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MODELING OF COAGULATION-MICROFILTRATION HYBRID PROCESS FOR TREATMENT OF OILY WASTEWATER USING CERAMIC MEMBRANES

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In this novel paper, fouling mechanisms of Mullite-alumina ceramic membranes in treatment of oily wastewaters in hybrid coagulation – microfiltration (MF) process have been presented. Hermia's models for cross flow filtration were used to investigate the fouling mechanisms of membranes at different time intervals with various coagulant concentrations. Four coagulant ((ferrous chloride ($FeCl_2 \cdot 4H_2O$), ferrous sulfate ($FeSO_4 \cdot 7H_2O$), aluminum chloride ($AlCl_3 \cdot 6H_2O$) and aluminum sulfate ($Al_2(SO_4)_3 \cdot 18H_2O$)) plus equal concentration of calcium hydroxide in form of calcium hydroxide ($Ca(OH)_2$) were evaluated in the coagulation – MF hybrid process at different concentrations (0, 50, 100 and 200 ppm). To determine whether the data agree with any of the considered models, the coefficient of determination (R_2) of each plot for one model was compared with the others. In addition, average prediction errors of models are calculated. The results showed that cake filtration model can be applied for prediction of the permeation flux decline for MF and coagulation – MF hybrid process with best and worst average error equal to 0.96% and 5.78% respectively. Results indicated that by increasing time in filtration pore blocking behavior changes and one model cannot predict pore blocking behavior in all filtration time with very good preciseness.

Keywords: microfiltration, coagulation, fouling, oily wastewater treatment.

1. Introduction

Oily wastewaters are one of the major pollutants of the aquatic environment and removing oil from these oil-in-water emulsions is an important aspect of pollution control. This is due to the emission of a variety of industrial oily wastewaters from sources such as refineries, petrochemical plants and transportation. Several methods have been used for treatment of theses wastes, such as chemical destabilization by using inorganic salts, coagulation and occulation, dissolved air flotation, and membrane processes [1 – 4]. It is well known that membrane separation is one of the effective technologies used to treat oily wastewaters. One major problem with membrane separation processes is the membrane fouling which can cause a permeation flux (PF) decline due to fouling [5, 6]. Using pretreatment applications before membrane processes the fouling can be reduced. Therefore, it was suggested to add a coagulant before membrane filtration process, not only in order to improve its oil removal effectiveness but also to reduce fouling, especially irreversible fouling for increasing PF of membrane [7 – 12]. Chemical coagulation aggregate particles and organic matter, and aggregation in turn limits pore blockage and enables formation of a more porous cake that can be easily removed by hydraulic cleaning. More frequent mode of coagulation-microfiltration (MF) hybrid process is the "in-line" process [13 – 15]. In the last two decades there have been a large number of studies focused on effects of operating parameters on flux decline and membrane fouling mechanisms. In these studies, membrane filtration testes under different experimental conditions were preformed to obtain data on permeates flux variation with time [5, 16 – 18]. Although some advances in fundamental MF membrane fouling mechanisms have been achieved, further researches are needed to better understand the fouling mechanisms. From the analyses of blocking chart and resistance coefficient of fouling, the filtration flux could then be predicted by using the blocking models [5, 6, 17]. Mullite-alumina ceramic membranes have very high chemical and thermal stability and are very cheap because they can be prepared by extruding and calcining kaolin clay [19, 20]. There are a few papers in literature regarding enhancement of oily wastewaters treatment using MF ceramic membranes with coagulant agents and modeling of PF decline with time. In this novel research, Hermia's models for cross flow filtration [17, 18] were used to investigate the fouling mechanisms involved in coagulation-MF process of oily wastewater at different time intervals ((0 – 2.5 min), (0 – 5 min), (5 – 20 min), (20 – 60 min) and (0 – 60 min)) with Mullite-alumina-alumina ceramic membranes. The fitted results of the Hermia's models for cross flow filtration were presented and compared with the experimental data. Also, more detailed study of the Hermia's models was provided for cross flow filtration to explain the fouling mechanisms in coagulation – MF of the oily wastewaters.

