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Seawater Desalination for Environment and Economic Sustainability: A Case Study at Sadong Jaya Pilot Plant

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Abstract— **Pre-treatment of seawater appears a vital processing unit for maximizing technical efficiency of water desalination plant. Recently developed membrane technology is more popular than former thermal technology due to its lower risk investment options with higher productivity and less harmful effects on environment. This paper is designed to bring insight into the operation process of the Sadong Jaya desalination plant being installed at Sarawak, Malaysia. This paper aimed to reveal the potable water production performance of the plant. Data recorded in the operating log book were verified with plant operations manual and plant design parameters. Verified data were used to estimate the production performances. Findings showed that the production performances were within acceptable economically and environmentally sustainable level. The capacity utilization of the machineries, economic efficiency and benefit cost ratio of the plant operation appeared to be 69%, 1.25 and 1.5 respectively, which are within sustainable level. Information was being generated from operation of this plant would be useful for building and operating other plants to produce potable water from the same nature of saline water. The findings would also be useful in policy making. This paper suggest for further study on the plant operations to reveal the non-value added inputs being used in production process in order to find out the amount of plant inefficiency.**

***Index Terms*— Production Performance, Environmental Sustainability, Potable Water, Economic Efficiency, Membrane Fouling.**

I. Introduction

Desalination is an indigenous technology that is being used from ancient time, but it was not economically and environmentally feasible. Recently membrane technology has been developed and getting popular due to lower investment options with higher productivity and less environmental effect [1]. In the aspect of energy consumption, membrane technology is cheaper compared to the thermal desalination though membrane technology is higher pressure intensive production process.

The productivity and performance of fresh water production of membrane depend highly on the pre-treatment quality of intake water. Seawater pre-treatment has long been an important productivity issue in the membrane desalination production process, particularly in plants using open intakes. Seawater constituents make difficult to achieve targeted production performance. The identified impact of ineffective pre-treatment on the Seawater Desalination Performance (SDP) are responsible for increasing driving pressure; reduce freshwater production rate; increase operating pressure across the membrane profile, increase membrane cleaning frequency, reduce membrane production life cycle and finally reduce Capacity Utilization(CU). The mentioned negative effects are associated with five distinct types of membrane fouling such as particulate fouling, scaling, bio-fouling, organic fouling and colloidal fouling. Basically, the source of membrane fouling is intake water. Hence pre-treatment efficiency is a dominant factor of seawater desalination performance [2]. The identified membrane fouling factors are sand, higher degree of ionic strength, various types of biomass algae, pollutants and colloid materials [3].

Nowadays, pre-treatment is a challenging issue and will likely continue to be the most important issue in aspect of achieving freshwater production performance. The main challenge is seawater quality fluctuation; and due to that reason, the seawater desalination industry is struggling to find a standard pre-treatment process. It is advised that historical intake quality data and conducting pilot testing at project site are the key to project success [4,5]. The objective of this paper is to focus on potable water production performance of seawater desalination plant that installed at Sadong Jaya, Sarawak, Malaysia. This paper is an outcome of a successful water desalination plant operation which contains effective pre-treatment that consists of high turbidity, biomass and bacterial contaminations. The originality of this paper is ‘a model building on potable water production performance with the aid of an efficient pre-treatment system.

II. Problem Statement

Membrane fouling factors are the determinants of desalination process. Brackish saline water contains salt with sand, biomass, various types of pollutants, bacteria and that are to be known as contributing elements of membrane fouling. Ultimately, these fouling contribute to reduce freshwater production rate; increase operating pressure across the membrane profile and finally production performance. This study got interest to know about “*what is the potable water production performance of Sadong Jaya seawater desalination plant? Is the plant performance economically and environmentally sustainable?* This paper is organized to get answer of these question.

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III. Research Objectives

The broad objective of this paper is to reveal potable water production performance of Sadong Jaya seawater desalination plant. The specific objectives of this paper are:

A. To determine production performance of desalination plant

Production performance is measured with the common indicators namely; plant capacity utilization (CU), economic efficiency (ηEC), operating reliability [R(t)], Benefits Cost Ratio (Rb/c). Fresh water production rate (Q/m2-hr), Silt density index (SDI), Plant down time for maintenance (Td), Plant availability for production [A(t)], and FeCl3 used in sedimentation process.

B. To evaluate economic and environmental sustainability of production performance

The sustainability of production performance is measured with common indicators available in literatures.

