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To cite this article: A B D Nandiyanto et al 2018 IOP Conf. Ser. Mater. Sci. Eng. 306 012011

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Economic Evaluation of the Production Magnesium Oxide Nanoparticles via Liquid-Phase Route

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Abstract. The purpose of this study was to evaluate the production of magnesium oxide (MgO) nanoparticles. The evaluation was done in two perspectives: engineering and economic evaluation. The engineering perspective concerned about the analysis of the production rate based on the available apparatuses and raw materials, completed with mass balance calculation. The economic analysis was conducted based on several economic parameters: gross profit margin (GPM), internal return rate (IRR), payback period (PBP), cumulative net present value (CNPV), break even point (BEP), and profit to investment (PI). The engineering perspective showed that the production of MgO is feasibly done in small scale industry. This is verified by the potential production using current available apparatuses and raw materials in the market. Economic analysis obtained that the present project is profitable. But, for some cases, further studies must be done to get the present production process is attractive for investor.

1. Introduction
Magnesium oxide (MgO) is one of the most useful ceramics materials because this material has high melting temperature (about 2800°C) [1]. MgO usually used for catalysis and toxic waste remediation or as additive material on paint [2]. MgO also has good additive properties, which can be applied in high fuel oil [3].

Several synthesis methods for the production of MgO have been reported: liquid-phase, gas-phase, and vapor-phase. But, in this study, we delivered the analysis in the liquid-phase method only [3]. The liquid-phase (known as wet method) is valuable from conservative to conventional process since this method uses simple equipment for the experiment [4].
MgO is needed in industry, environmental, and health product. MgO in industry used as catalyst in many applications include organic carbonates synthesis catalyst [5]. Another application of MgO is used in steel manufacturing because of its highly corrosion resistant [6]. MgO in recent year has been investigated and reported for its effectiveness in absorbing Uranium [7]. In addition, an experiment for MgO has been done for maintain the balance of the environment with green synthesis by using extract of natural source such as Rambutan (*Nephelium lappaceum* L.) [8]. The development of MgO research in health product has been found due to its antibacterial activity. This material is toxic for bacteria at specific concentration [4].

Based on current developments of MgO material, here, the purpose of this study was to analyze the production of MgO material. The evaluation was done in two perspectives: engineering and economic evaluation. The engineering perspective concerned about the analysis of the production rate based on the available apparatuses and raw materials, completed with mass balance calculation. The economic analysis was conducted based on several economic parameters: gross profit margin (GPM), internal return rate (IRR), payback period (PBP), cumulative net present value (CNPV), break even point (BEP), and profit to investment (PI). In this study, the analysis was focused on the production of MgO based on reference [3].

2. Methods

In short of this study, the first analysis is the production of MgO based on literature [3]. In this case, we selected Agrawal et al [3] as the main reference. Then, the analysis was continued by analyzing available apparatuses and raw materials in the online shopping web that are used for the production of MgO. This analysis is important to ensure the possible production of MgO in the small scale industry.

To ensure the engineering perspective, the analysis is followed by mass balance calculation. This mass balance is important for understanding how much mass flow must be done for the production of MgO per year.

The mass flow was then compared to the economic analysis to get gross profit margin (GPM), internal return rate (IRR), payback period (PBP), cumulative net present value (CNPV), break even point (BEP), and profit to investment (PI).

3. Results and Discussion

3.1. Engineering analysis

![Figure 1. Illustration model for the production of MgO nanoparticles. Apparatuses (a), (b), (c), (d), (e), (f), (g), (h), (i), and (j) are water container, water purification process, basic mixing tank, batch reactor, decantation container, filtration, ethanol container, oven furnace, ball mill, and oven vacuum, respectively.](image)
Figure 1 shows an illustration model for the production of MgO material. The system contains several apparatuses. Figure 1(a) is the water container for storing water from natural resource, such as river. Then, prior to using, the water must through water purification process (shown in Figure 1(b)). This purified water is then used for dissolving natrium hydroxide in basic mixing tank (See Figure 1(c)) as well as being used as solvent. The solute natrium hydroxide (as a basic solution) is then put into the Batch Reactor (see Figure 1(d)). In this batch reactor system, the basic solution is reacted with magnesium nitrite (as Mg(NO$_2$)$_3$·6H$_2$O). The process is stirred for 2 hours [4]. The reaction occurs can be described as [4]:

$$\text{Mg(NO}_3\text{)}_2\cdot6\text{H}_2\text{O} + 2 \text{NaOH} \rightarrow \text{Mg(OH)}_2 + 2\text{NaNO}_3$$

