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Improved membrane pretreatment of industrial wastewater

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ABSTRACT

The main objective of this research was to study the effect of coagulation on membrane performance by assessing the effect of retention of fine suspended and colloidal matter contained in industrial wastewater. Hybrid process was studied to show the improved efficiency of the coagulation–membrane filtration. It was found that some positively charged fine materials are forming a deposit on the inner surface area of the membrane that leads to its fast blockage, lowering the membrane performance life. In aiming to avoid such a fouling, a new technique was made from a combination between microfiltration and ultrafiltration used as a practical solution to overcome the problem. The combined process was named as micro-ultrafiltration (MUF) and investigated to check out the efficiency and the quality through the treatment plant for industrial wastewater of ceramic factory. The results showed (MF) modified devices were able to remove bacteria, cysts, and fine particles while the UF membranes were very effective to deal with viruses, color, and some colloidal natural organic matter. The whole process is aimed to find practical solution to deal with the extremely high turbidity where most of the standard process failed. The currently applied processes of treatment plant went through many modified stages starting from the equalization tank ending with UF passing through the type of coagulation/flocculation and the mixing conditions.

Keywords: Membrane performance; Membrane filtration; Coagulation; Industrial wastewater

1. Introduction

Industrial wastewater is one of the most important pollution sources of the environment. During the last century, a huge amount of industrial wastewater was discharged into rivers, lakes, open land, and coastal areas. These caused serious pollution problems in the water environment in addition to negative effects to the ecosystem and human life [1]. This study was carried out at the Ras Al-Khaimah ceramic factory, UAE. The studied factory is considered as one of the most important industrial plants in the city. The lack of the water resources in the region and the danger of groundwater pollution were the reasons behind the imposition of a strict legislation for the quantity and quality of discharged water by the UAE government.

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Besides, from the economical point of view, it is important to retain and reuse the clay carried by the waste streams.

The Ras Al-Khaimah ceramic factory is discharging wastewater with high turbidity and TDS (up to 22,000 NTU and 19,700 mg/l TSS). Fig. 1 shows the equalization tank which receives daily around 1,000 m^3 wastewater discharged from different technological processes.

Currently, many options have been used and investigated of using coagulation/flocculation plus membrane filtration to treat industrial wastewater with different characteristics according to the type of resources of pollution. Soffer et al. [2] have studied the ability of flocculation as a pretreatment of an industrial wastewater. The characteristics of the primary effluent are the following: turbidity: 52–60 NTU; DOC (dissolved organic carbon): 112–125 mg/l; Zeta potential: 27–31 mV; pH 7.8–7.9. As a first step, a flocculation/coagulation with selected ferric chloride dose was applied seeking for high removal efficiency of suspended solids before UF filtration using membranes with porosity higher than UF (50 kDa). It was proved that the coupling of flocculation with a UF membrane is a good compromise for producing effluent with characteristics suitable for industrial reuse.

The effect of combined coagulation/ultrafiltration on the turbidity of textile wastewater is shown also by Lee et al. [3]. A combination of coagulation (PAC coagulant) and membrane filtration was applied. During the treatment of wastewater with turbidity, ranging within 20.1–31.0 NTU, it was found that the MF membrane flux decreased due to the changes in the sizes of coagulated particles and their interaction with membrane pores. The data presented show that considerable turbidity removal efficiency (98.8%) was achieved. Similar example of multi-function process was studied by Amuda et al. (2006) in examining the effectiveness of coagulation and flocculation process using ferric chloride and polyelectrolyte (non-ionic polyacrylamide) for the treatment of beverage industrial wastewater. The addition of polyelectrolyte and $FeCl_3 \cdot 6H_2O$ to beverage wastewater with porosity higher than chemical oxygen demand (COD): 1,750 mg/l, TP: 89.5 mg p/l and total suspended solid (TSS) 1,620 mg/l) led to the reduction in COD, TP, and TSS by 91, 99, and 97%, respectively. Based on these results, it was proved that the coagulation/flocculation step is a useful pretreatment of the applied MF and UF [4].

Fig. 1. Equalization tank with different inflows of industrial wastewater.

The above studies showed that in case of treatment of industrial wastewater having low level of turbidity, the efficiency of the hybrid process of coagulation–membrane filtration is efficient, allowing to reach acceptable level of residual turbidity, COD, and TSS. However, the case of Ras Al-Khaimah ceramic factory is rather different because of high level of suspended solids. The traditional methods for dealing with such water are not effective because of the improper choice of mixing conditions and the subsequent problems of solid phase separation.

2. Material and methods

The wastewater of Ras Al-Khaimah ceramic factory was characterized by high TSS (mg/l), biochemical oxygen demand (BOD in mg/l), COD (mg/l), and total organic carbon (TOC in mg/l) (Table 1).

Such industrial wastewater needs application of effective processes of non-conventional coagulation and flocculation. In case of adding large amounts of traditional coagulants, alum or PAC, aiming to reduce repulsive forces between particles will lead to non-proper increase in chemical dosing used which causes extra cost and light sludge floating reducing the efficiency of process. An effective way to colloidal matter removal is to add cationic polymer such as polyamine as a booster of PAC. The booster (polyamine, ($H_2N{-}(CH_2)_4{-}NH_2$) is an organic compound having two or more primary amino groups with a molecular mass typically between 10,000 and 100,000 g/mole. One of the amino-(NH_2) groups possesses a strong cationic charge which allows the system to be of low sensitivity to pH in a large range of pH values. Particle charge analysis of the wastewater showed that in case of PAC (low molecular weight) addition, the amount of the positive charges could not compensate all negative charges carried by the water with high turbidity. The booster material increases the number of positive charges to clump and seize all negative charges. Our experience shows that the booster application leads to quick growing and easy physical separation of colloids from the water phase due to the strong positive charge of the booster [5].

Table 1
Industrial wastewater characteristics

Parameters	Units	Results
Total suspended solids (TSS)	mg/l	19,700
Total dissolved solids @ 180°C (TDS)	mg/	918
pH @ 25°C	–	7.8
Conductivity at 25°C	μS/cm	1,300
Turbidity	NTU	22,000
Total hardness as ($CaCO_3$)	mg/l	147
Total alkalinity to pH 4.4	mg/l	200
Total nitrogen	mg/l	8.3
Biochemical oxygen demand (BOD) (5 d @ 20°C)	mg/l	420
Chemical oxygen demand (COD)	mg/l	990
Total organic carbon (TOC)	mg/l	116
Boron (B)	mg/l	5.5
Silica as (SiO_2)	mg/l	24
Total Iron (Fe)	mg/l	26.2
Cadmium (Cd)	mg/l	LT 0.01
Strontium (Sr)	mg/l	0.56
Barium (Ba)	mg/l	0.70
Nickel (Ni)	mg/l	LT 0.22
Zinc (Zn)	mg/l	12.6
Lead (Pb)	mg/l	0.22

The treatment plant includes screen unit, equalization tank, chemical dosing unit (PAC, polyamines and polyacrylamide), static mixer, flocculation unit, settlement unit, filter press unit, multimedia sand filter, strainer, MUF unit, and R.O plant as a last step as shown in Fig. 2. In aiming to improve the mixing conditions, a static mixer was designed (Fig. 3).

