Cost Assessment on the Application of Hollow Fibre Membrane Module in Wastewater Treatment System in Small Scale Textile Industry

Nur Syamimi Jiran, Zaina Norhallis Zainol, Muhamad Zameri Mat Saman, Noordin Mohd Yusof

Abstract: Dwindling high-quality water source due to several factor including high water demand from the textile industry become one of the major problems around the world including Malaysia. Membrane technology is can be used to treat wastewater for reuse purposes so it will reduce the demand for fresh water for its operation and also maintain the environment. This paper aims to present the cost estimation model to calculate the overhead cost of implementing the membrane module to treat wastewater effluent from the textile industry in Malaysia. Activity-based costing (ABC) method has utilised as a cost estimation technique due to its ability to determine the accurate overhead cost based on the volume of resources consumed for each particular activities compared to the traditional costing method. This model is comparing two type of membrane modules; series hollow fiber membrane module (HFMM) and submerged membrane bioreactor (MBR)in term of the total overhead cost and other benefits in order to improve the overall productivity of the system and future reduce the overall operating cost of the system. The study shows that membrane replacement and backwashing activities contribute to increased the cost of operation and it is recommended further to investigate more on this problem.

Index Terms: Cost Assessment; Membrane module; Hollow Fiber Membrane Module; Activity-Based Costing; Wastewater Treatment; Textile Industry.

I. INTRODUCTION

World climate change, increasing number of population and also increasing water demand from the manufacturing industry contributes to water shortage problem around the world including Malaysia. Water is an essential need for human as well as cloth. As human population increased, the textile industry keeps growing and expanding [1]. It becomes an important source of economy income for certain countries such as India and China. However, textile industry is recognise as industry that need huge amount of water as high as 300m [2] and produce large volume of wastewater containing multiple and complex contaminants including biochemical oxygen demand (BOD) and chemical oxygen demand (COD) from its daily operation [3]. It is informed that 2 to 180L of wastewater is produced per kg of textile product produce based on the processes and the type of material used to produce the textile [4].

The textile industry is one of fastest growing industries in Malaysia [2] and it is dominated by SMEs especially at the East Coast Malaysia. Man-made textile craft, known as Batik is very popular garment craft in states of Kelantan and Terengganu and it contributes to the economic growth of the particular states [2]. Other than that, there are plenty of textile and garment factory located in Johor, Penang and also Selangor. It is reported that textile industry in Malaysia contributes 0.1% of total solid waste but wastewater generated from this industry id about 22% of the total of industrial wastewater generated around Malaysia [2]. As the industry becomes larger, it will contributes to increasing total of wastewater produced and discharged to the environment which contributes to bad impact in the future. Thus, the textile industry must play an important role in managing their wastewater to sustain the environment, to meet the environmental regulatory requirement and fulfil the demand for water cost reduction. Investment on a good and reliable wastewater treatment and increasing interest in water reclamation could be a major attention by the particular party to overcome the water pollution issue [2][3].

Recycling or reusing water from the textile wastewater can help overcome the shortages of natural and clean water resources [5][6] and it may suit various industrial applications [6]. Conventional wastewater treatment is not effective enough in removing the color dye in effluents due its chemical structure [7] thus, advanced technologies need to be used to ensure the effluents can be recycle in order to control the discharge of consumable chemicals and also reduce the environmental impact [8]. Membrane technology is proven as an effective method to remove all dyes in the textile effluent [5] because of able to restrict maximum micro-organisms present in the wastewater [9]. Thus, water recycling from the textile effluent can be done effectively and quickly through this filtration method [2].

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Membrane technology has known as an effective, environmentally and competitive method in water recycling compare to the traditional method. The membrane technology required smaller space compare to the huge space needed by the existing treatment method but, it has higher productivity due to its surface area per unit membrane [10][1]. In addition, it has less water consumption [11], offer plenty of ecological benefit [8] and it guaranteeing a great process sustainability since no by-product is produced by the membrane filtering activity that may be damaging the environment [12][13]. Apart from that, the membrane system can be easily installed to the existing treatment plant because of the compactness of the system and can operate automatically with minimum human monitoring [14].