2. Materials and methods

2.1. Membrane preparation. In this research, Mullite-alumina (50% alumina content) MF membranes were synthesized from kaolin clay and α-alumina powder. The chemical analysis of kaolin is listed in Table 1. Preparation and characterization of membranes has been illustrated in previous research [19].

2.2. Oily wastewater and coagulant agents. Synthetic oily wastewater with 1000 ppm oil content and mean droplet size equal to 1.09 μm. was employed in experiments. Detailed information has been illustrated in previous paper [19]. Four coagulants and lime in form of calcium hydroxide ($Ca(OH)_2$) produced in "Merck Company", Germany, were also used in all the coagulation – MF process experiments.

Table 1. Analysis of the kaolin clay

Component	Percent	Phases	Percent
SiO_2	61.62	Kaolinite	64
TiO_2	0.4	–	–
Al_2O_3	24–25	Illite	2.4
Fe_2O_3	0.45–0.65	–	–
K_2O	0.4	Quartz	27
Na_2O	0.5	–	–
L.O.I	9.5–10	Feldspar	6.6
Total	100	–	100

2.3. Experimental setup. The laboratory scale setup was operated in cross flow mode used in all the experiments (Fig. 1). More information has been presented in previous paper [10].

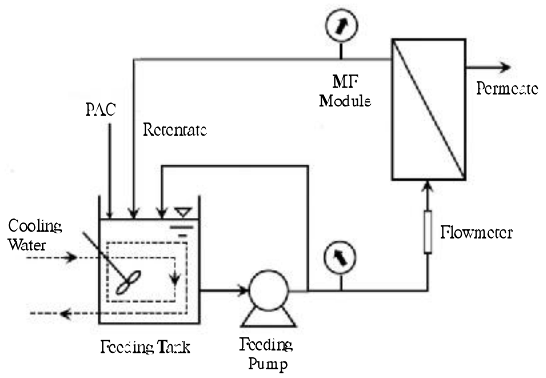

Fig. 1. Microfiltration setup.

2.4. Experimental procedure. In order to examine the applicability of the coagulation – MF process for oily wastewater treatment and investigate the effects of different coagulant agents on the MF process performance in terms of flux decline the experiments were carried out. Coagulant agents were added to the feed tank before MF and mixed well by a mixer at 6000 rpm for 5 min followed by slow mixing with 20 rpm for 30 min and thus flocs did grow and become large in alkaline pH range. In all experiments, equal concentration of each coagulant with calcium hydroxide in form of calcium hydroxide ($Ca(OH)_2$) was added to the synthetic oily wastewater in the coagulation – MF process with concentrations of 25, 50 and 100 ppm in best operating condition (P = 3 bar, CFV=1.5 m/s and T=35°C)[19]. A pump was then started and the mixture of oily wastewater and coagulant agent with calcium hydroxide was filtrated using the MF Mullite-alumina ceramic membranes. The results show that Iron salts have better performance compared with aluminum salts. At the best conditions (200 ppm of ferrous sulfate plus calcium hydroxide), PF increased from 118.32 (L/m^2 h) for MF process to 212.55 (L/m^2 h). Table 2 shows PF at the end of filtration for coagulation – MF hybrid process [19].

Table 2. PF in terms of liter per square meter per hour of membranes at the end of filtration (60 min) in coagulation – MF hybrid process

Coagulant concentration	50 ppm	100 ppm	200 ppm
Aluminum chloride + calcium hydroxide	133.17	164.59	49.24
Aluminum sulfate + calcium hydroxide	151.18	97.95	64.87
Ferrous chloride + calcium hydroxide	174.36	189.94	212.55
Ferrous sulfate + calcium hydroxide	187.62	171.21	142.68

