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The Effect of Pressure and Time Operation of Gasing River Water Treasure on Pollutant Concentration by Using Ceramic Membrane Separation

Sisnayati[1,2,*], Muhammad Said[3], Subriyer Nasir[3], and Dwi Putro Priadi[4]

[1.] *Doctor Candidate of Environmental Science Doctoral Study Program, Graduate School, Universitas Sriwijaya - Palembang INDONESIA*
[2.] *Chemical Engineering Department, Faculty of Engineering, Universitas Taman Siswa - Palembang INDONESIA*
[3.] *Chemical Engineering Department, Faculty of Engineering, Universitas Sriwijaya - Palembang INDONESIA*
[4.] *Agronomy Department, Faculty of Agriculture, Universitas Sriwijaya - Palembang INDONESIA*
**Corresponding Author: sisnayati75@gmail.com*

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Abstract: The purpose of this study was to treat water from Gasing River, Banyuasin District, South Sumatera Province, by using ceramic membrane to produce clean water. Also, this study analyzed the performance of ceramic membranes in terms of its ability to reduce the pollutants contained in water of Gasing River. The ceramic membrane was tube-shaped, made from clay (87.5% w), iron powder (2.5% w) and activated carbon of oil palm empty bunch (10 % w). In this membrane separation, the operation condition of membrane separation were of 15 minutes; 30 minutes; 45 minutes; 60 minutes; 75 minutes; 90 minutes and the applied pressure were of 1.0 bar, 1.5 bar and 2.0 bar. The reduction pollutants (Fe, Mn, Zn, NH_3-N, NO_2- and $PO^{4-3)}$ concentration increased with increasing the pressure and the operating time of membrane separation, and the pollutants concentration in effluent was met the Environmental Quality Standards.
Keywords: water treatment, ceramic membrane, pressure, time operation

Abstrak (Indonesian): Tujuan dari penelitian ini adalah untuk mengolah air yang berasal dari Sungai Gasing, Kabupaten Banyuasin, Provinsi Sumatera Selatan dengan menggunakan membran keramik guna menghasilkan aira bersih. Penelitian ini juga bertujuan menganalisis kinerja membran berupa kemampuan untuk menurunkan polutan yang terkandung dalam air Sungai Gasing. Membran keramik yang digunakan berbentuk pipa yang terbuat dari tanah liat (87 % berat), serbuk besi (2 % berat) dan karbon aktif yang terbuat dari tandan sawit kosong (10 % berat). Kondisi operasi dari pemisahan secara membran ini adalah 15 menit, 30 menit, 45 menit, 60 menit, 75 menit dan 90 menit, dan dengan tekanan 1,0 bar, 1,5 bar dan 2,0 bar. Penurunan konsentrasi polutan (Fe, Mn, Zn, NH_3-N, NO_2- and PO^{4-3}) meningkat dengan meningkatnya tekanan dan lamanya operasi pemisahan membran dan konsentrasi polutan dalam efluet memenuhi Baku Mutu Lingkungannya.
Kata kunci: pengolahan air, membrane keramik, tekanan dan temperatur operasi.

1. Introduction

Demand for clean water in the world continues to increase [1]. In Indonesia, it takes a budget of approximately four trillion rupiah per year to meet the shortage of clean water from 2000 to 2015. This is in line with the agreement of the Millennium Development Goals (MDG) and the UN General Assembly in September 2000 on the need for clean water [2]. Provision of clean water for the community is absolutely done as regulated in Article 5 of Law Number 7 Year 2004 and Law Number 11 Year 2005 regarding Resources. The rural water supply system in general is a non-piped system because of far-flung residents, while the water supply system in urban areas already use the services of Clean Water Corporation. The river water processed by the PDAM for clean water still does not meet the standard of the desired quality. The river water in urban areas is contaminated by household waste. For the region of South Sumatra, the provision of clean water must meet the standards of quality standards set out in the Governor Regulation of South Sumatra Number 16 Year 2005 on Water Allotment and River Water Quality Standards.