Besides the advantages of the membrane technology in water recycling application, the cost is the major and vital elements that need to be considered when implementing the membrane technology. Detail estimation costing of the membrane filtering process is needed to attract the textile firm to implement and invest in this technology. Fouling is the main problem occur in the pressure-driven membrane process including in the textile wastewater filtration activity. Fouling may reduce the filtering outcome and required frequent membrane replacement or chemical cleaning that may further increase the operating cost of wastewater plant [14]. Thus, cost analysis of membrane filtration process needs to perform in order to ensure that the treatment plant able to operate efficiently at minimal cost as possible but still able to generate the desired outcome as expected. The computerized costing system is one of a method that able to use in monitoring the overall cost and further reducing the operating cost, highlight the impact of profitability and cost management and also highlight the efficiency of particular services [15]. Cost assessment needs to be implemented to avoid any overestimate or underestimate the process cost to avoid any losses to the plant.

Recently, membrane technology had been widely used in the water and wastewater industry due to the current innovation towards the technology that makes it much cost effective and it promote a sustainable environment. Plenty of researchers had been done on assessing the cost of membrane application in water recycling from the textile industry. [7] have studied the effect of combination between nanofiltration (NF) with photocatalysis in improving the dye degradation process and investigate the effect on the total cost of the system. Costs are categorized into fixed and variable cost; amortization and maintenance are considered as fixed cost while, variable cost consist of membrane cost, energy cost, cleaning cost and also labour costs. All costs will be multiplying by the specific membrane replacement cost in order to determine the total operating cost of the plant.

Furthermore, [16] have performed a technical, performance and cost comparison between two membrane-based options; tertiary membrane filtration with the conventional activated sludge and membrane bioreactor (MBR) to treat wastewater for water reuse. This study examined the treatment efficiency in term of the water quality produced and cost-effectiveness of the following options. In term of cost assessment, both options are assessed based on the total capital cost of the system (initial installation cost of plant and equipment, legal fee and land cost), operating and maintenance cost (labour cost, renewal machinery cost, energy consumption cost and membrane chemical cleaning cost) and also the total life-cycle costs based on the present value (PV) factor. This study found that the effectiveness of the system relies on the plant capacity and it also affected the total life-cycle costs.

Next, [8] have investigated the application of the zero liquid discharge (ZLD) approach in treating the textile dye bath wastewater with the membrane process. This study performed a technical and economic study in order to determine the best option based on the high benefit per cost ratios and also the real volume of membrane distillation processed. Intelligen’s SuperPro Designer ® v7.5, a process simulation program has been used to conduct the cost analysis.

Besides that, [17] have performed a preliminary cost analysis on the application of a membrane separation technique for the purification of wastewater for water reused in the textile plant. This study focuses on analysing the investment and operating cost of the plant which considers the investment cost, energy cost, chemical product cost and cost of changing membrane only.

In addition, plenty of researchers focus on certain cost in their cost assessment on membrane application. [18] have compared the energy cost effectiveness between Nafion 117 and sulfonated poly-ether-ether-ketone (SPEEK) as Proton Exchange Membrane (PEM) in a microbial fuel cell which used as simultaneous electricity production and wastewater treatment. While [19] compared the capital cost and operating cost of various alternatives to obtain RO quality water from sewage and the sea. [20] analysed the capital and energy cost for processing industrial waste in order to determine the optimal operations, operated at lower imposed flux but at the very minimal cost. Meanwhile, [21] have carried out a study to determine the most factor that influences the overall cost of membrane application in water and wastewater industry. [22] have used the Donnan dialysis in their economic analysis to determine the operational expenses (OPEX) and the cost-benefit between the traditional method and recovery technologies based on electrodialysis and ultrafiltration. [23] have conducted a study focus on the operational and maintenance costs for Ground Water Replenishment System, Anaheim. [24] have conducted a research on recycling a treated wastewater and zero wastewater discharge concept in the textile dying industries at Tamil Nadu, focus on the installation, commissioning, operating and maintaining cost the plant.

Based on the previous studies, most of the study performed a cost comparative study based on several options but limit to certain cost only, mainly the initial installation cost of the plant, the operating cost, cost of maintaining the plant, energy consumption cost and the chemical cost. The limited study on estimating detail cost of membrane application in water recycling is due to several factors including, variation in the raw water characteristics, the efficiency of the process, the technological innovations, the system’s capacity, the permeate characteristics and other factors, which make the system cost evaluation vary significantly [25][3].

