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Physico-chemical Process for Fish Processing Wastewater Treatment

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ABSTRACT

The fishery products in Myanmar are from inshore, offshore, and inland fisheries and also from aquaculture. In Myanmar, there are 3 cold storages and 115 sea-food processing factories. The effluents from those factories released into water bodies directly after little or no treatments have added to the environmental problem. For fish processing wastewater treatment, the optimization of coagulant dosage, pH and flocculants dosage was investigated. Ferric chloride ($FeCl_3$) was used as coagulant and polyacrylamides was for flocculants aid. The experiments were conducted at several dosages of 150 – 650 mg/L for coagulant and 15 – 65 mg/L for flocculant within the pH range of 3.0 – 11.0 to access the feasibility of the process. The process efficiency evaluation was based on the removal of COD, TSS, TDS, TS, turbidity, and odor. The best process condition was the coagulant dosage of 369 mg/L and flocculant dosage of 28.5 mg/L at pH 8.5 where 68 % COD removal and 50 % TSS removal were recorded. It is noticed that the turbidity and odor of the fish processing wastewater were also significantly decreased.

I. INTRODUCTION

The environment is currently facing severe eutrophication problems due to the various types of the industrial effluents, agricultural run-offs and urban domestic sewage etc. Among the industries, the fish processing industries use the considerable amount of clean water and then discharge the water contaminated by blood, offal products, viscera, fins, fish heads, shells, skins, and fined meat after processing [1, 2]. Environmental issues in fish processing industries include water consumption and wastewater generation, solid waste generation and by-products production, and air pollution. The discharges of fish processing industries can be toxic to man and other aquatic life because of high dissolved and suspended organic matter contents in the wastewater [3].

The fishery products in Myanmar are from inshore, offshore, and inland fisheries and also from aquaculture. The production of fishery products for 2014 - 2015 fiscal year was 5,638,176.43 metric tons. Most of the fishery products were primarily distributed for local food security and the only 6% of total fishery production were exported. In Myanmar, there are 3 cold storages and 115 sea-food processing factories [4, 5].

The effluents from those factories released into water bodies directly after little or no treatments have added to the environmental problem. The quality of these effluents makes difficult to meet National Environmental Quality (Emission) Guidelines, Myanmar (2015). Due to the implementation of strict discharge limits, it is necessary to study the wastewater treatment techniques that allow obtaining water with quality requirements for its discharge or reuse in the industrial process.

To reduce contaminant level, several techniques can be used for treatment of the fish processing effluents. Many researchers reported that the primary treatment such as sedimentation, coagulation-flocculation [1, 6, 7, 8], chemical and biological process (aerobic biological process [2] or activated sludge treatment [3] or photobioreactor with microalgae-containing microbiota [9]) and also screening and dissolved air flotation methods [10] are widely used in fish processing wastewater treatment to reduce contaminated concentration.

Many studies have proved that the physico-chemical process is the essential to treat fish processing effluents. Therefore, the present study chooses coagulation-flocculation process for more economic and environmental friendly. The aim of this research work is to evaluate and propose the optimum physico-chemical treatment for the fish processing effluent. The specific objectives are to optimize the process parameters using response surface methodology (RSM) approach, to determine the removal efficiencies of COD, TSS and turbidity of the treated effluent and to provide the valuable information for the wastewater treatment system in the fish processing industries.

II. MATERIAL AND METHODS

1. Materials

The effluent sample was collected from only one sampling point of the final discharge from fish processing plant. To investigate the coagulation-flocculation process, the coagulant of ferric chloride and the flocculant of ployacrylamides were used. The pH of wastewater was adjusted using NaOH (1 mol/L) and HCl (1 mol/L). The chemicals were used without further purification. For analysis of fish processing wastewater, the standard methods for the examination were adopted for the measurement of pH, temperature, turbidity, odor, total solids (TS), total dissolved solids (TDS), total suspended solids (TSS), chemical oxygen demand (COD). The used equipment were Magnetic Stirrer (AGIMAN, J.P.SELECTA, s.a., Spain) for physico-chemical treatment efficiency; pH meter (OHAUS Corporation, STARTER 3100, USA) for pH and temperature measurement; TDS meter (HANNA Instruments, HI-8634, Singapore) for total dissolved solids; Turbidimeter (Lovibond Water Testing, Germany) for turbidity; Thermal digester and Photometer (Plaintest Ltd., APHA 5220-D Method, England) for COD analysis.