The number of Indonesian population which continues to grow from year to year affect the needs of clean water [3]. On the water supply side in Indonesia, there are still many obstacles, especially in the contaminated riverside area. Indonesia is a maritime country with an area of 1.9 million km^2 and a sea of 5.8 million km^2 [4]. More than 100 million people in

Indonesia do not have direct access to clean water and 70% take water from sources that have been contaminated by environmental pollutants. People from this group are susceptible to various diseases [3,5]. The World Water Forum in The Hague in March 2000 has predicted that clean water services for communities are still difficult to be implemented in Indonesia [6].

Clean water crisis always occurs in Sumatera and Kalimantan especially in dry season. The river water discharge start to decrease, well water has started to dry and concentration of soluble material in surface water is higher, acidic (low pH), brownish and organic [7]. This raises concerns for water users to consume. The difficulty to get clean water is also experienced by people in South Sumatera Province especially those domiciled in Lowlands area. Communities in this area generally receive clean water by collecting rainwater (rain-fed water), and some use well water and water in the form of packages sold by drinking water corporation. The availability and quality of water in the lowlands area is affected by topography and rainfall. the rainfall can affect the mineral content, thickness, level of decomposition of organic substances contained in peat soil [8]. The topography of the eastern part of South Sumatera Province is generally a swamp, while the western region is generally a highland with varying topography from flat, undulating to hilly [9].

Gasing River is one of the rivers located in the area of Lowlands precisely in Talang Kelapa subdistricts where most of the residents still rely on the river for the purpose of washing and sanitary. The activity of the people around the river greatly affects the quality of river water. In the Gasing River area, industrial growth is very fast, such as the CPO Palm Oil Factory, dock (barge), Food Factory and others that make this river very susceptible polluted due to these activities. So, to get a source of clean water, some residents use rain-fed water for the domestic sanitation. Several methods have been carried out for river water treatment in lowlands areas such as the use of Poly Aluminum Chloride (PAC) to decrease the color of river water in Siantan Hulu Pontianak City, the use of PAC at a dose of 110 mg/L can decrease the color from 624 mg/L PtCo to 15 mg/L PtCo [10]. The "One Stage Coagulation" method was able to reduce the turbidity of 97.18%, 96.79% color and 98.2% organic matter [11]. Then the river water treatment into clean water by Upflow Anaerobic Filter (UAF) and Slow Sand Filter (SSF) method could decrease the water color from 804 mg/L PtCo to 118,4 mg/L PtCo, but the result have not fulfilled the clean water standard as per PERMENKES NO. 416 / Menkes / PER / IX / 1990 [12].

Sample river water treatment using Aerasi Pump and Sieve Matching Technique (TP2AS model) conducted in Pangkoh Central Kalimantan area was able to decrease turbidity from 10 to 1.58 mg/L, color 500 mg/L PtCo to 10,0 mg/L PtCo, Fe from 0.4 mg/ L to 0.18 mg/L [13]. Yusmaniar successfully used bentonite to decrease the Fe+3 ion and Cu+2 ion parameters in peat water of Siak Riau river [14]. The weakness of this method is the decrease in Fe and Cu ion content has not reached the permitted quality standard and the use of inefficient bentonite 1 kg/50 L of peat water. Bentonite has a good ability that is almost 95% decrease the content of arsenic (As) and copper (Cu) in wastewater [15].

One of the elements contained in tidal river water is heavy metal which is a component very harmful to the environment. Laboratory tests in animals show that severe heavy metal poisoning can lead to tumor progression. From the problems that arise above, so needed another system which more economical and practical in processing river water using ceramic membrane made of clay, iron powder and activated carbon made from Empty Bunch of Palm Oil. Ceramic membranes primarily based on Palladium have long been used in microfiltration and ultrafiltration because they are stable against the effects of heat, chemicals and solvents [16].

The advantages of a ceramic membrane are good thermal stability, resistant to chemical substances, resistant to biological or microbial degradation. These properties show a better than membranes made from polymer compounds. The ceramic membrane is relatively easy to clean with a cleaning agent. Due to resistance to chemicals causes ceramic membranes to be widely used in food processing, biotechnology and pharmaceutical products [17]. Utilization of ceramic membrane as a river water treatment is expected to reduce the physical, chemical and biological parameters contained in river water. The concentration of pollutants of treated water are in accordance with the South Sumatra Governor Regulation No. 16 of 2005 on Water Allotment and River Water Quality Standard.

