

Optimal points of operational parameters of sulphuric acid, phosphoric acid, and ammonia production process

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ABSTRACT

Keywords:

optimum point
phosphoric acid
ammonia
downtime
Sulphuric acid

PT Petrokimia Gresik is the most complete fertilizer producer in Indonesia and produces various types of fertilizers. NPK is a fertilizer that contains nitrogen (N) to make plants greener, phosphorus (P) to stimulate root growth, and potassium (K) to make plants more upright and sturdy. This study aims to determine the optimum value of using sulfuric acid, phosphoric acid, and ammonia so as to obtain the best value in producing NPK fertilizer. This research method uses quantitative descriptive research methods by collecting secondary data, namely the use of sulfuric acid, phosphoric acid, and ammonia for a period of 1 year. Researchers use multiple regression analysis to determine whether or not there is an influence between the three variables to be studied, then the data is processed and analyzed to determine whether the regression model used is feasible to use before finally calculating the optimal point of NPK fertilizer production. The stages of data optimization in this study are the data collection stage, the data processing stage (descriptive data, parameter estimation, regression model), the data analysis and interpretation stage (F test, t test, IIDN assumption test for determining the optimum point), and the conclusion and suggestion stage. This study concluded that obtaining the optimum point for the amount of NPK fertilizer production can be done by regulating the use of phosphoric acid at 211.91 tons, Sulphuric acid at 844,099 tons, and ammonia at 308,055 tons. Total fertilizer production achieved with the use of optimum parameters amounted to 2085.38 tons.

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INTRODUCTION

NPK Phonska Reaction fertilizer factory is a factory that produces liquid-based fertilizer so it is called Phonska Reaction. NPK Phonska Reaction process includes granulation, drying, cooling, coating, and bagging. The initial process is to mix the main liquid raw materials, namely Sulphuric acid, phosphoric acid, and ammonia into a vessel (Pre-Neutranilizer Tank) with high temperature. The three liquids are then stirred until they mix using an agitator blade in the Pre-Neutranilizer Tank. The mixture of Sulphuric acid, phosphoric acid, and ammonia will become a thick grayish-white slurry which is then pumped into the granulator equipment for the granulation process of fertilizer granulation. Inside the granulator, the slurry will be mixed with solids and steam raw materials.

Products from granulators have a moisture content in the range of 4-5% then transferred through a belt conveyor to dryer equipment for drying or reducing moisture content to a maximum of 1.5%. The next process is to cool the product into the cooler equipment so that the product temperature becomes 50-55 degrees Celsius using cold air coming from the chiller. After cooling, the product is sent to the screen for a screening process between onsize, oversize, and undersize products. Oversized and undersized products will be recycled while onsize products will be sent to coater equipment using bucket elevators for further dyeing. Onsize fertilizer that has been coated is then bagging, with 50 kg packaging according to applicable standards at PT Petrokimia Gresik.

Research on optimizing the parameters of the operational process of NPK fertilizer plant production has been carried out by many previous researchers. According to research by Rasulov et al., (2022) with the use of washed and dried phosphorite concentrate (WDPC) as much as 487.06 kg, wet processing phosphate acid

(WPPA) as much as 4870.42 kg, ammonia as much as 283.01 kg, sulfuric acid as much as 227.69 kg will produce NPK superphosphate-based fertilizer as much as 931.59 kg and NPK-based fertilizer Ammophosphate amounted to 1329.33 kg. According to research conducted by Mukhtorovna et al., (2021) to produce 1000 kg of NPK fertilizer, it is necessary to use 360 kg of nitric acid (HNO_3), 264.88 kg of water (H_2O), 205.8 kg of potassium chloride (KCl), and the use of phosphoric acid (H_3PO_4) of 650 kg. Another study conducted by Allamuratova et al., (2021) to produce NPK fertilizer with the formula 16.7:16.7:16.7 requires the amount of nutritional components as much as 50.1%, the consumption coefficient of Kyzyl Kum phosphorite is 1.51, nitric acid consumption coefficient is 0.58, sulfuric acid consumption coefficient is 1.33, The consumption coefficient of potassium chloride is 0.55, the ammonia consumption coefficient is 0.24.

Nomozov et al., (2020) explained that in his research with the use of phosphoric acid of 1103.63 kg, ammonia of 86.90 kg, urea of 124.24 kg, and potassium chloride of 170.31 kg, NPK fertilizer of 1000 kg would be obtained. Rasulov et al., (2020) explained that to obtain fertilizer with nitrogen-phosphate (NPK) content with the use of wet processing phosphate acid (WPA) of 415.14 kg, sulfuric acid of 120.06 kg, ammonia of 61.45 kg, phosphorite powder as much as 119.84 kg will produce a total of 406.34 kg of fertilizer with an N content of 11.55% and P_2O_5 of 24.61%. Research conducted by Numonov et al., (2019) stated that the use of sulfuric acid as much as 985 kg, consumption of 1000 kg WBPC (Washed And Burned Phosphoconcentrate), the use of 215 kg of ammonia, nitric acid (HNO_3) as much as 550.4 kg, potassium chloride of 402 kg will produce NPK fertilizer of 1743 kg with a Nitrogen content of 14.34%, P_2O_5 13.91%, and K_2O 13.81%.

