International Journal of Advanced Smart Convergence Vol.8 No.4 26-33 (2019)
http://dx.doi.org/10.7236/IJASC.2019.8.4.26

IJASC 19-4-4

Engineering and Economic Evaluation of Production of MgO Nanoparticles using a Physicochemical Method

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Abstract

We conducted research to evaluate economically and engineering about the synthesis of Magnesium Oxide, MgO, nanoparticles using physicochemical methods. The method used was economic evaluation by calculating GPM, BEP, PBP, and CNPV. The other method used was engineering perspective. MgO nanoparticles were synthesized by reacting $Mg(NO_3)_2$ and NaOH with a mole ratio 1: 2. $Mg(OH)_2$ formed was heated and calcined to remove water content and to oxidation to form MgO. An economic evaluation by calculating GPM and CNPV for the production of MgO nanoparticles on an industrial scale shows that the payback period (PBP) occur in the third year and profits increase each year. Tax variations show that the higher of tax, the lower profits received. When there was an increase of selling prices, the profit was greater. The variable cost used is the price of raw material. When there was an increased in the variable cost price, the payback period was longer and the profits was reduced. The benefit of this research is knowing the industrial production of MgO nanoparticles is beneficial. The function of MgO nanoparticles is a material for the manufacture of ceramics and can be used as an antimicrobial in the water filtration process.

Key words: *economic evaluation, magnesium oxide, nanoparticles, antimicrobial*

1. Introduction

Magnesium oxide (MgO) is widely studied because of its unique nature of the crystal structure and its simple stoichiometric equation. MgO has many applications in various fields such as electronics, catalysis, ceramics, and absorption[1-2]. MgO also has applications in the health sector as an antimicrobial in the water purification process[3-5]. MgO can be synthesized using physicochemical techniques, but its nature and morphology depend on the conditions of reaction during synthesis[6].

Several previous studied had succeeded in synthesizing MgO nanoparticles through several ways such as sol-gel combustion[7], hydrothermal[8], precipitation[9], nonaqueous sol-gel[10], and physicochemical[11].

Manuscript Received: September. 9, 2019 / Revised: September. 14, 2019 / Accepted: September. 21, 2019
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The most appropriate method used in economic evaluation is physicochemical because the reaction process is simple and easily obtained raw materials. The synthesis of MgO nanoparticles using physicochemical method has been proven by Bindhu in his research.

The previous studied had not yet carried out an economic evaluation analysis for the synthesis of MgO nanoparticles on an industrial scale. Therefore, the purpose of this study was to evaluate engineering and economics the feasibility of making MgO nanoparticles on an industrial scale. In this study, we vary several factors to see the effect on the economic evaluation being investigated, such as an increase in tax prices, decreases and increases in product prices, and the effect of raw material prices.

2. Experiments

2.1 Theoretical Synthesis of MgO nanoparticles

All chemical reagents used were materials with the category "Analytical Grade" and were used without further purification. Synthesis was carried out by a simple chemical reaction method using magnesium nitrate and sodium hydroxide. 1:2 molar ratio of metal ions to hydroxide ions added and stirred constantly for 2 hours so that all reagents react perfectly then allowed to stand for 24 hours at room temperature to form magnesium hydroxide. The supernatant was carefully disposed of and the remaining residue was centrifuged (10,000 rpm) for 20 minutes. The residue was washed several times with double distilled water. Then the sample was dried in the oven for 3 hours at 100℃ and calcined at 400℃ for 5 hours to obtain the purest form of MgO nanoparticles. All the processes of nano MgO formation according to the flowchart below,

