# Economic Evaluation Analysis of Nano-silica Ultrafiltration Membrane Production from Sand

Kurnia[1], Asep Bayu Dani Nandiyanto[1*], Riska Ismiati[1], Ainnaya Annisa[1], Fiona Finandia[1], Noor Nazmi Aulia Nissa[1], Rita Chintia Dewi[1]

[1]*Departemen Pendidikan Kimia, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Jawa Barat, INDONISA*

*nandiyanto@upi.edu*

**Abstract** – *The purpose of this research was to analyze the production method of a membrane of silica nanoparticles from an economic perspective. Silica nanoparticles are synthesized using a coprecipitation method. Briefly, the process consists of immersion, heating, precipitation, washing and drying, and packaging. The parameters used for economic analysis are gross profit margin (GPM), internal rate return (IRR), payback period (PBP), cumulative net present value (CNPV), break-even point (BEP), and profitability index (PI). The production of this ultrafiltration nano-silica membrane can be done by varying the amount of initial sand from 6 to 14 kg. The production of ultrafiltration nano-silica membranes can be produced in both domestic and micro-scale industries. To get a very good profit, economic analysis shows the minimum amount of sand used should be more than six kg. This study is very important because the production of ultrafiltration nano-silica membranes have a high potential in the field of economics and will encourage further investigation for the possibility of industrial production of these ultrafiltration nano silica membranes.*

***Keywords**:Economic evaluation, nanoparticles, ultrafiltration membranes, nano-silica.*

Received: 19/05/2018 – Accepted: 20/06/2018

## I. Introduction

Indonesia is rich in mineral materials that can be used as high-technology applications such as ZnO, SiO2, MgO, Al2O3, TiO2, etc. In order to utilize the material to the fullest, it is required the support of new technologies namely nanotechnology. Silica (SiO2) has been utilized in many applications[1-5], and the most familiar usage of silica is for the main ingredient in the glass industry.

In this study, the purpose of this research was to analyze the production method of a membrane of silica nanoparticles from an economic perspective. Sand was used as a main material for ultrafiltration nano-silica membrane. Silica membrane is used to select and reduce the content of Fe, Mn, and Mg elements in water. Currently, clean water treatment with membrane technology is a very promising processing process with excellent quality and is also suitable for drinking water treatment in developing countries because the membrane has many advantages [6]. Ultrafiltration is a separation process with membranes based on pressure differences, in which the separate components in the liquid are a function of the size and structure of the dissolved components. Ultrafiltration membranes are principally used to hold colloids and macromolecules but pass on salt and water particle [7].

In the literature, sand-based silica synthesis using coprecipitation methods can be made with the highest percentage of Si content averaging 95.73% [8]. As for the results of the synthesized silica XRD test from PasirMerapi showed that the percentage of the third silica crystal phase of the samples was 56.27% (pH 7), 31.66% (pH 4), and 38.34% (pH 1), and the particle size of each sample is 89.55 ± 5.23 nm (pH 7), 63.55 ± 30.68 nm (pH 4), and 132.26 ± 19.26 nm (pH 1) [9]. The characterization of membrane physical properties showed that the greater the silica addition will create the better membrane filtration quality because the resulting silica grains are so tight to make smaller pores, as shown from the data obtained with the addition of silica of 5 grams to have 0.058 (cm3/min) of smaller flow rate and to get silica membrane density (SiO2) of greater than 1.67 (g/cm3) with membrane porosity of 6.67% [10].

Silica nanoparticles are synthesized using a coprecipitation method. This method is based on the precipitation of one or more substances together as it passes through its saturation point. Coprecipitation is a promising method because the process uses a fairly low temperature so that the time is relatively short, which is about 12 hours. Common precipitating agents used in coprecipitation are hydroxides, carbonates, sulfates, and oxalates. In addition, the coprecipitation process uses easily accessible tools and materials; Thus, the synthesis process can be carried out flexibly [9].

In this research, the economic feasibility analyses of the industry with parameters used are gross profit margin (GPM), internal rate return (IRR), payback period (PBP), cumulative net present value (CNPV), break-even point (BEP) and profitability index (PI) and so on, with production time of 20 years. The production of ultrafiltration nano-silica membrane is done by variation of the quantity of material in order to know the comparison of the results to be obtained. This study performed from 6 to 14 kg of sand. Economic analysis showed the interesting results that to get a very good profit, the minimum sand used production should be more than six kg. This suggested that the production of ultrafiltration nano-silica membranes from sand can be produced in home industry and micro-scale production. This research is very important and useful because the production of ultrafiltration nano-silica membranes have a high potential in the economic field.