After homogenious magnesium hydroxide (Mg(OH)$_2$) is obtained, the solution is flowed into decantation container (See Figure 1(e)). The decantation process is precipitated for 24 hours [4]. After sediments are formed, the solution is moved to other containers: one is for waste and the other is for the product. The product is then washed and filtrated (See Figure 1(f)). In short of the filtration process, three steps of purification are done [4]. First step is the washing process with water from water purification system (see Figure 1(b)), the second is by ethanol from ethanol container (see Figure 1(g)), and the last step is by rewashing process by water from water purification system (see Figure 1(b)). All utilized water and ethanol is streamed into waste container. The sediment is then dried using oven furnace (See Figure 1(h)) at 80 °C for 4 hours [3]. In the drying process, oxidation reaction of magnesium hydroxide happens, resulting MgO. The reaction is shown in the following [4]:

$$\text{Mg(OH)}_2 \rightarrow \text{MgO} + \text{H}_2\text{O}$$

After the oxidation process, dry solid of MgO is destroyed using ball mill process (See Figure 1(i)) [3]. Ball mill is selected since this method is effective to break down the particle size [9].

The next process is calcination process [3]. MgO, which has been destroyed to nanoparticles, is heated again in oven vacuum (see Figure 1(j)) [8]. This process takes 3 hours at 400 °C [3]. After the calcination process, MgO is wrapped and packaged for the market.

To calculate the mass balance, we used the following assumptions:

- As a raw material, we used magnesium nitrate (Mg(NO$_3$)$_2$·6H$_2$O) and natrium hydroxide (NaOH)
- The loss of material during the washing process is assumed approximately 5%.
- The efficiency of the reactions is assumed approximately 100%.
- The material lost during moving/transferring process is assumed approximately 5% for each movement. The movement occurs twice: after the decantation process and after the filtration.
- The loss of material mass during heating process is assumed approximately 5%.
- The loss of material mass during ball milling process is assumed approximately 5%.

Based on the ideal calculation, 260.5 g of Mg(NO$_3$)$_2$·6H$_2$O reacts with 40.1 g of NaOH. This reaction can create 116 g of MgO. However, using above assumptions, the mass balance calculate that the process can create 85.3 g of MgO nanoparticles.

3.2. Economic evaluation

To ensure the feasibility of the production of MgO nanoparticles, economic evaluation must be done. Several assumptions were made

- The analysis used USD as a main currency, in which 1 USD is equal to 13,000 IDR.
The basic electricity cost is assumed to be IDR 1.467,28/kWh
The labor wage is IDR 18.000.000 for the total of 5 workers.
Selling price for MgO is assumed approximately 139 USD/Kg.
The discount rate is 15% annually.
Import and shipping fees for the material or purchased equipment are omitted.
The project period is 20 years.

Figure 2 shows the relationship between total investment cost (TIC) with CNPV and the year of MgO production. The GPM being created is 2.631,82 USD per year. The result from the mass analysis showed that the PBP for this project is 11,89 years from starting year. From the graph, we concluded that the business still profitable near to 20 years production although in the initial 11 years results in the negative CNPV value.

Based on above analysis, the profit from this project is not attractive. The reason of this analysis is due to several reasons: high-cost equipment, high-cost precursor materials, and the high loss of mass in some processes such as filtration process.

4. Conclusions
The present study shows the economic evaluation and engineering perspective for the production of MgO nanoparticles via liquid-phase method. Engineering analysis showed that the process can be done in small scale industry. However, the result of economic evaluation shows approximately not too attractive and not profitable. This is because several reasons include loss is too high in filtration process, high-cost equipment and precursor materials.
References


