ECONOMIC FEASIBILITY STUDY OF $MgSO_4$ FROM SALINE WATER WASTE

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Abstract.
This study aims to analyze the economic feasibility of $MgSO_4$ plant from saline water waste with a capacity of 20,000 tons/year. Saline water waste is obtained from processing iron ore using STAL (Step Temperature Acid Leach) technology with a waste TDS of 120,000 ppm. This $MgSO_4$ plant was built using 439,597.65 liters of saline water/hour which produces 2,577.89 kg/hour of $MgSO_4$ through 4 stages. These stages are filtration using a screen filter, then followed by ultrafiltration, then nanofiltration, evaporation, crystallization to obtain salt in the form of powder. From the calculation of the economic parameters using the fixed estimation method, the value and break event point of 38% for the first year and the Internal Rate of Return of 37.5% are an indication that this $MgSO_4$ plant is a feasible investment.

Keywords: *Magnesium Sulfat, Saline Water, Nanofiltrasi, Internal Rate of Return, Break Even Point*

Introduction

Nickel extraction from limonite ore using STAL (Step Temperature Acid Leach) technology produces a liquid waste called saline water waste which contains high salt and a TDS (Total Dissolved Solid) content of more than 120,000 ppm [1]. Meanwhile, in the Regulation of the Minister of the Environment of Indonesia No. 5 of 2014 concerning waste water quality standards for businesses and or activities that do not yet have a wastewater standard, one of the parameters is that soluble solids (Total Dissolved Solid / TDS) must be in the range of 2000 – 4000 ppm [2]. Therefore, it is still necessary to carry out a process to reduce the TDS content in the water to be discharged and also to utilize saline water waste to become a useful product.

There are currently no processing or manufacturing plants for magnesium sulfate ($MgSO_4$) in Indonesia. Meanwhile, the need for magnesium sulfate ($MgSO_4$) in Indonesia is quite high and only relies on imports from countries such as Russia, India, China, to the U.S.A, around 384,865 tons in 2021 [3]. Magnesium sulfate ($MgSO_4$) is one of the inorganic salts contained in saline water waste and can be used as the main ingredient or supporting material for plant fertilizers, animal feed supplements, drugs, textile dye mixtures. Due to the increasing demand for magnesium sulfate ($MgSO_4$), the potential to establish a magnesium sulfate ($MgSO_4$) processing plant is also quite large. The establishment of this factory is based on the market demand for magnesium sulfate ($MgSO_4$) which is quite large, utilizing saline water waste, increasing employment opportunities and reducing dependence on imports from other countries.

Theory

Market analysis

The development of $MgSO_4$ imports in Indonesia has decreased and increased from year to year. Until now, imported $MgSO_4$ products have met the needs in Indonesia. To meet domestic MgSO4 needs, Indonesia still relies on imports from countries such as Russia, India, China, to the U.S.A [5]. In 2021 the demand for magnesium sulfate is around 384,865 tons and will continue to increase every year [3]. So it can be estimated that the demand for magnesium sulfate in 2024 is around 500,000 tons/year.

Magnesium sulfate has many benefits, one of which is the main ingredient for making fertilizers. Therefore, the Fertilizer industry is one of the market objectives of this $MgSO_4$ factory, because data on $MgSO_4$ consumption in Indonesia is not yet available. To find out data on $MgSO_4$ consumption in Indonesia, secondary data is used, namely data from fertilizer production in Indonesia. To know the amount of fertilizer production can be seen in Figure 1.

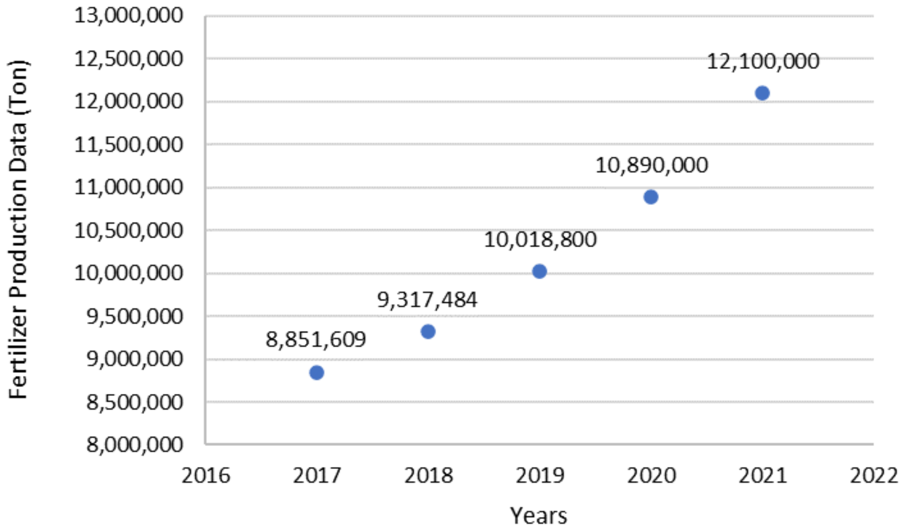

Figure 1. *Fertilizer production data in Indonesia*
Source: (Ministry of Industry of the Republic of Indonesia, 2021)

