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Research Article

Economic Evaluation of Potassium Carbonate Production to Support Fertilizer Production in Indonesia

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ABSTRACT: *Potassium carbonate is one of the chemicals that is widely used in the glass and fertilizer industries. Potassium carbonate was also used as a catalyst, a carbon capture, and a chemical activation agent. This study will examine the preliminary design and economic evaluation of a potassium carbonate plant using potassium hydroxide and carbon dioxide as raw materials to support the fertilizer industry in Indonesia. Banten Province was chosen as the location of the potassium carbonate plant considering its proximity to raw materials, ease of transportation and utilities, and proximity to the marketing target, which is the fertilizer factory. The hydroxide method was chosen as the process technology used in potassium carbonate production because of its simpler process and high conversion. The production of potassium carbonate using potassium hydroxide and carbon dioxide as raw materials was carried out using a bubble reactor at 100 °C and 0.43 atm. The results of the economic evaluation from Total Capital Investment (TCI) and Total Production Cost (TPC) calculation showed 41.10% Return on Investment (ROI), 1.87 years Payback Period (PBP), US$15,561,960, Net Present Value (NPV), and 42.58% Internal Rate of Return (IRR). The sensitivity analysis of the price parameters of potassium carbonate products at a deviation of 10% showed the largest NPV value of US$26,277,395 with a PBP of 1.27 years.*

Keywords: *economic evaluation, potassium carbonate, plant design.*

1. INTRODUCTION

Potassium carbonate is a chemical that is used in various industries, such as raw materials for fertilizers, glass, cleaning, and food. The Indonesian glass industry requires potassium carbonate as its primary raw material in its manufacturing process. Furthermore, potassium carbonate can be used as a fertilizer in various research projects to meet Indonesia's fertilizer needs [1], [2]. Potassium carbonate can also be utilized to produce other compounds in catalyst applications [3-5]. Recent developments have shown that potassium carbonate was widely used as a CO_2 capture agent [6-9] and chemical activation agent [10-14].

Because the high demand for potassium carbonate in Indonesia glass and fertilizer industries, Indonesia still imports potassium carbonate. Given the high potential demand for potassium carbonate in Indonesia, a potassium carbonate plant is needed to support domestic industrial needs, halt imports, boost the national economy, and create jobs.

Potassium carbonate can be produced in several ways, including using ion exchange systems [15], electrochemical [16], alkali carbonization [17], and hydroxide process [18]. From various existing processes, the hydroxide process was chosen over others due to its simplicity and high conversion.

Various studies have evaluated the economics of using potassium carbonate for CO_2 capture [19], [20], but no studies have evaluated the economics of potassium carbonate production. Therefore, this study will examine the economics of potassium carbonate plant design in Indonesia and its potential for controlling fertilizer prices.

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2. METODE PENELITIAN

2.1. Equipment cost calculation

Equipment prices in this economic evaluation calculation were obtained from Peters et al. (2003) and the Matches website [21], [22]. Equipment prices in 2028 were estimated using the data linearization method from Chemical Engineering Plant Cost Index (CEPCI) where the CEPCI value used in 2028 was 691.

2.2. Raw material and product price

Prices for potassium hydroxide, carbon dioxide, and potassium carbonate were taken from Alibaba (2023) as shown in Table 1.

Table 1. Raw material and product price

Chemicals	**Price (US$/Ton)**	**Reference**
Potassium Hydroxide (KOH)	1.020	[23]
Carbon Dioxide (CO_2)	280	[24]
Potassium Carbonate (K_2CO_3)	1.850	[25]

2.3. Calculation of total capital investment and total production cost

The calculation of Total Capital Investment and Total Production Cost can be seen in Tables 2 and 3. The calculation of Total Capital Investment and Total Production Cost was carried out by justifying the percentage of costs according to Peter et al. (2003) [21].