2. Coagulation-flocculation Treatment

For the coagulation-flocculation tests, the inorganic salt ($FeCl_3$) was tested as coagulant and the polyacrylamide was for flocculant aid. In order to see the effect of the coagulant dose, several dosages (150 – 650 mg/L) were studied at the pH influence that assessed in the range of 3.0 – 11.0 and the flocculant dosages (15 – 65 mg/L). For the different process conditions, each test was filled with 200 mL of sample and the coagulant dose was then added and/or the pH adjusted HCl (1 mol/L) or NaOH (1 mol/L). After coagulation, the flocculation process was conducted.

The experimental procedure consisted of a rapid mixing at 250 rpm for 1 minute and the coagulant was added during stirring and then pH adjustment was continued. The stirring speed was reduced to 50 rpm for 15 minutes. When the coagulation process was conducted, the flocculation process was followed at 100 rpm for 2 minutes and, after that, in order to form flocs, it is stirred at 50 rpm for 5 minutes. Finally, a sedimentation stage of 15 minutes allowed the flocs formed to be settled. The treated water samples were collected for analysis. From Figure 1, the supernatants obtained were then characterized in terms of TS, TDS, TSS, COD, pH and turbidity.

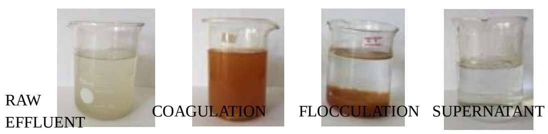


Figure 1. Coagulation-flocculation test for fish processing wastewater

III. RAW EFFLUENT CHARACTERISTICS

During the experiments running period, 50 L of wastewater of fish processing plant were collected from at the outlet of the process, after sieving and sedimentation pre-treatments that they are subjected to. Standard methods for the examination of wastewater were adopted for the measurement of TS, TDS, TSS, turbidity, pH, temperature and COD as can be seen in Table 1.

Table 1. Characteristics of raw effluent from fish processing plant

Parameter	Units	Values
Total Solids (TS)	mg/L	5300
Total Dissolved Solids (TDS)	mg/L	3300
Total Suspended Solids (TSS)	mg/L	2000
Turbidity	NTU	297.7
pH	-	5.9
Temperature	°C	22.4
Chemical Oxygen Demand (COD)	mg/L	1187.5

IV. EXPERIMENTAL DESIGN AND DATA ANALYSIS

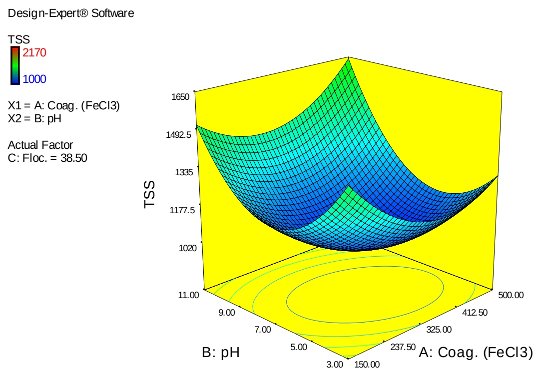
In the present work, the coagulant, ferric chloride, and the flocculant, polyacrylamides, were used in order to destabilize colloids and to settle suspended particles at various pH conditions. To verify the influence of coagulant dose, pH and flocculant dose factors in the removal of TSS and turbidity, we elaborate a central composite design, factorial (2^3) with levels (-1, and +1) and three replicates at the center point (0), which presented in Table 2. The selected operating ranges for each factor were described according to the values normally used in coagulation-flocculation process and considering the initial wastewater characterization.