## II. Method

The data used in this research analysis was adopted from textbooks and scientific articles. The average price of raw materials and some equipments (with specifications) for the production of nanoparticle membranes is taken from the online shopping web to determine the current price of the material. The data obtained was calculated using some economic evaluation parameters. The analysis used the assumptions that the exchange rate value of one USD is equivalent to 13,547 IDR. To perform the calculation of economic evaluation parameters, including GPM, IRR, CNPV, BEP, and PI, we used lang data from reference [11].

## III. Results and Discussion

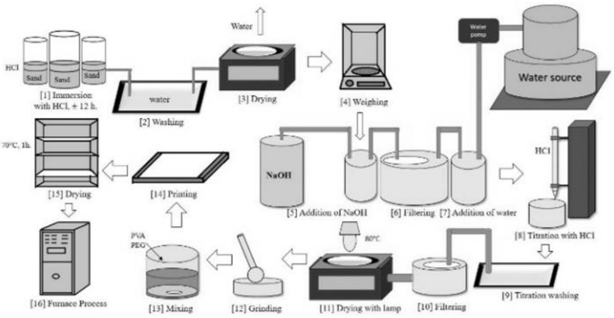

Figure 1.Schematic illustration image of the production process of ultrafiltration membrane of silica nanoparticles from sand

Figure 1 illustrates the production of the filtration membrane contained silica nanoparticles. Based on the figure, there are 16 processing steps in the production of the filtration membrane. The raw materials used in this production process are coastal sand, HCl solution, NaOH solution, aquadest, Poly Vinyl Alcohol (PVA), Ethylene Glycol Poly (PEG). In this study, beach sand used from the coast.

The first step is immersion (step 1). Sand immersion is done using HCl solution. HCl solution is used because HCl is very polar. Thus, it can dissolve polar minerals is also high, including silica. The event is in accordance that only solvent type can dissolve a molecule. It means the solvent and the solute molecule interact each other intermolecular by forming a certain bond, thermodynamically. Indeed, the solute will be dissolved into the solvent [7]. Immersion is done for 12 hours to maximize the dissolution process. The result of the process is washed with pure water (step 2) and dried (step 3). Weighing 4 grams of sand (step 4) was done for further reaction using NaOH solution (step 5), and the solution was then filtered (step 6). The equation of the reaction is as follows [13]:

$$SiO_2(s) + 2NaOH(aq) \rightarrow Na_2SiO_3(aq) + H_2O(l)$$

The filtering solution plus water (step 7) is then titrated bit by bit with HCl by controlling the pH to approximately 7-8. Next, silica gel is discontinued titration for pH 7-8 conditions or continue the titration until the final pH 4-5 and 1-2 (step 8) [14].

$$Na_2SiO_3(aq) + H_2O(l) \rightarrow H_2SiO_3(aq) + 2NaCl(aq)$$

The titration gel was washed using 300-mL pure water (step 9) to remove NaCl up to five times[15].

$$H_2SiO_3(aq) + H_2O(l) \rightarrow Si(OH)_4(aq)$$

Silica gel is filtered (step 10) and then dried at a temperature of 80° C (step 11). After the water content is removed, it is crushed with mortar (step 12) to obtain silica powder [8].

The next step is mixing the silica powder that has been obtained with Poly Vinyl Alcohol (PVA) solution. Poly Vinyl Alcohol (PVA) solution serves as a silica powder adhesive agent to become a solid membrane. Furthermore, Ethylene Glycol (PEG) solution was added and stirring was made using a stirrer until the mixture became homogeneous (step 13). The homogeneous mixture is then molded in a water (step 14) and set at room temperature for 30 hours. This is done to eliminate the water content. After 30 hours, the semi-finished solid membrane (still slightly wet) is removed from the mold of the hose, and put it in the oven for 1 hour at 70°C (step 15). Use of the 70°C temperature is expected only to remove the moisture present in the solid membrane after drying at room temperature. In addition, to strengthen the solid membranes that have been formed, the oven temperature at higher than 70°C was used. PVA and PEG in the membrane will melt before forming a strong bond between the silica compound in the silica solid membrane, resulting in the membrane becoming soft. After put it in the oven for 1 hours, the resulting solid membrane was then put in the furnace at 800°C for 5 hours (step 16). It aims to remove the organic compounds derived from PVA and PEG and to strengthen the bonds between silica in the membrane. The silica membrane is obtained with pores that are regular and not fragile [16].

