

# Process Design, Simulation, and Economic Evaluation of a DBSA Manufacturing Plant in the Philippines

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Dodecylbenzene Sulfonic Acid (DBSA) is a key industrial chemical primarily manufactured from Dodecylbenzene and Sulfur Trioxide. Utilizing the advanced Film Sulfonation Process, which involves three major steps, this method significantly enhances DBSA production efficiency. The process starts with the combustion of sulfur to generate sulfur dioxide, followed by the oxidation of sulfur dioxide into sulfur trioxide, and concludes with the sulfonation of dodecylbenzene using sulfur trioxide to produce DBSA. This project proposes the establishment of a modern DBSA manufacturing plant within the Calaca Industrial Seaport Park, with a planned annual production capacity of 30,000 t. Given the projected Philippine market demand of 80,057 t by 2030, the project showcases strong economic potential, starting with a capital cost of approximately 2.5 billion Php, offering a payback period of 5.07 y and an impressive 47.50 % return on investment (ROI). The facility will employ cutting-edge technologies and maintain strict quality standards to ensure the production of premium grade DBSA at competitive costs. Furthermore, the plant will fully adhere to the Philippine environmental and safety regulations, supporting safe, sustainable, and responsible operations. This project aims to address the rising domestic demand for DBSA, contributing to the nation's industrial growth and economic sustainability.

## 1. Introduction

Dodecyl benzene sulfonic acid (DBSA) is a key raw material widely utilized in the detergent and personal care industries for manufacturing products such as soaps, detergents, and shampoos (Verified Market Reports, 2025). It is a viscous brown liquid, with an irritating odor, water soluble, and corrosive to metals and tissues. It is also called as Lauryl benzenesulfonic acid. DBSA has three main structural components which are the benzene ring, a dodecyl chain, and a sulfonic acid group. The benzene ring is responsible for its hydrophobic properties and provides stability to the overall molecule. The dodecyl chain is the non-polar alkyl chain that makes it suitable for the interaction with oily or greasy substances. Lastly, the sulfonic acid group gives the acidic and polar characteristics of the molecule. This increases the ability of the molecule to interact with water as it is highly hydrophilic making it water soluble. The boiling point of DBSA is 227 °C at 1 atm and it has a 10 °C melting point (Spectrum Chemical, 2018).

The combination of DBSA's hydrophobic tail (dodecyl chain) and hydrophilic head (sulfonic acid group) makes it capable of reducing the surface tension between water, oils, and grease, making it suitable for cleaning. This property makes it an excellent surfactant thus, it is usually used to make detergents and other cleaning products due its good dispersing, wetting, foaming, and emulsifying properties. Some of its other applications are emulsifiers, lubricant additives, defoamers, etc. (Silver Fern Chemical Inc., 2024).

DBSA is globally recognized due to its biodegradability and cost-efficiency. It serves as a precursor to linear alkylbenzene sulfonic acid and are widely used in cleansing products. The expansion of the Philippine population, urbanization, and increase in hygiene awareness of people contributes to the demand of cleaning and personal care products. Cleaning products in the Philippines has a steady growth in the market may it be for domestic use or for industrial use (Verified Market Reports, 2025).

Due to DBSA's extensive applications and rising demand, there is an increasing need for large-scale production of DBSA. The Philippines, with its strategic location and growing industrial sector, presents a promising opportunity to establish a DBSA production facility. Currently, the country depends on imports to meet its DBSA needs, making it vulnerable to supply disruptions and fluctuations in global market prices (UN Comtrade, 2024). The primary objective of this plant design is to evaluate the production of DBSA using Dodecylbenzene via Film Sulfonation with Sulfur Trioxide in the Philippines. Specifically, this plant design aims to evaluate the current and projected market demand of DBSA and assess its economic potential in the Philippines and the broader international market, to identify and recommend an optimal location within the Philippines for the manufacturing plant using the Preference Ranking of Organization Method for Enrichment Evaluation (PROMETHEE) method, to simulate the production of DBSA using Aspen HYSYS V.11 to optimize process parameters and to confirm its technical feasibility, and to develop a thorough financial feasibility analysis for the proposed manufacturing plant.