From Figure 1 it can be seen that fertilizer consumption in Indonesia continues to increase. However, this data is still used for all types of fertilizers. In general, the use of $MgSO_4$ in fertilizer is around 16%, so it is estimated that the need for $MgSO_4$ in 2021 [8] is around 1,936,000 tons/year.

Process Description

A. Raw Material

The raw material for saline water waste to be used still has a high TDS level and also solid particles that are still contained in the saline water waste. The components of saline water waste include: $Al_2(SO_4)_3$, $CoSO_4$, $Cr_2(SO_4)_3$, $CuSO_4$, $Fe_2(SO_4)_3$, $MgSO_4$, $MnSO_4$, $NiSO_4$, $ZnSO_4$, H_2O, and TSS (Total Suspend Solid) with a composition of 0.005% ; 0.005%; 0.005%; 0.005%; 0.01%; 10%; 1%; 0.005%; 0.005%; 78.96%; and 10 ppm respectively [1].

B. Pre-treatment

The complete process goes through several stages, with stages of pre-treatment, main process, product purification and final treatment, which can be seen in the block flow diagram, which can be seen in Figure 2.
The raw material pretreatment process uses a screen filter and an ultrafiltration device before entering the main process unit. The mass flow retained in the screen filter unit is assumed to be 40% of the total TSS contained in the saline water feed. This is because the TSS particle size contained in saline water is around 63-105 m (230-140mesh) [7] which is based on the size of iron ore produced by PT.HMI and operates at a temperature of 27°C with a pressure of 3 bar. While the Ultrafiltration Module unit functions to reduce the Silt Density Index of seawater from 30 SDI to < 5 SDI and removes seawater impurities in the form of dissolved solid particles that can increase.

C. Main Process

The main process in magnesium sulfate recovery lies in the nanofiltration unit which is then stored in the NF Feed Tank and flowed to the nanofiltration module at a temperature of 27°C and a pressure of 10-35 bar. The separation process using a nanofiltration system lasted for 60 minutes with a rejection of 87.4% with operating conditions of 27°C with a pressure of 10 bar [6].

D. Product Purification

The solution that has gone through the nanofiltration process is then stored in a concentrated tank and then fed to the triple effect evaporator unit with operating conditions of 62°C - 90°C and a pressure of 0.6-0.25 bar which functions to evaporate water with the help of steam flowing from the boiler. After going through the evaporator unit, the concentration is flowed to the crystallizer unit which aims to crystallize the $MgSO_4$ solution using steam as a heater. After going through the crystallizer unit with operating conditions of temperature 62°C and pressure of 0.04 atm. MgSO4 in the form of slurry is fed to a centrifuge unit to separate the crystals from the mother liquor with the assumption that the separation is 90% mother liquor and 10% $MgSO_4$ crystal.

E. Final Treatment

After purification of the main product, $MgSO_4$, the final treatment is carried out before being marketed. The $MgSO_4$ product that is being marketed is $MgSO_4$ in the form of crystals with powder size. Then the product is $MgSO_4$ and converted into powder with the help of a ball mill up to a size of 200 mesh and then the product will be stored in the silo.