C. Characterization of plant operations

Revealing operating behaviors of pre-treatment, bio-reactor, and sanitization of the process plant.

IV. Scope of Study

Plant operations and production data collection from Sadong Jaya water desalination plant; and analysis with software are the scope of work of this study.

V. Novelty of Work

Model building on fresh water production performance from a mixture of saline water and city polluted water is not reported in relevant literatures, and we assume it was not done before. In this aspect, this study has its novelty; and reduce literature gap by providing new information on present knowledge stock of seawater desalination.

VI. Literature Review

Nowadays the capacity utilization of desalination machineries appears to be less than 50 percent and it is recognized as performance barrier of desalination technology. Production performance of plant machinery is positively associated with labour skills, degree of technology of process and internal working environment [6,7]. On the other hands, higher capacity utilization of chemical base process machinery contributes to achieve environmental sustainability [8]. Indeed, for achieving a higher degree of CU, technology of plant machinery must be used efficiently [9], because it is the determinant of achieving higher productivity and performance [10]. It is reported that production performance of water desalination plant depends on preventive maintenance of machinery, feed water quality and fouling behaviour of membrane. Silt Density Index (SDI) is a measure of feed water quality; and by controlling pre-treatment process, SDI could be improved to a sustainable level [11,12]. However, the typical membrane fouling factors are listed in Table 1.

Table 1. Typical Membrane Fouling

Membrane Fouling	Cause	Solutions
Biological fouling	Bacteria, microorganism, viruses and protozoan	Chlorination
Particle Fouling	Sand .Clay(turbidity, suspended solids)	Filtration
Colloidal fouling	Organic and inorganic complex, colloidal particles and micro algae	Coagulation, Filtration, Flocculation /Sedimentation
Organic Fouling	Natural organic matter, Humic acid and fulvic acid and bio-polymer	Coagulation, Ultra Filtration, Activated carbon
Mineral fouling	Calcium, magnesium, Barium sulphates and carbonate	Anti-sealant dosing and acid dosing
Oxidant Fouling	Chlorine , Ozone and $KMnO_4$	Sodium bi-sulphate dosing, Activated carbon

Many pre-treatment have been reported in literatures to solve fouling problems for achieving desired SDI. The summary of findings on pre-treatment for desalination and SDI are pictured in Fig. 1a and 1b [4,5,6].