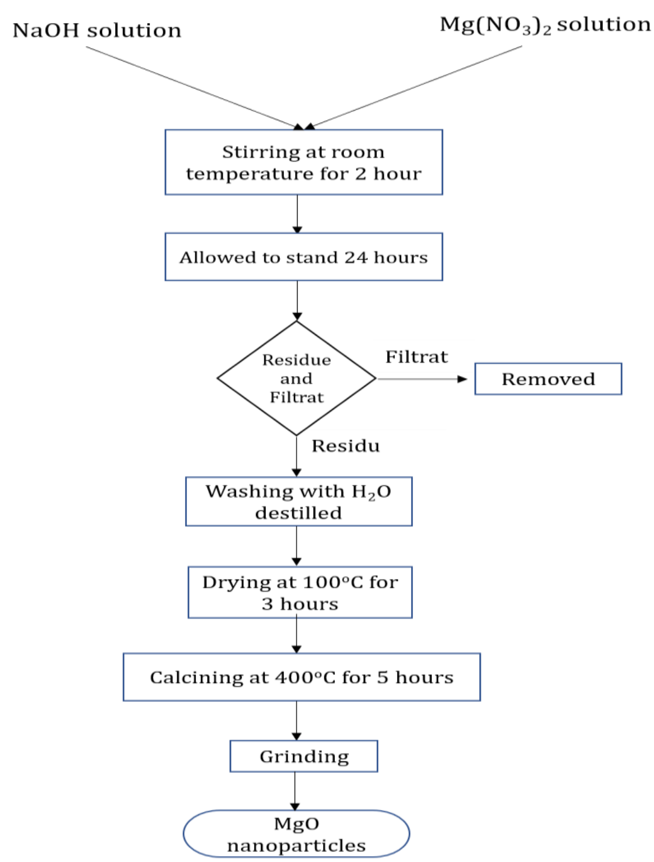

Figure 1. Flowchart Diagram of MgO synthesis nanoparticles

2.2 Energy and mass balance

Figure 2 shows the process of MgO synthesis using magnesium hexahydrate ($(Mg(NO_3)_3.6H_2O$ and NaOH as a ratio of 1:2 for the reaction. To produced 2 kg of MgO nanoparticles, 12.8 Kg $Mg(NO_3)_2.6H_2O$ and 4 kg NaOH were needed for the reaction. The synthesized process was carried out in a reactor by mixing raw material with 200 L of water and stirring for 2 hours then allowed to stand for 24 hours until all $Mg(OH)_2$ was precipited. Supernatant and residue were separated by filtering and the residue was washed with distilled water to remove impurities. After that the $Mg(OH)_2$ residue was heated in a furnace at 100°C for 3 hours and calcined for 5 hours at 400°C. The result of calcination was still in the form of flog and put into grinding so that the resulting MgO becomes powder. The formation of MgO in accordance with the chemical reaction equation as shown below:

$$Mg(NO_3)_2.6H_2O_{(aq)} + 2NaOH_{(aq)} \rightarrow MgO_{(s)} + 2NaNO_{3(aq)} + 7H_2O_{(g)}$$