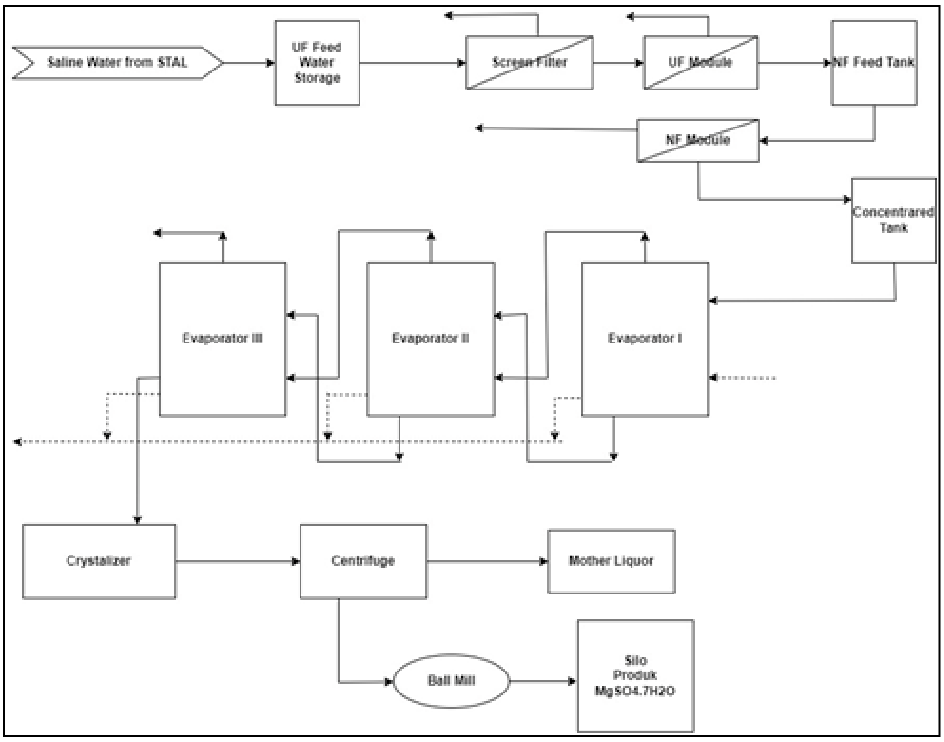

Figure 2. *$MgSO_4$ Factory BFD*

Operating Unit Dimension

The design of operating unit dimensions begins with determining the operating capacity of each unit. By using the feed flow rate data that must be processed. The dimensions for the process unit are then designed according to the principles described by the literature [9 - 12].

The manufacture of Magnesium sulfate ($MgSO_4$) is carried out in batches, and the process is completed within 8 hours. For units such as Screen Filters, cleaning needs to be carried out after each screen. Therefore, it is necessary to carry out a manual cleaning process. Therefore, the Screen Filter unit is installed in parallel so that the use of the screen filter tool can continue without waiting for the cleaning process to complete. With the units being carried out in parallel, the processing can be completed within 7-8 hours. The process dusration and unit specisications are shown in Table 1.

Table 1. *Tool specification data*

No.	Name	Code	Residence Time (hours)	Spesification	Total
1	Storage Tank	T-101	24	Dimension (PxT)= 3,35m x 7,15 m	1
2	Storage Tank	T-102	24	Dimension (PxT)= 3,05m x 6,89 m	1
3	Storage Tank	T-201	24	Dimension (PxT)= 1,69m x 3,72 m	1
4	Storage Tank	T-202	24	Dimension (PxT)= 3,2m x 6,98 m	1
5	Storage Tank	ML-401	24	Dimension (PxT)= 3,35m x 7,15 m	1
6	Screen Filter	F-101A F-101B	1	Dimension PxD= 0,42m x 0,05m	2
7	Ultrafiltrasi	UF-101	1	Dimension PxD= 2,3m x 0,225m	

	Module				
8	Nanofiltrasi Module	NF-201	1	Dimension PxD= 1,01m x 0,2m	
9	Evaporator	EV-301	1	Dimension PxD= 2,8m x 1,9m	1
10	Crystalizer	CR-301	1	Dimension PxD= 2,98m x 1,67m	1
11	Centrifuge	CF-401	1	Dimension Diameter = 1,67m	1
12	Ball Mill	BM-401	1	Dimension PxD = 0,92 m x 0,61 m Daya = 7 Hp	1
13	Screw Conveyor	SC-401	1	Dimension LxD = 36,6m x 1,83m Daya = 2 Hp	2
14	Silo		1	Volume Dimension = 1.006,39 m^3 Tinggi = 4,14 m	1
15	Centrifugal Pump	P-101 P-102 P-201 P-203 P-301 P-302 P-304 P-305 P-401	1	BHP = 7,5 Hp BHP = 7,5 Hp BHP = 25 Hp BHP = 7,5 Hp BHP = 2 Hp BHP = 2 Hp BHP = 2 Hp BHP = 2 Hp BHP = 0,7 Hp	9
16	Vacum Pump	VP-301 VP-302 VP-303 VP-304	1	BHP = 0,5Hp BHP = 0,9 Hp BHP = 2,1 Hp BHP = 2,6 Hp	4

Economic Analysis

Economic analysis is one of the main factors for assessing the feasibility of a production process. The economic feasibility of a magnesium sulfate treatment plant from saline water waste can be determined after analyzing several factors such as production capacity, raw material costs, chemicals, utilities and equipment investment.

