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The Fouling on MBR Membranes, Prevention, and Control-A Case Study

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Abstract - Membrane Bioreactor (MBR) technology is the latest technology to treat municipal sewage. The MBR technology by-passes conventional coagulation and clarification process operation units. It reduces the space and operation cost. The treated effluent is crystal clear and can be used for many purposes. The bottleneck of MBR technology is fouling on membranes. The fouling on membranes increases the treatment cost and decreases treatment efficiency. The present study focuses on to prevent fouling on membranes. The MBR backwash water contains 80% solids and 20% of wastewater. The solids and water were separated with a centrifugal machine from the MBR reject wastewater. As a result, the MLSS concentration in the aeration tank reduced. To control fouling, the membranes were placed in three different tanks. In-tank-1 and tank-2 the chemicals $AlCl_3$, $FeCl_3$ and H_2O_2 were added with 4 mg/l and 6 mg/l respectively. The tank-3 was filled with wastewater without any chemicals and the three tanks were kept under observation for 15 days. It was observed in the tank-2 that there was no fouling on the membrane. The fouling on membranes was reduced considerably by adding 6 mg/l aluminum chloride, 6 mg/l ferric chloride and 6 mg/l hydrogen peroxide in the MBR compartment. The best option to prevent fouling was to reduce mixed liquor suspended solids (MLSS) concentration in the aeration tank.

Keywords: fouling, membrane, ferric chloride, aluminum chloride, hydrogen peroxide.

I. INTRODUCTION

There are a good number of technologies such as aerobic treatment, anaerobic treatment, open pond system, conventional activated sludge (CAS), membrane bioreactor (MBR) and sequence batch reactor (SBR) available to treat municipal sewage. The early studies on MBR technology were concentrated in the UK, France, Japan, and South Korea, whereas extensive research in China and Germany began after 2000.[12]. The treatment efficiency of conventional activated sludge (CAS) is around 90%. The MBR technology is a combination of activated sludge followed by membrane filtration. The treatment efficiency of MBR technology is 98%. Moreover, the quality of treated effluent is on par with potable water. The outlet effluent can be used for domestic and agriculture purposes. The bottle-neck of MBR technology is fouling on membranes. The fouling is due to the accumulation of organic matter and suspended solids in the MBR compartment. These solids adhere to the membranes and obstruct the flow of effluent through the membranes. As a result, the life of membranes is decreasing; the efficiency of treatment decreasing and the cost of treatment is increasing. Treatment consists of three major stages which are primary, secondary and tertiary stages along with a process that can be provided for further sludge removal. In the primary or physical treatment, the large solids such as sand and grit are removed from the raw wastewater. In the secondary or biological treatment the quantity of solids will become lesser than the previous stage either floating or dissolved in the water which always is acting as a food provider for the organisms such as bacteria, fungi and algae hence it is called as a biological stage where air must be supplied to maintain the growth of organisms in order to eliminate the waste materials. Finally, in tertiary treatment the effluent is disinfected to kill the remaining bacteria and taken out as a treated effluent that can be reused for irrigation purposes.

MBR Technology is a combination of a membrane process like microfiltration or ultrafiltration with a suspended growth bioreactor. MBR technology is commonly used for municipal sewage treatment [8]. The Haya LLC, Oman is using MBR technology to treat municipal sewage. The MBR backwash wastewater samples were collected from Haya LLC, Al-Ansab STP plant for the present study. The sample collection area was shown in fig 1. One of the fastest-growing wastewater treatment processes are MBR technology. [9].

Membrane fouling is one of the most important considerations in the design and operation of membrane systems because during treatment processes the fouling is accumulating on the membranes which are used at the plant and this cumulated fouling leads to increase the hydraulic resistance. Consequently, it will affect the pretreatment and cleaning requirements as well as the cost and performance of the treatment.[8].