Table 2. Total capital investment

No.	**Parameters**	**Cost**	
1.	Purchased Equipment	Equipment Cost	Total Direct Cost (TDC)
2.	Installation	45% Equipment Cost	
3.	Instrumentation and Controls	18% Equipment Cost	
4.	Piping	16% Equipment Cost	
5.	Electrical System	10% Equipment Cost	
6.	Buildings	25% Equipment Cost	
7.	Yard Improvements	15% Equipment Cost	
8.	Services Facilities	40% Equipment Cost	
9.	Engineering and Supervision	33% Equipment Cost	Total Indirect Cost (TIC)
10.	Construction Expenses	39% Equipment Cost	
11.	Legal Expenses	4% Equipment Cost	
12.	Contractor's Fee	17% Equipment Cost	
13.	Contingency	35% Equipment Cost	
Fixed Capital Investment (FCI)		(TDC + TIC)	
	Working Capital (WC)	70% Equipment Cost	
Total Capital Investment (TCI)		(FCI + WC)	

Table 3. Total production cost

No.	Parameters	Cost	
1.	Raw Material	Raw Material Cost	Direct Production Cost (DPC)
2.	Labor	10% FCI	
3.	Supervision	10% Labor Cost	
4.	Utilities	20% FCI	
5.	Maintenance	2% FCI	
6.	Operating Supplies	1% FCI	
7.	Laboratory Charges	10% Labor Cost	
8.	Patents and Royalties	1 % Total Revenue	
9.	Depreciation	8% FCI	Fixed Charges (FC)
10.	Property taxes	2% FCI	
11.	Insurance	1% FCI	
Plant Overhead Costs (POC)		50% (operating labor + supervision + maintenance)	
Manufacturing Cost (MC)		DPC+FC+POC	
12.	Administration Costs	20% (operating labor + supervision + maintenance)	General Expense (GE)
13.	Distribution and Marketing Costs	2% Manufacturing Cost	
14.	Research and Development Costs	2% Total Revenue	
Total Production Cost (TPC)		MC + GE	

2.4. Profit Analysis

Profit analysis was conducted to determine the feasibility of A potassium carbonate plant. The profit analysis calculated Return on Investment (ROI), Payback Period (PBP), Net Present Value (NPV), and Internal Rate of Return (IRR). Return on Investment (ROI) was defined as the ratio between average profit (NP) and Total Capital Investment (TCI). Payback Period (PBP) was the ratio between Fixed Capital Investment (FCI) and Annual Cash Flow (Aj), which was identified as the payback period. Net Present Value (NPV) was the total profit, and the Internal Rate of Return (IRR) was the percentage profit that reduces the NPV to zero.

3. RESULTS AND DISCUSSION

3.1. Factory location

The potassium carbonate plant was planned to be established in Banten province. Some factors that considered the site selection were raw material sources, utilities, transportation facilities, labor, and market. The raw materials that used in this plant were potassium hydroxide and carbon dioxide. Potassium hydroxide was obtained from China, and carbon dioxide was obtained from Indonesia. The utility unit provided water, electricity, steam, and compressed air. Water requirements will be met by the Cibanten River in Serang City. Electricity will be supplied by Perusahaan Listrik Negara (PLN) North Banten. Land transportation can be provided by Serang Barat toll road, and sea transportation can be provided by Karangantu Port. Fertilizer industries such as PT Pupuk Kujang was located in Cikampek, West Java Province, and PT Pupuk Sriwidjaja was located in Palembang, South Sumatra Province, can be targeted as marketing partners for potassium carbonate as a raw material in fertilizer production [26].

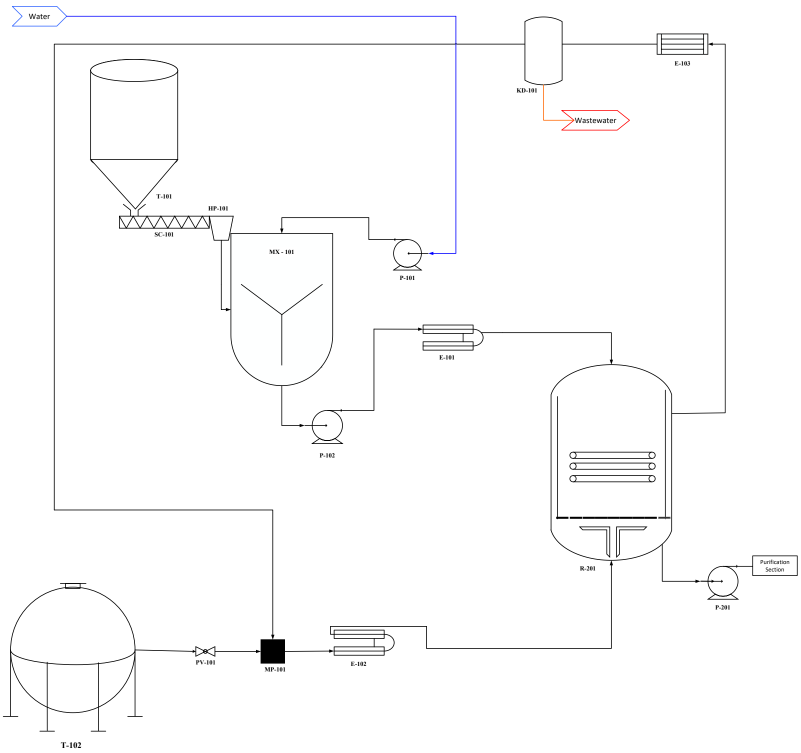
3.2. Potassium carbonate production process