Pagaleshkin and Kolpakov (2019) stated that there is a technology developed for NPK fertilizers with formula types 16-16-16 and 17-17-17. The process is carried out under conditions of producing nitroammophonska – fertilizer with a high molar ratio of ammonia (NH_3) and phosphoric acid (H_3PO_4) in fertilizer with a ratio of 1.65 : 1.8 mol / mol. According to the final project research conducted by Tania and Machdalia (2017) to produce NPK fertilizer with a capacity of 500 tons per day requires ammonia raw materials of 68784.11 kg, the use of sulfuric acid as much as 72807.86 kg, phosphoric acid of 251832.50 kg, urea of 29855.34 kg, ammonium nitrate of 65135.57 kg, KCl of 131341.21 kg, coating powder of 1100 kg, and coating oil of 1200 kg. Zhang et al., (2017) explained that to obtain fertilizer with an amount of 1 ton of product requires sulfuric acid as much as 1.53 tons, sulfur (sulfur) as much as 0.50 tons, phosphoric acid as much as 2.27 tons, water as much as 3.22 m^3 , ammonia as much as 0.14 tons.

Based on the existing explanation, an optimization step is needed from the use of plant operations which are parameters in the production process at the NPK Phonska Reaction plant. The optimization problem is a problem of finding the optimum value of a function. The necessary condition that must be met in order for the optimal functional is a partial derivative of the goal function against all its variables to zero (Khoiriyah, 2020). A partial differential equation is a differential equation involving a partial derivative containing two or more variables (Raming et al., 2023).

This study aims to know, identify the optimal value of using sulphuric acid, phosphoric acid, and ammonia for use in the production process at the NPK Phonska Reaction fertilizer plant, and determine the optimum point of operational parameters at the NPK Phonska Reaction plant in producing the amount of fertilizer with the use of sulphuric acid, phosphoric acid, ammonia. The results of this study provide recommendations for optimizing the operational parameters of the NPK Phonska IV (Phonska Reaction) plant at PT Petrokimia Gresik as a reference in order to carry out the production process effectively and efficiently in the long term.

METHOD

This research method uses quantitative descriptive research methods, while the analysis uses multiple regression models. This research methodology is divided into four stages, namely the data collection stage, data processing stage, data analysis and interpretation stage, and conclusion and suggestion stage. The flow diagram of the research stages is shown in the figure 1 below. These stages are carried out using Minitab and Microsoft Excel software. The data collection stage is a way to obtain data and needs that support the research conducted. The data collected by this study is secondary data sourced from the NPK Phonska Reaction fertilizer production process at PT Petrokimia Gresik from January 1, 2022 to December 31, 2022, namely phosphoric acid usage data, sulphuric acid usage data, ammonia usage data, downtime data, and the amount of fertilizer production. The data processing stage consists of descriptive data, parameter estimation, regression models. Descriptive statistics are a suite of statistics that summarize the characteristics and distribution of a set of data values (Lee, 2020). Parameter estimation is an estimation of population characteristic values based on sample characteristics (Aster, 2019). Meanwhile, regression models are used to determine the relationship between variables (Mohr, 2022).

The analysis phase includes testing the feasibility of the model and determining the optimum point. Model feasibility tests include F test, t test, correlation test, IIDN assumption test. Test F is performed to determine whether all independent variables entered into the model have a joint influence on the dependent variable (Siegel and Wagner, 2022). The t test is used to determine the effect of each independent variable on

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the dependent variable (Thukral and Paturu, 2023). The correlation test is used to describe how strong the relationship of a variable with other variables (Rizk, 2023). Testing identical residual assumptions is used to determine the homogeneity of the regression model's residual variance (Rositawati, 2020). Independent residual assumption testing is used to determine the presence of autocorrelation in (Salsabila, 2022). Testing of normally distributed residual assumptions can be done by looking at graphs, namely histogram graphs and normal probability plot graphs and by Kolmogorov-Smirnov testing (Dzikir, 2020).

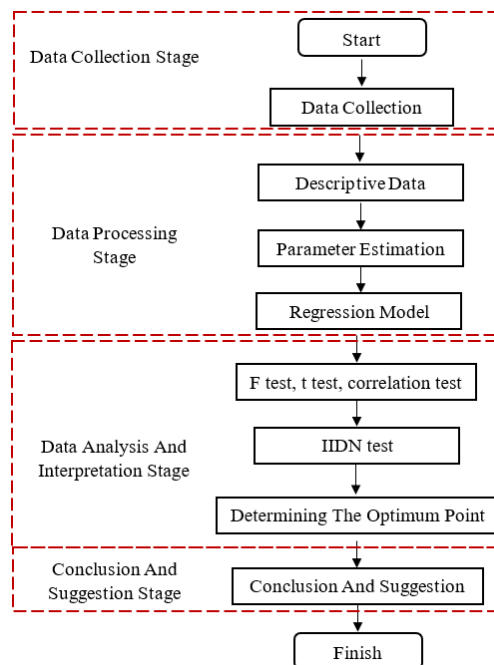


Figure 1. Research Flowchart

The results of the univariate analysis in this study will provide results in the form of average values, standard deviations, minimum values, and maximum values from the use of phosphoric acid, sulfuric acid, ammonia, downtime, and the amount of fertilizer production in the NPK Phonska Reaction. While the results of the bivariate analysis will show the relationship between each variable and the amount of NPK fertilizer production. These results were obtained using Minitab software.

RESULTS AND DISCUSSION

Researchers conduct model feasibility tests to determine whether the regression model is feasible to use in this study before determining the optimal point of operational parameters. Model feasibility tests include F test, t test, correlation test, identical assumption test, independent assumption test, and normal distribution assumption test.

Concurrent Regression Coefficient Test (F Test)

Total Fertilizer Production Against Phosphoric Acid Use (X1)

Table 1. Test F Amount of Fertilizer Production Against Phosphoric Acid Use

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	23447597	11723798	229,34	0,000
phosphoric acid	1	7461045	7461045	145,95	0,000
phosphoric acid ^2	1	3309207	3309207	64,73	0,000

- The hypotheses in this test are:
 - $H_0 : \beta_1 = \beta_2 = 0$, meaning that there is no significant effect together or simultaneously from variable X1 on variable Y.
 - $H_1 : \beta_1 \neq \beta_2 \neq 0$, meaning that at least one of the variables X1 has an effect on variable Y.
- The F test in this test uses a significance level of $\alpha = 5\%$. Degree of freedom (df_1) = $k - 1 = 3 - 1 = 2$, and $df_2 = n - k = 312 - 3 = 309$, so the F value of the table for significance 0.05 is 3.025.