The membrane fouling is considered as the major limitation of membrane process operation.[12]. It was found in their studies that Soluble Microbial Products (SMP) and Extracellular Polymeric Substances (EPS) are the main fouling factors that cause the MBR fouling [14]. As solutions, they added inorganic coagulants in several attempts to modify the properties of the activated sludge and to control the membrane fouling. For illustration, they used Aluminum- and iron-based coagulants to allow the filterability of the mixed liquor in the MBR because those ions are ideal for neutralizing sludge.

Membrane fouling can be defined as small particles that are sticking on the membrane surface which can be produced from the interaction between the membrane sheet and the components of the activated sludge liquor [4]. The membrane fouling can be produced from the interaction between the membrane sheet and the components of the activated sludge [3]. The membrane fouling depends on temperature, organic loading rate (OLR), the concentration of MLSS and MLVSS, extracellular polymeric substances (EPS) and soluble microbial products (SMP) [3]. There are different technologies available to clean the membrane fouling. One of the methods was back pulsing. It has been applied for membrane filtration (MF) and ultra-filtration (UF). The back pulsing process is similar to backwash. The required quantity of suction can be applied to clean the membrane fouling [13].Nitric oxide has been used to reduce the fouling on membranes. It yielded good results. However, the toxicity is to be identified [5].
Recent research studies revealed that the ceramic membranes have better resistance to fouling when compared with other types of membranes. It was observed that filtration resistance inversely proportional to the coagulation dosages [7].

1.1 Project Description

The present study focuses on how to reduce the fouling on membrane sheets by fixing doses of chemicals for the collected wastewater samples in three plastic tanks where the membranes were placed in these tanks in order to increase the life of membranes. In this study, $AlCl_3$, $FeCl_3$ and H_2O_2 were added to each tank with different concentrations and kept under observation for 15 days.

1.2 Project Significance and Objectives

Wastewater treatment is necessary to protect the environment either in local wide or in global wide. It minimizes the bad effects on the ecosystems and groundwater if it is operated properly. MBR technology has many advantages such as saving area for treatment units because it requires less area than the conventional technologies. For example, using this technology helped Haya Company especially at Al Ansab STP to get more free spaces than before because it is surrounded by hills.

1.2.1 Aim and Objectives

The aim of this project was to study and analyze the membrane fouling focusing on how it can be reduced in order to minimize the number of changing membrane sheets.
The main objectives of this study were:

- To reduce fouling on membranes.
- To increase membrane life.

Samples Collection Area:

The MBR backwash wastewater samples were collected from Haya LLC, Al Ansab STP. Muscat is located at 23.5452° N Latitude and 58.3432° E, Longitude. The STP is designed to treat 57,300 m^3/day of swage with MBR technology [1].
The sampling location was shown with Google map in Fig 1.

Fig 1: Samples collection site-Haya LLC, Ansab STP.

II. MATERIALS AND METHODOLOGY

2.1: The Fouling Reduction Process:

The methodology was divided into two stages. In the first stage, the MLSS concentration was reduced in the aeration tank. The MBR backwash wastewater solids and water were separated with a centrifugal machine. The separated solids were sent for drying and the water was recycled back into the aeration tank. The process was shown in Fig 2 and Fig 3.(Arwa 2018) In the second stage ferric chloride, aluminum chloride and hydrogen peroxide chemicals were added and observed fouling reduction on membranes.