The efficiency of suspended solid removal from industrial wastewater—which carries high concentration fouling and pollutants—depends on the type of coagulation agent. In case of adding traditional coagulant such as alum or PAC as traditional method to reduce repulsive force between particles leads to many side effects such as high amount of chemical dosing, extra cost, COD uprise, and light sludge will float, which made treatment process inefficient and low quality.

To increase the removal efficiency of fine particle colloids, a small amount of strong cationic polymer (polyamine) has been added as a booster with PAC. These materials led to zero of zeta potential and helped to allow quickly growing and separating collides from wastewater due to the strong positive charge of the booster. The advantages of this new technique are the economical benefits related to the reduction in coagulant consumption, sludge production, and improvement in water quality particularly BOD, COD, and color.

Also, it has been noticed that the added booster has no sensitivity to the fluctuation of the temperature and pH comparing to the traditional process, where usually coagulants are influenced in case of degree of the temperature drops to less than 5 and pH becomes low.

Several experiments have been made on mixing chemical materials by flash mixer and static mixer. As known, flash mixer is including two or three steps in the coagulation/flocculation process during the treatment of industrial wastewater.

During the process, the wastewater with polymers flows into the flash mixer chamber and then enters the flocculation basin. It was noticed that the longer mixing time led to an increase in floc breakage; at the same time, the collisions between the flocculants and colloids were not efficient to separate suspended solids from the wastewater to increase the quality of this stage.

Many methods have been examined to reach the stage where mixing process can be effective and smooth, and the option was to use static mixer. The idea behind a static mixer was to mix the chemicals (coagulants and flocculants) quickly and smoothly within the treated wastewater during short period of time not exceeding 1 s to avoid breaking of polymers during mixing process which happened during the usage of the flash mixer. From practical experiences, longer mixing time during this stage can cause an increase in floc breakage which usually leads to unstable settlement [6].

The clarifier (sedimentation unit) is shown in Fig. 4. It includes the following:

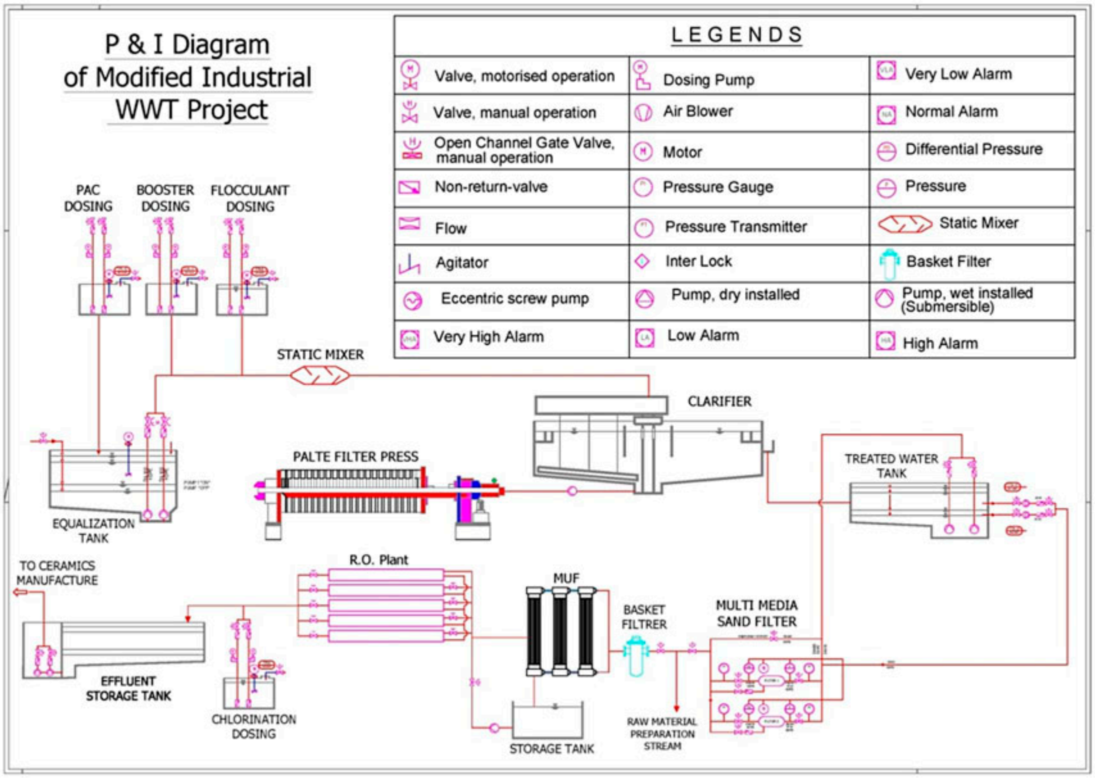

Fig. 2. Technological scheme of Ras Al-Khaimah Ceramic Industry WWTP.

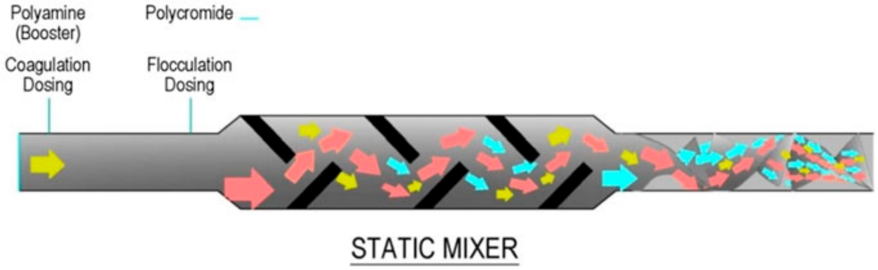

Fig. 3. Schematic of the static mixer applied.

(1) Flocculation unit (inlet zone) is divided into two parts: The first one is cylindrical shaped with dia. 0.6, 1 m height, to reduce the turbulence of water movement.
(2) Through the side holes, the raw water will enter into the incubator cylinder which has diameter 1, 1 m height that directs the water to the down and prevents diffusion of the raw water to the outside of the incubator.
(3) Inverted dish: It was designed to keep the static zone allowing to particles to be easily settled and it would be easy scraped to the sludge zone.
(4) Sludge zone: The sludge zone was located at the bottom of the tank, as a collection chamber, and it would be sent to the drying unit by the sludge pump.
(5) Outlet zone: The basin outlet zone should provide a smooth transition from the sedimentation zone to the outlet from the tank and shall control the overflow rate to prevent the solids from rising to the weirs and leaving the tank before they settle out.

