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The Development of Environmentally Friendly and Economically Biological Sulfur Recovery for Slow-released Fertilizer with Sulfur Coated Urea Method: A Case Study in Cepu Field

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Abstract - Agricultural land often experiences a shortage of nutrient due to the continuous farming system throughout the year. As a consequence, plant growth becomes hampered, and the need for artificial fertilizers increases. Currently, artificial fertilizers that are utilized by the farmers, are fast released but less absorbed by the plants. Therefore, an alternative artificial fertilizer that is slow to release is needed, so that it can be absorbed more effectively by plants in the long cultivation time. This study determined the long-term utilization of urea fertilizer that had been coated by sulfur from the Biological Sulfur Recovery Unit (BSRU) product in Cepu Oil Field with a Slow-Released Fertilizer (SRF) methodology. The dried sulfur is crushed and sieved to achieve a size of 200 mesh. Under a certain concentration ratio, sulfur and urea pellet are blended. The analysis was carried out to determine which concentration yielded the coating better. Based on the results, SRF with the sulfur to urea ratio of 1:2 and the mixing time of ten minutes, exhibited the best performance in dissolution tests with the longest dissolution time of five minutes, which is better than the uncoated urea. The project has the Pay Out Time (POT) of twenty-two months, and the Net Present Value (NPV) of 887 million. In conclusion, the benefit of BSRU product utilization from natural gas sweetening process has increased, and the potential to environmental disadvantage effects has reduced.

Keywords: gas sweetening, sulfur-coated urea, slow-releasedd fertilizer, environmental

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Introduction

Background

Sour gas has a H_2S contaminant concentration that influences its calories and prices. Therefore, sweetening processes are needed. This removal process is carried out by the Amine Unit and Biological Sulfur Recovery Unit (BSRU) to obtain selling-quality natural gas. The BSRU removes and extracts sulfur content biologically by the bacteria. Elemental sulfur is a bright yellow powder-like compound that can be in large piles near sweetening plants (Stewart and Arnold, 2011). In Cepu Oil Field, the production of its product thoseelemental sulfur approximately 14 tons/day. Therefore, the massive daily production needs to be transformed to be more beneficial for those surrounding the rice field farming ecosystem.

This study determines the application of BSRU product as a coating layer for urea fertilizer with SRF method. A laboratory study was conducted to analyze and to investigate the effect of sulfur coating in producing efficient SRF using extracted sulfur from a gas sweetening processing plant. Various sulfur concentration versus urea fertilizer are blended to get a better coating layer. Releasing process was determined by observing the soaking time of the coated urea when it was submerged into the water. Economic parameter as NPV and POT determines the project benefit in a full scale production (Shou, 2022).

SRF allow plants to absorb the elements that make up the plant differently. One is to delay the uptake of these elements by the plant, so they are available for using after application. Another possibility is to provide a mechanism to make these nutrients available over a long period of time. Nitrogen products broken down by microorganisms are called SRF (Fan and Liao, 1998). Slow-released fertilizers add nutrients to the soil gradually over a long period. Often, the nutrients in SRF become available in the soil over a period of six to eight weeks or longer (Blouin *et al.*, 1971). The optimal nitrogen uptake by crops from the urea fertilizer is around 30–35 % due to the uneasy urea fixing by soil particles before hydrolyzation (Entry and Sojka, 2008). Due to environmental and economic issues, global regulations regarding geothermal have been related to the common application of conventionally formulated urea (Fan and Liao, 1998). SRF development has gained attention to reducing environmental disadvantages caused by fertilizer application. This objective is to develop a slow-released urea fertilizer that is economically viable, minimizing the costs associated with the mitigation of nitrogen-related environmental pollution.

SRF can boost crop yield and reduce pollution caused by hazardous materials from the current fertilizer applications. The absorption of nitrogen from urea fertilizer is significantly inefficient due to its solubility in water. This problem can be overcome by producing SRF that inhibits urea from being dissolved in water.

Many materials, either organic degradable or polymers, had been researched as a coating component for the fertilizer to be slow released. Coating materials should have a diffusion system to release the nutrients of fertilizer when spread into the water or wetlands (Purnomo and Saputra, 2021). Sulfur-coated urea (SCU) as one of the SRF methods, is a type of SRF made by coating urea with elemental sulfur that can release nutrient slowly. Sulfur as the coating material is considered due to its degradability as organic compound also as the ingredients of plant nutrients. The coating creates an impermeable layer that has a slow degradation rate through microbial, chemical, and physical processes. Furthermore, SRF yields a high utility rate, making its utilization be more affordable than that of ordinary applications (Baboo, 2016).

The method that had been introduced by the researchers to develop SCU is a hot rolling cylinder. This method runs rolling drums and sprays injected steam to order coating process between fertilizer and sulfur (Purnomo and Saputra, 2021).

NPV and POT were used to propose economic consideration for the research. NPV is the difference between the present value of cash inflows and the present value of cash outflows over a period. NPV is used in capital budgeting and investment planning to analyze the project profitability. NPV results from calculations that find the current value of a future stream of payments using the proper discount rate. Projects with a positive NPV are worth undertaking, while those with a negative NPV are not (Shou, 2022).