3. Modeling

Hermia's models for cross flow filtration are the most useful and applicable models for microfiltration flux decline prediction. The general equation is as follows [17, 18]:

$$\frac{dJ}{dt} = -K(J - J_{ss})J^{2-n}. \quad (1)$$

Where n = 2 for complete blocking; n = 1.5 for standard blocking; n = 1.0 for incomplete pore blocking (intermediate fouling) and n = 0 for cake filtration. K is model constant and J_{ss} is steady state PF. PF can be predicted as follows for models:

for cake filtration model

$$J = \left[(1-Y)J_{ss}\right] - \frac{\sqrt{[(Y-1)(J_{ss})]^2 - 4(M-Y)(J_{ss}^2)}}{2(X-Y)},$$

$$Y = \left[\exp\left(KJ_{ss}^2 t\right)\right] - \frac{J_{ss}}{J_0};\ X = \frac{J_0 - J_{ss}}{J_0}; \quad (2)$$

for standard pore blocking model

$$\frac{1}{J^{0.5}} = \frac{1}{J_0^{0.5}} + (K)(t); \quad (3)$$

for complete pore blocking model

$$J = J_{ss} + (J_0 - J_{ss})\exp[(-KJ_0)t]; \quad (4)$$

for intermediate pore blocking model

$$J = \frac{J_0 J_{ss} B}{J_{ss} + J_0[P-1]};$$

$$B = \exp[(KJ_{ss})t]. \quad (5)$$

In equations (1) – (5), J_0 in the initial PF ($J = J_0$ at $t = 0$).

The Hermia's models that were defined for cross flow filtration by field et al. [18] for the description of various filtration laws were applied to PF data that were obtained in the current studies. A linear relationship of H versus t, $1/J_{0.5}$

versus t, Ln[$(J - J_{ss})/(J_0 - J_{ss})$] versus t and Ln[$J(J_0 - J_{ss})/J_0(J - J_{ss})$] versus t was determined experimentally for cake filtration model, standard pore blocking model, complete pore blocking model and intermediate pore blocking model to calculate constants (K) in models respectively.

$$H = \mathrm{Ln}\left[\left(\frac{J(J_0 - J_{ss})}{J_0(J - J_{ss})}\right) - J_{ss}\left(\frac{1}{J} - \frac{1}{J_0}\right)\right]. \qquad (6)$$

To determine whether the data agree with any of the considered models, the coefficient of determination (R^2) of each plot for one model was compared with the others. For better comparison of the models, average prediction errors of models are calculated. For determination of average prediction errors of models, by using the experimental data, average value of models constant (K) are calculated and replaced in equations (1) – (5) to calculate predicted permeation flux. Therefore average error at different times for predicted flux and actual flux are determined. It is possible that fouling mechanisms has been changed during filtration and transitions of fouling mechanisms were occurred [17]. Therefore Hermia's models were used to investigate the fouling mechanisms of membranes at different time intervals ((0 – 2.5 min), (0 – 5 min), (5 – 20 min), (20 – 60 min) and (0 – 60 min)) for MF and coagulation – MF process.

4. Results and discussion

4.1. Prediction of PF decline by models for MF process. Comparing the plots in Fig. 2 and Table 3 for all models, indicate that the cake filtration model with average error of 2.2% coincidence better relative to the intermediate pore blocking and complete pore blocking models (average error of 3.57% and 9.65% respectively). High deviations between experimental and predicted flux decline are observed for the standard pore blocking model with average error of 14.09%.

Results of Table 3 show that cake filtration model can predict flux of permeate better than other model at first times of filtration ((0 – 2.5 min) and (0 – 5 min)). By increasing time to 60 min, results indicate that prediction of PF with cake filtration model can be applied for prediction of permeation flux for other intervals. Therefore it can be conclude that pores of Mullite-alumina membranes becomes fill and cake layer formed and it become thicker by increasing time at the begin of filtration. It must be noted that by comparing particle size distribution of oil droplet and mean average pore diameter of Mullite-alumina membranes (0.728 mm), it can be found that mean diameter of oil droplets is higher than average pore diameter of Mullite-alumina membranes and a large percent of oil droplets cannot inter into membranes pores. After cake filtration model, intermediate pore blocking model, can predict filtration flux well.