Ceramic membrane performance can be measured from the value of flux and removed pollutants. The flux and removed pollutant are influenced by various factors, such as operating pressure, pollutant concentration in feed water, preliminary processing, type of filter media used and the time of operation. The main materials used in the manufacture of this ceramic membrane are clay. The clay will become a hard and rigid lump if it is dry, but will be plastic and attached if wet due to exposure to water, and will be vitreous if the clay is burned with high temperature. The use of clay in the membrane-making process serves to form and adhere the membrane mixture to a hard and rigid lump after the sintering process [18]. In addition, clay has a very low permeability (Sandra's ability to pass water) (2014). Another material used in the manufacture of ceramic membranes is activated carbon made from oil palm empty bunch as additive and iron powder. After tested using SEM-EDS, it is known that the greatest content of this additive is carbon (C) of 99.17% [19]. Oil palm empty bunch is one of good quality materials to be used as raw material of activated carbon. Preparation of activated carbon takes place in three stages: dehydration process, carbonization and activation process [20]. The iron powder used to form ceramic membrane serves as aggregate material. Besides its abundant availability in nature and easy to process, iron powder when mixed with other metals and carbon will produce very hard structures. If the composition of iron powder used for 2.5% will produce a compressive strength of 22.55 Mpa [21]. The purpose of this study is to treat water from Gasing River to produce clean water by using ceramic membrane and to analyze its performance in terms of the ability to reduce the pollutants contained in river water.

2. Experimental Sections

The water used as sampling was taken from the Gasing River. The variables studied were divided into two categories, treatment and response variables. As for the treatment variables in this study are the pump operating pressure, feed flow discharge and membrane process operation time. The response variables in this study include the measurement of physical parameters and chemical parameters. Physical parameters are temperature, TDS and TSS, and chemical parameters of chemical parameters are pH, iron (Fe), manganese (Mn), Zinc (Zn), sulfate (SO_4^{2}-), BOD_5, free ammonia (NH_3¬N), nitrite (NO_{2-}), and phosphates (PO_4^{-3}) commonly contained in river water.

The ceramic membrane was tube-shaped, made from clay (87.5% w), iron powder (2.5% w) and activated carbon of oil palm empty bunch (10% w). The housing membrane was made from glass fiber with outer diameter of 9 cm, 8.5 cm of inner diameter and 30 cm in length. Initial analysis of the pollutants contained in the water sample of the river. The pretreatment of river water sample by filtration technique used a sponge filter with 0.5 µm and 0.1 µm pore diameter. Sampling of river water that has passed the complete separation process was taken every 15 minutes; 30 minutes; 45 minutes; 60 minutes; 75 minutes; 90 minutes. The operation pressure was of 1.0 bar, 1.5 bar and 2.0 bar.

3. Result and Discussion

Optimal membrane performance can generally be expressed by permeate flux, magnitude of permeability, membrane selectivity to certain chemical pollutants and the percentage of rejection of undesirable pollutants in the feed. The increasing of the permeability and the selectivity level of a membrane showed better membrane performance.

The Figure 1 below shows the effect of applied pressure of liquid and the time of membrane operation separation on permeate flux. Different applied pressure caused a different permeate flux. The Increasing of applied pressure increased the permeate flux, because higher force applied on fluid will augment flowrate of permeate. Contrary, increasing of separation time decreased the permeate flux, because the pore of ceramic membrane time to time will be covered by pollutants.

Under 30 minute of operation, the permeate flux of three different pressure decreased rapidly, but after 30 minute until 90 minute, the permeate fluxes decreased slowly. This condition was due to the pollutant more and more close the pores of ceramic membrane. Consequently, the fluid was difficult passing through the pore. The highest permeate flux (114.14 L/ m2.hr) for this river water was achieved at the pressure of 2 bar and the lowest flux value (0.51 L/m2.hr) was reached at 1.2 bar of pressure at 90 minute of operation.