With this inadequate information, there is a need for a comprehensive study to assess the economic feasibility that considers all related cost of using membrane system for producing purified water from the textile effluent. Thus, this study aims to develop a cost estimation model to calculate the total overhead cost of implementing membrane filtration process in the water recycling activity in the textile industry. In the study, a water recovery and reuse system using membranes system were proposed for a textile company in Malaysia. Thus, the cost of operation of the proposed system was determined based on current market prices within Malaysia. The overhead cost of the system was estimated by using activity-based costing (ABC) method.

II. MEMBRANE MODULE AS A WASTEWATER FILTRATION SYSTEM IN THE MALAYSIAN TEXTILE FACTORY

There are three main processes occur in the wastewater treatment plant that used membrane system as a filtration process; wastewater filtration as the main process, backwashing and in-situ chemical cleaning as a membrane maintenance. Fig. 1 shows the wastewater flow in the wastewater treatment plant. Wastewater from the textile factory will be allocated into feed tank before undergoes filtering activity to remove contaminants before it saves to be reused in the textile factory operation or remove to the drainage system. In the same time, backwashing activity is set at a certain time as a fouling precaution activity. Once a week, chemical cleaning is performed to remove all foulants that form in the system. Both activities are important as fouling is a main problem for the pressure-driven membrane process. In addition, proper selection of membrane type and a number of membrane cleaning should carefully select because it will reduce the plant treatment capacity, disrupt the overall productivity of treatment activity and also shorten the membrane lifespan [26]. The wastewater treatment plant of the textile factory is operating six days per week with one day off for chemical cleaning activity.

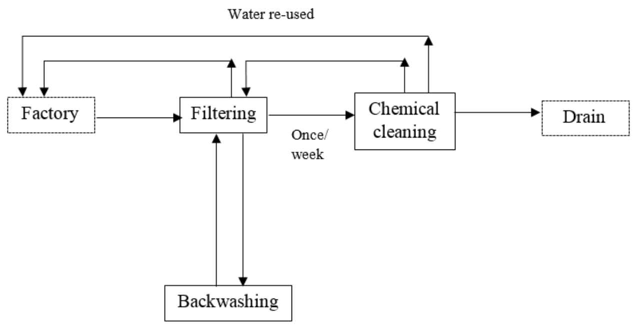

Fig. 1. Wastewater flow

A. Filtering

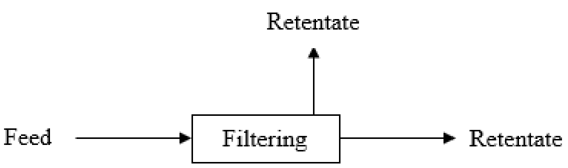

Fig. 2.: Basic flow in the membrane separation process

The filtering process is the main activity and it occurs continuously in the wastewater treatment plant as the factory operated. It involved a process of separating feed wastewater to permeate or retentate stream as illustrated in Fig. 2. Permeate is a clean wastewater and save to release into the drain while retentate is water that recirculates into the feed tank to undergoes the same process again. Usually, 95 percent of feed wastewater will exits as permeate while the more 5 percent will be rejected and need to redo the filtering process [27]. Permeate stream will be collected in a permeate tank before it can be released to the drainage system. Besides that, it will also be used in the backwashing process or reused in the production process again.

B. Backwashing

Backwashing or back pulse cycle is an important step for any system that applies the pressure-driven membrane separation especially microfiltration (MF) and nanofiltration (NF) membrane [28]. Backwashing process is designed to remove contaminants accumulated on the membrane during the filtration process. It is usually operated on a pre-set timeframe and it is initiated by the programmable logic controller (PLC) to control the backwashing activity. Filter water (permeate) is pumped in reverse direction to the membrane module to remove any foulants that disrupting the productivity of the membrane module, reduce the volume of permeate and increase the power consumption of the treatment plant. Usually, backwashing activity is generated automatically 10 to 60 seconds for every 10 minutes or few hours depends on the feed water quality [29]. The total backwash volume is limited within 5 percent of the daily permeate produced [30]. Backwashing activity has the ability to remove heavily fouled membrane without damaging the membrane [31] and it can be done without stopping the normal filtering operation of the system [31].

