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Economic Evaluation on Production of ZnO Nanoparticles from Laboratory Scale to Industrial Scale

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Abstract

Background/Objectives: ZnO nanoparticles are used to obtain inorganic antibacterial and UV-blocking properties. The purpose of this study is to evaluate the increase in the production of ZnO nanoparticles from the laboratory scale to the industrial scale. Methods/Statistical analysis: Economic evaluation is carried out from an engineering and economic perspective. From the engineering evaluation, the results show that the production of prospective ZnO nanoparticles uses modern methods and technology. Findings: From an economic point of view, the results show that the production of ZnO nanoparticles on an industrial scale can benefit from certain conditions of raw materials, certain conditions of selling prices, and certain conditions of income tax. All evaluation parameters give a positive price. The development of this project needs to be added especially regarding additional strategies to increase profits and to attract investors. Improvements/Applications: In this study provides sufficient promise for the production of ZnO nanoparticles in developing countries.

Index Terms

Export, R&D activities, logit, Multinomial logit, KIS Data

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I. INTRODUCTION

Economic evaluation is important in the industrial world, one of which is the Increase in Production of ZnO Nanoparticles from Laboratory to Industrial Scale. ZnO nanoparticles are used to obtain inorganic antibacterial and UV-blocking properties [1]. In addition, inorganic UV blockers are preferred over organic UV blockers [2]. In recent years, nano semiconductor particles have attracted more interest because of their optical, electrical and mechanical properties. Among these various semiconductor nanoparticles, zinc oxide (ZnO) has attracted tremendous attention. This is confirmed by facts in various applications, for example energy conversion, luminescence, photocatalysis, electrostatic dissipative coatings, transparent UV protective films, and chemical sensors [3,4]. In fact, zinc oxide (ZnO) and titanium dioxide (TiO2) are non-toxic and chemically stable under exposure to high temperatures and UV. In addition, nanoparticles have a large surface area to volume ratio, which will produce a significant increase in effectiveness in blocking UV radiation when compared to other bulk materials [5].

There are various methods of making ZnO nanoparticles, previous studies reported various approaches in the synthesis of ZnO nanoparticles, namely the vapor phase, solution, and solids [6]. In the vapor phase, synthesis methods can be found in chemical vapor condensation, plasma-metal hydrogen reactions, and laser pyrolysis. In the liquid phase, the method is the hydrothermal, sol-gel, microemulsion, sonochemical, and microbial processes. Processes in the solid phase can be found by means of ball milling [7,8]. The sol-gel method of metal oxide synthesis offers unique advantages because of the possibility of obtaining metastable materials, achieving superior purity and homogeneity of product compositions at moderate temperatures with simple laboratory equipment [9], and obtaining good crystallinity from the resulting product [10]. Although there are many reports that confirm prospective methods for producing ZnO nanoparticles, there are almost no reports on analysis for feasibility studies in large scale production. In fact, this information is important to provide better candidates for industry practitioners to apply this method in realistic applications [11].

The aim of this study is to evaluate the possibilities in large-scale production of ZnO nanoparticles. This method is evaluated using two main perspectives on ZnO nanoparticle production, namely engineering and economic evaluation. Several parameters are calculated to support economic evaluation [12]:

- Payback period (PBP; to assume the possibility for annual profit).
- Breakeven point (BEP; to get the minimum requirements of production capacity).
- Cumulative net present value (CNPV; to predict project conditions as an annual production function).

Some information from commercial websites is adopted to support engineering and economic analysis, such as chemical prices, components for utilization, and equipment specifications. To get a feasibility study, the data is calculated to get the maximum ZnO fabrication that can be applied to the small company industry. In addition, this research is important to help in making decisions whether fabricating ZnO nanoparticles is beneficial or not. Also, this study can be used to suggest ways to optimize projects, to benefit economic growth. All calculations of this study were carried out under specific conditions [13]. Additional variables used are variations in prices of raw materials, variations in selling prices and variations in taxes.

II. METHODE

A. *Synthesis of ZnO Nanoparticle Theory*

Zinc oxide nanoparticles are synthesized following procedures reported elsewhere [14]. Synthesis is carried out at a high saturation level, to achieve a nucleation rate that is far greater than the growth rate [15]. ZnCl2 (5.5 g) was dissolved in 200 mL of water at 90°C in an oil bath. 16 mL of 5 M NaOH solution is added dropwise to zinc chloride solution, with gentle stirring for 10 minutes at 90°C. The particles are separated from supernatant dispersion by sedimentation. Purified particles were then permeated with 2-propanol in an ultrasonic bath for 10 minutes at room temperature. The peptization process is needed to disrupt microaglomerates and release nano units from zinc oxide [16]. The particles were then collected by centrifugation at 6,000 rpm for 15 minutes. The thermal treatment of the particles at 250°C for 5 hours caused the formation of ZnO.