Treated water tank receives the treated water for saving it and pumping it to the sand filtration unit and microfiltration. Its volume is 60 m^3/h. It has installed pump with a capacity of 40 m^3/h, and this tank used to collect all the treated water through the

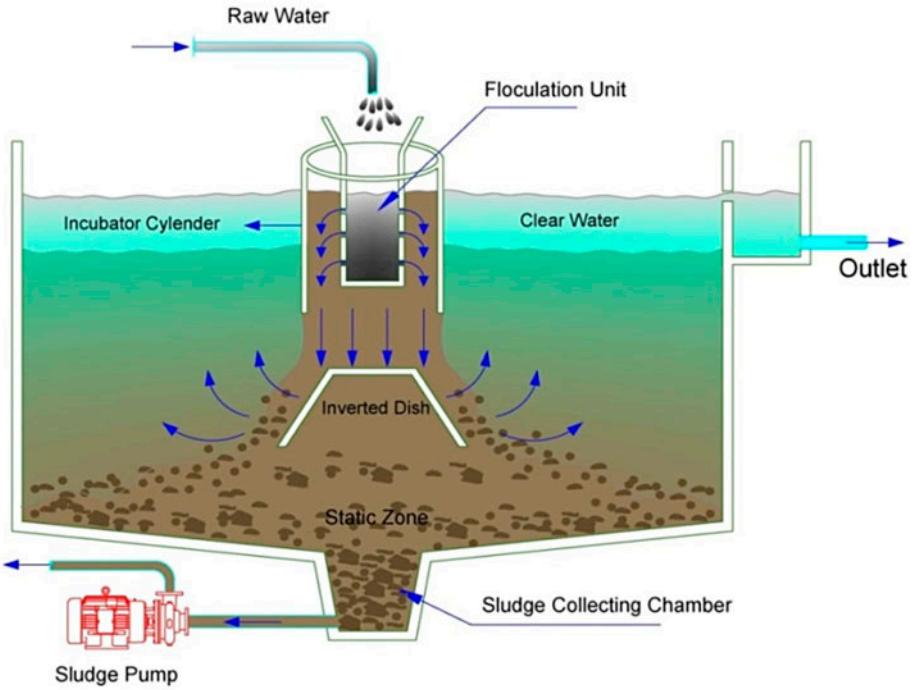

Fig. 4. The clarifier in use.

previous stage. The plate filter press comprises a set of chamber plates covered by filter clothes and squeezed by a hydraulic cylinder between a stationary frame and a mobile supporting beam. The plates determine a watertight volume in which it pumped the pressurized sludge. The pressure and media filter consists of multiple layers of sands and gravel with different size, the silica sand is the first layer from the vessel top, the grain size ranges from 04 to 08 mm, the second layer is a medium gravel with a size range (1–2) mm, and the third layer consisted of gravel size (6–12) mm. The water moves through the sand from up to down and passes through layers of sands to remove large particles, but almost small part will pass through the surface and the sand filter is not enough; hence, the other stage will use such a self-clean filter (200 μm) and MUF of size 0.1 μm to remove all the fine particles.

3. Chemicals in use

3.1. Poly aluminum chloride (PAC)

PAC was directly dosed to the balancing tank. The aim is at the initial stage of the coagulation PAC to attract a large amount of dissolved particles with negative charge. The added PAC is carrying positive charge and has the ability to attract the existed negative charge in the wastewater balancing tank. The added PAC is a solid material and has been dissolved in a water tank with a capacity of 1,000 L. The tank is provided with a flash mixer in aiming to convert the solid PAC into liquid phase for easy pumping into balancing tank.

3.2. Organic booster

The purpose of adding coagulant booster is to increase the efficiency of attracting negative charges that existed in the industrial water with positive charges that PAC and booster are carrying. In fact, PAC efficiency is weak when it is used alone in high turbidity, for this reason, to increase the efficiency of PAC, small dosing amount of organic poly amine is added. This added material carries a strong cationic charge which reaches 100,000 g/mole. This process includes mixing coagulant PAC and industrial water before reaching to the static mixer to mix for 1 s to avoid breaking of polymer. From practical experience, polyamines with two or more primary amino groups NH_2 have been used which created strong cationic charge and molecular mass reach around 10,000–100,000 g/mole. These compound material includes several synthetic substances which are important to

Table 2
The efficiency of the complex processes of coagulation and sedimentation

Parameter	Inlet	Outlet	Effect (%)
Turbidity (NTU)	22,000	37	99.80
TSS (mg/l)	19,700	23	99.88
COD (mg/l)	990	220	77.7
BOD (mg/l)	440	110	75

the chemical industry, such as ethylene diamine $H_2N–CH_2–CH_2–NH_2$ [7]. Usually, the PAC coagulant carries positive polymer charges with low molecular weight and it is not able to clump all colloidal particles, fine suspended particles, and colors. The booster material was added to increase the amount and the strength of the positive charges to clump and seize all negative charges. The new particles have extra size and weight which can settle quickly and easily. Fig. 6 shows the influence of adding booster on the process.

3.3. Polymeric flocculants

The polyacramide is an organic compound with a negative charge and high molecular mass that reaches easily to 10 million g/mole [8]. The added flocculent performs as mechanical bridge resulting to increase of settlement velocity.

4. Results and discussion

The results obtained in applying the complex processes of coagulation and sedimentation of suspended solids using coagulants plus booster are shown in Table 2 and Fig. 5 revealing that the turbidity, TSS, COD, and BOD are significantly reduced; it can be seen that the percentage of the removal of turbidity reached about 99.8% (22,000 to 37) of NTU and 99.88% of TSS (19,700 to 23) mg/l, while COD and BOD were reduced by 77.7 and 75%, respectively. The reason behind these results was the high efficiency of booster material (polyamine) to clump most of the negative charges which were available on the surface of the water.

However, our further studies revealed that in case of applying such treatment, it needs high settlement time in order to reduce additionally TSS, because small particles such as fine clays and silts have slow settling rate compared to coarse particles like sand. Applying further multimedia/strainer filtration, the turbidity was reduced approximately to 9 NTU and TSS approximately to 12 mg/l. The main target was to treat the industrial water with suitable characteristics to be reused in ceramics manufacturing. Specifically, the turbidity shall not exceed1 NTU, while TSS to be below 5 mg/l.