C. Chemical Cleaning

Besides the backwashing activity, chemical cleaning is another of precaution solution that can solve fouling problem in membrane separation process. Usually, the membrane cleaning procedure is applied every first time the fouling indications appears throughout the filtering process [32]. It can be done in two ways, either by clean-in-place (CIP) or ex-situ. CIP is a process of cleaning the membrane without removing the membrane from the treatment system while for ex-situ cleaning the membrane module is removed from the system while cleaning process is occurring [33]. CIP is frequently used because the process is much easier, membrane module remain at the system [5] and the specific chemicals will circulate through the system including the membrane module at certain time frame [28] and at high velocities to remove all residual traces.

Cleaning procedures, duration of the cleaning process and the frequencies will vary depending on the feed water quality, system design and operation, flux rates and recovery rates [34].Membrane cleaning by using specific chemical either bases, acids or oxidants is an essential part of membrane operation because it can affect the overall membrane performance [33]. Proper selection of membrane cleaning method should be compatible with membrane material and types and also type of foulants [35].

CIP membrane chemical cleaning is preferred compared to ex-situ because it does not need additional workers to perform the cleaning but it needs to be performed more frequently. The time interval for chemical cleaning is depending on membrane fouling condition and strategies used. However, a number of frequent cleaning should carefully select because chemical cleaning can change the physiochemical properties of the membrane [36] and it may shorten the membrane lifespan [33].

According to Advanced Membrane Technology Centre (AMTEC UTM), every 2.5 kg of wastewater from the textile factory used 0.0045 kg copper cathode and 0.0065 kg hydrogen chloride (HCL) for chemical cleaning activity. In addition, the buffer solution is added and the volume of the buffer can be calculated by multiply the total membrane area with the feed flow rate [37]. For this case study, approximately 2730 L wastewater being analysed. Therefore, 42.9 kg of copper cathode, 1 kg of HCL and 396 L of buffer solution are prepared for the chemical cleaning of the membrane module.

III. COST ESTIMATION MODEL

There are plenty of cost estimation technique available such as parametric method, detail estimation technique, intuitive method and analogical technique. Cost estimation activity is concerned with cost forecast which is related to any product, process or activities before it is performed [38]. Activity-based costing (ABC) is a quantitative cost estimation techniques, focus on calculating product cost based on the resources consumed by each activity in producing the end product [39]. Therefore, ABC provides more accurate product cost estimation [40][41] [42][43] and helps in highlighting the non-value-added cost improvement opportunity [44].

Usually, cost estimation is prepared by accounting department which is unfamiliar with the manufacturing process and term. Thus, it may lead to cost distortion. Therefore, the cost estimation model by using graphical user-interface is developed in order to make cost estimation is easy to perform, easy to understand for the unfamiliar user and able to provide accurate estimation cost in shorter time. Cost estimating model to calculate the overhead cost of HFMM in filtering textile wastewater is a component of ABC study and the procedure is as follows.

Step 1: Identify and collect information related to the wastewater flow and membrane module

Study the wastewater flow, list of equipment involved in the system and type of membrane module used in the system as it is the main component in calculating the overhead cost of utilising the membrane module in the wastewater treatment system. HFMM is chosen to filter the textile wastewater due to its larger surface area that provides more productive filtering process. Besides that, the production time, time interval of backwashing activity and also frequency of the membrane chemical cleaning need to be recognised. That information will be used in calculating the overhead cost of application membrane module in filtering textile wastewater.

Step 2: Identify the resourced consumed, identify the resource cost driver and calculate the cost driver rate

Next, list of resources consumed by each activity is recognized and the cost driver for each resource is identified. Resource cost driver is any factor that assigns the cost to the associate resource such as labour hour. The process of identifying and selecting the cost driver is a critical and a vital process because it may affect the aim and benefit of cost estimation system [45]. Brainstorming and survey may help in identifying the most suitable resource cost driver. List of resource, resource cost driver and cost driver rate applicable to this cost estimation model is illustrated in Table I.

Step 3: Calculate the overhead cost for each activity

Overhead cost for all resources and each activity is calculated and sump to get the total overhead cost for filtering, backwashing and chemical cleaning activity. Total overhead cost for each activity will be used to calculate the activity cost driver rate in the next step.