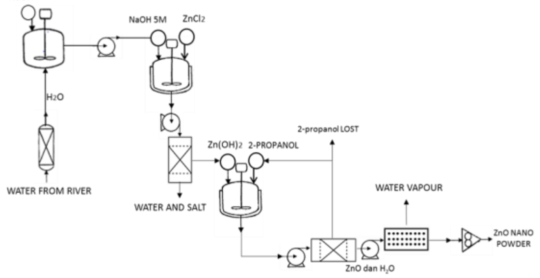

Fig. 1. Process Flow Chart of ZnO nanoparticle production

The chemical reactions that occur in the ZnO nanoparticle synthesis process are as follows:

$$ZnCl_{2\ (aq)} + NaOH_{\ (aq)} \rightarrow Zn(OH)_{2\ (s)} + NaCl_{\ (aq)}$$
$$Zn(OH)_{2\ (s)} \Leftrightarrow ZnO_{\ (s)} + H_2O_{\ (g)}$$

B. Economic Evaluation

The method used in this research is based on the analysis of material and equipment prices, as well as equipment specifications sourced from online websites such as Alibaba.com. Data processing is calculated based on simple mathematical calculations using the Microsoft Excel application to obtain economic evaluation parameters: BEP, PBP, and CNPV. Calculation of these parameters is based on literature [13], which is presented in the following formula:

- BEP (Break Event Point) to get the minimum production capacity.
- PBP is a calculation carried out to predict the length of time needed to return the total initial cost. The simplest way to get PBP is determined from the CNPV curve by looking at when CNPV reaches zero points for the first time.
- CNPV (cumulative net present value) is the calculation of the total NPV value from the start of factory construction to the end of factory operations. In short, CNPV can be obtained from the amount of cumulative financial flows each year.
- Economic evaluations in ideal conditions are based on references [12] with the following assumptions:
- The period of production evaluated is 10 years
- The price of all equipment is based on an online buying and selling site, Alibaba.com
- Raw material prices are based on an alibaba online buying and selling site from several manufacturers. The price of each chemical compound used in this evaluation is as follows: zinc chloride (ZnCl2) IDR 359,600/ Kg, sodium hydroxide (NaOH) IDR 42,000/ Kg, 2-propanol IDR 140,000/L and ZnO nanoparticles IDR 28,319,900/Kg.
- In one day of production, 2.639 Kg of nanoparticles were produced
- The utility cost is assumed to be IDR 1,467/ KWh. The amount paid in a year is IDR 69,975,900.
- Labor wages in ideal conditions for 5 people are IDR 186,000,000 per year
- All prices obtained in USD units are converted to IDR with a conversion value of 1 USD = IDR 14,150
- Income tax under ideal conditions is 10%
- All chemical compounds used in the production of ZnO nanoparticles are scaled up to 1000 times the amount stated in the literature [14]
- The reaction conversion rate is assumed to be 100%
- There is a loss of mass of chemical compounds transferred by 5% of the initial mass in each transfer process
- The water used in the production process is purified, deionized water obtained from the water treatment plant.
- This production process is carried out underground. Therefore, land is calculated as the initial cost of industrial development and is recovered after the project (at the end of the project).
- A working day in one year is 300 days and the remaining days are used to clean and prepare the process.

III. RESULTS AND DISCUSSION

A. Engineering Perspective

Synthesis of ZnO nanoparticles based on the technical point of view, it is possible to make more improvement. That's because, the scaling process can be implemented using commercially available equipment. Furthermore, by counting the project with 300 processing cycles per year, the suggested scheme is prospective to produce about 0.7917 tons of ZnO nanoparticles by consuming 1.632 tons of zinc chloride and 0.96 tons of sodium hydroxide per year. Then, analysis of total equipment costs requires a total cost of IDR 312,062,000. Adding Lang Factor to the calculation, the TIC must be less than IDR 1,385,555,280. This value is relatively economical, and this project requires less investment funds. With a project life span of 10 years, the results show that all projects can produce 7.917 tons of products in ideal conditions. Some of the raw materials used in this production are listed in Table 1, besides the conversion rate for all reactions is 100%. Costs of raw materials, utilities, and labor are shown in Fig. 2.