Table 3. (R^2) and average error of models for prediction of PF without coagulation

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.962	0.944	0.999	0.999	0.998	2.2
Intermediate pore blocking model	0.95	0.992	0.998	0.999	0.992	3.57
Standard pore blocking model	0.944	0.987	0.99	0.983	0.918	14.09
Complete pore blocking model	0.944	0.988	0.994	0.996	0.96	9.65

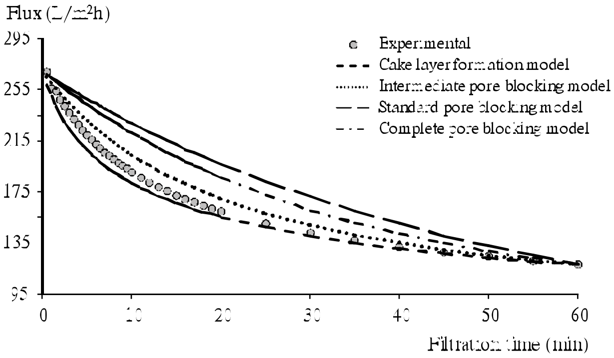

Fig. 2. Variation of actual and predicted PF with time in MF process (no coagulant agents).

4.2. Prediction of PF decline by models for coagulation – MF hybrid process with aluminum chloride plus calcium hydroxide. According to results of Fig. 3 and Tables 4 – 6, cake filtration model with average error of 2.1; 1.23 and 1.27% is best model for prediction of flux decline with 50; 100 and 200 ppm coagulant agent concentration respectively.

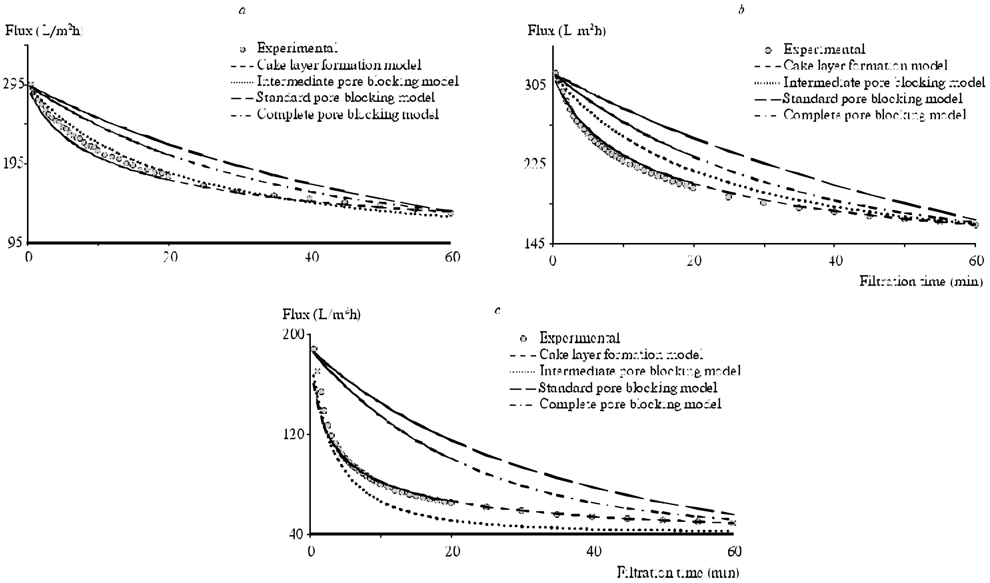

Fig. 3. Variation of actual and predicted PF with time in coagulation – MF hybrid process with Aluminum chloride plus calcium hydroxide: 50 (a), 100 (b), 200 (c).

Highest deviations between experimental and predicted flux decline were observed for the standard pore blocking model. It must be noted that by employing Hermia's models for different time intervals with 50 and 100 ppm coagulant agent, fouling mechanisms is cake filtration models for all time intervals (see Table 4 and 5) because R^2 of it is higher than other models. This is due to sweep flocculation by formation of large flocs and improvement of attraction energy between oil droplets. A further possibility is that surface precipitation of hydroxide can occur, with similar consequences. In fact, hydroxide precipitation leads to the possibility of sweep flocculation, in which impurity particles become enmeshed in the growing precipitation and thus porosity of cake layer are increased [10, 14]. It must be noted that $Al(OH)_3$ and $Ca(OH)_2$ have low solubility in water and precipitate during filtration on membrane surface and fill membrane pores. Of course at first time interval, membrane surface is clean and pores of membrane is empty, therefore large oil droplets and coagulant particles enter into membranes pore and complete the pores [5]. After filling of membrane pores, large oil droplets make a cake layer on the membrane surface by increasing time. Therefore by increasing time of filtration, cake filtration model can predict flux better than other models.