The potassium carbonate plant design used potassium hydroxide and carbon dioxide as raw materials. The reaction used in potassium carbonate production was a hydroxide reaction with 99% potassium carbonate purity as main product according to the Neumann patent (1973) [18].

$$2KOH_{(aq)} + CO_{2(aq)} \rightarrow K_2CO_{3(s)} + H_2O_{(l)}$$

Figure 1. Reaction for potassium carbonate production

The process of potassium carbonate production can be seen in Figure 2. Potassium carbonate production started mixing potassium hydroxide from the storage tank (T-101) through the hopper (HP-101) which was mixed with process water in the mixer (MX-101). The mixture was then heated through a heater (E-101) to a temperature of 100 °C before entering the reactor. On the other side, carbon dioxide in the storage tank (T-102) will be flowed through a vacuum pump (PV-101) and mixed with the recycling flow at the mix point (MP-101) and heated to a temperature of 100 °C to the reactor. The process of potassium carbonate formation will be carried out in the bubble reactor (R-201) at a temperature of 100 °C with 0.43 atm pressure. During the process, water will evaporate and mix with unreacted CO_2 gas. This gas mixture then entered the condenser (E-103) to convert water vapor into water, which will then be separated into the knock drum (KD-101). The recycled CO_2 gas was then mixed with fresh CO_2 through a mix point. The reactor output product, in the form of slurry, was a product that mostly contains potassium carbonate. This slurry entered the evaporator (EV-301) to dry the product, then flowed by a screw conveyor (SC-301) to the rotary dyer (RD-301). The rotary dryer dried the product using an air blower (BW-301) and was heated by a heater (E-301). After the rotary dryer, the potassium carbonate product will flow through a bucket elevator (BE-301) to the hopper (HP-301) and ball mill (BM-301) to reduce the size, and then through a screen (SN-301) to equalize the size of the potassium carbonate product. In the final stage, potassium carbonate will be stored in a potassium carbonate product tank (T-301).



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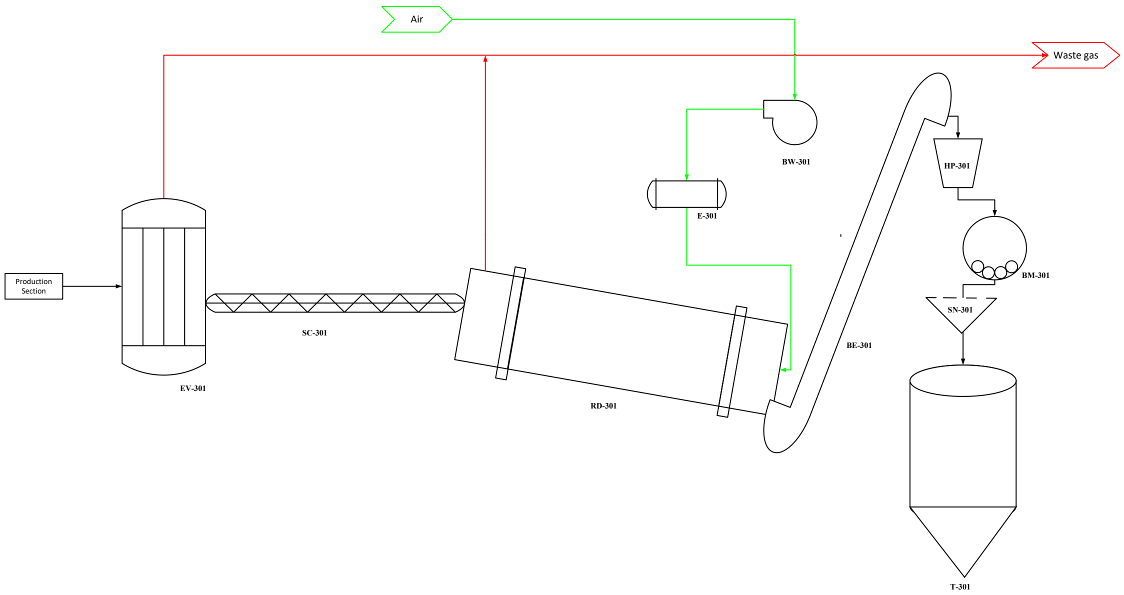