The data in Table 1 shows the amount of raw material used in the one-time synthesis of ZnO nanoparticles. In accordance with the literature [14], each raw material in the scale-up is 1000 times, so that the amount of sodium hydroxide which was originally as much as 3.2 grams changed to 3.2 kg. The amount of zinc chloride which was originally as much as 5.44 grams changed to 5.44 kg. Similarly, the amount of 2-propanol which was originally as much as 50 mL changed to 50 L. And the conversion of reactions in chemical reactions that occur by 100%.

The bar diagram in Fig. 2. shows a comparison of the prices of raw materials, utilities and labor required in the one-time process of nanoparticles ZnO synthesis. Where the price of raw materials is high above the price of utilities and labor, which is IDR 9,090,624 per day. While the prices of utilities and labor are IDR 233,253 and IDR 451,522. Based on the bar chart comparison between the prices of raw materials, utilities and labor, it can be seen that the price of raw materials is very influential in increasing the production of ZnO nanoparticles.

Table 1. SOME RAW MATERIAL USED

NaOH	$ZnCl_2$	2-Propanol	Reaction Conv
3.2 Kg	5.44 Kg	50 L	100%

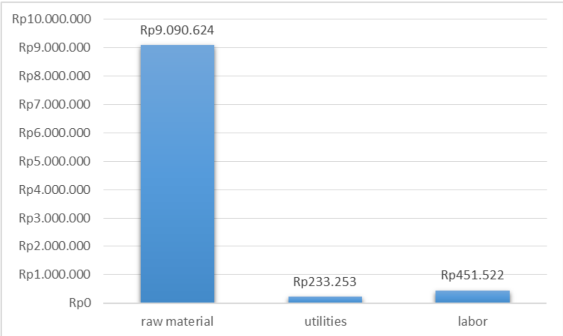

Fig. 2. Costs of raw materials, utilities, and labor

B. Evaluate the ideal conditions

The graph in Fig. 3. shows the curve of the CNPV / TIC relationship to lifetime under ideal conditions for the production of ZnO nanoparticles. From this picture, CNPV / TIC changes from year to year during ten years of production. There was a decrease in profits from year 0 to around year 2. This decrease occurred in the early stages of production due to the initial cost of the project. Increased profits began to occur in the second year as the production process began. Around the 2.3rd year, there was a shift back in investment costs or a payback period. And profits will continue to increase thereafter until the 10th year. Thus, based on this analysis, the nanoparticles ZnO synthesis project is declared profitable to be carried out on an industrial scale.

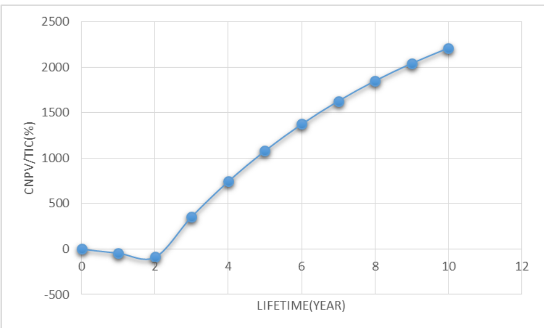

Fig. 3. Ideal conditions for CNPV under various economic evaluation parameters

C. Effect of raw materials

The graph in Fig. 4. shows the CNPV / TIC relationship curve to lifetime by comparing several different raw material values. Five variations in the value of raw material were carried out, namely curves under ideal conditions, the value of raw material varied by -100%, -50%, + 50%, + 100% of the value of raw material in ideal conditions. This variation is done with the assumption that the production capacity in each variation is the same as the production capacity under ideal conditions, but with different raw material prices. Changing variable costs to -100% means that all costs required to process at the factory are considered free, while changing variable costs to -50% means that all costs required for the production process are half of the original price. This evaluation is carried out to analyze the effect of changes in raw material prices on the profits of ZnO nanoparticles production, namely the CNPV / TIC value changes from year to year. There was a decrease from 0-2 in all variations, according to the curves under ideal conditions. This decrease occurred due to the condition of initial capital which was carried out before the production process began.

By comparing the five different raw material price conditions in Fig. 4., it can be seen that this project is still profitable to do if the production is carried out with raw material prices of -100%, -50%, + 50%, + 100% of the value of raw material in ideal conditions . However, the difference is seen in the rate of increase in CNPV / TIC annually. From the graph, it can be concluded that the greater the price of raw material used, the rate of increase of CNPV / TIC is slower. That means that with the price of raw material increasing, the rate of profit income will decrease. This happens because raw material is closely related to overall production costs. With a fixed production capacity and increasing raw material prices, the profits will decrease. But from this evaluation it is also known that this project is still profitable to do even if the price of raw material is 100% greater than the price of raw material in ideal conditions.