Table 4. (R^2) and average error of models for prediction of PF with 50 ppm Aluminum chloride plus calcium hydroxide

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.999	0.994	0.995	0.986	0.995	2.1
Intermediate pore blocking model	0.996	0.987	0.994	0.985	0.991	3.13
Standard pore blocking model	0.994	0.979	0.986	0.983	0.918	13.86
Complete pore blocking model	0.995	0.981	0.99	0.988	0.964	8.9

Table 5. (R^2) and average error of models for prediction of PF with 100 ppm Aluminum chloride plus calcium hydroxide

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.991	0.997	0.999	0.999	0.997	1.23
Intermediate pore blocking model	0.950	0.990	0.997	0.999	0.979	5.24
Standard pore blocking model	0.997	0.980	0.984	0.980	0.863	16.33
Complete pore blocking model	0.970	0.984	0.992	0.997	0.945	9.53

Results of Table 6 indicate that for coagulation-MF process with 200 ppm aluminum chloride plus calcium hydroxide concentration, fouling mechanisms is complete pore blocking model for first time interval (0 – 2.5 min) and cake filtration model for other time intervals.

Table 6. (R^2) and average error of models for prediction of PF with 200 ppm Aluminum chloride plus calcium hydroxide

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.974	0.994	0.998	0.999	0.998	1.27
Intermediate pore blocking model	0.996	0.992	0.993	0.999	0.974	17.29
Standard pore blocking model	0.998	0.974	0.969	0.976	0.777	51.11
Complete pore blocking model	0.999	0.974	0.981	0.998	0.887	34.00

4.3. Prediction of PF decline by models for coagulation – MF hybrid process with aluminum sulfate plus calcium hydroxide. As shown in Fig. 4 and Tables 7 – 9 cake filtration model with average error of 0.96% and 1.64% is the best model for prediction of flux decline with 50 and 100 ppm coagulant agent concentration respectively. But intermediate pore blocking model with average error of 4.31% is the best model for prediction of flux decline with 200 ppm coagulant agent concentration. According to results of Table 7 – 9 by employing Hermia's models for different time intervals with 50 and 100 ppm coagulant agent, fouling mechanisms is cake filtration models for all time intervals because R^2 of it is higher than other models. But for 200 ppm coagulant agent, mechanism of fouling for all time intervals is intermediate pore blocking model This is due to charge reversal and restabilisation of oil droplets by formation of the soluble anionic form $Al(OH)_4^{-1}$ occurs at beginning of filtration and because of interaction between negative charge of oil droplets with soluble anionic ions, large flocs are not formed. In other hand by increasing time of filtration, concentration of sludge particles such as $Al(OH)_3$ and $Ca(OH)_2$ on membrane surface increased. Also oil droplets accumulate in membranes pores during filtration and therefore filling membranes pores.