## 2. Market Study

Dodecylbenzene Sulfonic Acid (DBSA) is an anionic surfactant widely used in industrial, household, and personal care applications. Due to its strong emulsifying, foaming, and wetting properties, DBSA plays a crucial role in the formulation of detergents, enhancing oil recovery, textile and leather processing, lubricants, and corrosion inhibition as seen in Figure 1a. Its high biodegradability and cost-effectiveness make it increasingly favorable among environmentally conscious consumers (MarketQuest, 2023). DBSA consumption is driven globally by increased oil exploration, environmental sustainability efforts, and growing demand for personal and household cleaning products. Based on Figure 1b, in 2023, China leads global consumption, accounting for 40%, followed by the United States at 20% and Europe at 15%, according to MarketQuest (2023) and Data Horizon Research (2022). Meanwhile, emerging markets in Southeast Asia, such as the Philippines, are experiencing a rise in import volumes, and other notable contributors include India (10%).

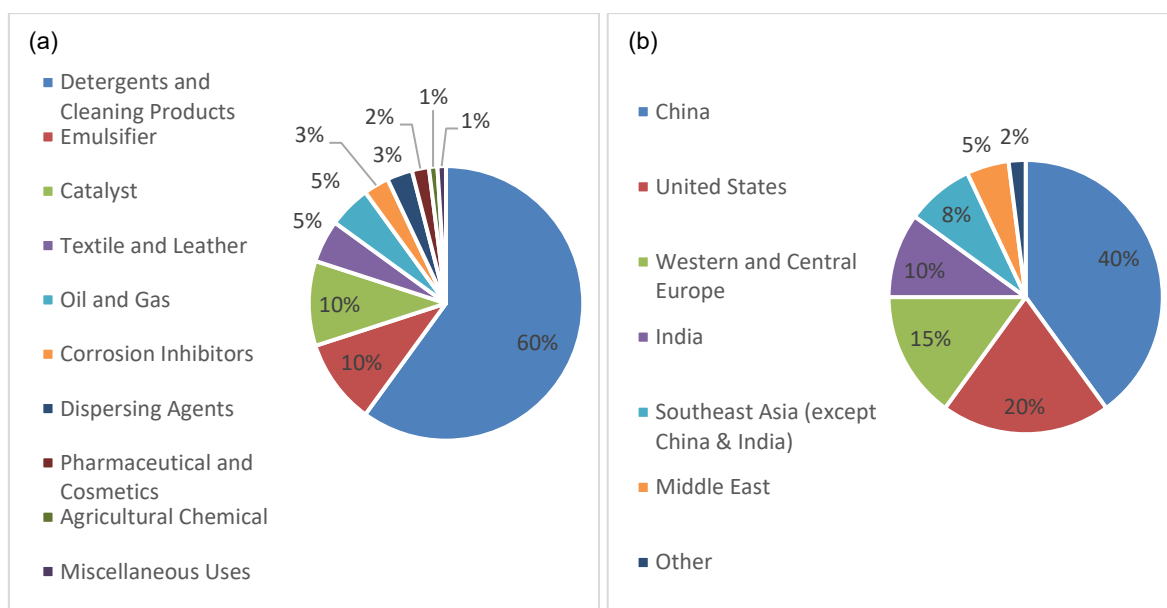


Figure 1: (a) Uses of DBSA and (b) World Consumption of DBSA in 2023

In the Philippines, DBSA imports have shown a significant upward trend, increasing from 16,357 t in 2014 to 51,953 t in 2023, based on trade data from UN Comtrade (2024). This growth reflects expanding domestic demand for cleaning products, personal care items, and industrial applications. To project future demand, various forecasting methods such as linear, exponential, logarithmic, second-order polynomial, and power models were evaluated. The linear projection method was selected based on the highest coefficient of determination ( $r^2 = 0.9296$ ), indicating strong correlation and prediction. Based on this method, imports are forecasted to reach approximately 95,950 t by 2034, as shown in Figure 2.