(b)

Figure 2. Process Flow Diagram Potassium Carbonate Plant (a) Pretreatment dan Production Section (b) Purification Section

3.3. Constant variables for economic evaluation

The fixed parameters used in the economic evaluation for this plant were:

a. The plant capacity was 10,000 tons/year of potassium carbonate production.
b. The plant's lifespan in the economic evaluation was 20 years.
c. The currency used for the economic evaluation was US dollar (US$), which an exchange rate of Indonesian rupiah was 15,000 per US dollar.
d. The bank interest rate used 10% of compound interest.
e. MACRS depreciation method was used with 15 years depreciation period.
f. 25% tax rate was used.

Total equipment cost calculated as shown in Figure 2 was $1,338,782. This equipment cost was used in total capital investment calculation as shown in Table 4.

Tabel 4. Total capital investment calculation

No.	Parameters	Cost	
1.	Purchased Equipment	1,338,728	
2.	Installation	602,452	
3.	Instrumentation and Controls	240,981	
4.	Piping	214,205	Total Direct Cost (TDC)
5.	Electrical System	133,878	
6.	Buildings	334,696	
7.	Yard Improvements	200,817	
8.	Services Facilities	535,513	
9.	Engineering and Supervision	441,798	
10.	Construction Expenses	522,125	Total Indirect Cost (TIC)
11.	Legal Expenses	53,551	
12.	Contractor's Fee	227,593	
13.	Contingency	468,574	

Fixed Capital Investment (FCI)	5,314,965
Working Capital (WC)	937,147
Total Capital Investment (TCI)	6,252,112

Tabel 5. Raw material cost calculation

Raw materials	Capacity (ton/year)	Price (US$/ton)	Total (US$/year)
Potassium Hydroxide (KOH)	8,970.75	1,020	9,150,172
Carbon Dioxide (CO_2)	4,138.75	280	1,158,852
Total			10,309,024

Tabel 6. Total revenue calculation

Product	Capacity (ton/year)	Price (US$/ton)	Total (US$/year)
Potassium Carbonate (K_2CO_3)	10,000	1,850	18,500,000
Total			18,500,000

Tabel 7. Total production cost calculation

No.	Parameters	Cost	
1.	Raw Material	10,309,024	Direct Production Cost (DPC)
2.	Labor	531,496	
3.	Supervision	53,150	
4.	Utilities	1,062,993	
5.	Maintenance	106,299	
6.	Operating Supplies	53,150	
7.	Laboratory Charges	53,150	
8.	Patents and Royalties	185,000	
9.	Depreciation	425,197	Fixed Charges (FC)
10.	Property taxes	106,299	
11.	Insurance	53,150	
Plant Overhead Costs (POC)		345,473	
Manufacturing Cost (MC)		13,284,381	
12.	Administration Costs	138,189	General Expense (GE)
13.	Distribution and Marketing Costs	265,688	
14.	Research and Development Costs	370,000	
Total Production Cost (TPC)		14,058,257	

Raw material costs and total revenue were calculated based on Tables 5 and 6, where raw material and product capacity were obtained from mass balance calculations. Total raw material cost and total revenue were used to calculate total production cost as shown in Table 7. Based on total capital investment (TCI) and total production cost (TPC), profit analysis of ROI, PBP, NPV, and IRR were 41.10%, 1.87 years, US$15,561,960, and 42.58%.