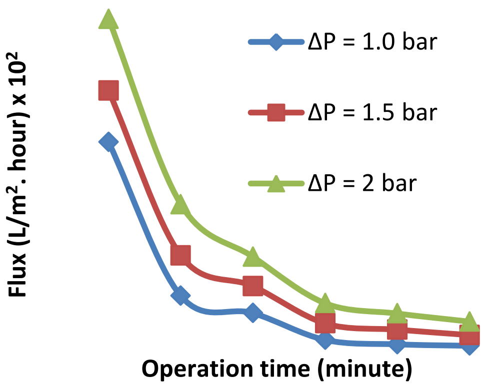

Figure 1. The effect of applied pressure and time of separation process on permeate flux of river water.

A membrane performance can also be determined by its ability to decrease the concentration of pollutants. Seven figures below (from Figure 2 to Figure 8) show the permeate quality indicated by the decrease of Fe, Mn, Zn, NH_3-N, NO_2^- and PO_4^{-2} concentrations by using the ceramic membrane with variation pressure of 1 bar, 1.5 bar and 2 bar and operation time until 90 minutes. The decreasing in flux value in this study was probably caused by dissolved solids. This dissolved solid accumulated on the membrane surface in the form of gel or fouling layer. Consequently, it resulted in clogging and increasing resistance on the membrane surface [22]. The effect of operating pressure on the permeate flux was shown in Figure 1. This Figure 1 shows that permeate fluxes increase with increasing operating pressure. This was consistent with the driving force of the membrane operation. The pressure applied to the feed stream passing through the membrane will result a smaller flow of fluid, while larger particles such as contaminants will be retained on the membrane surface [23]. The flux will tend to decrease with increasing the time. This decreasing of flux can be caused by fouling on the membrane. There was a phenomenon of accumulation of material on the membrane which causes the membrane pores to become smaller and over time the pores will be clogged by pollutants [24].

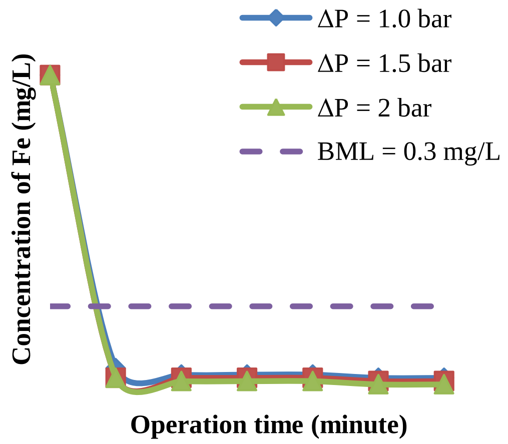

Figure 2. The effect of applied pressure and time of separation process on Fe concentration of river water.

At the beginning of the operation, the feed (water from the Gasing River) was passed through the pretreatment process by using activated carbon. The Fe concentration in the water was of 1.01 mg/L. This value is above the Environmental Quality Standard for Fe which is 0.3 mg/L. After operation for 15 minutes at the pressure of 1 bar, the Fe concentration decreased to 0.11 mg/L, whereas at the pressure of 1.5 bar and of 2 bar the Fe concentration dropped to 0.06 - 0.08 mg/L. Based on the Figure 2 above, the highest Fe concentration reduction in permeate was occurred at 2 bar pressure at operating time of 75 minutes and 90 minutes. At that condition, Fe concentration decreased and reaching to 0.06 mg/L, or Fe rejection percentage was of 96.06 %. The lowest reduction of Fe concentration was 89.11% at 1 bar pressure and 15 minutes operation time. The Fe concentration reached in permeate was met the Environmental Quality Standard.

The tendency to decrease Fe concentration was inversely proportional to the applied pressure. This was due to the greater pressure causing the water containing the solute to pass faster through the membrane pore. Consequently, the larger colloidal particles were held and polarized on the membrane surface. This condition causing the particles of colloid were difficult to pass through the membrane pore. Concentration polarization occurred the material contained in the bait collects on the surface of the membrane. The particles formed a layer causing the layer to become thicker. The particle caused a blockage of feed water through the membrane [25].