Table 2. Levels of the experimental factors in the experimental design

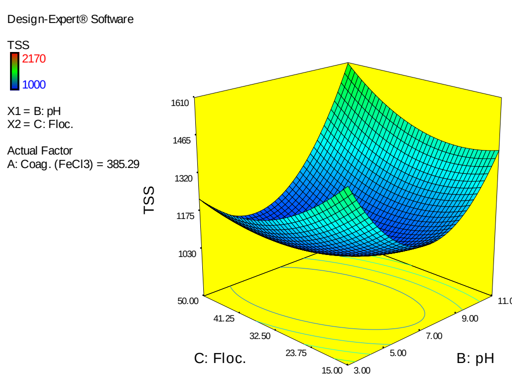
Factor	Unit	Coded Level		
		- 1	0	1
A: Coagulant ($FeCl_3$)	mg/L	150	325	650
B: pH	-	3	7	11
C: Flocculant (Polyacrylamides)	mg/L	15	32.5	65

The coagulant dosage was a minimum value of 150 mg/L and a maximum of 650 mg/L. Since the center value of flocculant dose was 32.5 mg/L, the upper and lower limits of 65 and 15 mg/L, respectively, were chosen and the pH values were between 3 and 11. The experimental design matrix and processing data from each run were carried out by Design Expert 7.0.0 software. Response surface method was used for the best variant of coagulation-flocculation based on removal of TSS and turbidity. In this work, coagulant dosage (A), pH (B), and flocculant dosage (C) were chosen as three independent variables, which resulted in 17 trials.

The performance of the coagulation-flocculation process for fish processing wastewater treatment was optimized applying a factorial design. Using the results from 17 experiments, the removal of TSS and turbidity were predicted within the range of factors chosen. The TSS removal results predicted by the quadratic model are presented at each experimental point (Figure 2).



(a)



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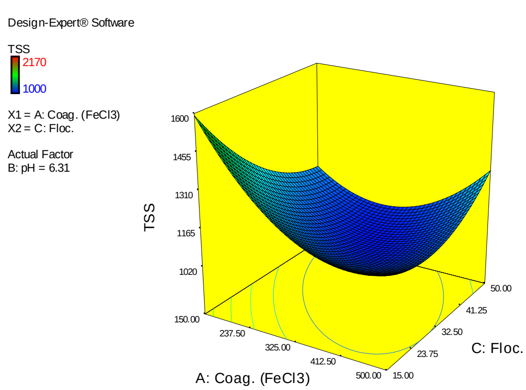


(c)

Figure 2. Response surface plots of TSS showing (a) the effects of pH and coagulant dose, (b) the effects of pH and flocculant dose, (c) the effects of coagulant and flocculant doses

However, the quadratic model was not fitted adequately to the experimental data, in which the high p-value ($p > 0.05$) and also R^2 value (0.68). Although the ANOVA results show that inadequate model, the 50 % TSS removal of fish processing wastewater could be attributed to the variables, i.e., it could not be explained by the model. The response surface graphs, see Figure 2, display the statistically relevant effect of each factor on the response and it is a practically mode to view the results. The quadratic term of response seems to slightly affect on the process parameters, but the interaction among factors was shown to be almost statistically insignificant for TSS of the response variables evaluated.

The model suggested that the condition of 385 mg/L dosage of ferric chloride and 38.5 mg/L dosage of polyacrylamides and pH 6.3 can remove the TSS value up to 1028 mg/L. Additionally, the better performance was achieved for TSS removal within the given range, which explains the removal efficiency up to 50 %. It can be seen that the model is slightly deviated from the experimental data.

The supernatant turbidity removal efficiency is an important denotation for the treatment efficiency in the coagulaion-flocculation process. Using RSM, the effects of factors on turbidity removal are known, the response can be predicted and the optimum values can be determined. The contour plots (Figure 3) generated from factorial design, show the turbidity removal of the fish processing wastewater as a function of pH, coagulant dose and flocculant dose in this study. The statistical testing of the model was shown as linear model of significant because the p-value was 0.0374. The contour plots display the statistically relevant effect of each factor on the response and it is a practical mode to view the results.