Following the multimedia/strainer filtration, the water undergoes treatment in a micro-ultrafiltration (MUF) unit (Fig. 2). The treated water from MUF is divided into two streams. The first one is directed to the ceramics factory to be used for the preparation of raw materials, while the second one goes to reverse osmosis aiming to reduce additionally TDS from 1,000 to 250 mg/l. Such water quality is required for other processes of ceramic manufacturing. Through ultra-filtration, it was expected to reduce the fouling within acceptable level. However, in applying UF membrane processes when a conventional UF treatment was used, several problems arised [9]. The polyethersulfone

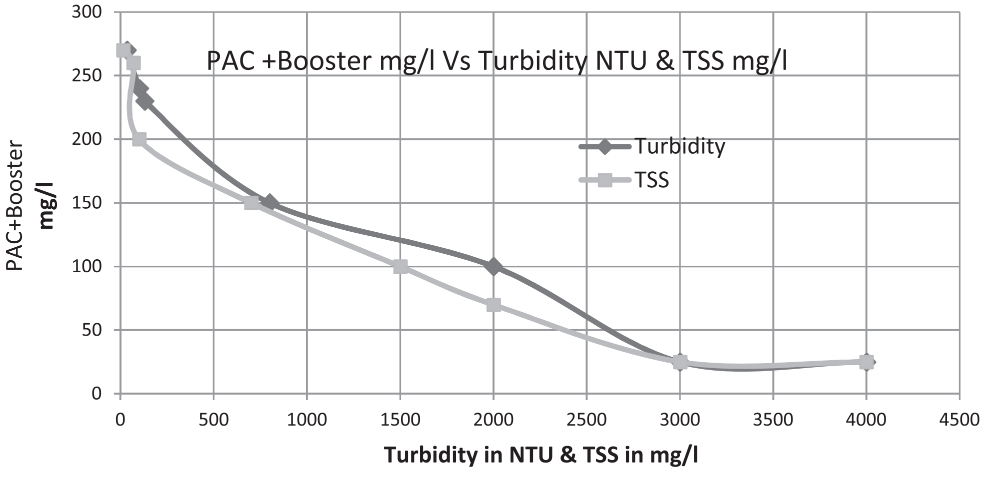

Fig. 5. The effect of adding booster on turbidity and TSS (initial maximal turbidity 22,000/TSS 19,780 mg/l).

Table 3
Main parameters of the UF system

Parameter	Unit	Value
Scheme		Ultrafiltration
Total flow rate of UF at outlet	m^3/h	15
Recovery	%	80
Total flow rate of UF at inlet	m^3/h	18.75
Total number of membranes		6
Module surface area	m^2	60
Total surface area	m^2	360
Quantity of U.F. skids		1 duty
Number of membranes for each skid		6
Skid dimensions	mm	2,040 L × 616 W × 2, 2,050 H
Skid weight dry, approx.	kg	500
Skid weight operation, approx.	kg	700
Flux	$l/h/m^2$	52
Filtration time	min	35
Backwash time	s	60

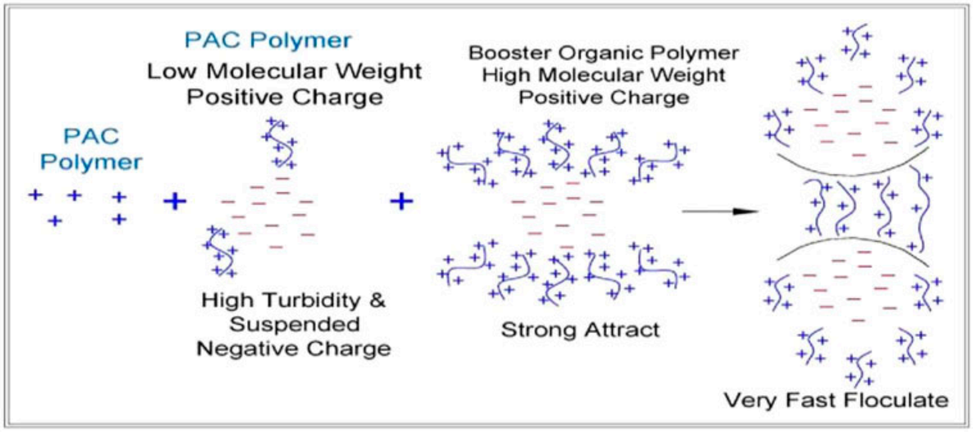

Fig. 6. Image of attraction of charges after adding the booster (polyamine).

Table 4
Inlet and outlet parameters of the UF unit

Day from the beginning of the trial	Outlet flow (m^3/h)	Turbidity (NTU)	
		Inlet	Outlet
1	15	10	1
2	15	8	0.8
15	14	3	0.5
22	14	7	0.6
31	12	8	0.8
35	9	4	0.5
43	10	8	0.5
44	9	6	0.8
45	9	8	0.9
46	6	5	0.8
55	4	7	0.9
65	4	5	1

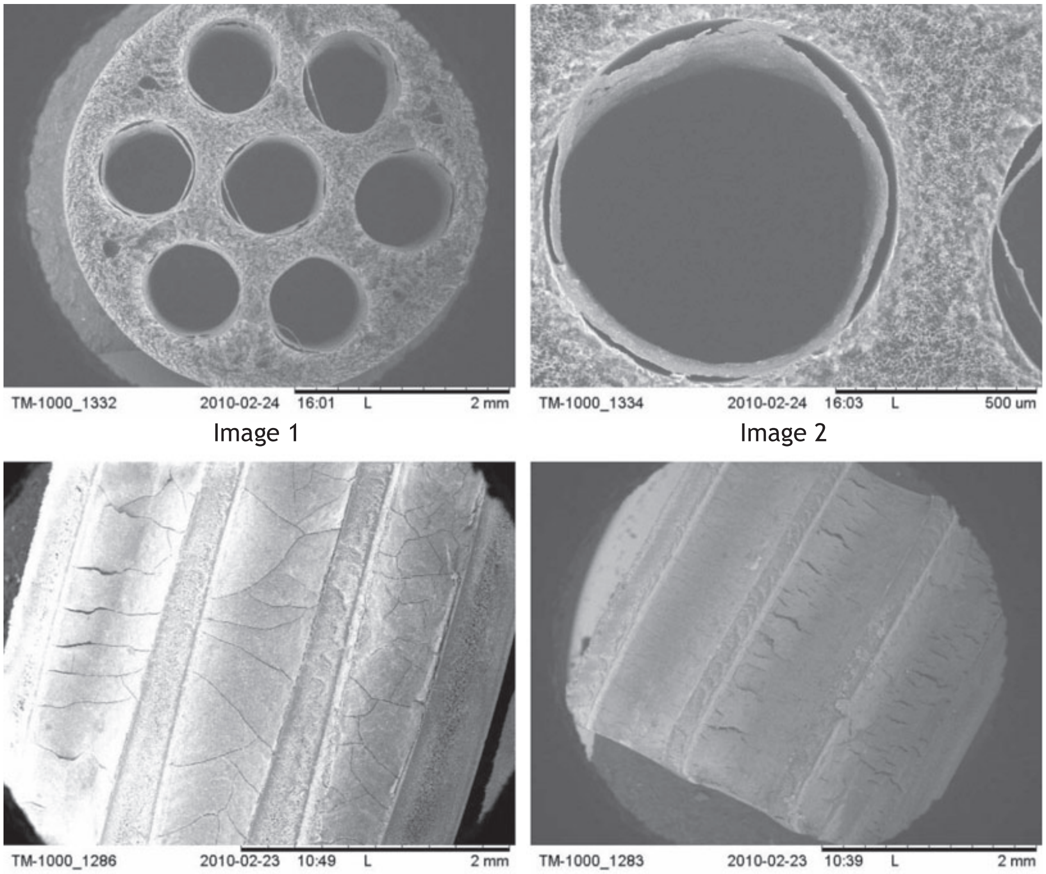

Image 1 Image 2

Image 3 Image 4

Fig. 7. Images of membrane fouling (1–4).