- 3) The calculated F test value is 229.34.
- 4) Statistical test criteria:
 - a) If the value of $F_{\text{count}} < F_{\text{table}}$ then H_0 is accepted (no effect)
 - b) If the value of $F_{\text{count}} > F_{\text{table}}$ then H_0 is rejected (effect)
- 5) Decision Making: From the test results, it is found that $F_{\text{count}} > F_{\text{table}}$ or p-value value < 0.05 , then a **decision can be made to reject H_0** which means that individually there is a significant influence of the variables studied.

Total Fertilizer Production Against the Use of Sulphuric Acid (X2)

Table 2. Test F Amount of Fertilizer Production Against the Use of Sulphuric Acid

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	29597279	14798639	474,03	0,000
Sulphuric Acid	1	4134448	4134448	132,43	0,000
Sulphuric Acid^2	1	750155	750155	24,03	0,000

- 1) The hypotheses in this test are:
 - a) $H_0 : \beta_1 = \beta_2 = 0$, meaning that there is no significant effect together or simultaneously from variable X2 on variable Y.
 - b) $H_1 : \beta_1 \neq \beta_2 \neq 0$, meaning that at least one of the variables X2 has an effect on variable Y.
- 2) The F test in this test uses a significance level of $\alpha = 5\%$. Degree of freedom (df_1) = $k - 1 = 3 - 1 = 2$, and $df_2 = n - k = 312 - 3 = 309$, so the F value of the table for significance 0.05 is 3.025.
- 3) The calculated F test value is 474.03.
- 4) Statistical test criteria:
 - a) If the value of $F_{\text{count}} < F_{\text{table}}$ then H_0 is accepted (no effect)
 - b) If the value of $F_{\text{count}} > F_{\text{table}}$ then H_0 is rejected (effect)
- 5) Decision Making: From the test results, it is found that $F_{\text{count}} > F_{\text{table}}$ or p-value value < 0.05 , then a **decision can be made to reject H_0** which means that individually there is a significant influence of the variables studied.

Total Fertilizer Production Against Ammonia Use (X3)

Table 3. Test F Amount of Fertilizer Production Against Ammonia Use

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	29531404	14765702	469,77	0,000
Amonia	1	4222376	4222376	134,33	0,000
amonia^2	1	1135800	1135800	36,14	0,000

- 1) The hypotheses in this test are:
 - a) $H_0 : \beta_1 = \beta_2 = 0$, meaning that there is no significant effect together or simultaneously from variable X3 on variable Y.
 - b) $H_1 : \beta_1 \neq \beta_2 \neq 0$, meaning that at least one of the variables X3 has an effect on variable Y.
- 2) The F test in this test uses a significance level of $\alpha = 5\%$. Degree of freedom (df_1) = $k - 1 = 3 - 1 = 2$, and $df_2 = n - k = 312 - 3 = 309$, so the F value of the table for significance 0.05 is 3.025.
- 3) The calculated F test value is 469.77.
- 4) Statistical test criteria:
 - a) If the value of $F_{\text{count}} < F_{\text{table}}$ then H_0 is accepted (no effect)
 - b) If the value of $F_{\text{count}} > F_{\text{table}}$ then H_0 is rejected (effect)
- 5) Decision Making: From the test results, it is found that $F_{\text{count}} > F_{\text{table}}$ and the p-value < 0.05 then a **decision can be made to reject H_0** which means that individually there is a significant influence from the variables studied.

Amount of Fertilizer Production Against Plant Downtime

Table 4. Test F Amount of Fertilizer Production Against Plant Downtime

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	38993104	19496552	130592,83	0,000
Downtime	1	5342569	5342569	35785,88	0,000

Downtime^2	1	2928	2928	19,62	0,000
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- 1) The hypotheses in this test are:
 - a) $H_0 : \beta_1 = \beta_2 = 0$, meaning that there is no significant effect together or simultaneously from variable X3 on variable Y.
 - b) $H_1: \beta_1 \neq \beta_2 \neq 0$, meaning that at least one of the variables X3 has an effect on variable Y.
- 2) The F test in this test uses a significance level of $\alpha = 5\%$. Degree of freedom (df_1) = $k - 1 = 3 - 1 = 2$, and $df_2 = n - k = 312 - 3 = 309$, so the F value of the table for significance 0.05 is 3.025.
- 3) The calculated F test value is 130592.
- 4) Statistical test criteria:
 - a) If the value of $F_{count} < F_{table}$ then H_0 is accepted (no effect)
 - b) If the value of $F_{count} > F_{table}$ then H_0 is rejected (effect)
- 5) Decision Making: From the test results, it is found that $F_{count} > F_{table}$ and the p-value < 0.05 then a **decision can be made to reject H_0** which means that individually there is a significant influence from the variables studied.