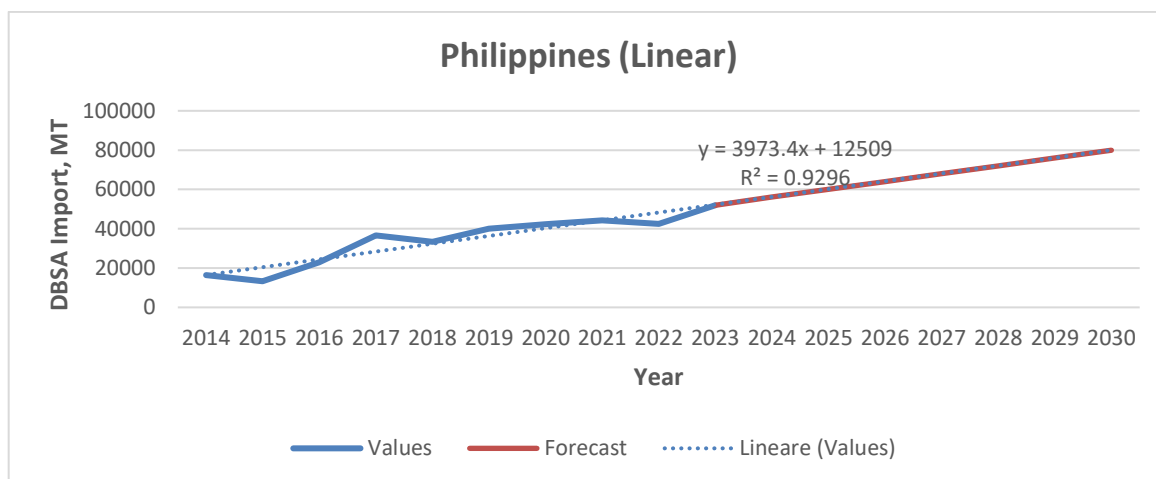


Figure 2: DBSA Import of the Philippines – Linear Projection

Based on the 2030 projection of 80,057 t total demand, a plant capacity of 30,000 t/y, as shown in Table 1, is proposed, capturing an estimated 38 % market within the local market. DBSA is playing an increasingly vital role in sustainable formulations, and the Philippines is a strategic location for its production due to demand growth and its advantageous position in the Asia-Pacific market.

Table 1: Plant Capacity Calculation of DBSA

Year	Country	Available Market (t)	Market Share (%)	Market Share (t)
2030	Philippines	80,057	38	30,000
			Total Plant Capacity	30,000

### 3. Technical Study

#### 3.1 Process Selection

This study employs the Visual PROMETHEE, a multicriteria decision aid (MCDA) tool, to assess and compare three alternative methods for producing Dodecylbenzene Sulfonic Acid (DBSA). The production processes, as listed by De Groot (1991), were evaluated, which include: (1) Sulfonation using Sulfuric Acid, (2) Sulfonation using Oleum, and (3) Film Sulfonation. Visual PROMETHEE is used to analyze each method based on several critical selection criteria, aiding in the systematic comparison of their overall performance.

The criteria considered in the decision-making process include: yield efficiency, product purity, process complexity, environmental impact, and economic viability, each weighted equally at 20 %, signifying their balanced importance in selecting the most suitable production route for DBSA.