Step 4: Find activity cost driver, the quantity of each activity cost driver and the total number of activity annually

Activity cost driver is referring to any factor that causes the activity incurred the cost product such as machining time. Critically identify and select the activity cost driver for each activity then, determine the quantity of each cost driver. In this case study, the activity cost driver is activity time; filtering time, backwashing time and cleaning time. Therefore, time to complete one cycle of each activity is determined. Next, a total number of each activity is identified to calculate the total capacity of the activity for specific time frame such as annually, monthly or weekly. For this case study, the capacity is calculated based on annually time frame. Capacity is referring to total number hour spend to perform particular activity annually. Capacity is defined by the following equation.

$$\text{Capacity} = \text{number of hour (1 cycle)} \times \text{number of activity (annually)} \quad (1)$$

Table I: List of resources, resource cost driver and cost driver rate for particular resource

Resource	Cost driver	Cost driver rate
Equipment and machine (Eq/Mc)	Depreciation cost of each equipment and machine. The economic life of equipment and machine is given by the manufacturer.	Depreciation cost = [(purchase cost – salvage value)/economic life] Eq/Mc cost (RM) = depreciation cost × machine time (hr)
Water	Volume consumption.	Cost driver rate (water) = RM2.80 per every m^2 (SAJ rate). Water cost (RM) = volume (m^2) × RM2.80
Electricity	Total electrical power (kilowatt) consumed for each equipment and machine.	Cost driver rate (electricity) = RM38/kWh (TNB rate) Electricity cost (RM) = Machine time (hr) × total kW × RM38
Chemical	The volume of chemical used for chemical cleaning.	Cost driver rate (chemical) = chemical price Chemical cost (RM) = chemical volume × cost driver rate (chemical).
Material handling (MH)	The number of equipment and membrane movement from and to the system.	Cost driver rate (MH) = total number of trip / budgeted MH cost Material handling cost (RM) = MH per trip × number of trip.
Space	The land price, based on the location of the factory.	Cost driver rate (space) = land price/land area Space cost (RM) = total area for each activity × cost driver rate (space)

Step 5: Calculate the activity cost driver rate

The value of capacity calculated in step 4 is used to calculate the cost driver rate for each activity based on the equation 2. The total overhead cost is calculated in step 3. By

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completing step 5, the second stage of cost allocation in ABC analysis is done.

$$\text{Cost driver rate} = \frac{\text{total overhead cost}}{\text{capacity}} \quad (2)$$

Step 6: Calculate the overhead cost for each activity

After completing the second stage of cost allocation in the previous step, the overhead cost of each activity is calculated. Determine the total number of activity and calculate the total overhead cost. In this case study, one filtering activity is performed every day, 60 backwashing activity occur per day and once a week the chemical cleaning is done. To make calculation simple, the cost of using membrane module is calculated on either monthly or annually time-based. Therefore, annually total number of filtering activity is 318, a total number of backwashing activity is 3180 and the total number of chemical cleaning is 53. The overhead cost for each activity is calculated based on the following equation.

$$\text{Overhead cost} = \text{number of activity cycle} \times \text{cost driver rate} \quad (3)$$

IV. CASE STUDY OF COST ESTIMATION MODEL

There are two cases studies are examined by using the developed cost estimation model. Both cases studies are assuming will undergoes the same production line with the same volume of wastewater. The first case study is membrane filtering process by using 4 series of HFMM in the system while the second case study is HFMM in the submerged MBR in the treatment system. Both case study is compared based on the overhead cost result and other advantages comparing both options based on the results gain from the cost estimation model. Detail of both case study is explained in the next sub-section.

A. Case Study 1: 4 HFMM in Series

The first case study is adopted by AMTEC UTM, planned to be installed in the garment factory at Batu Pahat Johor. The equipment configuration and water flow involve in the HFMM filtering process are illustrated are Fig. 3. HFMM is used because it offers higher productivity compared to another type of membrane. A wastewater stream is collected in the feed tank, the feed pump is used to direct the feed stream to the series HFMM for filtering purposes. Cartridge filter 5μm is used to reduce the amount of sediments that carry by feed stream before it undergoes the filtering process by HFMM. After filtering process, permeate will be collected in permeate tank while retentate stream will re-enter the feed tank before re-circulate again. To prevent fouling, backwashing activity is activated by PLC by using permeate. Excessive permeate now save to be used in the factory operation or it can drain out to the drainage system.