Partial Regression Coefficient Test (t Test)

Total Fertilizer Production Against Phosphoric Acid Use (X1)

Table 5. Test t Amount of Fertilizer Production Against the Use of Phosphoric Acid

Term	Coef	SE Coef	T-Value	P-Value
Constant	-325	122	-2,67	0,008
Phosphoric Acid	10,632	0,880	12,08	0,000
Phosphoric Acid^2	-0,01279	0,00159	-8,05	0,000

- 1) The hypotheses in this test are:
 - a) H_0 : the independent variable has no significant effect on the yield of the amount of fertilizer production in the NPK Phonska Reaction plant unit.
 - b) H_1 : the independent variable has a significant effect on the yield of the amount of fertilizer production in the NPK Phonska Reaction plant unit.
- 2) The t test in this test uses a significance level of $\alpha = 5\%$. Degree of freedom (df_1) = $n - 2 = 312 - 2 = 310$, so the table t value for significance of 0.05 is 1.9676.
- 3) Statistical test criteria:
 - a) If the significance value of the t-test < 0.05 then H_0 is rejected and H_1 is accepted (effect).
 - b) If the significance value of the t-test > 0.05 then H_0 is accepted and H_1 is rejected (no effect).
- 4) Decision Making: From the test results, it was found that the significance value was 0.008 or p-value < 0.05 , then a decision could be made **to reject H_0** which means that the independent variable has a significant effect on the results of the amount of fertilizer production in the NPK Phonska Reaction plant unit.

Total Fertilizer Production Against the Use of Sulphuric Acid (X2)

Table 6. Test t Amount of Fertilizer Production Against the Use of Sulphuric Acid

Term	Coef	SE Coef	T-Value	P-Value
Constant	-168,0	91,7	-1,83	0,006
Sulphuric Acid	5,818	0,506	11,51	0,000
Sulphuric Acid^2	-0,003430	0,000700	-4,90	0,000

- 1) The hypotheses in this test are:
 - a) H_0 : the independent variable has no significant effect on the yield of the amount of fertilizer production in the NPK Phonska Reaction plant unit.
 - b) H_1 : the independent variable has a significant effect on the yield of the amount of fertilizer production in the NPK Phonska Reaction plant unit.
- 2) The t test in this test uses a significance level of $\alpha = 5\%$. Degree of freedom (df_1) = $n - 2 = 312 - 2 = 310$, so the table t value for significance of 0.05 is 1.9676.
- 3) Statistical test criteria:
 - a) If the significance value of the t-test < 0.05 then H_0 is rejected and H_1 is accepted (effect).
 - b) If the significance value of the t-test > 0.05 then H_0 is accepted and H_1 is rejected (no effect).

- 4) Decision Making: From the test results, it was found that the significance value was 0.006 or p-value < 0.05, then a decision could be made **to reject H0** which means that the independent variable has a significant effect on the results of the amount of fertilizer production in the NPK Phonska Reaction plant unit.

Total Fertilizer Production Against Ammonia Use (X3)

Table 7. Test t Amount of Fertilizer Production Against Ammonia Use

Term	Coef	SE Coef	T-Value	P-Value
Constant	-320	105	-3,06	0,002
Amonia	13,97	1,21	11,59	0,000
amonia^2	-0,02049	0,00341	-6,01	0,000

- The hypotheses in this test are:
 - H0: the independent variable has no significant effect on the yield of the amount of fertilizer production in the NPK Phonska Reaction plant unit.
 - H1: the independent variable has a significant effect on the yield of the amount of fertilizer production in the NPK Phonska Reaction plant unit.
- The t test in this test uses a significance level of $\alpha = 5\%$. Degree of freedom (df1) = $n - 2 = 312 - 2 = 310$, so the table t value for significance of 0.05 is 1.9676.
- Statistical test criteria:
 - If the significance value of the t-test < 0.05 then H0 is rejected and H1 is accepted (effect).
 - If the significance value of the t-test > 0.05 then H0 is accepted and H1 is rejected (no effect).
- Decision Making: From the test results, it was found that the significance value was 0.002 or p-value < 0.05, then a decision could be made **to reject H0** which means that the independent variable has a significant effect on the results of the amount of fertilizer production in the NPK Phonska Reaction plant unit.

Amount of Fertilizer Production Against Plant Downtime

Table 8. Test t Amount of Fertilizer Production Against Plant Downtime

Term	Coef	SE Coef	T-Value	P-Value
Constant	2000,88	1,34	1490,22	0,000
Downtime	-2050,6	10,8	-189,17	0,000
Downtime^2	65,0	14,7	4,43	0,000

- The hypotheses in this test are:
 - H0: the independent variable has no significant effect on the yield of the amount of fertilizer production in the NPK Phonska Reaction plant unit.
 - H1: the independent variable has a significant effect on the yield of the amount of fertilizer production in the NPK Phonska Reaction plant unit.
- The t test in this test uses a significance level of $\alpha = 5\%$. Degree of freedom (df1) = $n - 2 = 312 - 2 = 310$, so the table t value for significance of 0.05 is 1.9676.
- Statistical test criteria:
 - If the significance value of the t-test < 0.05 then H0 is rejected and H1 is accepted (effect).
 - If the significance value of the t-test > 0.05 then H0 is accepted and H1 is rejected (no effect).
- Decision Making: From the test results, it is found that the significance value is 0.000 or p-value < 0.05, then a decision can be made **to reject H0** which means that the independent variable has a significant effect on the results of the amount of fertilizer production in the NPK Phonska Reaction plant unit.

Correlation Test

Correlation of the Amount of Fertilizer Production to the Use of Phosphoric Acid

Table 9. The Value of the Correlation of the Amount of Fertilizer Production to the Use of Phosphoric Acid

Sample 1	Sample 2	N	Correlation	95% CI for ρ	P-Value
Production Quantity	Phosphoric Acid	312	0,716	(0,658; 0,766)	0,000

From the results of the correlation test, a value (r) of 0.716 was obtained. This value indicates that there is a strong correlation with a positive direction between the amount of fertilizer production and the use of phosphoric acid.