Based on the evaluation (as illustrated in Figure 3a), Film Sulfonation of Dodecylbenzene with Sulfur Trioxide emerges as the most favorable method. It is closely followed by Sulfonation using Oleum, while Sulfonation with Sulfuric Acid ranks lowest with a significant gap in preference. Ultimately, Film Sulfonation is selected as the optimal process for DBSA manufacturing due to its superior performance in terms of yield and environmental sustainability compared to the other two methods.

#### 3.2 Plant Location Selection

The selection of plant location has a significant effect on the feasibility of the project considering the start of operations of the production plant and possible expansion in the future (Towler and Sinnott, 2022). AGV Manufacturing Corporation's reference plant for the required land area in the production of DBSA is Stepan Company DBSA plant located in Bauan, Batangas. This reference plant has a plant capacity of 60,000 t/y occupies a total land area of 2.1 ha. Calculating the plant size of AGV Manufacturing Corporation with a DBSA production capacity of 30,000 t/y using Eq(1), will result to a plant size of 1.05 ha.

$$\frac{\text{Plant Capacity}_{\text{Reference}}}{\text{Land Area}_{\text{Reference}}} = \frac{\text{Plant Capacity}_{\text{AGV Corp.}}}{\text{Land Area}_{\text{AGV Corp.}}} \quad (1)$$

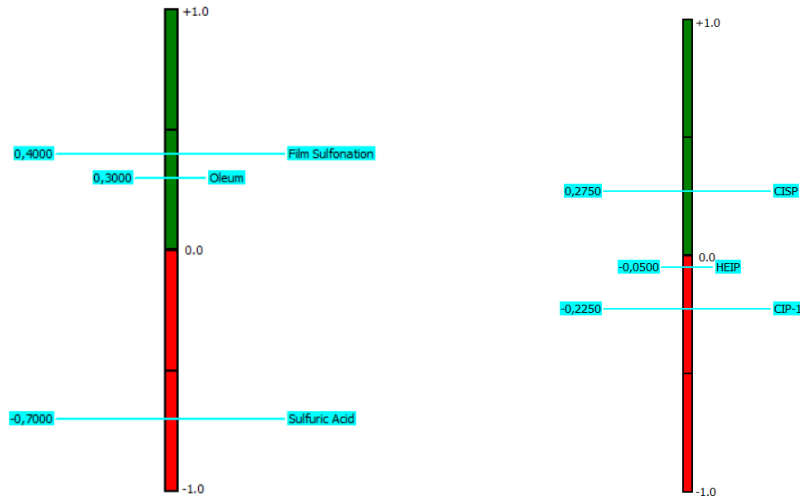


Figure 3: Visual PROMETHEE Complete Ranking for (a) Process Selection and (b) Plant Location Selection

Calaca Industrial Seaport Park (CISP), Hermosa Ecozone Industrial Park (HEIP), and Carmelray Industrial Park 1 (CIP-1) were the three industrial parks in the Philippines under PEZA considered in the selection of the best location for the DBSA plant. In selecting the optimal plant location, several key criteria were considered and weighted according to their impact on both initial investment and long-term operations. Land cost (25%) was given the highest weight since it represents a major capital expense that significantly influences project feasibility and future expansion opportunities. Proximity to the target market (25%) was equally prioritized because being close to customers reduces transportation costs, shortens delivery time, and enhances competitiveness. Proximity to port (20%) was also emphasized, as it facilitates efficient import and export of materials and products, reducing logistics expenses and ensuring supply chain reliability. Meanwhile, labor cost (15%) was assigned a moderate weight due to its direct effect on operational expenses and profitability, while also considering the availability and skill level of the workforce. Lastly, electricity cost (15%) was factored in as it is a recurring operational expense, especially critical for energy-intensive industries, where stable and affordable power supply ensures consistent and cost-effective production. Using Visual PROMETHEE, CISP is the best among the three, Figure 3b shows the Complete Ranking for Site Location Selection.