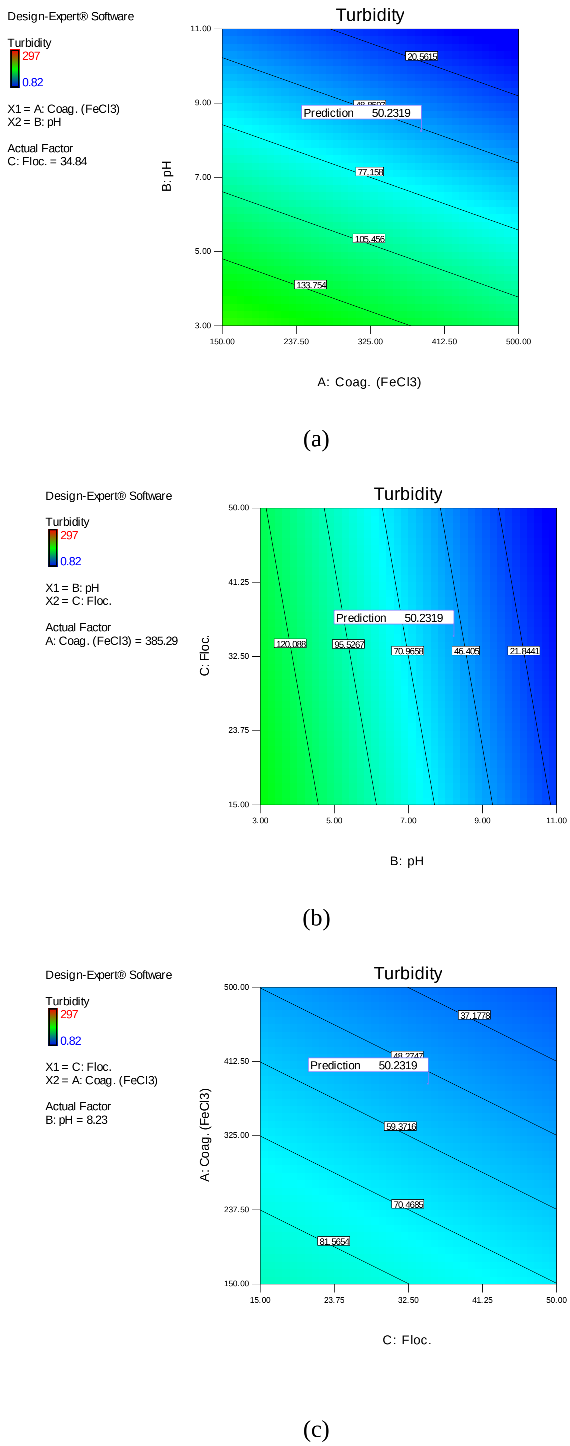
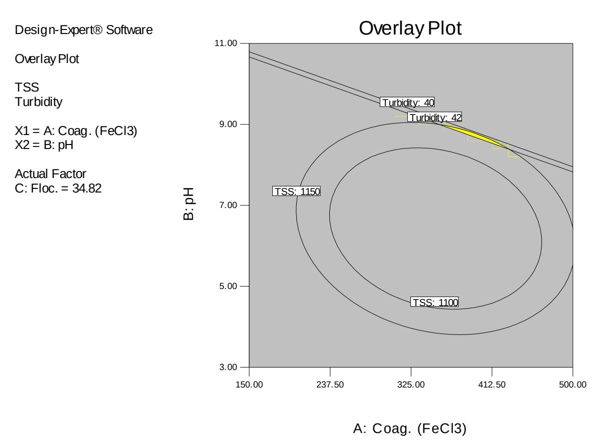


Figure 3. Contour plots of Turbidity showing (a) the effects of pH and coagulant dose, (b) the effects of pH and flocculant dose, (c) the effects of coagulant and flocculant doses

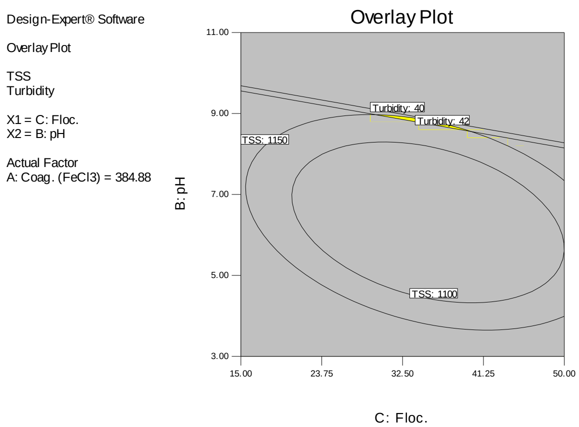
With the turbidity removal efficiency as the response, the response surfaces of the linear model with one variable kept at the best level and the other two varying within the experimental ranges. The best conditions for turbidity removal efficiency of 86 % were obtained as follows: coagulant dosage of 385 mg/L, pH of 8.23 and flocculant dosage of 35 mg/L. In this case, we have got the results of 68 % COD, 50 % TSS and 86 % turbidity removal efficiencies. Nevertheless, COD and TSS values were not achieved to the environmental pollution protocol. We need to conduct more test runs and another integrated system.