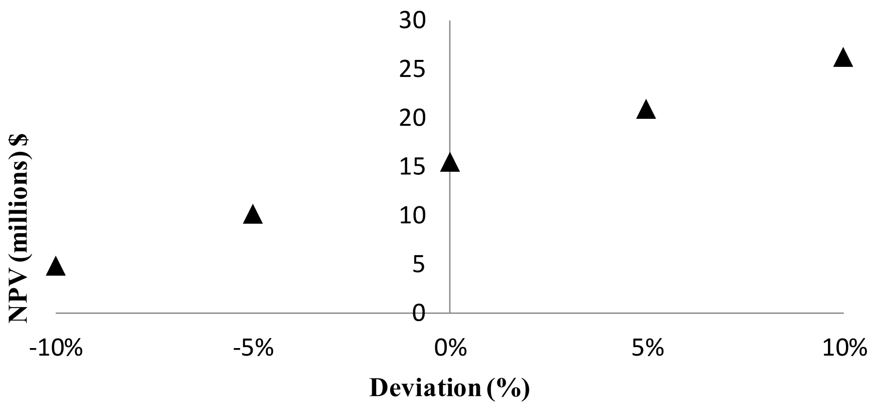
3.4. Potential of potassium carbonate in controlling fertilizer prices

Potassium carbonate can be used as a raw fertilizer. Potassium carbonate prices can increase in line with increasing fertilizer demand. Indonesia's high fertilizer demand come from subsidized fertilizers and palm oil fertilizers. From fertilizer consumption, 67% was used for food crops, 31% was used for plantation crops, and 2% was used for horticultural crops [27].

In general, global fertilizer prices have increased compared to the previous year. This could be due to several reasons, such as the COVID-19 pandemic, geopolitical conditions where Russia plays a significant role as a fertilizer exporter, export restrictions by several fertilizer-producing countries, and natural disasters. Higher global fertilizer prices could impact national fertilizer prices in Indonesia. National fertilizer prices were projected to rise in 2025, possibly due to the end of the natural gas price policy, which could impact nitrogen fertilizer prices in 2024 [28]. In 2022, the price of NPK fertilizer in Indonesia was around IDR 18,000-30,000/kg or approximately maximum around USD 1,900/ton, where the potassium component was generally imported from Canada, the Russian Federation, and Belarus [27]. Therefore, this study used a potassium carbonate price of $1,850/ton.

One way the government controls fertilizer prices is by providing subsidized fertilizer to the public. However, many farmers struggle to access subsidized fertilizer from the government, possibly due to several factors, including manipulation of definitive farmer group data, impractical subsidized fertilizer distribution, and discrimination in subsidized fertilizer distribution [29].

Based on available information, an economic sensitivity analysis of potassium carbonate production as a fertilizer ingredient was done to identify and maintain potassium carbonate prices, which could influence fertilizer prices. Figure 3 shows the economic sensitivity analysis of potassium carbonate product prices against NPV, PBP, ROI, and IRR with deviation variations of -5%, -10%, 5% and 10%.



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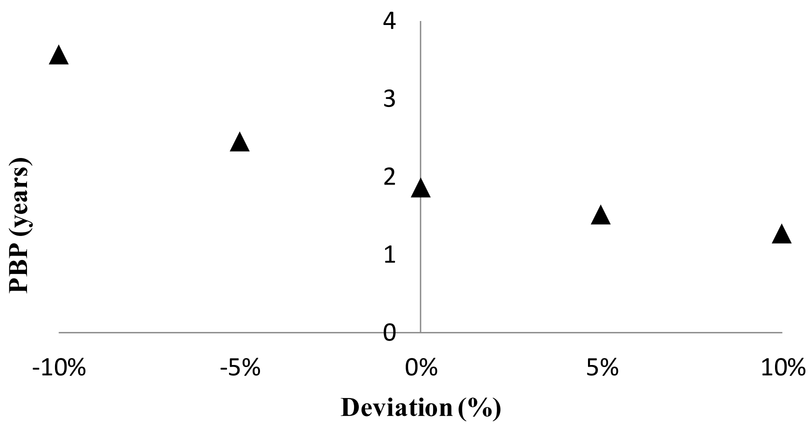