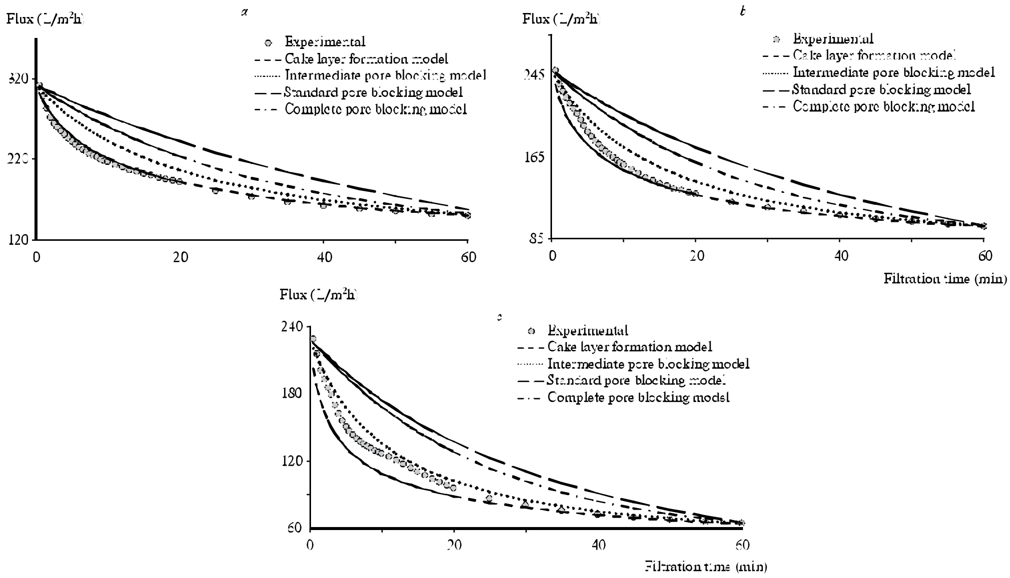

Fig. 4. Variation of actual and predicted PF with time in coagulation – MF hybrid process with Aluminum chloride plus calcium hydroxide: 50 (a), 100 (b), 200 (c).

Table 7. (R^2) and average error of models for prediction of PF with 50 ppm Aluminum sulfate plus calcium hydroxide

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.997	0.982	0.998	0.995	0.998	0.96
Intermediate pore blocking model	0.994	0.971	0.994	0.993	0.986	5.92
Standard pore blocking model	0.990	0.953	0.981	0.960	0.884	18.87
Complete pore blocking model	0.991	0.958	0.987	0.954	0.954	11.50

Table 8. (R^2) and average error of models for prediction of PF with with 100 ppm Aluminum sulfate plus calcium hydroxide

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.990	0.988	0.999	0.999	0.999	1.64
Intermediate pore blocking model	0.980	0.995	0.996	0.999	0.983	4.98
Standard pore blocking model	0.973	0.993	0.981	0.981	0.864	20.8
Complete pore blocking model	0.974	0.993	0.989	0.997	0.935	13.32

Table 9. (R^2) and average error of models for prediction of PF with 200 ppm Aluminum sulfate plus calcium hydroxide

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.991	0.982	0.974	0.993	0.99	5.78
Intermediate pore blocking model	0.997	0.996	0.997	0.997	0.994	4.31
Standard pore blocking model	0.987	0.995	0.996	0.953	0.907	26.52
Complete pore blocking model	0.986	0.994	0.996	0.981	0.948	20.03

4.4. Prediction of PF decline by models for coagulation – MF hybrid process with ferrous chloride plus calcium hydroxide. According to results of Fig. 5 and Tables 10 – 12, cake filtration model with average error of 1.89%, 1.77% and 2.97% is best model for prediction of flux decline with 50, 100 and 200 ppm coagulant agent concentration respectively. Highest deviations between experimental and predicted flux decline were observed for the standard pore blocking model. It must be noted that by employing Hermia's models for different time intervals with 50 ppm coagulant agent, fouling mechanisms is complete pore blocking model for first time interval (0 – 2.5 min) and cake filtration models for other time intervals. Also for 100 ppm coagulant agent, mechanism of fouling is cake filtration model for all time intervals. In addition, for 200 ppm coagulant agent, mechanism of fouling is complete pore blocking model for (0 – 2.5 min) and (20 – 60 min) time intervals and cake filtration model for other time intervals (see Tables 10 – 12).

Table 10. (R^2) and average error of models for prediction of PF with 50 ppm ferrous chloride plus calcium hydroxide

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.985	0.993	0.998	0.999	0.992	5.27
Intermediate pore blocking model	0.991	0.993	0.996	0.998	0.969	6.02
Standard pore blocking model	0.994	0.988	0.984	0.978	0.837	18.05
Complete pore blocking model	0.993	0.990	0.992	0.996	0.929	10.66

Table 11. (R^2) and average error of models for prediction of PF with 100 ppm ferrous chloride plus calcium hydroxide

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.987	0.995	0.997	0.996	0.992	1.77
Intermediate pore blocking model	0.980	0.987	0.996	0.995	0.977	3.38
Standard pore blocking model	0.974	0.979	0.982	0.962	0.861	14.98
Complete pore blocking model	0.976	0.982	0.992	0.991	0.944	7.85