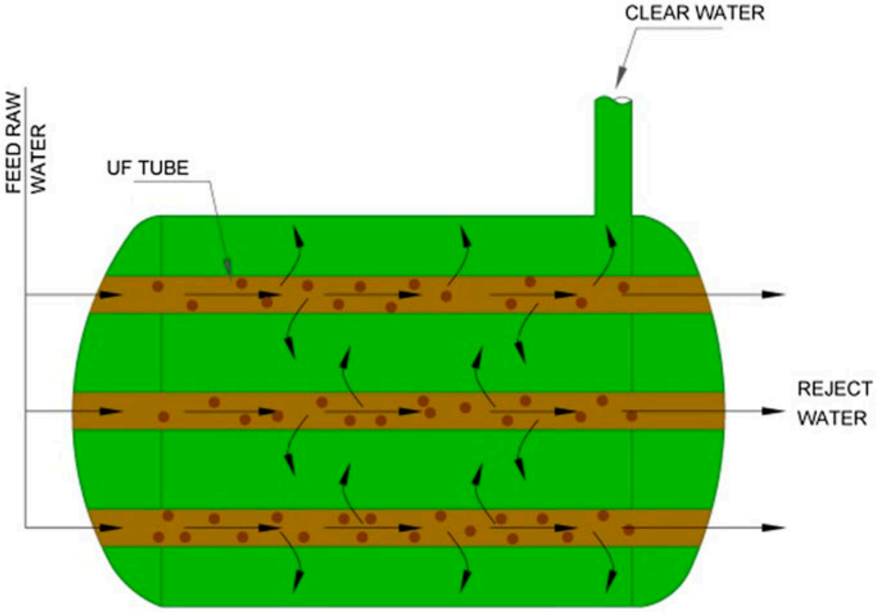

Fig. 8. Direction of water stream through the UF pores.

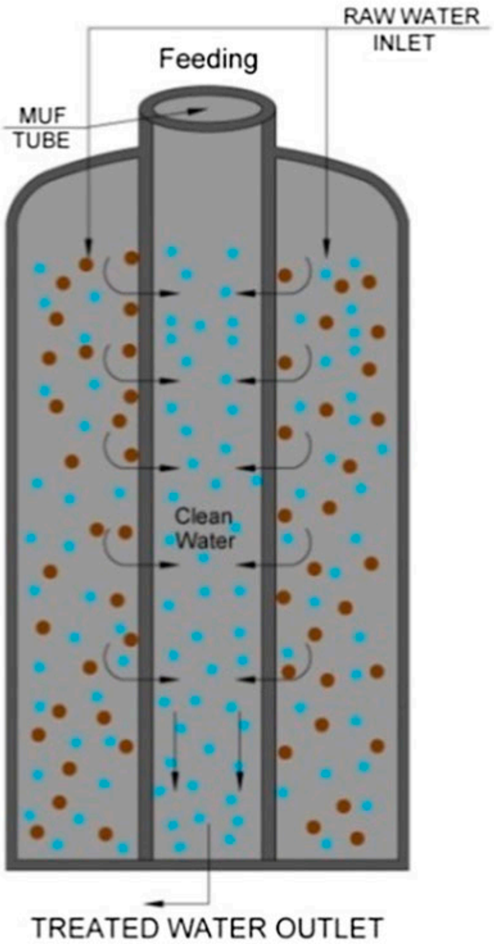

Fig. 9. Direction of feed water through the membrane.

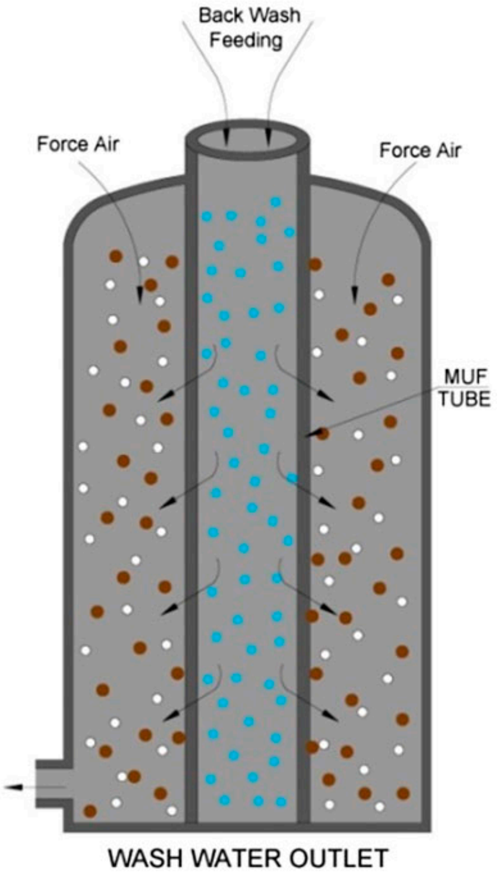

Fig. 10. Direction of backwash and air through the membrane.

(PES) membrane was incorporated in an UF unit with the parameters as listed in Table 3. During operation process, it was found that the membrane surface was completely covered with a layer of deposition. Images of the fouling are shown in Fig. 6. The UF unit feed and outlet water are given in Table 4.

The reason behind the failure of the UF unit was the manufacturing material of polyethersulfone (PES), which carries a slightly negative charge [10–12]. The membrane surface attracts the positively charged species, such as the remaining PAC. In case of using conventional UF process, the filtered water passes from the inner UF pore to the outside through fine hole size of 0.01 μm as shown in Fig. 7, the fouling carrying a positive charge was deposited on the inner surface of the membrane causing clogging of membrane holes (Fig. 8).

In traditional treatment plant for industrial wastewater, UF membrane useful life does not exceed two months because of daily chemical cleaning and continuous backwash for the system. In order to avoid the fouling, a new membrane technique was used based on the application of Pall Aria membranes, behaving as a hybrid MF/UF membrane. The Pall Aria membrane under the name micro-ultrafiltration (MUF) is characterized with a pore size of 0.1 μm [9].