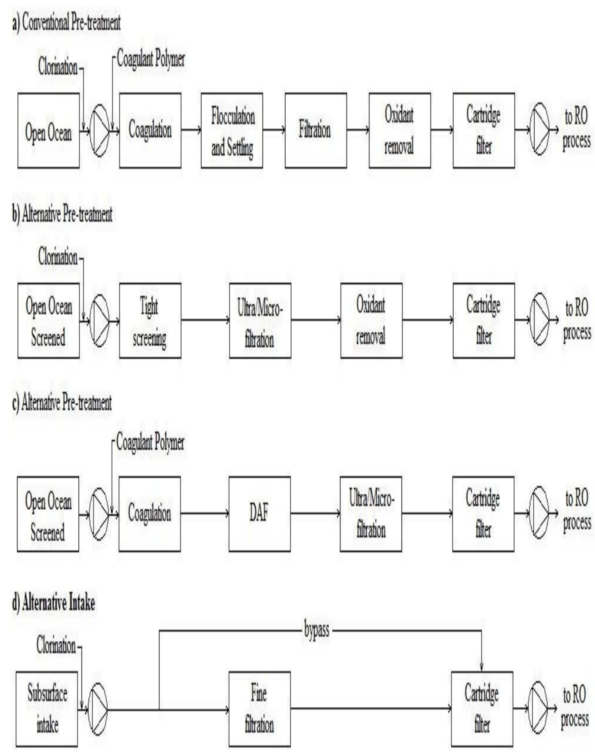

Fig 1a Conventional Pre-treatment

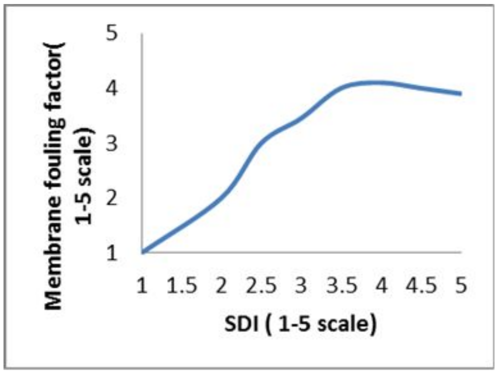

Figure 1b SDI-Membrane Fouling

VII. Membrane Bio-fouling Causes and Solutions

Seawater contains various types of microorganisms and bacteria that would contribute to form bio-film on the membrane surface; it grows faster if carbon source and nutrients are available in water. Eliminating bacteria and microorganism from water before it enters into membranes is essential to prevent bio-fouling. A cost-effective way to avoid biological fouling is chlorination; but chlorine oxidizes the membrane material. Nowadays the major percentage available membranes can only tolerate chlorine level of 1000 milligram per hour (mg/hr). Usually, chlorine dosing to water is about 3 milligram per litter of water. To safe membrane from chlorine shock, a common de-chlorination process is the injection of sodium bisulphite or meta-bisulphite to water. But this process is acknowledged as an environmental hazard. Nowadays, at large scale desalination plants, electro-chlorination process is being used to produce sodium hypochlorite (NaOCl) from the sodium chloride salt (NaCl) available in seawater. It is reported that to produce NaOCl, the pH of seawater should be within 5.5<pH<6.5 [5,6,13].

VIII. Membrane Particulate Fouling: Causes and Solution

Particulate fouling refers to the deposition of organics, suspended materials, colloids on high pressure side of membrane surface and build up thin film. Indeed, particulate fouling is an especially persistent problem in all membrane; contributes to reduce water production and increased operational costs. Reliable way of preventing particulate membrane fouling is to use high quality feed water. The way of producing high quality feed water (SDI≤3) are of using media filter and UFM in pre-treatment system as described in ASTM 4189-95 [13].

IX. Membrane Natural Organic Fouling: Causes and Solution

Natural organic materials (NOM) are available in all sources of seawater. NOM is considered a major contributor to membrane fouling in a desalination process [15,16]. It is an strong fouling agent that contribute to reduce membrane life cycle and production performance [17].Understanding NOM fouling mechanisms and getting a way to eliminate is considered a higher value added work in the aspect of desalination. It is reported that dossing of Ferric Chloride ($FeCl_3$) in pre-treatment phase is an effective way to remove organic compounds from feed water. The coagulation by $FeCl_3$ at optimum dosage contributes to remove about 95% of hydrophobic compounds. It is also suggested that the application of UFM in pre-treatment has shown an extremely good result [18].

X. Mineral Fouling and Solution

Mineral fouling of membrane is predominantly composed of divalent metal ions. Monovalent metals such as Sodium and Potassium are nearly completely soluble, whereas, in the presence of divalent ions such as Calcium, Iron, Magnesium, Barium, Strontium, Radium, Beryllium, Lead, and Silicon are nearly insoluble. These molecules precipitate on the membrane surface and form crystals. It is reported that common forms of mineral scale are Calcium Carbonate, Calcium Sulphate, Calcium, Phosphate, Barium Sulphate, Strontium Sulphate, Iron Hydroxide and Silicon Dioxide (Silica) [19]. Nowadays, "anti-sealants" are being used to reduce mineral fouling threat [20].

XI. Oxidant Fouling and Solution

Chlorine and its associated products have been used for many years to destroy all sort of microorganism. Usually feed water passes through engineered water pre-treatment equipment before the water feed into membrane. In order to reduce membrane bio-fouling threat, free residual chlorine concentration of 0.50mg/L to 1.0mg/L is being maintained through the entire pre-treatment line. When higher chlorinated water feed to membrane its structural materials get started to degrade. The common chemical elements that contribute to damage membrane materials properties are chlorine dioxide, hydrogen peroxide, ozone and permanganate. The desalination process should carry on at acid condition (5.5<pH<6.5) and remove free chlorine [21].

XII. Literature Review Findings

Pre-treatment efficiency plays a vital role in achieving water desalination performance. Specially, the identified membrane fouling factors namely sand, higher degree of ionic strength, various types of biomass algae, pollutants and colloid materials must be removed from intake water in order to achieve high quality feed water. It is suggested that in order to achieve higher production performance, SDI of feed water must be about 3 (SDI ≤3). It is also suggested that desalination process must be carried out at acidic condition of water (5.5<pH<6.5). In order to reduce bio-fouling threat to membrane, the concentration chlorine ranges shall be within tolerable limit. However, the relationship between production performance and pre-treatment quality is not available in the published literature which appears a gap in the desalination research. This study has designed to fill- up this gap. This case will establish statistical relationship among the operating variables in order to identify the inputs that could significantly contribute to increase production performance of water desalination process.