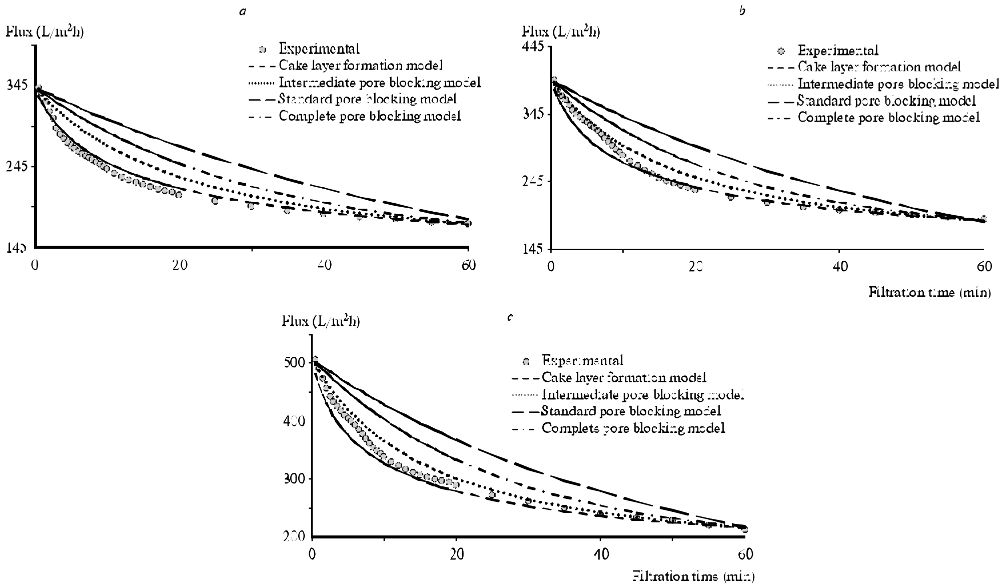

Fig. 5. Variation of actual and predicted PF with time in coagulation– MF hybrid process with Ferrous chloride plus calcium hydroxide: 50 (a), 100 (b), 200 (c)

Table 12. (R^2) and average error of models for prediction of PF with 200 ppm ferrous chloride plus calcium hydroxide

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.995	0.995	0.991	0.974	0.992	2.97
Intermediate pore blocking model	0.998	0.986	0.979	0.977	0.990	2.70
Standard pore blocking model	0.999	0.976	0.954	0.985	0.893	16.84
Complete pore blocking model	0.999	0.987	0.966	0.987	0.964	8.93

4.5. Prediction of PF decline by models for coagulation – MF hybrid process with ferrous sulfate plus calcium hydroxide. According to results of Fig.6 and Table 13 – 15, cake filtration model with average error of 1.39% and 5.75% is best model for prediction of flux decline with 100 and 200 ppm coagulant agent concentration respectively. In addition, intermediate pore blocking model can predict PF decline with time for coagulation-MF process with 50 ppm coagulant concentration and average error of 1.29%. By employing Hermia's models for different time intervals with 50 ppm coagulant agent, fouling mechanisms is cake filtration model for (20 – 60 min) time interval and intermediate pore blocking model for other time intervals (see Table 13). Also for 100 ppm coagulant agent, mechanism of fouling is complete pore blocking model for (5 – 20 min) time interval and cake filtration model for other time intervals.