In aiming to increase the membrane surface area the feed water and backwash directions were changed. The feed water was directed to pass from outside to inside the membrane wall, as shown in Fig. 9, while the backwash was from inside to outside. In aiming to remove all the fouling deposited on the membrane surface and the micro-holes, the driving force of air (6 bars) was applied to detach the fine particulate lifted by the backwash to the outside MUF membrane. Fig. 10 shows the modification of unit, while Fig. 11 shows the MUF unit details. The system includes feed tank, feed pump, strainer, membrane skid, backwash tank, control system, and feeding line system. Fig. 12 represents the steps of operation work. When the feed tank reaches a prerequested operating level, the system starts the fill process. This process pushes all the

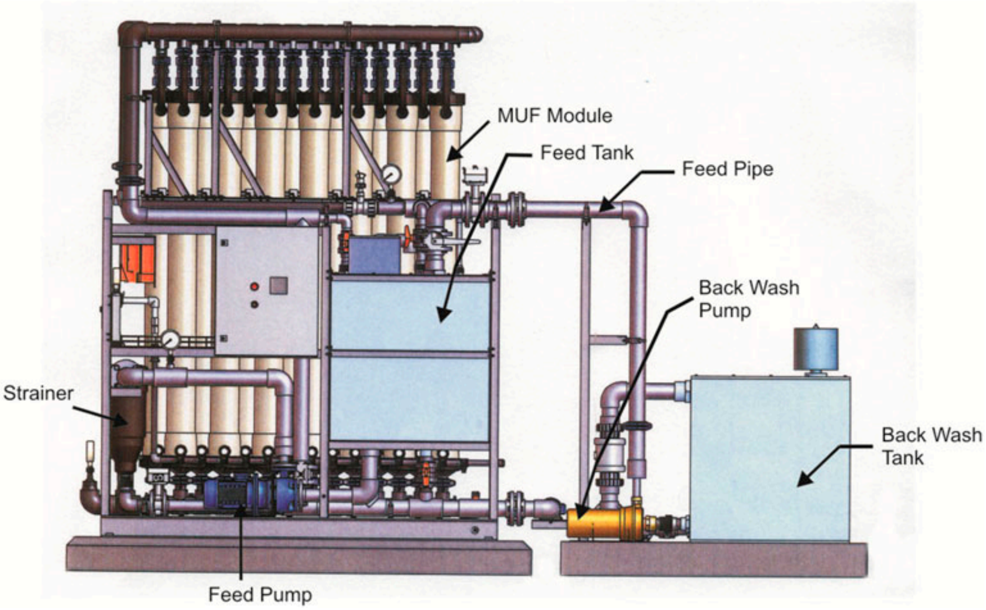

Fig. 11. Detailed scheme of MUF unit.

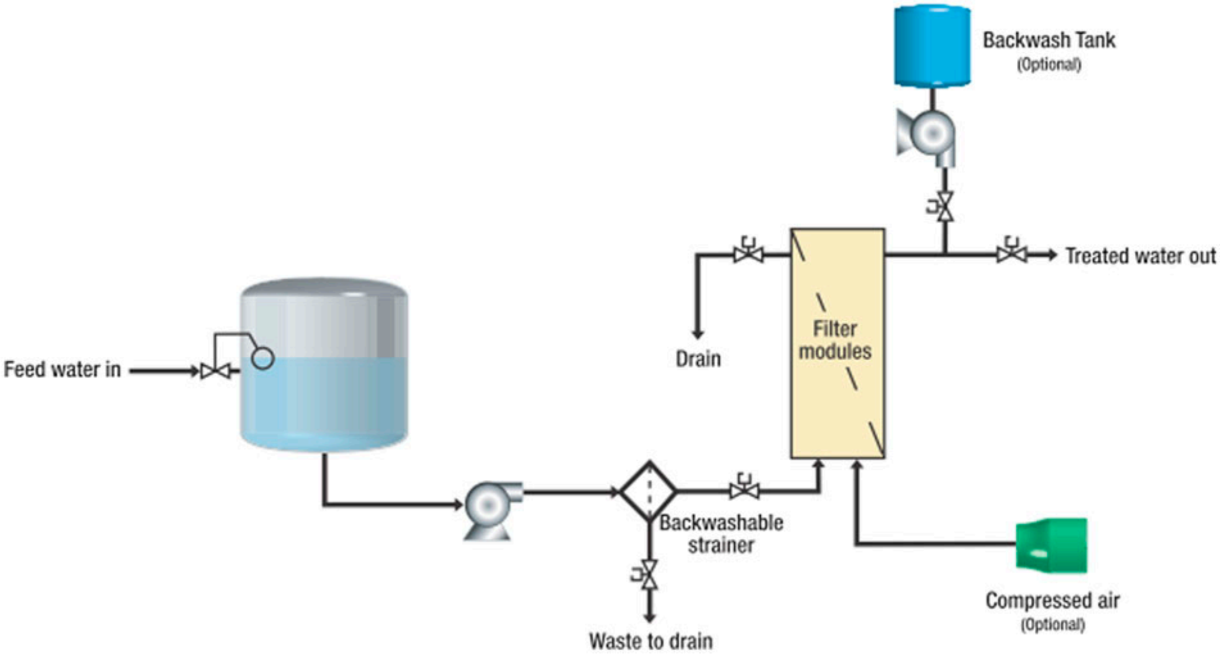

Fig. 12. Generic PID.

air out of the feed side of the modules. After fill stage has been completed, the system moves to forward flow and begins to produce filtrate. The water flows through the bottom of each fiber wall and enters inside the fibers with pressure of 1.7 bar. Treated water exits the module from the upper head, and it was collected in a tank for treated water as shown in Fig. 13.

Further, the water from the feed tank passes through a strainer which removes any large solids

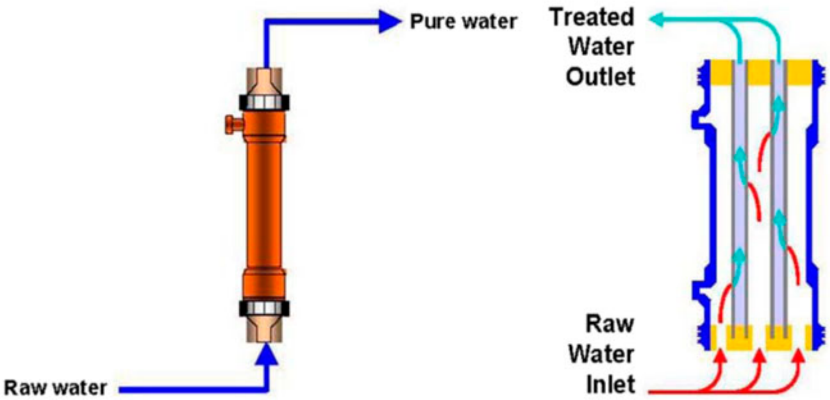

Fig. 13. Direction of water in MUF module.