POT is the amount of time that will be taken for the project to be profitable in a cash flow. The economic estimation of sulfur if used as the urea coating material over a period of ten years, is delivered in this study.

Materials and Methods

This study used a laboratory-scale experimental methodology with various sulfur concentrations to blend with urea fertilizer. The coated fertilizer dissolution time in water was compared and analyzed. The sulfur concentration with the longest dissolving time is expected to give optimal results. The materials used were urea and sulfur cake obtained from the BSRU in Cepu Oil Field. The composition of sulfur cake was accurately determined using the X-ray fluorescence method. This method analyzed the composition of the material based on the interaction between the X-ray and the material tested.

The main equipment used for the coating process was a sieve shaker set to separate materials with gradual sieving mixing and coating material. In the drying process, a vacuum drying oven was used to heat and to dry the sulfur cake, so that it can be easily crushed. The other additional equipments used were a digital scale, glass dish, spatula, laboratory pan, and hammer.

Sulfur Preparation

The preparation of sulfur involves several steps, because sulfur cake from processing plants cannot be used directly as the coating material. Firstly, the sulfur cake was placed and evenly distributed on the surface of a laboratory pan to facilitate the drying process, allowing the removal of water content. Subsequently, the laboratory pan was placed in the oven, which was set to a temperature to 120˚C and allowed to heat for 90 minutes (about 1 and a half hours). After the drying, sulfur was removed from the oven and crushed into a powder form using a hammer. Sulfur powder was sieved with a sieve that had an opening diameter of 200 mesh.

Coating Process

Sulfur powder obtained from the previous process was ready to be used to coat the urea. The urea coating method at this stage was to mix the urea and sulfur in various concentrations. The mixing process was carried out with a sieve number 200. A certain amount of sulfur and urea was sieved at a certain time of treatment. The result of the sieve process is a certain amount of urea coated by sulfur. In this study, the sulfur powder and urea were mixed and sieved with two different ratios, which are 1:2 (20 g urea and 40 g sulfur) and 1:1 (40 g urea and 40 g ulfur). Urea and sulfur were sieved for 5, 10, and 30 minutes using a sieve shaker set that allowed the outer part of urea grains to be coated with sulfur. After the duration was achieved, the coated urea was weighted.

RESULT AND DISCUSSION

The results of the X-ray fluorescence analysis are presented in Table 1. The main component of the BSRU product is sulfur (98.1 %) as SO_3 (98.6 %) and aluminum (1 %) as Al_2O_3 (1.1 %). The ingredient fits the study requirements as the coating material in SRF method. Sulfur, as a major component of the BSRU product, will be used as as shown in Table 2.

Blending of 20 g urea and 40 g sulfur with a duration of only 5 minutes yields coated urea of 26.7 g. On the other hand, if the blending shaking is 10 minutes, this yields 29.6 g coated urea. The longest duration of the shaking, 30 minutes, produces 31g of coated urea. The ideal mixing condition: 1:2 (20 g urea and 40 g sulfur) achieved 60 g coated urea (Table 3). From this experiment, the result of coated urea in 5 minutes was only 26.7 g or less than 50 %. Therefore, for the next step of laboratory process, the sieving period was 10 minutes due to 30 minutes of shaking did not much influence to yield more coated fertilizer.

Table 1. Sulfur Cake Composition from X-ray Fluorescence Analysis (Without Oxidation)

No.	Element	1st Reading (%)	2nd Reading (%)	Methode
1	Al	1	0.84	X-Ray Fluorescence
2	S	98.1	98.2	X-Ray Fluorescence
3	Ca	0.59	0.59	X-Ray Fluorescence
4	Fe	0.24	0.25	X-Ray Fluorescence
5	Cu	0.095	0.094	X-Ray Fluorescence

Table 2. Sulfur Cake Composition from X-ray Fluorescence Analysis (Oxidation)

No.	Element	1st Reading (%)	2nd Reading (%)
1	Al_2O_3	1.1	1.1
2	SO_3	98.6	98.6
3	CaO	0.23	0.23
4	Fe_2O_3	0.091	0.091
5	CuO	0.03	0.03

Table 3. SCU Weight After Coating Process (1:2 Ratio)

No.	Duration of Sieve Shaking (mins)	SCU Weight (gr)
1	5	26.7
2	10	29.6
3	30	31

Furthermore, Table 4 describes the blending results of 40 g urea and 40 g sulfur with a duration of 5 minutes, yielding coated urea of 44.6 gr. Meanwhile, the shaking lasted 10 minutes, yielded 47.1 g coated urea. The last duration of the shaking, 30 minutes, yielded 48 g coated urea. The ideal condition of mixing 1:1 achieved 80 grcoated urea. However, from this experiment, the result of coated urea in 5 minutes was only 44.6 g or less than 50 %. The next step of the sieving period was 10 minutes based on previous experiments presented at Table 3.

