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Computation Application: Techno-Economic Analysis on the Production of Sodium Dithionite

Sultan Nazmi Chairul Islam
Kimia, FPMIPA, Universitas Pendidikan Indonesia
Snazmi25@upi.edu

Abstract (English)
The economic evaluation is one of the key points in building chemical industries. This paper presented a preliminary economic evaluation of the large-scale production of Sodium Dithionite using precipitation method, which is very useful for helping decision whether the fabrication of this material profitable or not. Particularly, the study was done by changing the cost of raw material, which was compared to several economic parameters such as GPM, PBP, and CNPV. The result showed that the project was profitable by increasing raw material cost below 100% from the estimated raw material cost, informing the fact for the prospective fabrication for fulfilling the demand of Sodium dithionite.

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Abstrak (Indonesia)
Evaluasi ekonomi adalah salah satu poin penting dalam industri kimia bangunan. Makalah ini menyajikan evaluasi ekonomi awal produksi Sodium Dithionite skala besar menggunakan metode presipitasi, yang sangat berguna untuk membantu memutuskan apakah fabrikasi bahan ini menguntungkan atau tidak. Secara khusus kajian tersebut dilakukan dengan mengubah harga bahan baku yang dibandingkan dengan beberapa parameter ekonomi seperti GPM, PBP, dan CNPV. Hasilnya menunjukkan bahwa proyek ini menguntungkan dengan meningkatkan biaya bahan baku di bawah 100% dari perkiraan biaya bahan baku, sehingga menginformasikan prospek fabrikasi untuk memenuhi permintaan Sodium dithionite..

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Introduction

Environmental pollution, caused by industrial and agricultural activities, has seriously influenced the quality of life and eco-system in the past several decades [Reddy *et al.*, 2015]. Various environmental pollution problems was led by different industries due to their diverse processes and products such as refractory halogenated organics generated from organic chemical industry [Bigot *et al.*, 2017], heavy metal pollutants from mining and electroplating industry [Song *et al.*, 2018], and high-valent oxyacid salts, for example nitrates, produced in human life [Sergi *et al.*, 2018] etc. Hence, it is a great challenge to remove the various toxic pollutants effectively [Santhosh *et al.,* 2015]. Several emerging pollutants have high potential toxicity to living organisms and are a great concern to the ecosystems, for example, the typical halogenated organic pollutants (perfluorocarboxylic acids, pesticides, personal cares (PPCPs) and pharmaceuticals), toxic inorganic pollutants including metal ions etc. It is urgent and necessary to degrade these pollutants effectively. However, it is difficult to remove the typical refractory organics using the traditional treatment (bio-oxidation, adsorption, coagulation and sedimentation etc) [Amin *et al.*, 2014].

Dithionite or hydrosulfite (S2O42-) is a strong reducing agent and of great industrial significance, commonly known as insurance powder. It was named by the special chemical bond of S-S between the two SO2- [Makarov & Silaghi, 2013]. It always has two different forms of dihydrate and anhydrous salt. The dihydrate salt is a slight yellow flaky crystal, which is extremely unstable in nature and only exists in the alkaline solution. The dihydrate salt will be dehydrated and converted into the anhydrous one when being heated to a certain temperature. In addition, the anhydrous salt is a white crystalline powder and is unstable in the drying state at room temperature. The structural formula of dithionite is shown in Figure 1.

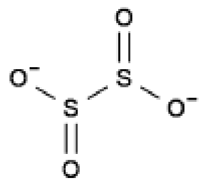

Fig 1. The Structural Formula of dithionite

Dithionite has been widely used in pollution control due to the low cost, reactive properties, and low toxicity. The dithionite is widely applied for the removal of heavy metal and organic pollutants in groundwater. The most common applications focus on the dehalogenation of halogen organic, reduction of high-valence oxyacid salt (e.g. ClO_3^-, NO_3^- etc.) and heavy metal etc. Except for the environmental application, dithionite also can be applied in the chemical industry such as printing, dyeing, and food handling. It can be served as the reagent of dyeing, cleaning, and bleaching, especially for the wood pulp paper (Song, 2020).