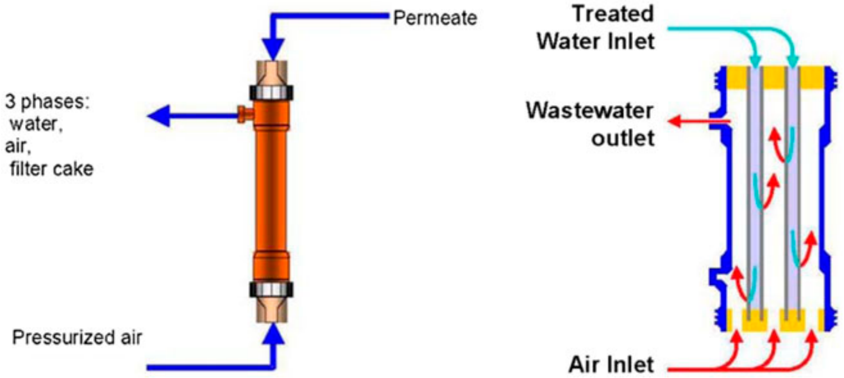

Fig. 14. Directions of inlet, outlet, and air in MUF module.

Table 5
MUF design specifications

Description	System
Skid flow output	23 m^3/h
Installed modules/skid	12
Recovery	80%
Maximum operating pressure	3 bar
Normal operation pressure	1.7 bar
Required backwash in operation pressure	1.9 bar
Optimization pressure	1.8 bar
Required CIP cleaning in operation pressure	2.2–2.5 bar
Filtration direction	Cross flow, outside to inside
Operating temperature	(5–40˚C)
Operating humidity (non-condensing)	10–90% relative

before reaching the filter membranes. Solids collected on the feed strainer are discharged into a drain during the strainer backwash cycles. The filtrate (treated water) discharges to downstream equipment. Because of fouling through the operation process, the feeding water pressure was allowed to reach 1.9 bar. The flux maintenance cycles always begin with an air scrub, which is followed by a feed flush. Flux maintenance processes were started after the filtration skid has processed a certain amount of filtrate volume or the

Table 6
Change of inlet/outlet TSS, BOD and turbidity in a 64-d MUF run

Number of the sample	Elapsed time (d)	Turbidity (NTU)			COD (mg/l)			BOD (mg/l)		
		Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction	Inlet	Outlet	% Reduction
1	1	5.5	0.27	95	70	59	15.71	14	11	21.43
2	23	8.73	0.87	90.03	40	15	62.25	14	9	35.7
3	24	5.00	0.50	90.00	125	88	29.60	31	29	6.45
4	29	7.38	0.62	91.61	79	42	46.8	11	6	45.45
5	35	9.60	0.78	91.88	73	54	26.03	18	14	22.22
6	38	10.80	0.62	94.26	72	66	8.33	18	15	16.67
7	42	5.04	0.21	95.83	63	51	19.05	18	15	16.67
8	45	5.10	0.27	94.71	75	66	12.00	20	17	15.00
9	49	4.90	0.33	93.26	68	62	8.82	19	17	10.53
10	52	9.63	0.29	96.98	93	87	6.45	27	25	7.41
11	56	10.10	0.51	94.95	93	88	5.38	28	25	10.67
12	59	13.10	0.49	96.25	87	75	13.79	26	20	23.08
13	64	9.01	0.40	95.55	127	122	3.94	37	34	8.11
Average values		*8.20*	*0.47*	*94.38*	*80*	*67*	*19.03*	*21*	*18*	*18.4*

Note: The italic values emphasis the average values in the table.

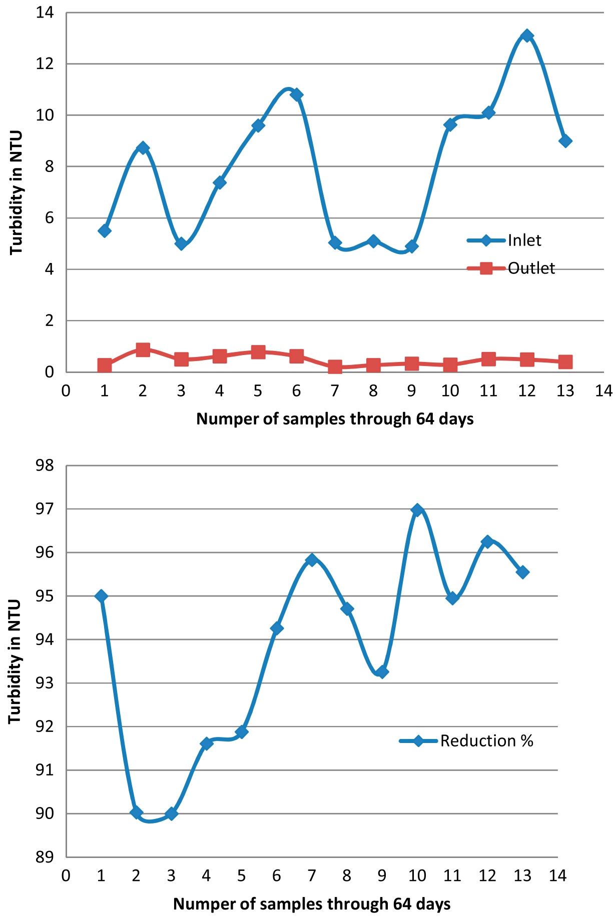

Fig. 15. Inlet/outlet turbidity and turbidity reduction in applying MUF.

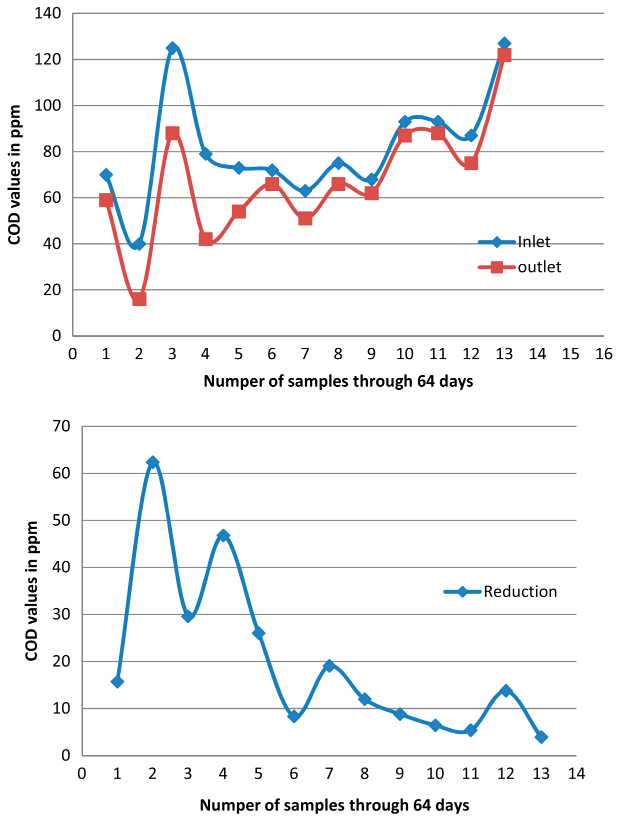

Fig. 16. Inlet/outlet COD and COD reduction in applying MUF.