In Figure 3 as following, the Mn concentration in the feed from the Gasing River that has passed the pretreatment process using activated carbon was of 0.26 mg/L. This Mn concentration was greater than the Environmental Quality Standard (0.1 mg/L). After passing in membrane operation, the Mn concentration decreased to 0.02 - 0.05 mg/L.

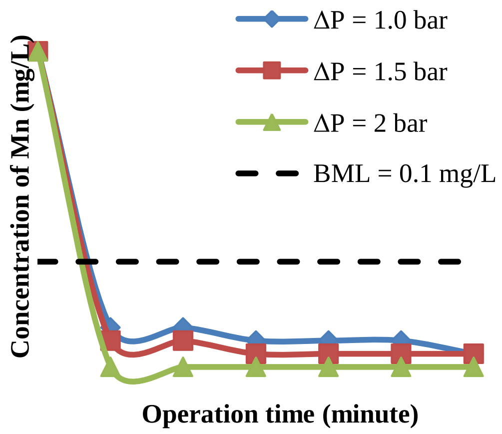

Figure 3. The effect of applied pressure and time of separation process on Mn concentration of river water.

Based on the Figure 3, the highest reduction of Mn concentration in permeate was occurred at 2 bar pressure and at operating time from 15 minutes to 90 minutes, and reached of 0.02 mg/L, or the Mn rejection percentage was of 92.31%. The lowest reduction of Mn concentration was of 80.77% at the operation condition of 1 bar pressure and at the operating time of 15 minutes and 30 minutes.

The greater the pressure applied to the microfiltration membrane, the concentration of pollutants was decreased. This was due to the greater the pressure of flow passing through the membrane increased and more contaminant particles were retained in the membrane [26]. So that the resulting permeate was clearer.

In the water of Gasing River, the Zn concentration after passing the pretreatment process using activated carbon was of 0.49 mg/L, while the maximum of Zn concentration according to the Environmental Quality Standard is of 0.005 mg/L. After membrane operation, the Zn concentration decreased becomes 0.01 - <0.003 mg/L. According to the Figure 4, the highest permeate reduction occurred at the operation condition of 2 bar pressure and at operating time from 15 minutes to 90 minutes, where the Zn concentration was <0.003 mg/L or the Zn rejection percentage was 99.80%. The minimum reduction of Zn concentration was 97.96%

when the pressure operation was 1 bar and at operating time of 15 minutes to 60 minutes.

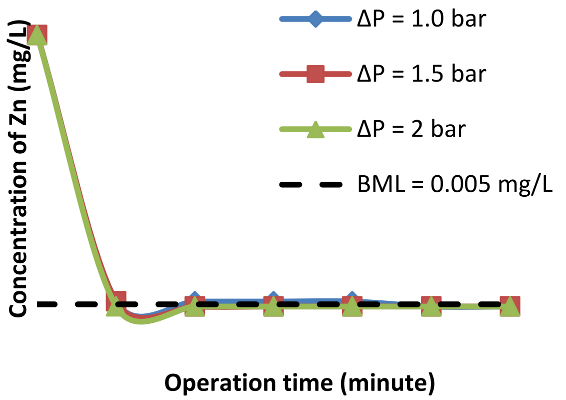

Figure 4. The effect of applied pressure and time of separation process on Zn concentration of river water.

The effect of pressure can reduce heavy metal concentration. It can be caused by the phenomenon of concentration polarization. Gel formation was due to concentration polarization. It can contribute to a decreasing of heavy metal concentrations [27] [28].

The Figure 5 shows the effect of the applied pressure and the time operation of membrane separation on NH_3-N concentration in river water.