The experiments on the effect of factors showed that coagulant dose of 385 mg/L, flocculant dose of from 35 to 39 mg/L and pH of from 6.3 to 8.2 to get the maximum removal of TSS and turbidity. The optimum condition can be visualized graphically by the contours for the various response surfaces in an overlay plot.

According to Figure 4, defining the optimization criteria for the chosen response TSS (between 1100 and 1150 mg/L) and turbidity (between 40 and 42 ntu), the shaded portion of the overlay plot was generated using the Design Expert software.



(a)



(b)

Figure 4. Overlay plot for optimum region: (a) pH versus coagulant dosage and (b) pH versus flocculant dosage

The optimum region corresponds to the areas, within the range of the coagulant dosage from 369 to 439 mg/L, flocculant dosage from 28.5 to 36.9 mg/L and pH from 8.5 to 8.8, respectively. This indicates that near the center point in any of these variables, within the ranges studied resulted in reducing efficiencies.

The results from this study are compared with other ones from the literatures in Table 3. From literature reviews, we find that the coagulation-flocculation method is one of the most suitable processes to treat water or industrial wastewater using different dosages and different types of coagulant or floculants. Some literatures reported that they use only coagulation-flocculation process or its integrated with others such as dissolved air flotation unit.

R.O. Cristovao et al., (2014) reported removal percent of TSS from fish processing wastewater were 62.6%, 72.4% and 85.8% in the ferric chloride dosage of 100 mg/L, 200 mg/L and 400 mg/L, respectively. RSM design in fish processing wastewater treatment was applied in the process of biological treatment (activated sludge) [3] to obtain the removal efficiency of 88 % dissolved organic carbon and coagulation-flocculation process (chitosan as coagulant) [7] to obtain the removal efficiency of TSS and COD between 70-90% and 26-30%, respectively.

Table 3. Comparison of TSS, COD and Turbidity removal efficiencies obtained in this study with other results from literatures

Types of Wastewater	Treatment Process	Dosage	Removal Efficiency	References
Landfill leachate and Municipal wastewater	Coagulation-flocculation	470-2970 mg/L ferric chloride; 100 smg/L polyacrylamide	79 % COD 93 % Turbidity 90 % TSS	M.Verma et al., 2016 (Engineering and Material Science)
Oil-Water Emulsion of refinery wastewater	Coagulation – DAF	50-1000 mg/L (Alum, Ferrous sulphate, Ferric chloride)	87 % Oil	M.H.A.Megid et al., 2014 (Engineering Sciences)
Pulp mill wastewater	Coagulation-flocculation	0 - 2100 mg/L Aluminum chloride and 0 - 48 mg/L polyacryla-mide	99 % Turbidity	J-P. Wang et al., 2011 (Water Research)
Fish canning Wastewater	Sedimentation Coagulation/ Flocculation – Flotation treatment	Inorganic salts: $Al_2(SO_4)_3 \cdot 16H_2O$, $Fe_2(SO_4)_3$, $FeCl_3$, $CaCl_2$ and PAX-18	99.2 % O&G, 85.8 % TSS, 25.2 % DOC	R.O. Cristovao et al., 2014 (Water Resources and Industry)
Fish Processing Wastewater	Coagulation-Flocculation	150 – 650 mg/L ferric chloride 15 – 65 mg/L polyacryla-mide	68 % COD 86 % Turbidity 50 % TSS	This Study

V. CONCLUSION

The statistical experimental design and response surface methodology were found to be efficient tools to optimize some parameters. The most objectionable and environmentally unfriendly pollutants of fish processing wastewater were typically reduced COD by 68 % to less than 380 mg/L, TSS by 50 % to less than 1028 mg/L and turbidity by 86 % to less than 42 mg/L using coagulation-flocculation process. The best conditions in the ranges studied were found to be a coagulant dose of 369 mg/L and flocculant dose of 28.5 mg/L at pH 8.5. Depending on the purpose for the treated water, it might be necessary other integrated systems.

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