2.2 MLSS Concentration Reduction Process in the Aeration Tank.

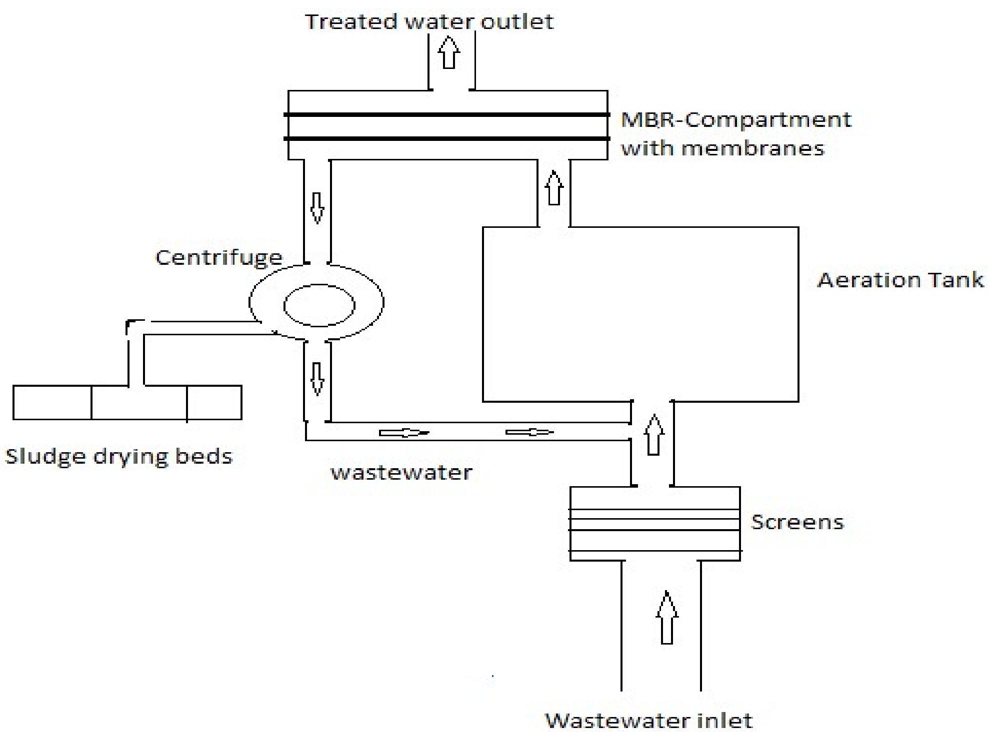

Fig 2: MBR-Backwash water MLSS removal process

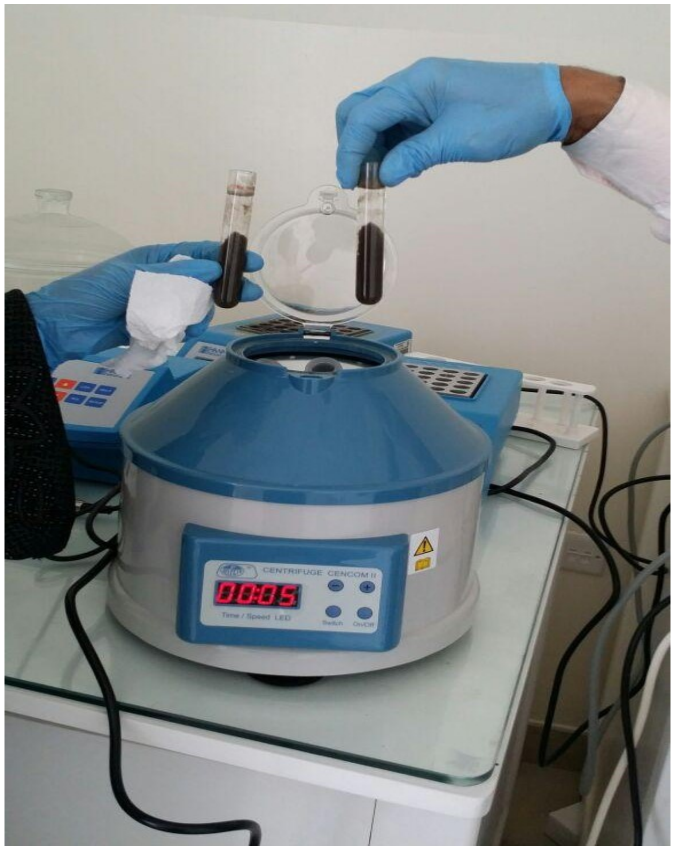

Fig 3: Centrifugal method to separate solids and water.