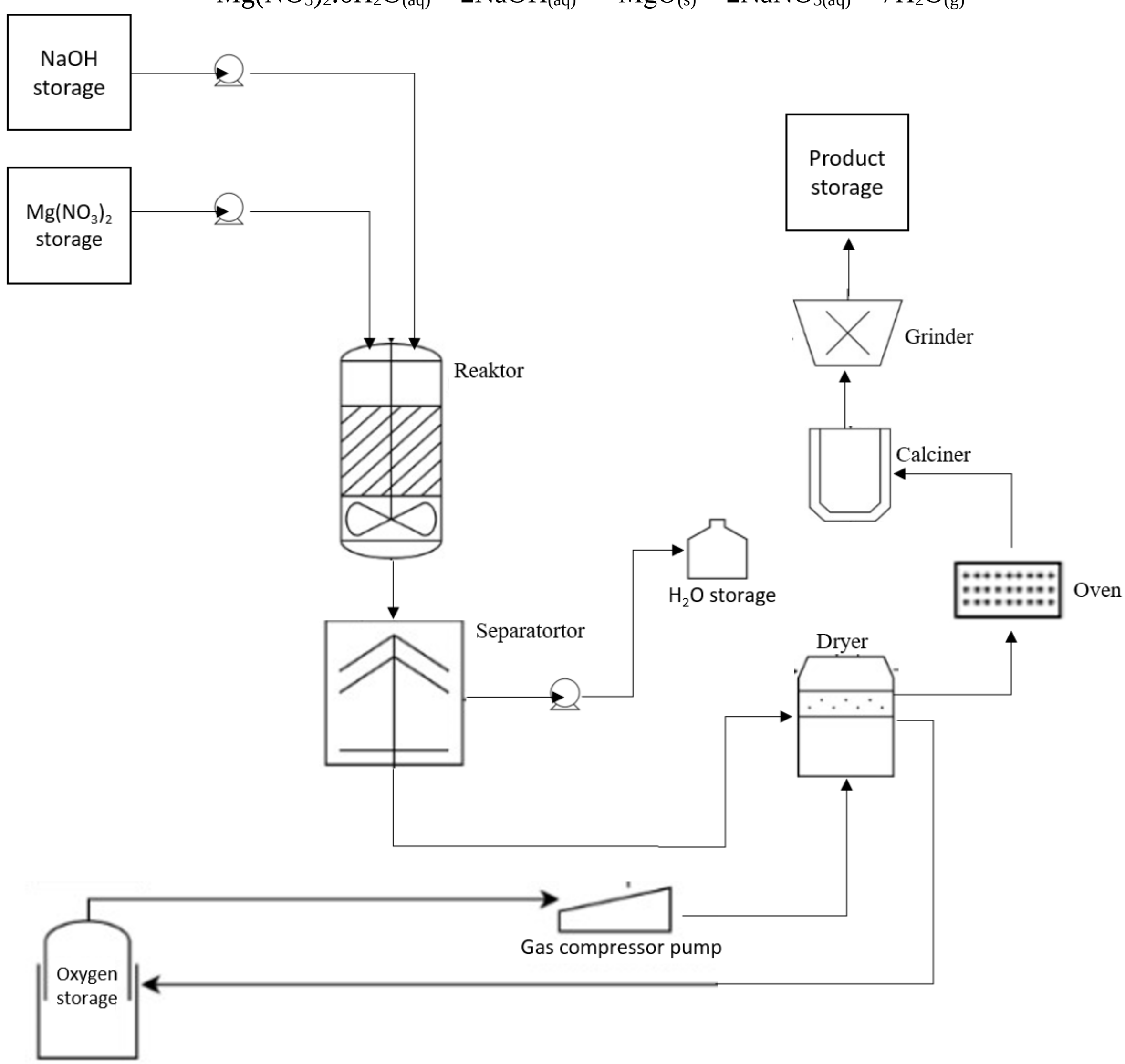

Figure 2. Process flow diagram of the synthesis of MgO nanoparticles

From a technical point of view, it was possible to increase the amount of production of MgO nanoparticles because the tools and materials used can be enlarged in capacity and quantity. Through 300 cycles for one year to obtain 600 kg of MgO nanoparticles, magnesium hexahydrate is 3,846 tons and sodium hydroxide as much as 4 tons with a total water solvent of 60,000 L. With a total cost of raw materials to be paid at IDR 1,659,600,000.00 and outcome for one year at IDR 15,000,000,000.00 in ideal conditions with a life span of project as 20 years.

2.3 Economic Evaluation

This method was used to analyze raw data on material prices, utilization units, and equipment specifications including prices obtained from online shopping sites such as alibaba. Then, all data is calculated by simple mathematical calculations to get various economic evaluation parameters such as GPM, PBP, BEP and CNPV from various variable costs. It was all calculated based on literature. In short, to get the results of this research calculation using several formulas such as :

(1) GPM was calculated by selling substitution and raw material costs

(2) PBP is the length of time required to return the investment costs. The simplest way to get PBP was obtained from the CNPV curve. The value of PBP was determined the first time the CNPV value reaches zero.