The economic analysis in this study is based on several assumptions:

- The production process lasts for 330 days/year. To carry out comprehensive maintenance, shutdowns have been carried out 35 days a year.
- The process used is a batch process.
- The physical construction of the factory will be carried out in early 2023 with a construction, investment, and installation period of one year so that the factory is expected to start operating in 2024.
- Working capital is calculated for 3 months.
- The working period of each unit is 10 years.
- The assumption of the dollar value against rupiah is 1 US$ is Rp. 15.000,-
- In 2023 with stable market conditions with a bank interest rate of 7.5% per annum.
- An increase in the price of raw materials and production output by 10% per year.
- Salvage Value is 10% of Direct Fixed Capital Investment (DFCI) without land price.

The approach to calculating the economic analysis used is a fixed estimation approach where the analysis is only based on process flow diagrams and rough calculations of the main unit dimensions. More detailed diagrams such as plot plans, piping diagrams, and instrumentation are not required in this method. In this method, the cost other than the investment for the unit is obtained by comparing it with the price of the main unit. Prices of production equipment and supporting equipment are calculated using data from reference manuals and several related online sites[13][14]. The steady-state estimation method has an accuracy range of +30% to -20%, so the results of this study may not accurately reflect the actual economic feasibility of magnesium sulfate production. However, the results of this study can be used as a reference to analyze the parts of the production process that need to be optimized.

A. Total Modal Investment (TCI)

Capital Investment or Total Capital Investment is the amount of capital invested to establish a factory until the factory is ready to operate. TCI consists of FCI (Fixed Capital Investment) and WCI (Working Capital

Investment). FCI consists of equipment, installation, plumbing, instrumentation, electrical, building, utilities, storage, area development, additional building costs, contractor costs, and incidental costs. While WCI is the investment required to operate the factory for 3 months, during which all operating variables are adjusted until the factory is ready for production[15]. TCI calculation results are shown in Table 2.

Table 2. *Summary of TCI calculation results*

	Fixed Capital Investment			
	DFCI			
No.	**Main and Support Equipment**	**A**		**Total Price (Rp)**
1	Procurement of Equipment (Process Equipment and Utilities)	100%	A	58030830714
2	Instrumentation and control	39%	A	22632023978
3	Installation	13%	A	7544007993
4	Installed Piping	31%	A	17989557521
5	Electricity Installed	10%	A	5803083071
	Civil & Structural Cost			
6	Factory Building	29%	A	16828940907
7	Yard improvements	10%	A	5803083071
8	Service facilities	55%	A	31916956893
9	The Land Price (Land survey & cost)			37500000000
10	Land acquisition	6%	A	2250000000
	Total DFCI (A')			206298484149
	IFCI			
		B		
11	Engineering and Supervision	32%	**A'**	66015514927
12	Contractor and Construction Costs	34%	**A'**	70141484610
13	Trial Run Cost			208519273
	Unexpected IFCI	10%	**A'**	20629848414
	Total IFCI			156995367226
	Total FCI = DFCI + IFCI			363293851375
	Working Capital Investment			
14	Product Packaging and Distribution Costs	1%	Bahan baku	990000000
15	Quality Control Cost	1%	Bahan baku	990000000
16	Maintenance and Repair Costs	2%	FCI	7265877027
17	Employee Salary	3	x gaji /bulan	2498700000
	Subtotal WCI			9784377027
	Loan Interest during Construction	10%	DFCI	20629848414
	Total Capital Investment (TCI) = FCI + WCI + Loan Interest during Construction			**393708076818**

B. Total Product Cost (TPC)

Production costs are one of the determining factors for the selling price of a product. From this calculation, it can be estimated the profit that will be obtained from the sale. Total Product Cost (TPC) consists of 2 parts: production costs or costs needed to make a product and general costs or costs used to support factory operations. [15].

Production costs consist of direct cost, factory overhead, and fixed costs. Direct costs are costs that are used directly for factory operations including costs of raw materials, costs of supporting facilities, employee salaries, maintenance and repairs, royalties and patent costs, and laboratory costs. Meanwhile, factory overhead costs include hospital service and maintenance costs, general factory maintenance, security, rescue, and distribution costs. Fixed costs are costs that are fixed from year to year or do not change with changes in production capacity, including depreciation, taxes, and insurance costs. Finally, general expenses are costs used to support the operations of factory activities, including administrative costs, distribution and sales costs, research and development costs, and bank interest payments. The TPC for the Magnesium sulfate processing plant in the first year with a new production capacity of 80% is shown in Table 3.