2.3 MBR Fouling Reduction Process.

The second stage of fouling reduction process was shown in fig 4.Three plastic tanks of 250 liters capacity were fabricated. In each tank, one membrane was placed. The wastewater samples were collected from Haya LLC Al Ansab STP in a tanker and transferred into the tanks. The process was shown in fig. 5.

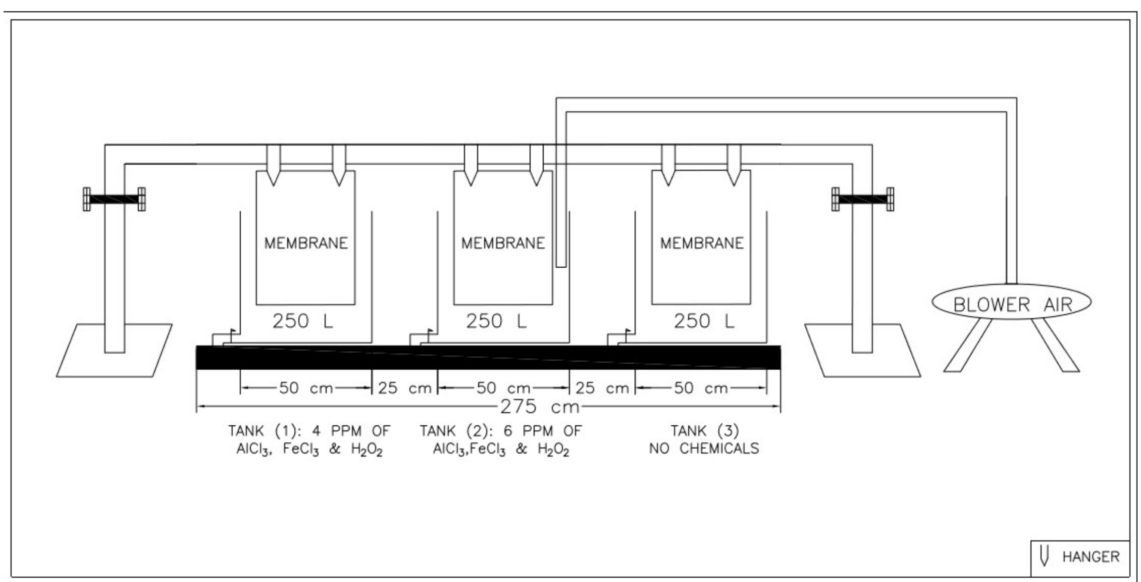

Fig. 4: Membrane fouling study

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Fig 5: Wastewater transfer from tanker in to the tanks.

2.4 The dosages of chemicals in the three tanks:

In tank-1: (4 mg/L) of each Aluminum Chloride, Ferric Chloride, and Hydrogen Peroxide were added.
In tank-2: (6 mg/L) of each Aluminum Chloride, Ferric Chloride, and Hydrogen Peroxide were added. In addition, the air was passed continuously into tank-2.
In tank-3: The membrane was placed without any chemicals.
After the dosages, the tanks were kept under observation for 15 days.
2.5: Dissolved Oxygen Concentration in the Membrane tanks.

After 15 days the dissolved oxygen values were analyzed in the membrane tanks with calibrated DO meter.

III. RESULTS AND DISCUSSIONS

3.1: Water recovery by coagulation process:

It was observed that the MBR backwash wastewater contains nearly 80% solids and 20% of water. An attempt was made to separate the sludge and to recover water from the backwash water with the coagulation process by adding aluminum chloride and ferric chloride coagulants. The sludge was settled with a dosage of 600 mg/l of aluminum chloride and 200 mg/l ferric chloride. The settled sludge and clear water layer were shown in Fig 6.(Arwa 2018)

Fig 6: Settled sludge in the MBR backwash wastewater.

The sludge separation by coagulation process was not economically viable.

3.2: Sludge separation by centrifuge method:

The centrifuge was used to separate solids and to recover water. The centrifuge was operated at 1000 rpm for 10 minutes. The sludge settled down and clear liquid was decanted. The centrifuge process does not allow the accumulation of MLSS concentration in the aeration tank. The original concentration of sewage MLSS remains.