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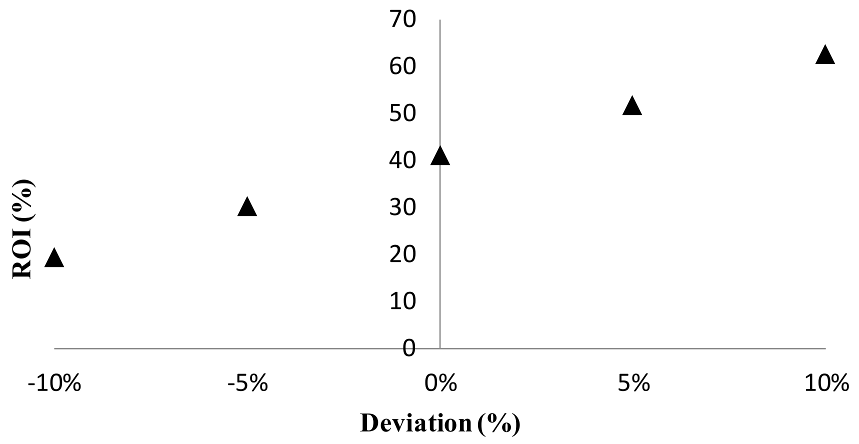

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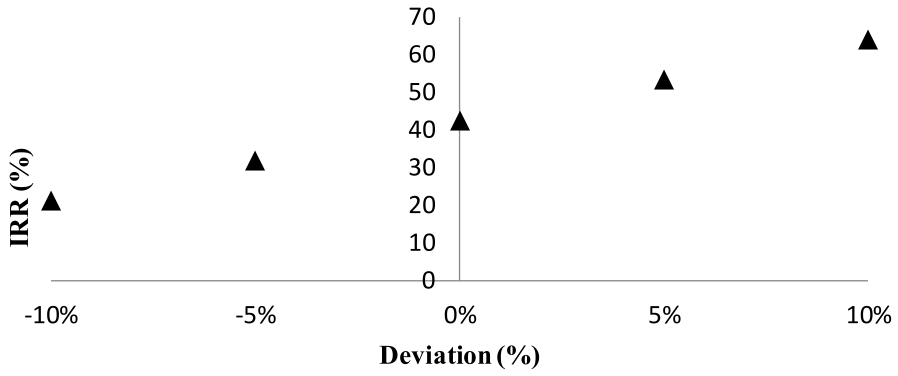

(d)

Figure 3. Economic sensitivity analysis of potassium carbonate production to product price (a) NPV, (b) PBP, (c) ROI, (d) IRR

Figure 3 showed that higher deviation (5% and 10%) in product price resulted in higher NPV, ROI, and IRR, and vice versa. The highest NPV was US$26,277,395. Meanwhile, the PBP value that showed the smallest value at 10% deviation was 1.27 years. This indicated the fastest payback period compared to other deviations. The increase in potassium carbonate product prices in Indonesia may be due to high demand in various industries, one of which is the fertilizer industry. Therefore, controlling potassium carbonate prices is necessary to support the fertilizer industry in Indonesia.

4. CONCLUSION

Potassium carbonate plant using potassium hydroxide and carbon dioxide as raw materials with a capacity of 10,000 tons/year was planned to be established in Banten at 2028. This location was chosen due to its proximity to raw materials, ease of transportation, and the utility that offers to support the Indonesian fertilizer industry. The process technology used in the potassium carbonate plant was the hydroxide method, considering the gas-liquid phase reaction and the high conversion rate. Potassium carbonate was produced by reaction between potassium hydroxide and carbon dioxide in a bubble reactor at 100℃ and 0.43 atm. Based on the Total Capital Investment (TCI) and Total Production Cost (TPC) calculations, the profitability analysis of potassium carbonate plant were 41.10% ROI, 1.87 years PBP, US$15,561,960 NPV, and 42.58% IRR. The sensitivity analysis of potassium carbonate products showed that 10% deviation produced largest NPV which was US$ 26,277,395 with 1.27 years PBP.

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