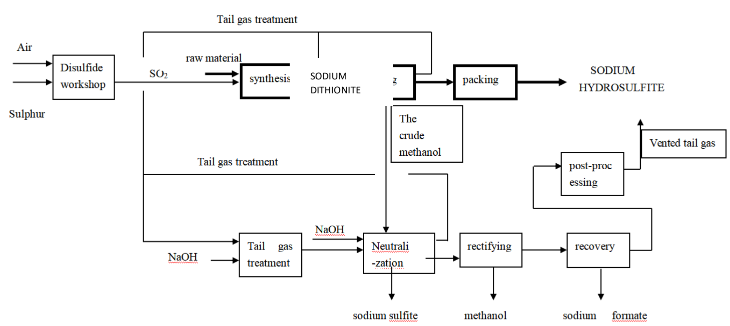

Fig. 2. Flowchart the process of making sodium dithionite

Figure 2 provides a brief explanation of each symbol used in the flowchart image for making sodium dithionite. Each symbol has a specific meaning and function in describing the steps in the production process. This explanation will help readers understand each section of the flowchart better.

Here, the purpose of this study was to evaluate the possibility in the large-scale production of Sodium Dithionite. This method was evaluated using two main perspectives of Sodium Dithionite production: engineering and economic evaluation. Several parameters were calculated to support the economic evaluation [Nandiyanto,2018]:

 Gross profit margin (GPM; to predict the economic condition in rough calculation).

 Payback period (PBP; to assume the possibility for annual profit).

 Cumulative net present value (CNPV; to predict the project condition as a function of annual production).

Several informations from commercial website was adopted to support both engineering and economic analysis, such as chemical price, components for utilization, and specification of the apparatuses. To get the feasibility study, the data was calculated for getting the maximum yield of Sodium Dithionite fabrication that can be applied on the small enterprise industry. In addition, this study is important to help in making decision whether the Dithionite fabrication is profitable or not. Also, this study can be used for suggesting ways to optimize the project, indeed, to give benefit for economic growth. All the calculations of this study were done in the specific conditions [Nandiyanto *et al.*,2018]. Additional variables used was raw materials [Rubio *et al.*, 1997].

Method

The method used in this study based on an analysis of the prices of materials and equipment, as well as the specifications of the equipment sourced from the online web such as alibaba.com. Data processing is calculated based on simple mathematical calculations using Microsoft Excel applications to obtain economic evaluation parameters: GPM, PBP, and CNPV. The calculation of these parameters based on the literature [Garret,2012], which presented in the following formula.

 The GPM parameter is obtained by reducing sales (S)with raw materials (R).

GPM = S – R (Mucillo *et al.*,2004)

 PBP is a calculation conducted to predict the length of time needed to return the total initial cost. The simplest way to get PBP was determined from the CNPV curve by seeing when CNPV reaches zero points for the first time.

 CNPV (Cumulative net present value) is the calculation of the total NPV value from the onset of the factory construction to the end of the plant operation. In short, CNPV can be obtained from the amount of cumulative financial flows each year.

CNPV = Σ NPV (Kargari *et al.*, 2007)

 TIC (Total Investment Cost), is the initial cost of capital that must be provided at the beginning of production. TIC must be predicted based on the Lang Factor [Shalahuddin *et al.*,2019].

Then the feasibility test for the present economic evaluation was done by varying the value of raw materials in five conditions (i.e., 100%, 50%, 0%, -50%, -100%).

Result and Discussion

In this Sodium Dithionite production project, several key factors need to be taken into account. These factors include the amount of sodium dithionite production, and the details of the work and time required by each worker. In this discussion, we will evaluate the results of these calculations.

Based on this research, the results obtained show that sodium dithionite production can be carried out using the sulfur dioxide reduction method with zinc powder. This method is the most commonly used industrial method for producing sodium dithionite. The sodium dithionite production process involves a chemical reaction between sulfur dioxide and zinc powder carried out in a chemical reactor. After the reaction is complete, the sodium dithionite formed is separated from the reaction mixture and then produced in solid form.

To calculate the salary of a laboratory assistant who works in a laboratory making sodium dithionite, several factors need to be taken into account such as educational qualifications, work experience and work location. The salary set for workers is IDR 85,000 per day, this salary may vary depending on the factors previously mentioned. In addition, keep in mind that laboratory assistant salaries are usually lower than the salaries of technicians or chemical engineers who have higher educational qualifications and work experience.