3.3: Fouling on Membranes Visual Observation:

It was observed that the membrane in tank-1 with 4 mg/L of $AlCl_3$, $FeCl_3$ and H_2O_2 covered with fouling. It was observed that the membrane in tank-2 with 6 mg/L of $AlCl_3$, $FeCl_{3,}$ and H_2O_2 free from fouling. It was observed that the membrane in tank-3 without chemicals and hydrogen peroxide thickly covered with fouling. The visual observations of fouling on membranes in tank-1, tank-2 and tank-3 were shown in Fig 7.(Arwa 2018).

		
Tank (1): 4 mg/L of $AlCl_3$, $FeCl_3$ and H_2O_2	Tank (2) : 6 mg/L of $AlCl_3$, $FeCl_3$ and H_2O_2	Tank (3) : Blank -No chemicals

Fig 7: Visual observation of fouling on the membranes.

3.4 Dissolved Oxygen Values;

Dissolved oxygen was analyzed in all the three tanks. The DO in Tank-1 was 1.4 mg/l in the Tank-2, DO value was 2.3 mg/l and in the Tank 3 DO value was 0.6 mg/l. Tank-2 was aerated and there was no fouling. That is why the DO was slightly more than other two tanks. The DO values were shown in Table 1 and in figure 8.

Table 1: DO concentration

DO Values in the membrane tanks.	
Samples	**DO(mg/l)**
Tank-1	1.4
Tank-2	2.3
Tank-3	0.6

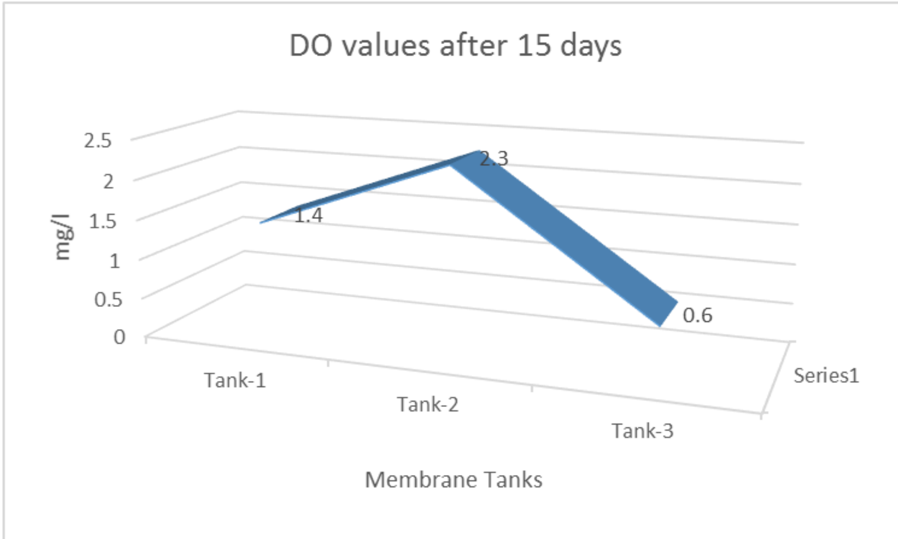

Fig 8: DO concentration in membrane tanks.

IV. CONCLUSIONS

The project study found optimum dosage to reduce fouling on MBR membranes. The following conclusions were drawn.

- The optimum dosages of chemicals are aluminum chloride 6 mg/l, Ferric chloride 6 mg/l and hydrogen peroxide 6 mg/l.
- Hydrogen peroxide keeps the organic matter in suspension. It will not allow the sludge to settle down.
- The aeration process in the tank-2 had kept the organic matter in suspension. It will not allow the fine particles to adhere to the membrane.

Data Availability:

The research findings of this study are available with the corresponding author on request.

Conflicts of Interests

The authors declare that there are no conflicts of interests regarding publication of this paper.

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