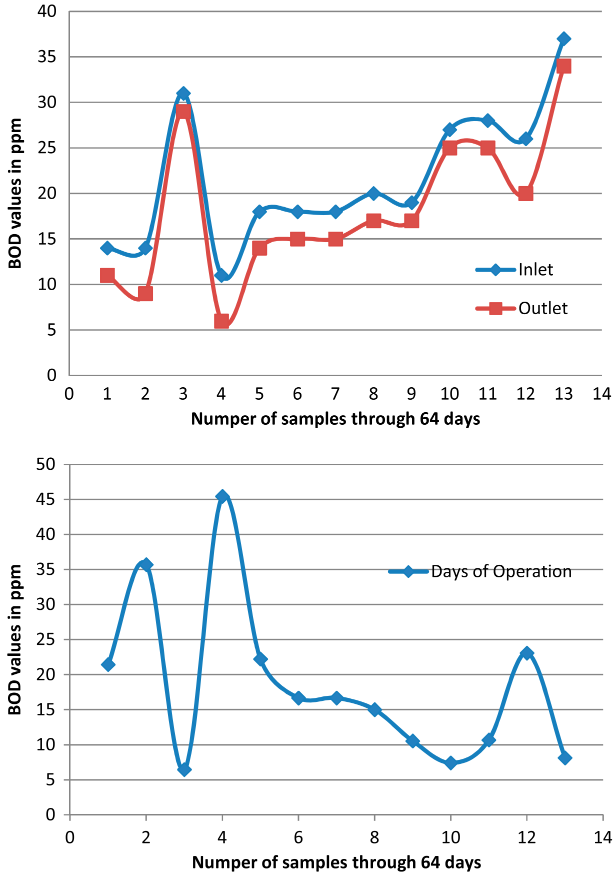

Fig. 17. Inlet/outlet BOD and BOD reduction in applying MUF.

filtration skid could be filtered for a certain amount of time. Typically, the flux maintenance cycles interrupt water production for 2 min for every 20–30 min. The actual process settings vary depending on water source and volume of water being produced. Air is introduced to the feed side of the membranes and pump moves water at adjusting rate. The pump pushes filtrate back through the membranes and, while air continues to agitate the fiber bundle, carries any solids to the drain. This process lasts for about 30–60 s, as shown in Fig. 14.

After completion of the air scrub process, a feed flush is performed. The feed pump sends feed water, through the feed side of the modules to flush to the drain any remaining solids and air bubbles. This process lasts for about 30 s. The optimized pressure is 1.8 bar. The feed strainer is a self-cleaning type that requires a backwash at regular intervals to avoid clogging. The strainer backwash cycle can be triggered on time with different pressure. The operator can also manually initiate a backwash whenever the system is running in forward flow. During a feed strainer backwash, the strainer will flush any debris collected on the strainer to drain. This process lasts approximately for 35 s. The chemical cleaning is required when pressure reaches to 2.25 bar due to heavy metals depositing on the outside body. After well cleaning, the operating pressure for the system drops to 1.7 bars, and after completing this process, a cleaning solution must be used to return the membranes to their original situation. Usually, chemicals such as sodium hypochlorite, caustic solutions, and acid solutions have been used. The MUF design specifications are shown in Table 5.

The main difference between conventional approach and the new approach was the feeding of the water crossing the conventional (UF) from inside to the outside of the membrane, while the filtration direction for the new one flows from outside to inside. This modification through the unit led to many advantages achieved by increasing the surface area of membranes, while the change in the flow direction facilitates the fouling removal through the backwash process and sweeps the fouling to the outside through air force of the system. The result showed stability in the flow and reduction in chemical usage.

The obtained results are presented in Table 6 and Figs. 15–17. Table 3 shows the change of inlet/outlet TSS, BOD, and turbidity during 64 d MUF run. The application of MUF led to considerable reduction, over 94%, during the last stages of the filtration cycle. The residual turbidity is below 0.47 NTU (in average) which allows the effluent to be reused in the factory. At the same time, considerable reduction in COD and BOD observed was 19 and 18%, respectively.

The results, as shown in Tables 4 and 6, led to a conclusion that efficiency of turbidity removal did not subject to big difference in both approaches (MF and MUF). However, in the case of UF application a considerable inlet flow (from 15 to 4 m^3/h within 65 days was observed. This is due to the fouling of the inner surface of the membrane.

Figs. 15–17 showed the trends of turbidity, COD, and BOD following the MUF filtration. The turbidity curves (Fig. 15) reveal that the inlet NTU deviations practically do not influence the membrane performance while a steady trend of improved outlet water quality was recorded. On the other hand, the COD and BOD curves (Figs. 16 and 17) showed the quality of the treatment follows the inlet parameters of wastewater.

As an aggregate result of the treatment, including both the coagulation/flocculation with booster addition and membrane separation (MUF), the turbidity was reduced from 22,000 to 0.4 NTU to achieve turbidity removal rate about 99.998%.

5. Conclusions

The results obtained showed that in case of applying PAC (low molecular weight), the amount of the positive charges could not compensate all negative charges carried by the water that has high turbidity. Using the booster (polyamine, $H_2N–(CH_2)_4–NH_2$) as an alternative flocculant material increases the number of positive charges in the system and allows all negative charges of colloidal matter to be neutralized. The data obtained show that the application of the coagulant booster considerably increases turbidity removal up to 99.9%.

It was shown that converting flash mixer to static mixer can be very effective to reduce chemical consumption, avoid polymer breakdown, and obtain smooth mixing process in shorter time.

The use of conventional UF is facing technical difficulties during operation related to the severe deposition accumulated on the inner surface walls of membranes. The deposition causes clogging of micropores irrespective of the frequently applied backwash and chemical regeneration. Based on this situation, a new technique of filtration was developed allowing to treat heavily TSS polluted water and to remove fine particles. Modifying the UF by feeding the water from outside to inside increases the membrane surface area which allows to reduce the load on micropores and diminishing the fouling effects.

Based on the result obtained, it was found that the MUF technique allows to treat efficiently wastewater with high range of turbidity and different particle charge.

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