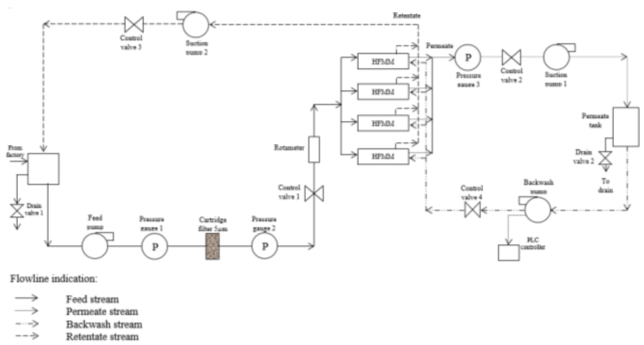

Fig. 3. Equipment configuration in HFMM filtering process

The developed cost estimation model is applied to calculate the overhead cost of HFMM filtering process. Table II shows the result of the first stage cost allocation in ABC analysis. All cost of consuming the resources for each cost pool or activity is calculated based on the resources cost driver rate.

Table II: Resources and overhead cost of each cost pool (Case study 1)

No.	Cost pool	Material handling	Space	Equipment/ machine	Water	Electricity	Chemical	Total Overhead (RM)
1	Filtering	7.55	4882.97	31.09	-	1355.20	-	6276.82
2	Backwashing	-	1877.34	0.01	-	12.69	-	1890.05
3	Chemical cleaning	3.78	1877.34	0.40	7.60	12.69	1699.25	3596.26
	TOTAL (RM)	11.33	8,637.66	31.50	7.60	1,380.59	1,699.25	

For this case study, the filtering process occurs continuously throughout the production hour and total filtering hours daily is 590 minutes (9.83 hours). Backwashing process will automatically occur every hour and it takes 10 seconds (0.0167 hours) per session [29] because it deals with mild fouling only. There will be 10 backwashing activities occur in a day by using 100mL of permeate for every session [26]. For chemical cleaning, CIP is occurred once in a week [29] to maintain the performance of the membrane module and avoid membrane fouling. Table III shows the second stage of cost allocation and the cost driver rate of each activity is tabulated.

Table III: Cost driver rate of each activity (case study 1)

No.	Cost pool	Total overhead	Cost driver	Qty. each cycle (hr)	No. of activity (annual)	Capacity	Cost driver rate (RM/activity)
1	Filtering	6276.82	filter-time	9.83	318	3125.94	2.007979442
2	Backwashing	1890.05	b/wash-time	0.0167	3180	53.106	35.59008795
3	Chemical cleaning	3596.26	clean-time	2.1667	53	114.8351	31.31672587

After completing the second stage cost allocation, the monthly overhead cost of HFMM filtering process is calculated and shows in Table IV. Based on the analysis, total monthly overhead cost of HFMM filtering process is RM 9,609.85. The cost involved 26 filtering activity, 265 backwashing activity and 4 chemical cleaning activity.

Table IV: The overhead cost of HFMM filtering process

No.	Cost pool	Cost driver rate (RM/activity)	Monthly freq.	Monthly cost
1	Filtering	2.007979442	26	53.21
2	Backwashing	35.59008795	265	9431.37

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3	Chemical cleaning	31.31672587	4	125.27
				RM9,609.85