To calculate the mass balance of the production process, the following assumptions are used:

1. Based on reference [12], to produce membrane filtration of silica nanoparticles. The required materials are beach sand, HCl solution, NaOH solution, aquadest, Poly Vinyl Alcohol (PVA), Poly Ethylene Glycol (PEG).
2. The temperature used in this procedure is 70 and 800°C.
3. The sand used contains 95.33% silica [8].

Based on the above assumptions (see Table 1), the data shows that the quantity of sand and the quantity of the product affect GPM every year. The highest GPM value is obtained if the quantity of sand reaches 14 kg. The lowest GPM ratio in six kg sand quantity. Meanwhile, to calculate other advantages, it takes other parameters that will be explained in the next discussion.

| *Quantities of Sand (kg)* | *Quantities of Product (pack)* | *GPM (USD)* |
|---|---|---|
| *6* | 150 | 52,395 |
| *8* | 200 | 69,890 |
| *10* | 250 | 87,325 |
| *12* | 300 | 104,790 |
| *14* | 350 | 122,255 |

Table 1. Gross profit margin for various quantities of sands

To evaluate the economic analysis we used the following assumptions:

1. The wage of labor is 15,501.58 USD per year. The wage is applied to five workers.
2. The duration of operation of this production is 20 years with total TIC of 13,720.84 USD per year.
3. The discount rate for this project is 15% per year.
4. Income tax is 10%.
5. The project does not develop with loans from banks.
6. Sale of silica membrane is 7.38 USD/pack.

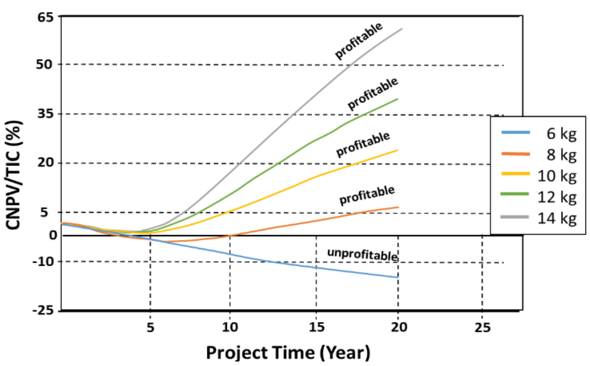


Figure 2. CNPV/TIC curve in accordance to project time with various raw sand productions

From the Figure 2, it can be seen the relation between CNPV/TIC with the duration of membrane filtration production of silica nanoparticles for 20 years. With the price of 7.3817 USD/pack, for once production, it produced 25 packs then the project will be profitable when the main raw material used is more than six kg. To achieve the payback period, production must be done at least five years. Likewise, at 6 kg, production using 8, 10, 12, and 14 kg also gave profit.

Table 2. Analysis of IRR, BEP, and last CNPV on the project

| **Type of project (kg)** | **PI to Invesment (%)** | **IRR (%)** | **BEP (pack)** | **Last CNPV/TIC (%)** |
|---|---|---|---|---|
| *6* | -0.46 | 170 | -0.5410 | -15.08 |
| *8* | 0.61 | 180 | 0.1892 | 2.93 |
| *10* | 1.69 | 200 | 0.0805 | 20.95 |
| *12* | 2.78 | 210 | 0.0511 | 38.97 |
| *14* | 3.86 | 210 | 0.0375 | 56.99 |

From the above analysis, it can be concluded that the higher the quantity of basic materials creates the higher CNPV to go. In the quantity of six kg of production, the value of PI to investment is negative. It identifies that with the amount of that production, the production is a loss.

Production was conducted in this study in accordance with the literature. This is because the production of ultrafiltration membranes can achieve remarkable advantages if it is developed on an industrial scale. However, if this research is done by a conventional method, the project will suffer losses. This is because the value of the sale cannot cover the value of expenditure, especially on the tools used for production.

## IV. Conclusion

The production of membrane with silica nanoparticles has been evaluated from an economic evaluation study. Economic evaluation presents the profitability of this project. To increase the quantity of profit, the number of raw materials was to achieve the standard profits per year that it is required more than six kg of raw materials. We found that profits will be obtained when using the amount of eight kg of raw materials. Further development of this research should be undertaken. Thus, profits continue to persist or even increase. Additional innovation is also required for this product after several years of production.