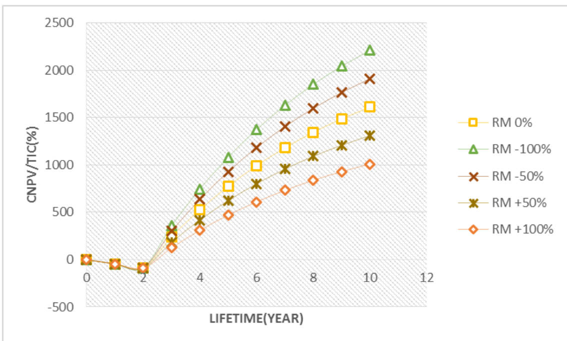

Fig. 4. CNPV curves under various conditions of raw material costs

D. Effect of sales

The graph in Fig. 5. shows the CNPV / TIC relationship curve to lifetime with a comparison of several different sales prices. There are seven variations in sales value, namely the curve under ideal conditions, the value of sales prices varied by 90%, 80%, 70%, 60%, 50% and 40% of the value of sales prices under ideal conditions. This variation is done with the assumption that the price of raw materials for the production process in each variation is the same as the price of raw materials under ideal conditions, but with different sales prices, so that it can be seen the effect of changes in sales prices on the production benefits of nanoparticles ZnO. CNPV / TIC value changes from year to year. There was a decrease from year 0 to year 2 in all variations, according to the curves under ideal conditions. This decrease occurred because the initial cost of setting up the project carried out before the production process begins.

From the graph in Fig. 5., it is known that the rate of increase of CNPV / TIC will decrease along with the decrease in the specified sales price. This happens because the sales price is one aspect of the production costs associated with profits derived from the project. However, despite the decline in the rate, it can be concluded that changes in sales prices to 40% variation in sales prices will remain profitable in the production of ZnO nanoparticles.

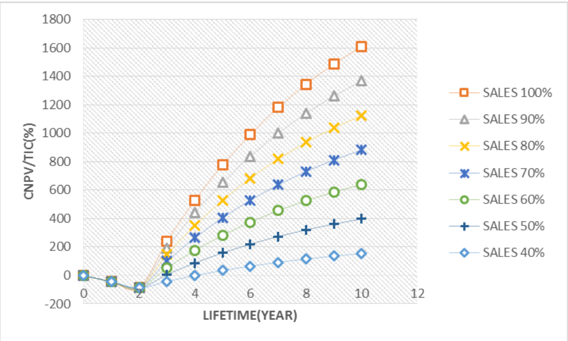

Fig. 5. CNPV curves in various conditions of sales prices

E. Effects of income tax

The graph in Fig. 6. shows the CNPV / TIC relationship curve to lifetime by comparing several different income tax values. Five variations in the value of income tax were carried out, namely 15%, 20%, 25%, 30% and income tax under ideal conditions of 10%. This variation is done with the assumption that the production capacity is the same, but with a different amount of income tax. CNPV / TIC value changes from year to year. There was a decrease from year 0 to year 2 in all variations, according to the curves under ideal conditions. This decrease occurred because the initial cost of setting up the project carried out before the production process begins.

From the graph in Fig. 6., it is known that the rate of increase in CNPV / TIC will decrease with increasing income tax. The income tax has a significant effect on the CNPV / TIC rate so that there is a different payback period in each variation. Under ideal conditions and other income tax conditions, the payback period occurs before the 2.5th year. From the graph it is known that the ideal conditions are the most favorable conditions and with increasing income tax, it will cause the rate of increase in cash flow. This happens because the incoming cash flow will be reduced because it is cut off by the income tax issued, thereby reducing the incoming profits.

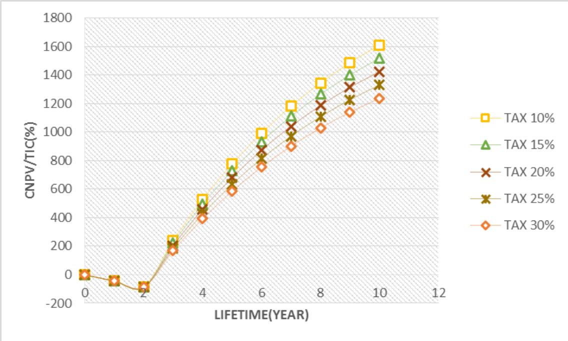

Fig. 6. CNPV curves under various income tax conditions

IV. CONCLUSION

In this study, the production of ZnO nanoparticles on an industrial scale is quite useful if seen from several factors: CNPV / investment for 10 years, BEP which is quite low with only 1 production / day, and rapid PBP that is less than 3 years. This research shows that the industry will be a promising project for ASEAN in the future.

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