### 3.3 Process Specifics

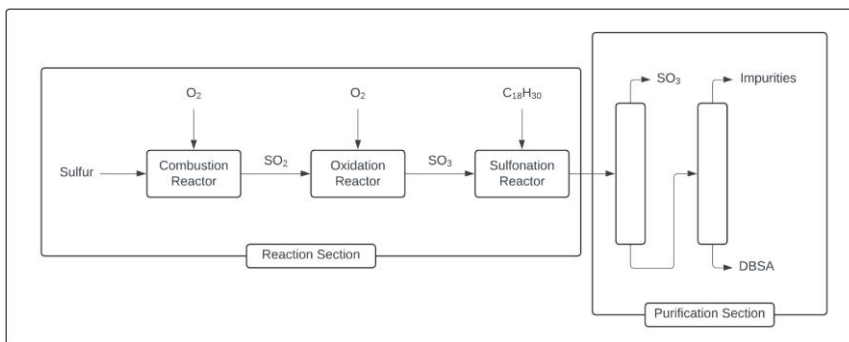


Figure 4: Film Sulfonation for DBSA Manufacturing Process

A five-section industrial process for producing dodecylbenzene sulfonic acid (DBSA), simulated using Aspen HYSYS V11, is based on the study of Mohamed et al., (2022) with some modifications. The key sections consist of air drying, sulfur melting, sulfur combustion,  $\text{SO}_3$  production, and sulfonation. The Peng-Robinson thermodynamic model was selected due to its suitability for gas-liquid equilibrium systems involving hydrocarbons and sulfur oxides. Since Aspen HYSY does not natively handle solid sulfur (inconsistencies encountered during sulfur melting), the sulfur liquid phase stream was utilized.

Ambient air is compressed, cooled through sequential heat exchangers using water and ethylene glycol, and dehydrated in a separator to yield a dry air stream with minimal water vapor (0.06 mol%). This dry air is split for use in  $\text{SO}_2$  and  $\text{SO}_3$  production, with respective heating to 161.8 °C and 460.8 °C. Liquid sulfur (due to Aspen's

simulation limits) is introduced at 30 °C and heated to 131.9 °C. This step is essential for sulfur melting and prepares for combustion.

Dry air and molten sulfur are reacted at 700 °C, producing a stream with 15.40 mol% SO<sub>2</sub> and trace SO<sub>3</sub>. This combustion stream is cooled to 450 °C, preparing it for catalytic conversion. The cooled SO<sub>2</sub> stream undergoes catalytic oxidation, increasing SO<sub>3</sub> concentration to 14.49 mol% while reducing SO<sub>2</sub> to 0.40 mol%, closely aligning with the values reported by Mohamed et al. (2022) and De Groot (1991). Byproduct separation yields oleum, and the purified SO<sub>3</sub>-rich gas is cooled to 52°C for sulfonation. SO<sub>3</sub> is reacted with pure dodecylbenzene at 52 °C and 101.3 kPa. The primary product stream contains 96.44 mol% DBSA, with minimal unreacted dodecylbenzene and byproducts. Further stabilization improves DBSA purity to 99.05 mol%, while gaseous effluents are safely treated. The high conversion rate indicates the effectiveness of Film Sulfonation process in achieving maximum product yield while minimizing unreacted components. Furthermore, the simulation showed that air dehydration significantly affected the oxidation and sulfonation steps, supporting the observations from Towler and Sinnott (2022) regarding gas-phase equilibrium control.

#### 4. Financial Feasibility

Towler and Sinnott (2022) outlined the expense computation to estimate the expenses for the facility of the plant. The costs of the manufacturing plant are summarized in Table 2.