Correlation of the Amount of Fertilizer Production to the Use of Sulphuric Acid

Table 10. The Value of the Correlation of the Amount of Fertilizer Production to the Use of Sulphuric Acid

Sample 1	Sample 2	N	Correlation	95% CI for ρ	P-Value
Production Quantity	Sulphuric Acid	312	0,857	(0,825; 0,884)	0,000

From the results of the correlation test, a value (r) of 0.857 was obtained. This value indicates that there is a very strong correlation with a positive direction between the amount of fertilizer production and the use of Sulphuric acid.

Correlation of the Amount of Fertilizer Production to Ammonia Use

Table 11. The Value of the Correlation of the Amount of Fertilizer Production to the Use of Ammonia

Sample 1	Sample 2	N	Correlation	95% CI for ρ	P-Value
Production Quantity	Ammonia	312	0,851	(0,817; 0,879)	0,000

From the results of the correlation test, a value (r) of 0.851 was obtained. This value indicates that there is a very strong correlation with a positive direction between the amount of fertilizer production and ammonia use.

Correlation of the Amount of Fertilizer Production to Plant Downtime

Table 12. The Correlation Value of the Amount of Fertilizer Production to Factory Downtime

Sample 1	Sample 2	N	Correlation	95% CI for ρ	P-Value
Production Quantity	Downtime	312	-0,999	(-0,999; -0,999)	0,000

From the results of the correlation test, a value (r) of -0.999 was obtained. This value indicates that there is a very strong correlation with the negative direction between the amount of fertilizer production and plant downtime.

Testing of Identical Residual Assumptions

The Amount of Fertilizer Production Against the Use of Phosphoric Acid

Table 13. Testing of Identical Residual Assumptions of Phosphoric Acid

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	22151	11075	0,29	0,751
Phosphoric Acid	1	3710	3710	0,10	0,757
Phosphoric Acid^2	1	7717	7717	0,20	0,655

- 1) The hypotheses in this test are:
 - a) H_0 : Residual data on the amount of fertilizer production against the use of phosphoric acid in the NPK Phonska plant unit The reaction is identical.
 - b) H_1 : Residual data on the amount of fertilizer production against the use of phosphoric acid in the NPK Phonska plant unit The reaction is not identical.
- 2) The t test in this test uses a significance level of $\alpha = 5\%$. Degree of freedom (df) = $n - 2 = 312 - 2 = 310$, so the F value of the table for significance of 0.05 is 3.024.
- 3) Statistical test criteria:
 - a) If the significance value < 0.05 or $F_{\text{count}} > F_{\text{table}}$ then reject H_0 or not identical.
 - b) If the significance value > 0.05 or $F_{\text{count}} < F_{\text{table}}$ then H_0 reject fails or is identical.
- 4) Decision Making: From the test results, it was found that the significance value was 0.751 or P-value > 0.05 , then a decision could be made to **fail to reject H_0** which means that residual data on the amount of fertilizer production on the use of phosphoric acid in the NPK Phonska plant unit The reaction is identical.

The Amount of Fertilizer Production Against the Use of Sulphuric Acid**Table 14.** Testing of Identical Residual Assumptions of Sulphuric Acid

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	29149	14574	0,51	0,599
Sulphuric Acid	1	26608	26608	0,94	0,334
Sulphuric Acid^2	1	28924	28924	1,02	0,314

- 1) The hypotheses in this test are:
 - a) H0: Residual data on the amount of fertilizer production against the use of Sulphuric acid in the NPK Phonska plant unit The reaction is identical.
 - b) H1: Residual data on the amount of fertilizer production against the use of Sulphuric acid in the NPK Phonska plant unit The reaction is not identical.
- 2) The t test in this test uses a significance level of $\alpha = 5\%$. Degree of freedom (df) = $n - 2 = 312 - 2 = 310$, so the F value of the table for significance of 0.05 is 3.024.
- 3) Statistical test criteria:
 - a) If the significance value < 0.05 or $F_{\text{count}} > F_{\text{table}}$ then reject H0 or not identical.
 - b) If the significance value > 0.05 or $F_{\text{count}} < F_{\text{table}}$ then H0 reject fails or is identical.
- 4) Decision Making: From the test results, it was found that the significance value was 0.599 or P-value > 0.05 , so a decision could be made to **fail to reject H0**, which means that the residual data on the amount of fertilizer production on the use of sulphuric acid in the NPK Phonska plant unit The reaction is identical.

The Amount of Fertilizer Production Against Ammonia Use**Table 15.** Testing of Ammonia's Identical Residual Assumption

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	94588	47294	1,59	0,205
Ammonia	1	23060	23060	0,78	0,379
Ammonia^2	1	38740	38740	1,31	0,254

- 1) The hypotheses in this test are:
 - a) H0: Residual data on the amount of fertilizer production against ammonia use in the NPK Phonska plant unit The reaction is identical.
 - b) H1: Residual data on the amount of fertilizer production against ammonia use in the NPK Phonska plant unit The reaction is not identical.
- 2) The t test in this test uses a significance level of $\alpha = 5\%$. Degree of freedom (df) = $n - 2 = 312 - 2 = 310$, so the F value of the table for significance of 0.05 is 3.024.
- 3) Statistical test criteria:
 - a) If the significance value < 0.05 or $F_{\text{count}} > F_{\text{of the table}}$ then reject H0 or not identical.
 - b) If the significance value > 0.05 or $F_{\text{count}} < F_{\text{table}}$ then H0 reject fails or is identical.
- 4) Decision Making: From the test results, it was found that the significance value was 0.599 or P-value > 0.05 , then a decision could be made to **fail to reject H0**, which means that residual data on the amount of fertilizer production on ammonia use in the NPK Phonska plant unit The reaction is identical.