(3) CNPV is the value obtained from the net present value (NPV) at a certain time. NPV was calculated by adding a discount factor to the calculation on the cash flow multiplication.

(4) BEP is a value that explains the minimum value of production to get profit or loss. It has been calculated by dividing fixed costs and profits. After that, the project feasibility study was tested by ideal conditions, raw material effects, and various variable costs.

Some of the assumptions in this study include:

- All chemical compositions in the reaction, such as magnesium nitrate hexahydrate, sodium hydroxide and distilled water used for the production of MgO nanoparticles were increased up to 1000 times
- Magnesium nitrate hexahydrate and sodium hydroxide were reacted in a ratio of 1: 2. Both of them were assumed to have finished reacting to produce magnesium oxide with 99% purity.
- The conversion rate for the formation of magnesium oxide is 100%.
- Loss of each 5% transfer process
- Total investment cost (TIC) was calculated based on the Lang Factor
- Land purchased. As such, land costs were added at the beginning of the factory construction year and recovered at the end of the project.
- One cycle of the process of making MgO nanoparticles takes 12 hours.
- Shipping costs were borne by the buyer.
- MgO nanoparticles were sold at IDR 25,000.00 / pack (10 grams).
- The one-year project lasts 300 days
- To simplify utilities, utility units can be explained and converted as electrical units, such as kWh. The unit of electricity is converted to cost by multiplying the cost of electricity. Assuming utility costs is IDR 1,500 / kWh.
- The total salary per worker was assumed to be a fixed value of IDR 3,600,000.00 / month
- The discount rate is 15% per year.
- Income tax is 10% every year.
- The project operation length was 20 years.

3. Results and Discussion

3.1 CNPV in ideal conditions

Figure 3 shows the relationship between the x-axis with the y-axis where the x-axis is the year of production and the y-axis is CNPV/TIC. Figure 3 is a CNPV/TIC in ideal conditions. Payback period (PBP) occurs in the third year and was increased. This shows that the production of MgO nanoparticles can be considered as a project that can generate profits. Trend of the graph obtained was accordance with ideal conditions in previous studied [12].

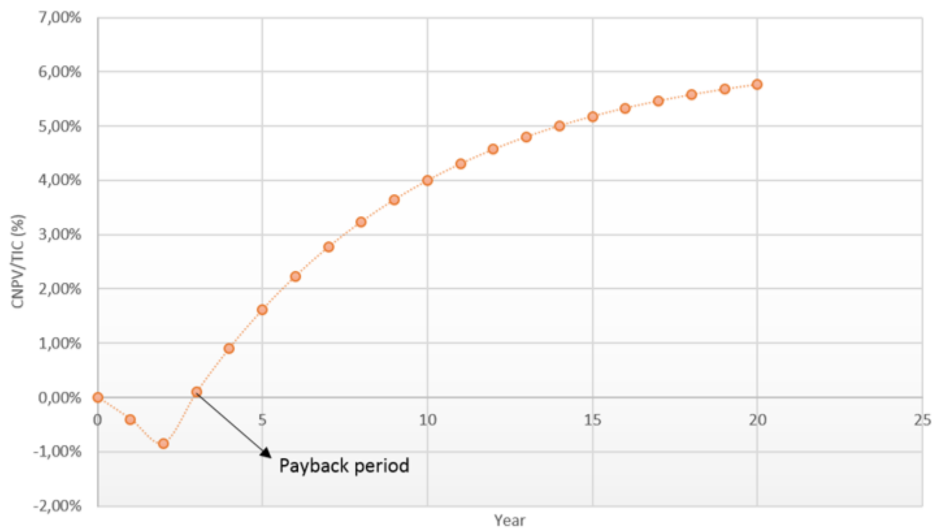

Figure 3. CNPV in ideal conditions

In the first and second years there was a graph decline because at the beginning of production there were costs incurred for the needs of projects such as the purchase of production equipment and land to build industry. The payback period occurs when the initial capital issued has returned due to a sale and generated profit. Profits obtained each year increase until the 20th year. Based on the graph, the production of MgO nanoparticles carried out on an industrial scale was considered a profitable project in accordance with previous research [12].