Table 4. SCU Weight After Coating Process (1:1 Ratio)

No.	Duration of Sieve Shaking (mins)	SCU Weight (gr)
1	5	44.6
2	10	47.1
3	30	48

As shown in Tables 3 and 4, the amount of sulfur used to coat the urea increased with a longer duration of the coating process, indicating a thicker coating. However, the thickness of the sulfur coating can prolong the release of nitrogen, affecting the effectiveness of nitrogen absorption. Therefore, the optimum coating duration is needed to yield an effective SRF.

Table 5 presents the result of the dissolution test from six various samples blending concentration and just urea (batch 7) as a reference sample. The sulfur coated urea at batch 1,2, and 3 (40 g sulfur *vs*. 40 g urea) had the similar dissolution time, despites duration of its blending treatment. Furthermore, a similar trend also occurred in the group batch 4, 5, and 6. The sulfur coated urea of batch 4 had less than 1 minute dissolution time than others. However, batch 5 and 6 showed an increase of dissolution time, which is 5 minutes, and had higher dissolution time than previous batch experiments. Therefore, it can be resumed that the treatment of blending 20 g urea *vs* 40 g of sulfur at 10 minutes of blending had the effective result for this study, which is 5 minutes. An economic analysis was carried out to investigate the economic feasibility of this study. Several economic parameters such as NCF, NPV, POT, and others were calculated as follows (Shou, 2022).

Table 5. Results of The Dissolution Test

No	Sample	Dissolution Time (minutes)
1	1:1; 5 minutes	1.5
2	1:1; 10 minutes	1.5
3	1:1; 30 minutes	1.5
4	1:2; 5 minutes	<1
5	1:2; 10 minutes	5
6	1:2; 30 minutes	5
7	Urea $(NH_2)_2CO$	<1

1. Expenditure (Annual Basis)

The expenditure total including equipment, materials, and other costs in millions of IDR in one year is shownin Table 6. The factory produces 6,000 ton/year sulfur coated urea and has 164-man labour with a regional salary regulatory at Blora, Central Java, 2023.

2. Earn Before Tax (EBT)

EBT = Annual Revenue (million IDR) - Total Production Cost (million IDR)
= 15,000 - 9,465.05
= 5,534.95 million IDR/year

3. Earn After Tax (EAT)

Based on the Regulation of Income Taxt Article 21, a tax of 30 % is applied to the petroleum and chemical industries.
EAT = EBT - Tax
= 5,534.95 million IDR/year – (30 % x 5,534.95 million IDR/year)
= 3,874.465 million IDR/year

4. Depreciation Calculation

Depreciation = 15,000: 10
= 1,500 million IDR for 10 years

Table 6. Expenditure (Annual Basis)

Expenditure (All in Million IDR)	
Equipment	Cost (Million IDR)
Sieve Shaker	32.1
Vacuum Drying Oven	110.4
Digital Balance	5.75
Material	Cost (Million IDR)
Urea	4,500
Other	Cost (Million IDR)
Employee Salaries	3,916.8
Land Rental	100
Maintenance	250
General Costs (Electricity, Water, *etc.*)	550
TOTAL	9,465.05

5. Revenue Estimation

Table 7 shows a revenue estimation sulfur coated urea consists of annual production, sale price, and annual revenue.

Table 7. Revenue Estimation

Product	Annual Production (ton/year)	Sales Price (million IDR/ton)	Annual Revenue (million IDR/year)
Sulfur Coated Urea	6,000	2.5	15,000

6. Net Cash Flow (NCF)

Calculation NCF = EAT + Depreciation

= 3,874.465 + 1,500

= 5,374.465 million IDR/year

Net Present Value (NPV) Calculation

PV Proceed = NCF x i

MARR = 12 %

The total NPV for the period of 2021−2030 which is obtained from the value of NCF (million IDR/year) is presented in Table 8.

Table 8. Net Present Value (NPV)

Period	NCF (million IDR/ year)	i	PV Proceed (million IDR)
2021	5,374.465	0.892857143	-36.523.080
2022	5,417.665	0.797193878	10.579.401
2023	54,610.205	0.711780248	48.316.359
2024	55,045.321	0.635518078	78.121.903
2025	5,548.200	0.567426856	101.233.677
2026	55,920.258	0.506631121	118.718.155
2027	5,636.009	0.452349215	131.492.795
2028	5,680.150	0.404883228	140.345.457
2029	5,724.451	0.360610025	145.951.388
2030	5,768.911	0.321973237	148.888.089
Total			**887.124.144**

7. Pay Out Time (POT)

POT = NCF/Total Investment

= 5,374.465 million IDR/year / 9,465.05

= 1.762 years

= 22 months

Conclusions

Based on the results, the utilization of sulfur product of BSRU in Cepu Oil Field exhibited a great potential to be further used as a coating material due to its ability to decelerate the release of nutrients. From the results of these experiments, it is concluded that 1:2 ratio treatments with a blending sieve time of 10 minutes is the optimal result in this study. From the experimental study conducted, sample of batch 5 possessed the proper dissolution time. The scale up factory has 22 months of pay out time and net present value of 887 million (IDR).

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