XIII. Materials and Methods

Sadong Jaya desalination plant case study is formulated based on study the desalination process design, operating principal of the plant and collecting input-output data of potable water production. Literature review on water desalination and operating performance data on membrane process of the case industry are the basis of this research. The theoretical framework related to production performance has developed from the published literatures of the relevant field. Relevant input-output data of production have collected directly from the operating log books of the plant machinery operation; and production performance models have estimated by using plant operating data.

XIV. Description of Case Study

Sadong Jaya water desalination plant has started to operate on 31 January, 2015. Sadong Jaya is small down under Samarahan division of Sarawak Malaysia. The plant able to produce 50,000 litres per day of potable water. The feed water is highly turbid (3100 NTU). The salt content of the feed water is 35,000 milligrams per litre of water. The basic components of the plant are water intake, bio-reactor, dual media filter, UFM and desalination membrane pack. This plant is designed for 24 hour operations per day. The output water quality is conform to Malaysian potable water standard.

XV. Modelling the Production Performance

Scaling and fouling on high pressure sides of membrane create resistance to fresh water production. The thickness of the scale and degree of fouling in membrane are determinants of feed water quality and capacity utilization of desalination machinery. The declining water production rate is an indicator of scale formation on the membrane surface and fouling of membrane materials. However, the water production performance models are listed below:

$$\text{Plant Capacity Utilization, } CU = \frac{\text{Actual Capacity } Q_A}{\text{Potential Capacity} Q_p} \quad (1)$$

$$\text{Benefit} - \text{Cost Ratio } R_{b/c} = \frac{\text{Value of Water}}{\text{Production Cost of Water}} \quad (2)$$

$$\text{Plant Operating Reliability}, R(t) - \int_0^t f(t)dt - 1 - e^{\alpha t} \quad (3)$$

$\alpha = \text{failure rate of machine}$; $t = \text{failure time}$

$$\text{Plant Economic Efficiency}, \eta_{EC} = \frac{\text{Value of Water}}{\text{Production Cost of Water}} \quad (4)$$

$$\text{Slit Density Index}, SDI = \left[\frac{1 - \frac{Ti}{Tf}}{T}\right] \times 100\% \quad (5)$$

$T = \text{elapsed time}$; $T_i = \text{initial time}$; $T_f = \text{final time}$

$$\text{Plant Availability}, At = \frac{T_{op} - T_d}{T_{op}} \quad (6)$$

$T_{op} = \text{design operating time}$; $T_d = \text{downtime for maintenance}$

XVI. Data Analysis and Findings

This study aims to evaluate the production performance of Sadong Jaya water desalination plant. Particularly, this study got interest to reveal the relationship between production performance and membrane fouling factors during potable water production from high turbid saline water. The ultimate target of this study was to capture information on the operational behaviours of water desalination plant in the aspect of economic and environmental sustainability.

XVII. Statistical Validation of Input-Output Data of Potable Water Production

At pre-treatment process, five potential operating variables have used to produce high quality feed water for desalination membrane pack. Our interest was to measure the degree of contributions of variables to produce desired feed water (SDI≤3). Input-out data have analysed by SPSS 19 version software to establish correlation with operating parameters of bio-reactor and SDI. The findings of analysis are listed in Table 2.

Table 2. Statistical Relationship of Feed Water Quality and Plant Operating Parameters

Independent Variables	Coefficient of Inputs to Outputs (β)	Correlation (r)	Significance (p-value)
H	0.30	0.39	0.00*
T	0.32	0.55	0.00*
$FeCl_3$	0.40	0.40	0.001*
AC	0.2	0.10	0.25
FS	0.35	0.32	0.01*

H-Height of tank. T-sedimentation tank. AC-activated carbon filter, FS-fine sand filters.
**One-tailed test at 95% confidence level.*

XVIII. Production Performance Analysis of Water Desalination Plant

Six models relating to potable water production performance have estimated by using input-output data of the plant. Input-output data have been standardized by using SPSS 19 version software. In order to increase reliability of research findings, out-layer data of production information have removed from dataset prior to analyse. Outputs of software analysis are listed in Table 3.