Amount of Fertilizer Production Against Plant Downtime**Table 16.** Testing Identical Residual Assumptions Factory Downtime

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	388694	194347	1,55	0,213
Downtime	1	155544	155544	1,24	0,266
Downtime^2	1	37169	37169	0,30	0,586

- 1) The hypotheses in this test are:
 - a) H0: Residual data on the amount of fertilizer production against plant downtime in the NPK Phonska plant unit The reaction is identical.

- b) H1: Residual data on the amount of fertilizer production against plant downtime in the NPK Phonska plant unit The reaction is not identical.
- 2) The t test in this test uses a significance level of $\alpha = 5\%$. Degree of freedom (df) = $n - 2 = 312 - 2 = 310$, so the F value of the table for significance of 0.05 is 3.024.
- 3) Statistical test criteria:
 - a) If the significance value < 0.05 or $F_{\text{count}} > F_{\text{table}}$ then reject H0 is rejected or not identical.
 - b) If the significance value > 0.05 or $F_{\text{count}} < F_{\text{table}}$ then H0 reject fails or is identical.
- 4) Decision Making: From the test results, it was found that the significance value was 0.213 or P-value > 0.05 , then a decision could be made **to fail to reject H0**, which means that the residual data on the amount of fertilizer production on plant downtime in the NPK Phonska plant unit The reaction is identical.

Independent Residual Assumption Testing

The Amount of Fertilizer Production Against the Use of Phosphoric Acid

Table 17. Durbin-Watson Test Calculation Table Total Production of Fertilizer-Phosphoric Acid

d_{count}	1,8532
dL (table)	1,7483
dU (table)	1,7887
4 - dU	2,2113

- 1) The hypotheses in this test are:
 - a) H0 : Residual amount of fertilizer production against the use of phosphoric acid in the NPK Phonska plant unit The reaction is independent.
 - b) H1 : Residual amount of fertilizer production against the use of phosphoric acid in the NPK Phonska plant unit The reaction is dependent.
- 2) The Durbin-Watson test in this test uses a significance level of $\alpha = 5\%$ with $n = 2$ and a lot of data as much as 200, so that from the Durbin-Watson table obtained a dL value of 1.7483 and a dU value of 1.7887.
- 3) Statistical test criteria:
 - a) If the value of $d_{\text{count}} < dL$ then reject H0 or residual is not independent.
 - b) If the value of $dU \leq d_{\text{calculate}} \leq 4 - dU$ then it fails to reject H0 or the residual is independent.
- 4) Decision Making: From the results of the Durbin-Watson test, a calculated d value of 1.8532 is obtained, so that $1.7887 \leq 1.8532 \leq 2.2113$, a decision can be made **to fail to reject H0** which means that residual data is independent.

The Amount of Fertilizer Production Against the Use of Sulphuric Acid

Table 18. Durbin-Watson Test Calculation Table Total Production of Fertilizer-Sulphuric Acid

d_{count}	1,9575
dL (table)	1,7483
dU (table)	1,7887
4 - dU	2,2113

- 1) The hypotheses in this test are:
 - a) H0: Residual amount of fertilizer production against the use of Sulphuric acid in the NPK Phonska plant unit The reaction is independent.
 - b) H1: Residual amount of fertilizer production against the use of Sulphuric acid in the NPK Phonska plant unit The reaction is dependent.
- 2) The Durbin-Watson test in this test uses a significance level of $\alpha = 5\%$ with $n = 2$ and a lot of data as much as 200, so that from the Durbin-Watson table obtained a dL value of 1.7483 and a dU value of 1.7887.
- 3) Statistical test criteria:
 - a) If the value of $d_{\text{count}} < dL$ then reject H0 or residual is not independent.
 - b) If the value of $dU \leq d_{\text{count}} \leq 4 - dU$ then it fails to reject H0 or the residual is independent.
- 4) Decision Making: From the results of the Durbin-Watson test, a calculated value of 1.9575 is obtained, so that $1.7887 \leq 1.9575 \leq 2.2113$, a decision can be made **to fail to reject H0** which means that residual data is independent.

The Amount of Fertilizer Production Against Ammonia Use**Table 19.** Durbin-Watson Test Calculation Table Total Fertilizer-Ammonia Production

d_{count}	1,9596
dL (table)	1,7483
dU (table)	1,7887
4 - dU	2,2113

- 1) The hypotheses in this test are:
 - a) H_0 : Residual amount of fertilizer production against ammonia use in NPK Phonska plant unit The reaction is independent.
 - b) H_1 : Residual amount of fertilizer production against ammonia use in NPK Phonska plant unit The reaction is dependent.
- 2) The Durbin-Watson test in this test uses a significance level of $\alpha = 5\%$ with $n = 2$ and a lot of data as much as 200, so that from the Durbin-Watson table obtained a dL value of 1.7483 and a dU value of 1.7887.
- 3) Statistical test criteria:
 - a) If the value of $d_{count} < dL$ then reject H_0 or residual is not independent.
 - b) If the value of $dU \leq d_{count} \leq 4 - dU$ then it fails to reject H_0 or the residual is independent.
- 4) Decision Making: From the results of the Durbin-Watson test, a calculated value of 1.9596 is obtained, so that $1.7887 \leq 1.9596 \leq 2.2113$, a decision can be made to **fail to reject H_0** which means that residual data is independent.