## References


[1] N. Permatasari, T. N. Sucahya, & A. B. D. Nandiyanto, Agricultural Wastes as a Source of Silica Material. Indonesian journal of science and technology, vol 1 (1), 2016, pp 82-106.

[2] A. B. D Nandiyanto, T. Rahman, M. A. Fadhlulloh, A. G. Abdullah, I. Hamidah, & B. Mulyanti, Synthesis of silica particles from rice straw waste using a simple extraction method. IOP Conference Series: Materials Science and Engineering, 128(1), 2016, 012040.

[3] A. B. D Nandiyanto, R. Zaen, R. Oktiani, A. G. Abdullah, & A. A. Danuwijaya, Monodispersed and Size-controllable Potassium Silicate Nanoparticles from Rice Straw Waste Produced Using a Flame-assisted Spray Pyrolysis. Pertanika Journal of Science & Technology, 26 (1), 2018, pp 391-408.

[4] A. B. D Nandiyanto, N. Permatasari, T. N. Sucahya, A. G. Abdullah, & L. Hasanah, Synthesis of Potassium Silicate Nanoparticles from Rice Straw Ash Using a Flame-assisted Spray-pyrolysis Method. In IOP Conference Series: Materials Science and Engineering, 180 (1), 2017, 012133.

[5] A. B. D Nandiyanto, N. Permatasari, T. N. Sucahya S. T. Purwanti, H. S. H. Munawaroh, A. G. Abdullah, & L. Hasanah, Preparation of Potassium-Posphate-embedded Amorphous Silicate Material from Rice Straw Waste. IOP Conference Series: Materials Science and Engineering, 180(1), 2017, 012138.

[6] A. Mirwan, V. Indriyani, & Y. Novianty, (). Pembuatan Membran Ultrafiltrasi dari Polimer Selulosa Asetat dengan Metode Inversi Fasa. *Konversi*, *6*(1), 11-16.

[7] Piluharto. Kajian Sifat Fisik Film Tipis Nata de Coco Sebagai Membran Ultrafiltrasi. JurnalIlmuDasar, 4, 2017, 55 2003.

[8] S. Hadi, Munasir, & Triwikantoro. Sintesis Silika Berbasis Pasir Alam Bancar Menggunakan Metode Kopresipitasi. *JurnalFisikadanAplikasinya*, 7 (2), 2011, pp 1-10.

[9] N. Qisti & N. S. Indrasti, Optimization of process condition of nanosilica production by hydrothermal method. *IOP Conference Series: Materials Science and Engineering*, 162 (1), 2016, 012036.

[10] A. Mufid, & E. Hastuti, Karakterisasi Sifat Fisis Membran Padat Silika ($SiO_2$) untuk Filtrasi Air Laut Menjadi Air Tawar. *Jurnal Neutrino*, 6(1), 2013, pp 40-46.

[11] A. B. D Nandiyanto, and RistiRagadhita. *EvaluasiEkonomi PerancanganPabrik Kimia*. Bandung: UPI Press (2018.)

[12] L. Yogantari, & S. Sulistiyani, Purifikasi Silika dari Pasir Vulkanik Gunung Merapi sebagai Bahan Baku Sel Fotovoltaik. *Jurnal Kimia Dasar* 4(2), 2016, pp 22-127.

[13] R. T. Bakri, Utari, & I.P. Sari. Kaolin sebagai Sumber $SiO_2$ untuk Pembuatan Katalis Ni/$SiO_2$: Karakterisasi dan Uji Katalis pada Hidrogenasi Benzena Menjadi Siklohesana.*Makara Saims*, 12(1), 2008, pp 37-43.

[14] B. Gu, D. Ko, S. Ahn, D. C. Hyun, H. K. Lee, & J. Kim, Synthesis of high purity silica from low cost water glass via sol–gel process and soxhlet extraction. *Journal of Sol-Gel Science and Technology*, *82*(3), 2017, pp 675-681.

[15] Kurniati. Ekstraksi Silika White Powder dari Limbah Padat Pembangkit Listrik Tenaga Panas Bumi Dieng, UPN Press, Surabaya (2009).

[16] K. Pratiwi, & R. Gunawan, (Pembuatan Membran Silika dari Fly Ash Batubara untuk Penurunan Intensitas Warna dari Limbah Cair Industri Sarung Samarinda. *JurnalAtomik*, *3*(1), 2018, pp 31-38.