Table 2: Summary of Cost (In millions of pesos)

Cost	Specifics	Value (PHP)	Total (PHP)
Total Fixed Capital Investment	Inside Battery Limits	901.56	2,468.61
	Outside Battery Limits	134.29	
	Engineering Cost	103.58	
	Contingency Cost	103.58	
	Land Cost	105.00	
	Working Capital	155.38	
	Variable Cost (Year 1)	869.44	
Total Variable Cost	Fixed Production Cost (Year 1)	95.78	869.44
	Raw Materials	755.48	
	Water	1.46	
	Electricity	47.99	
	Telecommunication	0.40	
	Shipping and Transportation	64.11	
	Total Fixed Cost of Production	Labor Cost	
Maintenance Cost	27.05		
Insurance	10.36		
Licenses and Permits	0.14		

Initially, the cost estimations were assessed in U.S. Dollars (USD) which is then converted to Philippine Peso (PHP). Wherein the conversion is 57.95 PHP for every 1 USD. Towler and Sinnott (2022) noted that the Payback Period must be calculated to check the Financial Feasibility of the Plant. The payback period was determined by identifying the final year when the cumulative income remained negative and using the corresponding cash flow values from the following year. Based on Table 3, the last year with negative income is year 6, giving a cumulative net cash flow of PHP 74 million, while the total cash inflow for year 7 is PHP 1,172 million. These values result in a payback period of 5.07 years. In addition, the return on investment (ROI) at year 7 was calculated to be 47.50%, as referenced by Towler and Sinnott (2022), indicating the overall economic performance of the plant.

The methods in cost estimation are based on the cost indices and historical data to help in comparing the past and current cost values which includes the prices of energy, labor, and materials. A composite index used in U.S. process plant industry is published monthly in the Chemical Engineering magazine is the Chemical Engineering Plant Cost Index (CEPCI) also known as the CE Index. Our reference plant, Stepan Co., was built and begun its operation in 2005. Based from the CE Index reference, at year 2005, the cost index is 468.2. On the other hand, AGV manufacturing corp. would utilize the June 2024 cost index, which is 798.8.

Table 3: Income Statement (In Millions of Philippine Pesos)

Year	%Plant Capacity	Revenue	Total Cost of Production	Depreciation	Taxable Income	Income Tax	Income (Net Profit)	Cumulative Income
0	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	- 2,469	- 2,469
3	-	-	-	-	-	-	- 2,469	- 2,469
4	50%	1,565	965	55	421	-	421	- 2,048
5	75%	2,347	1,372	52	799	-	799	- 1,249
6	100%	3,129	1,781	49	1,175	-	1,175	- 74
7	100%	3,129	1,781	52	1,173	-	1,172	1,098
8	100%	3,129	1,782	52	1,171	-	1,171	2,270
9	100%	3,129	1,781	52	1,173	-	1,173	3,442
10	100%	3,129	1,781	52	1,173	-	1,173	4,615
11	100%	3,129	1,781	52	1,173	-	1,173	5,788
12	100%	3,129	1,782	52	1,171	351	820	6,608

## 5. Conclusions

This study successfully demonstrated with financial viability and technical aspect that there is a possibility for a facility of DBSA production plant in the Philippines. The software used in this study were Visual PROMETHEE which has multi-criteria decision-making for the Process and Site Location selection, and Aspen HYSYS V.11 for the simulation of the process. This result validates the potential of Philippines to establish a domestic manufacturing plant allowing the country to meet local demands. The identified optimal location considering logistics and economic factors is at Calaca Industrial Seaport Park in Batangas after Production of 30,000 MT of DBSA with high purity (99.05 %). With a payback period of 5.07 y and an ROI of 47.50 % from the financial projections indicating a strong economic viability of the plant.

Beyond technical and financial validation, this study carries significant practical implications for the Philippine industry. Establishing a domestic DBSA production facility would reduce the dependency on imported surfactants, stabilize local supply chains, and lower production costs for detergent and personal care manufacturers. The adoption of the Film Sulfonation process also shows safer, more sustainable, and energy-efficient operations with lower sulfur emissions. Overall, this study demonstrates the technical feasibility, financial viability, industrial opportunity, reduction of import dependency of the establishing a domestic production facility of DBSA.

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