Equipment and Material Cost Analysis in Sodium Dithionite

In our analysis of the costs of equipment and materials required in gold production, we have identified equipment and materials that are essential to running gold mining and production operations. The following are the results and discussion regarding the equipment and materials needed:

Required Equipment

In the production of sodium dithionite, there are several equipment and materials needed. The following is an analysis of the costs of equipment and materials required in the production of sodium dithionite:

1. Equipment
• Chemical reactor: around IDR 135 million
• Electric Furnace: around IDR 375 million
• Pump: around IDR 7 million
• Storage tank: around IDR 45 million
• Temperature, pressure and flow measuring equipment: around IDR 5 million
• Mechanical powder grinding: around IDR 120 million
• Condenser: around IDR. 19 million
• Analytical Balance: around IDR 10 million
• Mixer: around IDR. 85 million
• Oven: around IDR 54 million
• Factory Scales: around IDR 3 million

The total cost of equipment required for sodium dithionite production is around Rp. 859 million.

2. Material

- Anhydrous Sodium Carbonate: around IDR 45,000 per kg
- Zinc powder: around IDR 300,000 per kg
- Sodium metabisulphate: around IDR 11,500 per kg
- Sodium bisulfite or sodium pyrosulfite: around IDR 10,000 per kg
- Methanol: around IDR 11,347 per liter
- HCl: IDR. 45,000 per liter

The total cost of materials required in the production of sodium dithionite depends on the amount of production produced. However, to produce 3.5 kg of sodium dithionite, approximately 2 kg of anhydrous sodium carbonate, 5 kg of zinc powder, 4 kg of sodium metabisulphate, 2.5 L of methanol and 2 liters of HCl are required. Assuming the price of the materials mentioned, the cost of the materials required to produce 3.5 kg of sodium dithionite is around IDR 136,000.

Engineering Persepective

Some assumptions based on the process are shown below:

- All chemical compositions in the reaction, such as Sodium Carbonate anhydrous, sodium metabisulphate, methanol, Zn Powder, and HCl used for the production of Sodium Dithionite were scaled up 1000 times and calculated based on literature.
- Conversion rate for all reaction was 100%
- Sodium Dithionite obtained have 100%
- The level of production is carried out based on the small industry scale

Economic Condition

Several factors were assumed to analyze the economic perspective:

- The USD (American currency) exchange rate against IDR (Indonesian currency) has been set at 1 USD = 15000 IDR [Bank Indonesia "Foreign Exchange Rate"].
- Prices of In short Sodium Carbonate anhydrous, sodium metabisulphate, HCl and components were based on prices (www.alibaba.com).
- The total investment cost (TIC) was calculated based on the Lang Factor [Nandiyanto *et al.*, 2018].
- This production process was carried out under the purchased soil. Therefore, the land was calculated as the initial cost of industrial development and is recovered after the project (at the end of the project).
- Direct-type depreciation was used for calculating depreciation [Garret, 2012].
- The process needed 1 day to produce 3500 kg of Sodium Dithionite in one cycle [Bari *et al.*, 2019].
- Minimum product purchase is one pack (1 kilograms).
- Working days in one year were 300 days and the rest of the days are used to clean and prepare the process.

- Basic electricity cost was Rp. 1.380 / kWh.
- The total labor was assumed with a fixed value of Rp. 85.000/day.
- The discounted rate and the income tax were 15 and 10% annually, respectively.

Ideal Condition

Fig. 3. shows the payback period occured after the third year of production, and the profit will continuously increase afterwards until the year of 20th. Thus, the production of Sodim Dithionite can be considered as profitable project.