Table 3. Statistical Relationship of Feed Water Quality and Plant Operating Parameters

Performance Parameters	Performance	Sustainability Index*	Comment
CU	69%	>50%	*Achievement is significant*
η_{EC}	1.25	>1	*Achievement is sustainable*
$R_{b/c}$	1.5	>1	*Economicall y feasible*
Q/m^2-hr	360 liter	>350 liter	*Achievement is significant*
SDI_{15}	2.81	3<	*Achievement is significant*
T_d	12%	15%<	*Achievement is significant*
A(t)	69%	>60%	*Achievement is significant*

R(t)	0.85	>0.75	*Achievement is significant*
$FeCl_3$	2.25 mg/l	5%<	*Achievement is significant*

*A(t)- Plant Availability, R(t)-Reliability, Td-down time, * is the reference from published literature*

Findings indicate that production performance of water desalination plant is within the standard range stated in various published literature [7, 8, 9]. These findings demonstrate that quality feed water might contributed to achieve sustainable performance for Sadong Jaya water desalination plant.

XIX. Economic and Environmental Sustainability Analysis of Plant Operations

Six common parameters have been used to measure economic and environmental sustainability that shown in Table 3 Column 3. The estimated values of parameters are listed in Table 3 Column 3. The estimated values of parameters are demonstrating that performance indicators are within the sustainable range. These findings indicate that Sadong Jaya water desalination plant is economically and environmentally sustainable.

XX. Scenario Analysis of Findings and Conclusion

The objectives of this study were to evaluate the potable water production performance of Sadong Jaya desalination plant in the aspect of economy and environmental sustainability. Six models relating to production performance have estimated; and findings are listed in Table 2 and Table 3. Findings demonstrate that pre-treatment plant is positively associated with achieving economic and environmentally sustainable.

Plant operating data indicate that in order to reduce chemical consumption (FeCl3), they allowed higher time and higher bio-reactor height for sedimentation. Results also show that height of bio-reactor and sedimentation time both parameters are positively correlated; Table 2, Column 3, RH=0.35, RT=0.55. But contribution of AC to achieve desired SDI is insignificant ($p>0.05$) though it has a positive correlation with SDI ($r=0.15$).

The estimated CU of the plant machinery is found 69 percent, it indicates that 69 percent potential capacity of the plant machinery is being used to produce water; and it is within the acceptable limit as suggested by Shahidul et al, 2014; Nakajima, 1988; and Christian et al. 2013 [5,19,22]. The estimated economic efficiency of the plant is found 1.25. As per the basic economic theory, it indicates that the value of outputs is more than the expenditure; the plant will sustain [5].The estimated benefit cost ratio is found 1.5; meaning is benefit of the plant is 1.5 times more than cost. It indicates plant is feasible to operate and to be sustainable [5,23]. The water production rate is found 360 litter per square feet of membrane which is within the standard value stated by GE water system and TFE water system. These findings indicate that operations of the plant to be sustainable. The estimated plant down time is found 12%, plant availability for production is 69% and operating reliability is found 85%. These findings also indicate that the plant operations are feasible because all values are within the acceptable limit [5,19,21]. The chemical consumption is found less than 3 mg/L of water which is the average value being used in other plants. The lessons learned from this case study are described below:

A. Production performance of Sadong Jaya water desalination plant is economically and environmentally sustainable

B. The general operating characters of the plant are:

(i) Technically efficient pre-treatment plant contributed to achieve sustainable operating condition of Sadong Jaya water desalination plant.

(ii) Feed water to membrane contained about 0.5mg/L of chlorine that contributed to prevent the formation of biofilm in membrane.

(iii) Bio-reactor that used in Sadong Jaya to separate colloid materials and pollutant contributed to achieve sustainable production performance.

(iv) Preventive maintenance strategy that adopted at Sadong Jaya water desalination plant also contributed to achieve sustainable production performance.

This study concludes that the operating procedure adopted in Sadong Jaya can be adopted by other desalination plants with similar water characteristics. This study suggests that for future research on the plant operation machineries to reveal its capacity gap and to optimize capacity utilization.

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References

[1] A. Azarperkayni, R. Motallebi, A. Takdastan, A.H. Madani, "Study on performance of RO water treatment system of Jask City in terms of physical and chemical quality of the produced water, Linear Networks and Systems", Belmont, CA, 1993, pp.123-135.

[2] L. Hernthorne, "Trends in pretreatment for seawater reverse osmosis, Newsletter on Water Condition and Purification", Rocky Mountain Research Lab, Boulder, CO, 1995, pp. 1-2.

[3] H. Poor, An Introduction to Signal Detection and Estimation, New York, 1985, Chapter 4.