Amount of Fertilizer Production Against Plant Downtime**Table 20.** Durbin-Watson Test Calculation Table Total Fertilizer Production-Plant Downtime

d_{count}	2,1751
dL (table)	1,7483
dU (table)	1,7887
4 - dU	2,2113

- 1) The hypotheses in this test are:
 - a) H_0 : Residual amount of fertilizer production against plant downtime usage in NPK Phonska Reaction plant unit is independent.
 - b) H_1 : Residual amount of fertilizer production against plant downtime usage in NPK Phonska plant unit The reaction is dependent.
- 2) The Durbin-Watson test in this test uses a significance level of $\alpha = 5\%$ with $n = 2$ and a lot of data as much as 200, so that from the Durbin-Watson table obtained a dL value of 1.7483 and a dU value of 1.7887.
- 3) Statistical test criteria:
 - a) If the value of $d_{count} < dL$ then reject H_0 or residual is not independent.
 - b) If the value of $dU \leq d_{count} \leq 4 - dU$ then it fails to reject H_0 or the residual is independent.
- 4) Decision Making: From the results of the Durbin-Watson test, a calculated value of 2.1751 was obtained, so that $1.7887 \leq 2.1751 \leq 2.2113$, a decision can be made to **fail to reject H_0** which means that residual data is independent.

Normal Distribution Residual Assumption Testing

The Amount of Fertilizer Production Against the Use of Phosphoric Acid

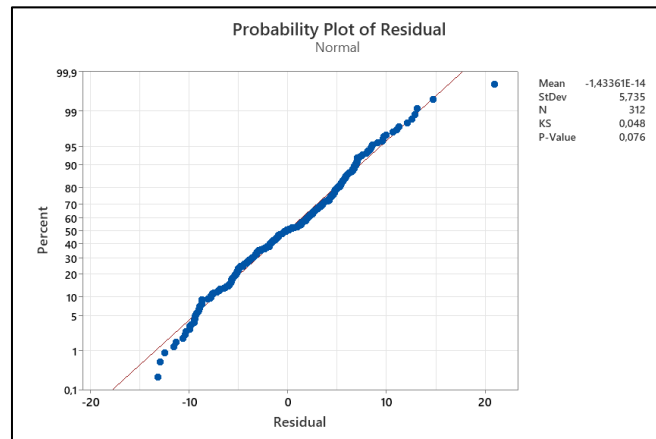


Figure 2. Residual Graph of the Amount of Fertilizer Production Against Phosphoric Acid Use

- 1) The hypotheses in this test are:
 - a) H_0 : Residual amount of fertilizer production against the use of phosphoric acid in the NPK Phonska plant unit The reaction is normally distributed.
 - b) H_1 : Residual amount of fertilizer production against the use of phosphoric acid in the NPK Phonska plant unit The reaction is not normally distributed.
- 2) The Kolmogorov-Smirnov test in this test uses a significance level of $\alpha = 5\%$.
- 3) Statistical test criteria:
 - a) If the significance value (P-value) < 0.05 then reject H_0 or residuals are not normally distributed.
 - b) If the significance value (P-value) > 0.05 then it fails to reject H_0 or the residual is normally distributed.
- 4) Decision Making: From the picture above, a P-value of 0.076 or a P-value of > 0.05 can be made, so a decision can be made to **fail to reject H_0** , which means that residual data on the amount of fertilizer production against the use of phosphoric acid is normally distributed.

The Amount of Fertilizer Production Against the Use of Sulphuric acid

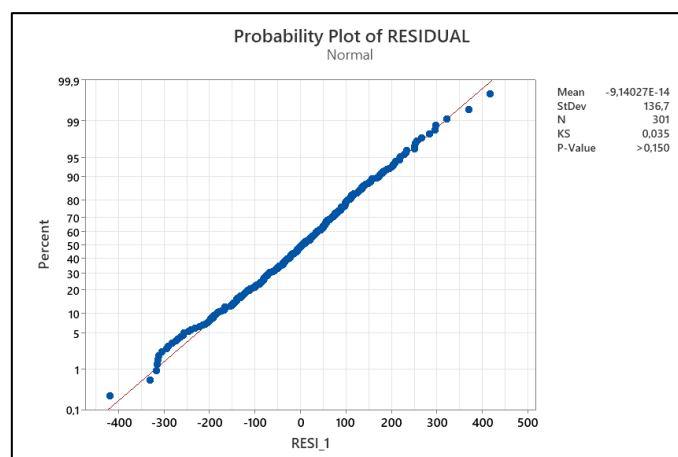


Figure 3. Residual Graph of the Amount of Fertilizer Production Against the Use of Sulphuric Acid

- 1) The hypotheses in this test are:
 - a) H_0 : Residual amount of fertilizer production against the use of Sulphuric acid in the NPK Phonska plant unit The reaction is normally distributed.
 - b) H_1 : Residual amount of fertilizer production against the use of Sulphuric acid in the NPK Phonska plant unit The reaction is not normally distributed.

- 2) The Kolmogorov-Smirnov test in this test uses a significance level of $\alpha = 5\%$.
- 3) Statistical test criteria:
 - a) If the significance value (P-value) < 0.05 then reject H_0 or residuals are not normally distributed.
 - b) If the significance value (P-value) > 0.05 then it fails to reject H_0 or the residual is normally distributed.
- 4) Decision Making: From the picture above, a P-value of > 0.150 or a P-value of > 0.05 can be made, so a decision can be made to **fail to reject H_0** , which means that residual data on the amount of fertilizer production against the use of Sulphuric acid is normally distributed.