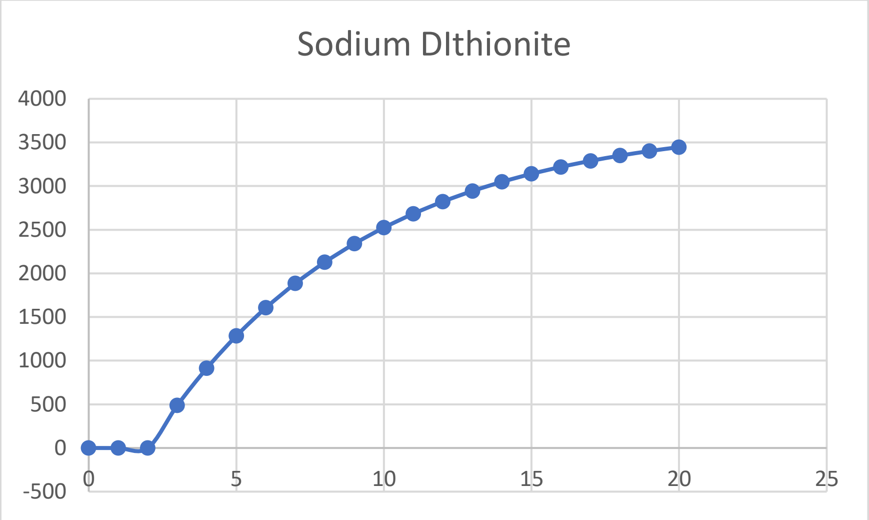

Fig 3. Ideal Condition for CNPV under various parameters of economic evaluation

Effects of raw material

The calculation was carried out by subtracting the sales cost of the product (revenue of products that can be sold) with initial cost of raw materials [Nandiyanto, 2018] to analyze the effect of raw materials on GPM. The result shows that changing raw materials gave a negative impact on the values of GPM, as shown in Fig. 4. Therefore, by increasing the prices of the raw materials, it brought a negative effect on the project. The significant impact occurred when changing the prices of methanol, while Sodium carbonate anhydrous and Zn powder gave a similar impact

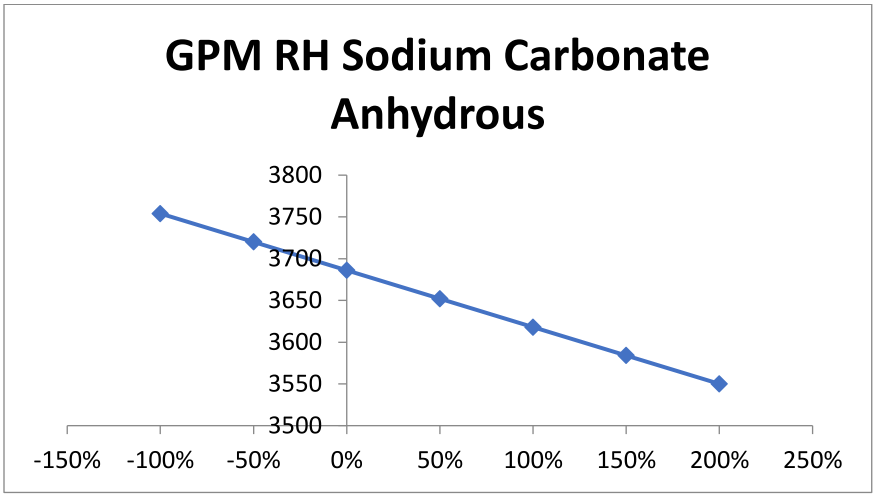

Fig 4. Effect of raw materials i.e Sodium Carbonate Anhydrous

The result from Engineering Perspective

Based on the engineering point of view, it is possible to do more scaling up. It was because the scaling process can be implemented using commercially available and inexpensive equipment. Furthermore, by calculating projects cycles per year, the suggested scheme is prospective to produce around 3.5 tons of Sodium Dithionite by consuming 2 tons of Sodium Carbonate anhydrous, 4 tons of sodium metabisulphite, and 5 tons of Zn powder per year. Then, an analysis of total equipment costs requires a total cost of 57332 USD. Adding the Lang Factor to the calculation, TIC must be less than USD 225.888. This value is relatively economical, and the project requires fewer investment funds. With a project life span of 20 years, the results showed that the entire project can produce 10.5 tons of products in ideal conditions.

The result from Preliminary Economic Analysis

Based on the economic analysis carried out, the project is very feasible both under ideal or non-ideal conditions. However, this is considered only based on changes in the prices of raw materials. The result would be different when there is a change in other parameters of economic evaluation. All analysis were compared to the condition of the bank and the Indonesian currency [Nandiyanto *et al.,* 2018]. A detailed description of the specific conditions based on the analysis is explained as follows:

- Projects can still be profitable if the increase in raw material costs is below than 100% of the estimated raw material costs. The significant decreament occurred due to the changes in the amount of methanol. Zinc powder and Sodium carbonate anhydrous did not cause significant changes.
- Product sales must be carried out in a minimum amount of around 3500 kg per day to maintain the project. When sales prices are reduced, the number of sales product increased. On the contrary, the project will give a loss. Based on the technical analysis, the product from the reaction was not so high.
- Labor costs, utility costs, taxes, and other economic parameter are kept in ideal conditions. It was due to in this analysis, only the effect of changes in raw materials is considered.

In addition to the economic outlook, a project feasibility analysis also needs to be carried out. In this project, GPM and CNPV for cost variables showed promising results in ideal conditions. This perspective based on the Indonesian capital market standards with PBP's analysis showing that this investment will benefit from the third year

Conclussion

Based on the results of the analysis, the ZnO nanoparticles project is prospective from both engineering point of view and preliminary economic analysis. Projects are considered profitable if the increase in raw material costs is below than 100% of the estimated raw materials costs.

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