B. Case study 2: Submerged MBR

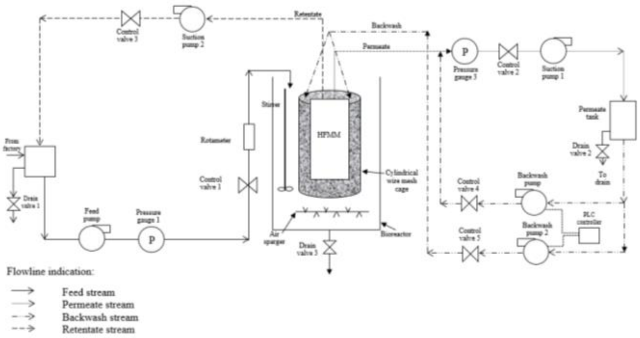

Fig. 4. Equipment configuration in MBR filtering process

MBR is one of solution that applicable in filtering textile wastewater. The schematic of the experimental setup of submerged MBR is illustrated in Fig. 4. Submerged MBR offers less energy consumption compared to the MBR besides it offers the same benefits as MBR including easy to install in the existing wastewater treatment plant, smaller footprint and the effluent is suitable to be reused in the production system [26]. The cylindrical wire-mesh cage acts as pre-filter to avoiding any direct deposition of mass to the HFMM. Wastewater feed stream is collected in the feed tank, drive to the bioreactor by the feed pump. It will undergo the wire mesh before continue with filtering process in the HFMM. The metal stirrer is installed and used to ensure complete mixing of the influent and the activated sludge at the same time to avoid deposition of sediment in the bioreactor. Air was fed to the bioreactor from the bottom to create air turbulence and reduce the occurrence of foulants to the membrane surface. Apart from that, backwashing is activated and controlled by PIC to overcome fouling problem occur to the HFMM and also the wire-mesh cage.

For this case study, filtering activity is running continuously for 6 days per week and the operating hour is 10 hours daily. The backwashing activity is set for 90 seconds every hour for HFMM and also the wire-mesh cage. The chemical cleaning is prepared once a week for major membrane maintenance and it took 12 hours per activity. Therefore, for overall the wastewater treatment is running seven days per week, six days for filtering operation and one day for chemical cleaning activity.

The developed cost estimation model is applied to calculate the overhead cost of submerged MBR filtering process. Table V, VI and VII tabulate the result of the cost estimation by using ABC method. Based on the calculation, the monthly overhead cost of submerged MBR is RM903.22 and it involved of 30 filtering cycle, 304 backwashing activity including of membrane module and wire-mesh cage backwash and only four cycles of chemical cleaning activity.

Table V: Resources and overhead cost of each cost pool (Case study 2)

No.	Cost pool	Material handling	Space	Equipment/ Machine	Water	Electricity	Chemical	Total Overhead (RM)
1	Filtering	7.55	5019.31	3.95	-	1491.17	-	6521.98
2	Backwashing	-	2099.29	0.02	-	26.34	-	2125.65
3	Chemical cleaning	3.78	1729.46	0.17	7.88	299.16	1699.25	3739.70
	TOTAL (RM)	11.33	8,848.06	4.14	7.88	1,816.67	1,699.25	

Table VI: Cost driver rate of each activity (case study 2)

No.	Activity	Total overhead	Cost driver	Qty. each cycle (hr)	No. of activity (annual)	Capacity	Cost driver rate (RM/activity)
1	Filtering	6521.98	filter-time	9.75	318	3100.5	2.103525079
2	Backwashing	2125.65	b/wash-time	0.25	3180	795	2.673772032
3	Chemical cleaning	3739.70	clean-time	12	53	636	5.880030394

Table VII: Overhead cost of submerged MBR filtering process

No.	Cost pool	Cost Driver Rate (RM/Activity)	Monthly freq.	Monthly cost
1	Filtering	2.103525079	30	63.98
2	Backwashing	2.673772032	304	813.27
3	Chemical cleaning	5.880030394	4	25.97
				RM903.22

V.DISCUSSION AND FINDINGS

The objective of the development cost estimation model to calculate the overhead cost of membrane module is achieved and it can be applicable to any type of membrane module system. The overhead cost of two membrane module systems; a series HFMM and the submerged MBR is estimated by using the developed cost model. Based on the ABC analysis, total overhead cost of series HFMM is RM9609.85, while for submerged MBR is RM903.22.

ABC method is useful in estimating detail of a product or process cost. Besides, it can be a decision-making tool in comparing several alternatives and options especially in monetary term and also the management point of view. For example, there are two case studies presenting in this paper. Both case studies had applied the cost estimation model that utilised the ABC analysis to calculate the overhead cost of the membrane module. Based on the ABC analysis, referring to the first stage cost allocation, both membrane modules consume the same amount of material handling and chemical for chemical cleaning activity. However, series HFMM required less space, consumed less water and need less electricity compared to the submerged MBR. In another hand, submerged MBR required less equipment and machine to be operated compare to the series HFMM.