3.2 Variation in tax increases

Figure 4 shows the effect of tax increases on CNPV/TIC. The x-axis is the year of production while the y-axis is the CNPV/TIC value which is affected by changes in tax prices. The price of taxes varied from 10%, 15%, 20%, 25%, 30%, 35%, and 40%.

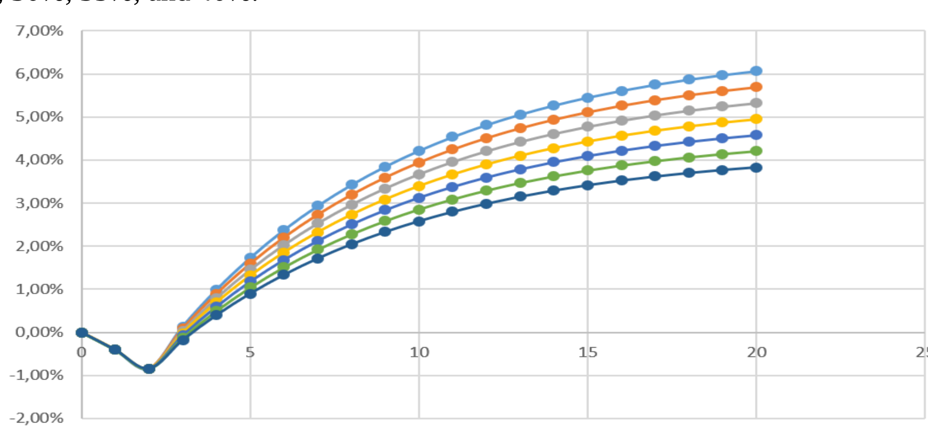

Figure 4. Variation of the tax increase to the value of CNPV / TIC

PBP value for each variation of the tax increase becomes different, the greater the value of the tax, the year of return or PBP is longer. With the same production time of 20 years, the company with the obligation to pay tax of 10% has the biggest profit compared to the company's profit if there is a tax increase. This shows that the greater the tax value that must be paid, company received more less profit [13].

3.3 Variation in Selling Prices

Figure 5 shows the effect of the selling price on the value of CNPV/TIC with the x-axis is the year of production and the y-axis is CNPV/TIC with the effect of the selling price value. Variations in selling prices made were the range if increased and also reduced, namely 130%, 120%, 110%, 100%, 90%, 80%, and 70%.