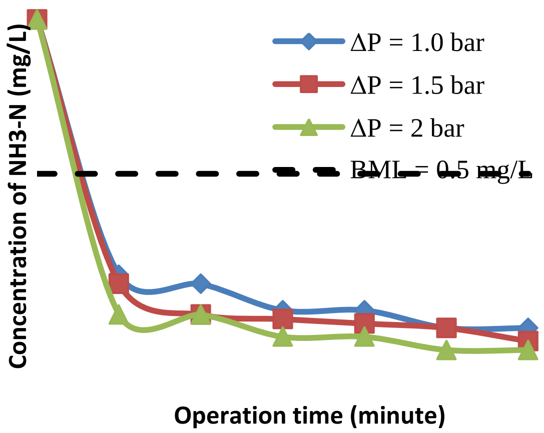

Figure 5. The effect of applied pressure and time of separation process on NH_3-N concentration of river water.

The NH_3-N concentration in river water after pretreated by activated carbon adsorption was 0.85 mg/L. This concentration was greater than the Environmental Quality Standard value (0.5 mg/L). After treatment passing to membrane operation, the NH3-N concentration decreased to 0.1 - 0.27 mg/L. Base on the Figure 5, the highest permeate decrease occurred at the operation condition of 2 bar pressure at operating time from 75 minutes to 90 minutes, of where the NH3-H concentration reached 0.1 mg/L, or the NH_3-N rejection was 88.24%. The lowest NH_3-N concentration rejection was 68.24% at the operation condition of 1 bar pressure and at 15 minutes operation time. The NH_3-N concentration in effluent was met the Environmental Quality Standards.

The Figure 6 shows the effect of applied pressure and time of separation process on NO_2^- concentration of river water.

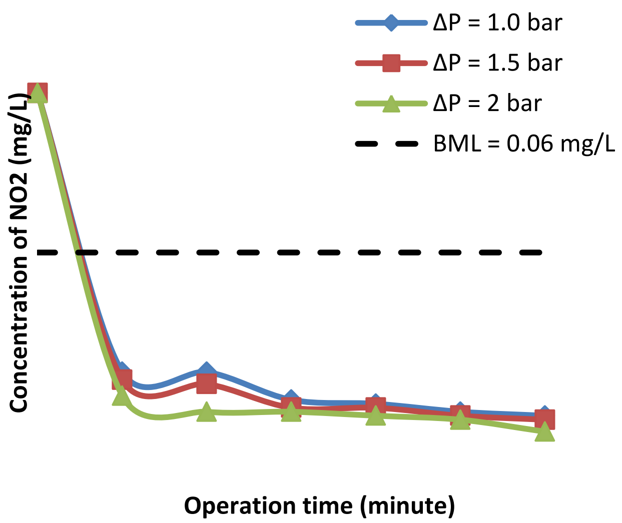

Figure 6. The effect of applied pressure and time of separation process on NO_2^- concentration of river water.

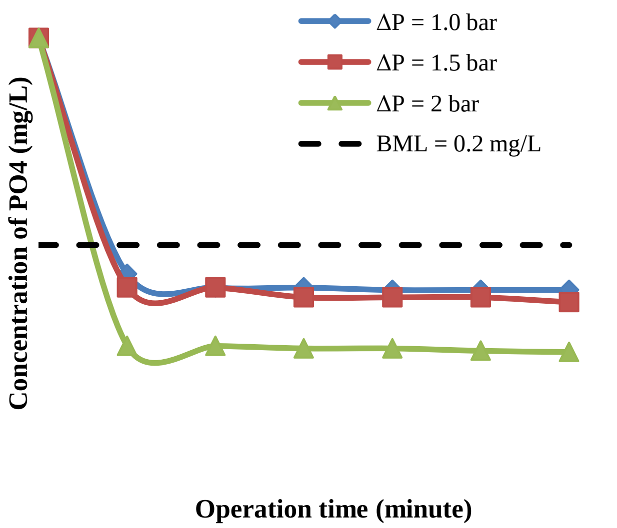

Figure 7. The effect of applied pressure and time of separation process on PO_4^{-3} concentration of river water.