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Even though both modules consume same volume and cost of the chemical in the chemical cleaning activity, submerged MBR has cheaper chemical cleaning cost, but it required a longer time for that activity. It happens because there is a cylindrical mesh-wire cage in the submerged MBR treatment system that also needs to clean by chemical cleaning activity to ensure remove all foulants formed around the cage. It shows that the longer time taken for chemical cleaning can reduce the total cost of chemical cleaning even the frequency for chemical cleaning performed for both modules is the same, which is it occurs four times per month.

In addition, series HFMM required less space compared to the submerged MBR because of the submerged MBR treatment system there is a bioreactor that required more space compare to the size of HFMM that placed in series. However, both space cost could be reduced by determining other factory location that has a cheaper land price. Land price influence the total cost of space for both cases, therefore selecting new factory location may help further reduce the cost.

Volume water consumption for each membrane module is depending on the total volume of the feed tank, which is the total water volume needed to cover the volume of the membrane module and also the whole pipe available in the system. Water is used in the chemical cleaning, to flushing out all chemicals and foulants before continue with the new cycle of filtering activity. Submerged MBR required more water because of the volume of the bioreactor and it has longer pipeline due to a double pipeline of backwashing activity compare to the series HFMM.

Additionally, submerged MBR consumed more electricity because it has more equipment and machine that required electricity to be operated in the system. Some additional equipment that available in submerged MBR is including the stirrer, air blower and gas flowmeter that needed to make sure the system function well and as a fouling prevention step.

However, the submerged MBR required less resource equipment and machine compare to the series HFMM due to the additional equipment has less depreciation cost. In the series HFMM, cartridge filter is used as a pre-filter as fouling precaution step. The lifespan of the filter is short and the cost is considered cheap. However, it needs a costly housing that may increase the overall cost but it required to hold the filter.

According to the ABC analysis, submerged MBR has more filtering activity, but it has higher monthly filtering cost. It shows that more filtering activity consumes more cost. Furthermore, it also has more frequent backwashing activity, flushing the membrane module and also the mesh-wire cage. However, the backwashing cost for submerged MBR is cheaper compared to the series HFMM. The more frequent backwashing activity by using the same amount of chemical may reduce the total cost of the backwashing activity. Therefore, careful selection of backwashing activity needs to be highlighted in order to further reduce the cost, ensure the membrane module is used in every effective way and the wastewater system can operate at the maximum operating condition.

Based on the comparison, it shows that submerged MBR has more advantages compare to the series HFMM because it has more filtering activity, so more textile effluent can be reused in the system. In addition, it has cheaper total overhead cost, cheaper backwashing and chemical cleaning cost. Fouling occurs spontaneously during the filtering process but it increases the overall operating costs [46]. As the fouling problem disrupt management in adapting the membrane technology in the textile factory, ABC analysis shows that submerged MBR has cheaper cost for both prevention activities (backwashing and chemical cleaning) in order to control the fouling problem.

VI. CONCLUSION

The aim of the study to developed cost estimation model for membrane module by applying the ABC cost estimation technique is achieved. Detail cost estimation for membrane separation process is a complicated process because it involves plenty of equipment, tangible and intangible cost and also confusing process flow. Therefore, the developed cost estimation model is helpful in calculating the overhead cost of the membrane module.

The cost estimation model had been tested by using two case studies, a series HFMM and a submerged MBR. The total overhead cost of series HFMM is RM9609.85 and the total overhead cost of submerged MBR is RM903.22. This model helps estimator to estimate the overhead cost that usually causes a cost distortion if it performs by using the traditional cost estimation method. Apart from that, result from the cost estimation model reveal the most and the less consumed resources for both cases, space for the most consumed and water for the less consumed. This information helps the operation in controlling the resources, ensure it fully utilised to avoid any losses and increased the total operating cost. In addition, the information is useful in improving the overall operation such as relocating the factory in order to further reduce the cost. Based on the detailed comparison, the management can choose the best option based on their preference of the membrane module for filtering activity in the textile factory.

The developed cost estimation model act as a decision-making tool because of its ability to comparing several alternatives in term of costing and also non-monetary. Based on the analysis, submerged MBR has plenty advantages compare to the series HFMM in term of the frequency of the filtering, backwashing and chemical cleaning activity and also the cost of each activity.

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