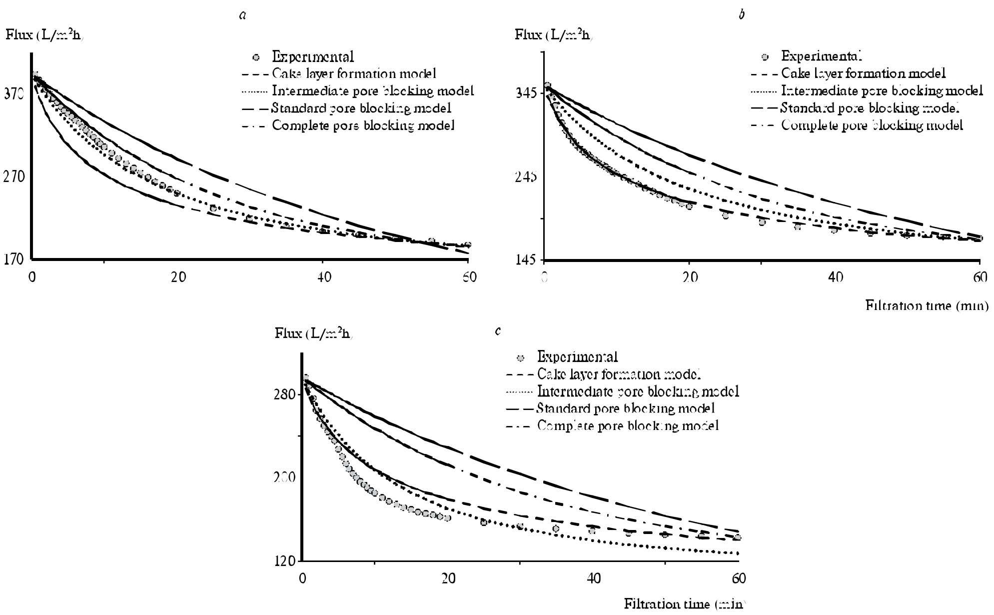

Fig. 6. Variation of actual and predicted PF with time in coagulation – MF hybrid process with ferrous sulfate plus calcium hydroxide: 50 (a), 100 (b), 200 (c)

Table 13. (R^2) and average error of models for prediction of PF with 50 ppm ferrous sulfate plus calcium hydroxide

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.997	0.998	0.988	0.996	0.991	4.24
Intermediate pore blocking model	0.997	0.999	0.999	0.994	0.997	1.29
Standard pore blocking model	0.996	0.998	0.998	0.948	0.935	9.42
Complete pore blocking model	0.996	0.998	0.998	0.987	0.984	3.54

Table 14. (R^2) and average error of models for prediction of PF with 100 ppm ferrous sulfate plus calcium hydroxide

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.999	0.998	0.993	0.980	0.990	1.39
Intermediate pore blocking model	0.999	0.992	0.998	0.976	0.974	5.91
Standard pore blocking model	0.998	0.994	0.997	0.932	0.867	18.3
Complete pore blocking model	0.999	0.986	0.999	0.967	0.939	11.26

In addition, for 200 ppm coagulant agent, mechanism of fouling is complete pore blocking model for (0 – 2.5 min) time intervals and cake filtration model for other time intervals (see Table 15). This is due to sweep flocculation and filling of membranes pores with $Fe(OH)_3$ and $Ca(OH)_2$ insoluble particles in the begin of filtration and formation of cake by increasing time of filtration.

Table 15. (R^2) and average error of models for prediction of PF with 200 ppm ferrous sulfate plus calcium hydroxide

Hermia's Models	0 – 2.5	0 – 5	5 – 20	20 – 60	Total time (0 – 60)	Average error (%)
	min					
Cake filtration model	0.984	0.993	0.984	0.987	0.915	5.75
Intermediate pore blocking model	0.989	0.992	0.970	0.985	0.863	6.84
Standard pore blocking model	0.981	0.985	0.929	0.964	0.707	25.36
Complete pore blocking model	0.991	0.987	0.953	0.980	0.799	17.7

5. Conclusions

In this novel research, analysis of membrane pore blocking models of Mullite-alumina MF membranes for treatment of oily wastewaters with hybrid coagulation – MF process was investigated. Aluminum and iron salts with calcium hydroxide plus calcium hydroxide were used for in-line coagulation in the hybrid process with 50, 100 and 200 ppm concentration. According to the obtained results, it can be conclude that Hermia's models for cross flow filtration can be applied for prediction of PF in limited intervals times ((0 – 2.5 min), (0 – 5 min), (5 – 20 min), (20 – 60 min) and (0 – 60 min)) with very high accuracy and with good accuracy for entirely times since by increasing time in filtration pore blocking behavior changes and one model cannot predict pore blocking behavior in all filtration time with very good preciseness. The best fit to experimental data was for the cake filtration model for MF and coagulation – MF process with best and worst average error equal to 0.96% and 5.78% respectively. Of course, for 50 ppm Ferrous sulfate plus calcium hydroxide, intermediate pore blocking model is best model for prediction of PF decline with 1.29% average error. Results of modeling for different time intervals show that pore blocking behavior of membrane during filtration is changed. Therefore it is better to employed Hermia's model for prediction of PF in short time intervals.

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