 80 mg/L, the stirring velocity is 40.0 rpm, and the stirring time is 8.2 minutes.

Recommendation

There should be further research on the water treatment capacity of dried *Nopal Cactus* powder on different textile wastewater samples combining with other treatment methods to improve the efficiency of color and COD treatment in textile wastewater.

References

Do, T.L., 2006. Những cây thuốc và vị thuốc Việt Nam. in lần thứ 14, Nhà xuất bản Y.

Hoang, M.C., Pham, X.S., Nguyen, M.T. 2002. Bước đầu nghiên cứu thành phần hóa học của vị thuốc Đảng Sâm Việt Nam. Tạp chí dược liệu, tập 7 số 1.

Nguyen, T., 2006. Danh lục Đỏ cây thuốc Việt Nam. Tạp chí Dược liệu, tập 11, số 3, tr. 97-105.

Nguyen, T.B., 2007. Sách đỏ Việt Nam (phần II - Thực vật). NXB. Khoa học tự nhiên và công nghệ, tr., 152-153, Pp. 303-304.

Peng, M., Yao, J., Yang, X.L., Yang, J., 2011. Preliminary Study of Polysaccharide on Gastro Intestinal Movement in Mice. Journal of Mountain Agriculture and Biology, Pp. 2011-05.

Truong, H.D., Le, P.T.Q., Tran, T.H.C., Pham, T.K.N., Dong, T.A.D., 2015. Tối ưu hoá trích ly thu nhận dịch saponin từ Đảng Sâm *Codonopsis javanica (Blume) Hook. f.* bằng enzyme alpha-amylase. Tạp chí Khoa học công nghệ; Số, 4 (99), Pp. 1-3.

Ueda, J.Y., Tezuka, Y., Banskota, A.H., Le, T.Q., Tran, G.K., Harimaya, Y., Saike, I., Kadota, S., 2002. Antiproliferative activity of Vietnamese medicinal plants. Biological & Pharmaceutical Bulletin, 25 (6), Pp. 753-760.

Võ, V.C., 2012. "Từ điển cây thuốc Việt Nam", NXB Y học, trang, Pp. 566-567.

Wang, Z.T., Ma, G.Y., Peng-Feitu, Xu, G.J., Ng, T.B., 1995. Chemotaxonomic Study of C*odonopsis* (Family Campanulaceae) and its Related Genera. Biochemical Systematics and Ecol., Vol. 23, No.7/8, Pp. 809-812.

Yang, D.S., L, Z.L., Wang, X., Yang, Y.P., Peng, W.B., Liu, K.C., Li, X.L., 2015. Chemical constituents from roots of *Campanumoea javanica* and their antiangiogeneic activities. Chinese Traditional and Herbal Drugs, 04, Pp. 002.