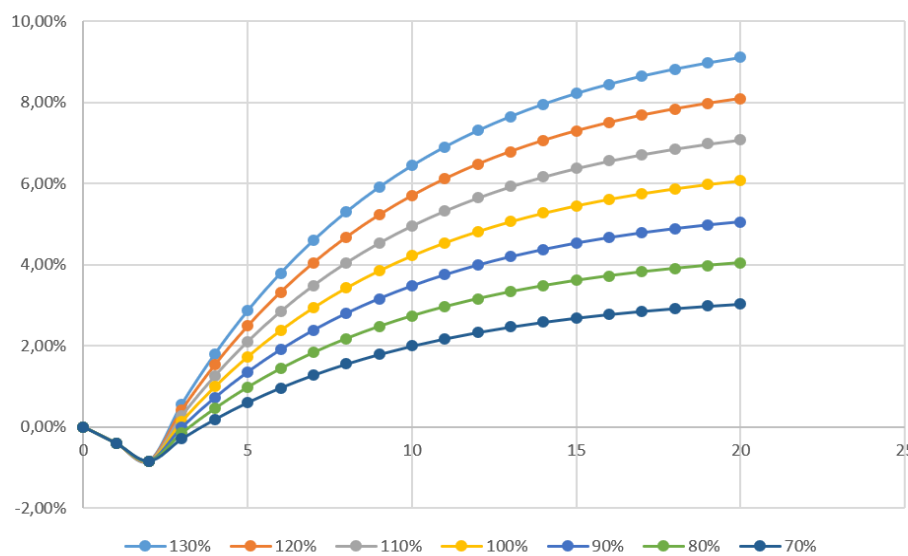

Figure 5. Variations in selling prices to CNPV / TIC values

Based on Figure 5, the variance of selling price 130% shows the fastest payback period or PBP while the 70% selling price shows the longest PBP. The payback period (PBP) was faster if the selling price increased, and was longer if the selling price lowered. The profits obtained with the same production time that is 20 years show that if the selling price is higher, the profit gained is greater, and if the value of the selling price is reduced, the profits obtained is less [12].

3.4 Variation in Raw Material Prices

Figure 6 shows the variation of raw material price against the value of CNPV/TIC. The x-axis is years of production and the y-axis is CNPV/TIC which is affected by the increased of raw material price. Variations in the increase in raw material prices made were 0% (no increase), 10%, 20%, 30%, 40%, and 50%. Raw materials without price increases show the highest graph with the fastest PBP period. Raw material with an increase of 50% shows the longest PBP.

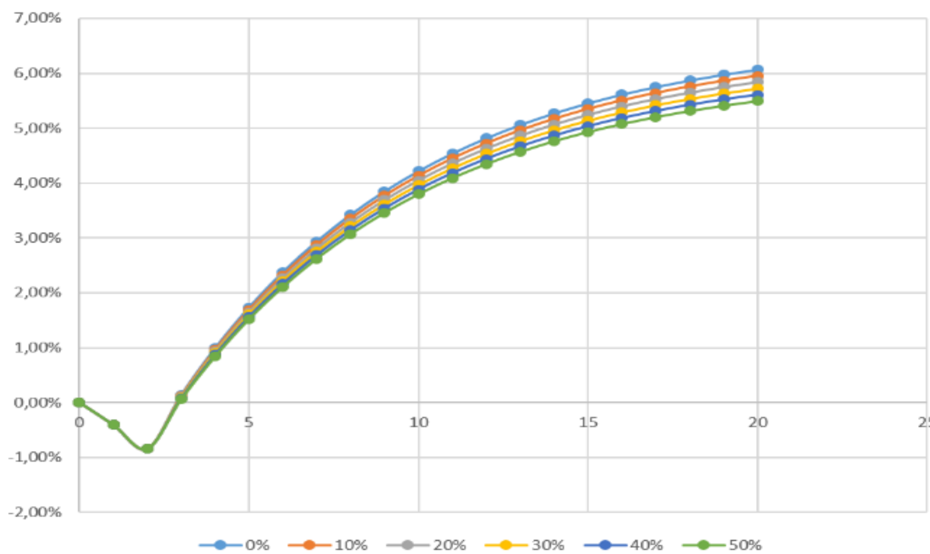

Figure 6. Variations in raw material prices for CNPV / TIC

Based on Figure 6, if an increase in raw material prices occurs, the CNPV/TIC graphic was change. The payback period or PBP does not change too much if the raw material has increased slightly. However, if the increase reached 50%, PBP and the benefits seen decreased. This shows that the greater the price of raw material, the benefits obtained is reduced and the PBP was longer [13].

4. Conclusion

We have conducted a study to evaluate economics and analyzed the feasibility of producing MgO nanoparticles by physicochemical methods. Under ideal conditions, PBP or the payback period occurs in the third year and profits increase until the project period is 20 years. The value of CNPV/TIC and PBP is greatly influenced by several factors such as variable costs, sales tax, and product selling prices. One of the benefits of MgO nanoparticles is as an antimicrobial in the water filtration process.

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