[4] F. Azam, J.A. Fuhrman, "Measurement of bacterioplanton growth in the sea and its regulation by environmental conditions", *Heterotrophic Activity in the Sea*, 1984, pp.179-196.

[5] M.I. Shahidul, S.T.S. Shazali, Y. Abdullah, C.H. Ting, M.D. Lee, A.H. Hishamuddin, M.S.M. Azrin, A.F.K. Adzlan, "Determinants of desalination machinery capacity utilization: evaluate in the aspect of energy", in Environment and Economic Sustainability, Engineering Conference 2014, Kuching, Malaysia, 2014.

[6] C. Shea, J.C. Williamson, "Rapid analysis of bacterial adhesion in a microplate assay", *BioTechniques*, 1990, Vol.8, No. 6, pp 610-611.

[7] M.I. Shahidul, S.T.S. Shazali, Y. Abdullah, C.H. Ting, A.H. Hishamuddin, "Manufacturing capacity utilization and its impact on production performance and environment", *J. of Manufacturing Operations Research and Sustainability*,2013, pp. 7-12.

[8] M.I. Shahidul, S.T.S. Shazali, M.J.S. Hashimi, "An approach to optimize manufacturing productivity: a pilot study on labour intensive

industries", in 2nd International Conference on Technology and Operations Management (ICTOM), Bayview Hotel, Langkawi, 2010, pp. 5-7.
[9] M.A.E. Houssein, M.I. Shahidul, "Determinants of manufacturing SMEs growth: a review", *J. of Manufacturing Operations Research and Sustainability*, 2013, Vol. 1, No. 2, pp. 46-47.
[10] S. Nakajima, "Introduction to TPM", Productivity Press, Portland, 1988.
[11] E. Brauns, E. Van Hoof, B. Molenberghs, C. Dotremont, W. Doyen, R. Leysen, "A new method of measuring and presenting the membrane fouling potential", *Desalination*, 2002, Vol. 150, No. 1, pp. 31-43.
[12] J.E. Farmerie, "Eliminating membrane fouling", information on http://www.wwdmag.com/desalination/eliminating-membrane-fouling.
[13] G.R. Faulhaber, "Design of service systems with priority reservation", Conf. Rec. 1995, IEEE Int. Conf. Communications, 1995, pp.3-8.
[14] S.F.Boerlage, "Scaling and particulate fouling in membrane filtration systems", CRC Press, 2001.
[15] N. Kawasaki, "Parametric study of thermal and chemical nonequilibrium nozzle flow", M.S. Thesis, Department of Electronic Engineering, Osaka University, Osaka, Japan, 1993.
[16] J. Cho, G. Amy, J. Pallegrino, "Membrane filtration of organic matter: comparison of flux decline, NOM rejection and flux decline with charged ultrafiltration (UF)", *Desalination*, 2000, Vol. 127, pp. 283-298.
[17] J. Cho, G. Amy, J. Pallegrino, "Membrane filtration of natural organic matter: factors and mechanisms affecting rejection and flux decline with charged ultrafiltration (UF)", *Journal of Membrane Science*, 2000, Vol. 164, No. 1-2, pp. 89-110.
[18] J.A. Nilson, F.A. DiGiano, "Influence of NOM composition on nanofiltration", *Journal of American Water Works Association*, 1996, Vol. 88, No. 5, pp. 53-66.
[19] S. Jeong, "Novel membrane hybrid systems as pretreatment to seawater reverse osmosis", 2013, information on http://hdl.handle.net/10453/21907.
[20] J. Mallevialle, I.H. Suffet, U.S. Chan, "Influence and removal of organics in drinking water", Lewis Publishers, 1992.
[21] I. Bremere, M. Kennedy, P. Michel, R. Emmerick, G. Witkamp, *Desaination* (1999) 51-62.
[22] M.I. Shahidul, S.T.S. Shazali, "Determinants of manufacturing productivity: a pilot study in labour-intensive industries", *Int. J. of Productivity and Performance Management*, 2001, pp. 567-582.
[23] E.B. Anthony, H.G. David, R.V. Aidan, L.W. David, "Cost-benefit Analysis Concept and Practice", 4th Ed., 2010, pp.1-27.
[24] B. Christian, D.V. Matthew, M.P. Joshua, "Distributed recycling of waste polymer into RepRap feedstock", *Rapid Prototyping Journal*, 2013, Vol. 19, No. 2, pp.118-125.

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