The concentration of NO_2^- in the feed of the Gasing River that passed the process of pretreatment by using activated carbon adsorption was 0.1 mg/L. This concentration is still higher than the Environmental Quality Standard (0.06 mg/L). After membrane separation process, the NO_2^- concentration decreased become 0.015 - 0.03 mg / L. Based on the Figure 6, the highest permeate reduction occurred at a pressure of 2 bar and at the time of 90 minutes operation, which reached 0.015 mg/L with NO_2^-

rejection percentage of 85.0%. The lowest reduction of NO_2^- concentration was 70.0% at the condition operation of 1 bar pressure and at the operating time of 15 minutes to 30 minutes. The NO_2^- concentration in effluent is met the Environmental Quality Standards. From Figures 5 and 6 it can be seen that there were a decreasing in ammonia and nitrite concentrations. This was be caused ammonia and nitrite stick to the dissolved solids in water. so that was filtered together with solids [29].

The Figure 7 shows the effect of applied pressure and time of separation process on PO_4^{-2} concentration of river water.

The PO_4^{-3} concentration in the water from the Gasing River that has passed through the pretreatment process using activated carbon adsorption was 0.1 mg/ L. This PO_4^{-3} concentration is greater than the Environmental Quality Standard (0.2 mg/L). After membrane separation operation, PO_4^{-3} concentration decreased of 0.112 - 0.176 mg/L. The highest reduction of permeate occurred at 2 bar pressure and at 90 minutes operation time, where the PO_4^{-2} concentration reached of 0.112 mg/L or the rejection percentage is of 69.73%. The lowest of PO_4^{-3} rejection was 52.43% at operation condition of 1 bar pressure and 15 minutes operation time. The PO_4^{-3} concentration in effluent is met the permissible Environmental Quality Standards.

This is due to the phenomenon of concentration polarization (gel polarization). This polarization phenomenon can cause a decrease in the permeate concentration passing through the membrane. It was due to the increasing formation of gel layer [26].

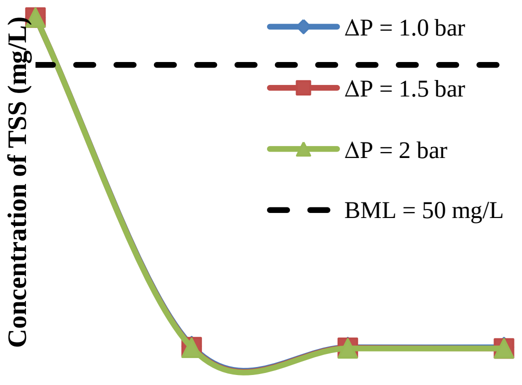

Figure 8. The effect of applied pressure and time of separation process on TSS concentration of river water.

According to the Figure 2 to Figure 7, the reduction pollutants (Fe, Mn, Zn, NH3-N, NO2- and PO4-3) concentration were increased with increasing the pressure and the operating time of membrane separation. This phenomena is due to the concentration of polarization, i.e the concentration of pollutant in the membrane wall was greater than the concentration of pollutant in the feed solution. With increasing concentrations of pollutant on ceramic membrane walls, the flow rate across the membrane was reduced.
The reduction of TSS concentration in Gasing river water after membrane process can be seen on Figure 8 as below.

Based on the Figure 8, the increasing of operation pressure, the percentage of TSS removal is increased. The TSS removal capability is affected by time and pressure. If the operating pressure applied to the membrane is too low, the removal suspended particles was few. Otherwise the higher the applied operating pressure to the membrane, so the TSS removal percentage in the permit was increased. This condition is because of the higher the pressure, it provides the speed of water to pass through the membrane is also faster. The suspended particles having a high molecular weight can not pass through the membrane, because the particle deposition on the membrane surface to be more easily formed and making the particles suspended to penetrate the membrane together water was difficult. Consequently, the TSS concentration in permeate will be decreased, and finally it increases the percent of rejection of suspended particles. It suggest that membrane rejection was strongly influenced by membrane structures, where the TSS having greater molecular size than the pore of membrane. This TSS will be retained on the membrane wall [26]. In this condition, the particle will be deposited on the membrane wall and indirectly providing a filtering effect for the feed going through the membrane so that it increases the permeate quality.

4. Conclusion

The conclusion of this research is the reduction pollutants (Fe, Mn, Zn, NH3-N, NO2- and PO4-3) concentration increased with increasing the pressure and the operating time of membrane separation, and the pollutants concentration in effluent was met the Environmental Quality Standards.

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