The Amount of Fertilizer Production Against Ammonia Use

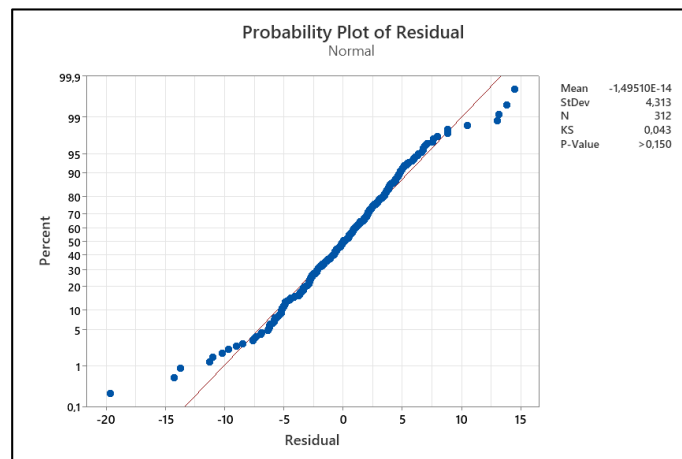


Figure 4. Residual Graph of the Amount of Fertilizer Production Against the Use of Sulphuric Acid

- 1) The hypotheses in this test are:
 - a) H_0 : Residual amount of fertilizer production against ammonia use in NPK Phonska plant unit Normal distributed reaction.
 - b) H_1 : Residual amount of fertilizer production against ammonia use in NPK Phonska plant unit The reaction is not normally distributed.
- 2) The Kolmogorov-Smirnov test in this test uses a significance level of $\alpha = 5\%$.
- 3) Statistical test criteria:
 - a) If the significance value (P-value) < 0.05 then reject H_0 or residuals are not normally distributed.
 - b) If the significance value (P-value) > 0.05 then it fails to reject H_0 or the residual is normally distributed.
- 4) Decision Making: From figure 4.19 above, a P-value of > 0.150 or a P-value of > 0.05 can be made, so a decision can be made to **fail to reject H_0** , which means that residual data on the amount of fertilizer production against the use of ammonia is normally distributed.

Optimum Point Determination

Ways to determine the optimum values of operational parameters of phosphoric acid, Sulphuric acid, ammonia in the plant units of NPK Phonska Reaction using partial derivatives of regression model equations. The equation of the regression model of the amount of fertilizer production against operational parameters is as follows:

$$Y = -245,9 - 1,17 X_1 + 0,00277 X_1^2 + 2,718 X_2 - 0,00161 X_2^2 + 8,49 X_3 - 0,01378 X_3^2$$

Where:

Y : Total Fertilizer Production

X₁ : Phosphoric Acid

X₂ : Sulphuric Acid

X₃ :Ammonia

To find the optimum value, it is necessary to find a value where the partial derivative of each variable X₁, X₂, and X₃ is equal to zero (0).

Partial derivative of X₁:

$$\frac{\partial Y}{\partial X_1} = -245,9 - 1,17 X_1 + 0,00277 X_1^2 + 2,718 X_2 - 0,00161 X_2^2 + 8,49 X_3 - 0,01378 X_3^2$$

Optimal points of operational parameters of sulphuric acid, phosphic acid, and ammonia production process

$$\begin{aligned}\frac{\partial Y}{\partial X_1} &= -1,17 + 0,00554 X_1 \\ 0 &= -1,17 + 0,00554 X_1 \\ X_1 &= 211,191\end{aligned}$$

So that the optimum value of phosphoric acid (X1) operational parameters is 211,191 tons.

Partial derivative of X2:

$$\begin{aligned}\frac{\partial Y}{\partial X_2} &= -245,9 - 1,17 X_1 + 0,00277 X_1^2 + 2,718 X_2 - 0,00161 X_2^2 + 8,49 X_3 - 0,01378 X_3^2 \\ \frac{\partial Y}{\partial X_2} &= 2,718 - 0,00322 X_2 \\ 0 &= 2,718 - 0,00322 X_2 \\ X_2 &= 844,099\end{aligned}$$

So that the optimum value of Sulphuric acid (X2) operational parameters is 844,099 tons.

A partial derivative of X3:

$$\begin{aligned}\frac{\partial Y}{\partial X_3} &= -245,9 - 1,17 X_1 + 0,00277 X_1^2 + 2,718 X_2 - 0,00161 X_2^2 + 8,49 X_3 - 0,01378 X_3^2 \\ \frac{\partial Y}{\partial X_3} &= 8,49 - 0,02756 X_3 \\ 0 &= 8,49 - 0,02756 X_3 \\ X_3 &= 308,055\end{aligned}$$

So that the optimum value of ammonia (X3) operational parameters is 308,055 tons.

The optimum value of fertilizer production amount (Y):

$$\begin{aligned}Y &= -245,9 - 1,17 X_1 + 0,00277 X_1^2 + 2,718 X_2 - 0,00161 X_2^2 + 8,49 X_3 - 0,01378 X_3^2 \\ Y &= -245,9 - 1,17 (211,191) + 0,00277 (211,191)^2 + 2,718 (844,099) - 0,00161 (844,099)^2 \\ &\quad + 8,49 (308,055) - 0,01378 (308,055)^2 \\ Y &= 2085,38\end{aligned}$$

So that the optimum value of fertilizer production is 2085.38 tons.

From the calculation above, the optimum value of operational parameters of phosphoric acid (X1) is 211,191 tons, Sulphuric acid (X2) is 844,099 tons, ammonia (X3) is 308,055 tons, and the amount of fertilizer production in the NPK Phonska Reaction unit is 2085.38 tons.

CONCLUSION

The optimum value of using phosphoric acid in the production process at the NPK Phonska Reaction plant unit is 211,191 tons, the optimum value of Sulphuric acid is 844,099 tons, and the optimum value of ammonia is 308,055 tons. The minimum factory downtime value is 0 days and the maximum is 0.94 days. The higher the factory downtime value, the amount of fertilizer production will decrease and the lower the factory downtime value, the amount of fertilizer production will increase. The optimum value of the fertilizer production process in the NPK Phonska Reaction plant unit is 2085.38 tons with the use of phosphoric acid of 211.91 tons, Sulphuric acid of 844,099 tons, and ammonia of 308,055 tons.

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