Table 3. *Summary of TPC calculation results*

	Total Production Cost (TPC)			Biaya Tetap (Rp)	Biaya Variabel (Rp)
A	**Production Cost**				
1.	Direct Manufacturing Cost (DMC)				
a	Raw Material Cost				197835014904
b	Employee salary			5220145000	
c	Maintenance and Repair Costs (increase by 5% /year)	2%	DFCI	3791816486	
d	Patent Royalties and Fees	0,5%	TS		4663200000
e	Laboratory Fee	0,5%	BB		989175075
f	Product Packaging Fee	5%	BB		9891750745
g	Support Facility Fee			106278356	492474863819
h	Initial Cost			4453947104	
	Total Direct Manufacturing Cost (DMC)			13572186945	705854004543
	Factory Overhead Cost	20%	(b+c)	1802392297	
	Fixed Production Cost (FMC)				
2.	Depreciation			41483719541	
3	Land and Development Tax is estimated at 0.1% x (land + Building), increasing 10% /year			31136037	
a	Insurance fee (increase 10%) /year	0,5%	DFCI	947954122	
b	Total Fixed Production Cost (FMC)			42462809700	
B	**General Expenses**				
a	Administrative costs	5%	b	261007250	
b	Distribution and Sales Costs	10%	f		989175075
c	Bank interest				9500000000
	Total General Expenditure			261007250	10489175075
	Total Production Cost			58098396193	716343179618
	Total Production Cost			77441575811	

C. Internal Rate of Return (IRR) and Break Even Point (BEP)

Internal Rate of Return (IRR) is the loan interest rate (rate of interest) in percent at Net Cash Flow Present Value (NCFPV) = 0. within the technical life span of the machine/equipment. or a period that is expected to be sooner than the technical age. IRR analysis is carried out to assess the feasibility of establishing a factory. If the existing bank interest in the bank during the life of the factory is less than the IRR. then the establishment of the factory is feasible.

Table 4. *Summary of IRR calculation results*

	Net Cash Flow (Rp)	**Interest 1/(1+1)^n**	**Present Value**
0	-393709076818	1	-393709076818
1	82051297212	0,701	57545551550
2	129690146565	0,492	63791036673
3	186569314932	0,345	64360459055
4	216595225391	0,242	52402752645
5	249294049962	0,170	42300299285
6	330130310504	0,119	39286490340
7	369876974510	0,083	30870341541
8	413533548611	0,059	24205897586
9	461491576736	0,41	18945258144
10	514181784854	0,29	14804022673
	Total		**0**

Based on Table 4. the IRR value is 37.54% using the Goalseek method by changing the total NCFPV value to 0. The IRR value for the establishment of this factory is greater than the loan interest rate offered by Bank BNI as a reference for this factory.

The Break Even Point (BEP) or the break-even point is the percent of production capacity where the total cost incurred by the company is within 1 year. BEP is useful for controlling the company's operational activities. including controlling total production. total sales. and controlling finances for the current financial year. The table 5 shows the Break Even Point cost of the Magnesium Sulfate plant. The general formula for calculating BEP can be seen in equation (1)

$$BEP = \frac{FC}{TC - VC} \times 100\ \% \quad (1)$$

Table 5. *Summary of BEP calculation results*

Year	Total Sales (Rp)	Total Fixed Cost (Rp)	Total Variabel Cost (Rp)	Total Cost (Rp)	BEP (%)
1	304000000000	111543019863	12366563446	123909583309	38
2	376200000000	113635179455	14418994777	128054084233	31
3	459800000000	113758043015	16640086408	130389129423	26
4	505780000000	115179876576	18304095048	133483971625	24
5	556358000000	116838553553	20134504553	136973058107	22
6	611993800000	87056956918	22147955009	109204911927	15
7	673193180000	89260592838	24362750509	113623343348	14
8	740512498000	91777101357	26799025560	118576126968	13
9	814563747800	94636979851	29478928117	124115907968	12
10	896020122580	124115907968	32426820928	156542728897	14

Conclusion

Research has been carried out to analyze the economic feasibility of producing magnesium sulfate from saline water waste. Through a fixed estimation approach, it is known that this production process is broadly economically feasible. With a production capacity of 20,000 tons/year, with an IRR value of 37.5% greater than the interest rate used, which is 7.5%. With a BEP value of in the first year of 38%.

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