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Water Quality Control at the Tirta Tarum Regional Drinking Water Public Company to Improve Services to the Community

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ABSTRACT

Water is a fundamental necessity for human life, and access to clean water is essential. Drinking water must meet health standards to be safe for consumption, while clean water is used for daily needs and can be consumed if boiled. However, consumer complaints regarding water quality remain a concern. Data collected over a three-month period indicated that the average turbidity level of clean water was 2.4 NTU. This study aims to control water quality using the Taguchi method. The key objective is to evaluate whether the water quality complies with established standards and regulatory requirements. Water quality that meets these standards is expected to enhance customer satisfaction. By applying the Taguchi experimental design, the results demonstrated a turbidity level of 1.4 NTU and a pH level of 7.3, both of which comply with the Ministry of Health Regulation No. 2 of 2023. The findings suggest that implementing quality control through the Taguchi method can effectively monitor and regulate water quality, thereby improving water services provided to the community.
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Keywords: *Analytical Hierarchy Process, plywood supplier, decision making PT Techno Wood Indonesia.*

Introduction

Clean water is a water-based resource that has good quality and is commonly used by humans in daily life, such as for consumption and sanitation [1]. In the process of supply, quality control is an important aspect that must be considered by the company to ensure that the product is in accordance with specifications and meets consumer expectations [2], [3]. In the midst of the current fierce market competition, companies are required to be able to produce high-quality products in order to increase consumer satisfaction and loyalty [4], [5], [6].

According to Genichi Taguchi, quality is the ability of a product or service to meet consumer needs and expectations, including its reliability over time. The concept of quality engineering developed by Taguchi emphasizes the importance of integration between design techniques and manufacturing processes in every stage of product development, from design to distribution [7], [8].

The Taguchi method, introduced in the 1940s, is a Design of Experiment (DoE) approach that aims to improve product quality and process efficiency at minimal cost [5]. This method is a Design of Experiment approach method which is a key element to achieve high quality at minimal cost [6]. This method aims to reduce variability in production and improve process capabilities [7], using an optimal combination of various factors and levels that are systematically tested. Taguchi also emphasized the importance of controlling variables so that the influence of external interference can be minimized, so that product quality characteristics can be effectively optimized [9], [10], [11].

This research was conducted at the Tirta Tarum Regional Public Drinking Water Company (PERUMDAM) Tirtajaya Karawang branch, a Regionally Owned Enterprise (BUMD) engaged in providing clean water for the people of Karawang. With more than 4,000 customers, PERUMDAM has a big responsibility in maintaining water quality to meet feasibility standards. To realize excellent service, the company carries the slogan GO-SPRINT (Service Excellent, Professional, Respect, Integrity, Nimble, Trust) as a guide for work values [9]. The following graph is the average level of turbidity of raw water and clean water that occurred during the 3 months I conducted this study.

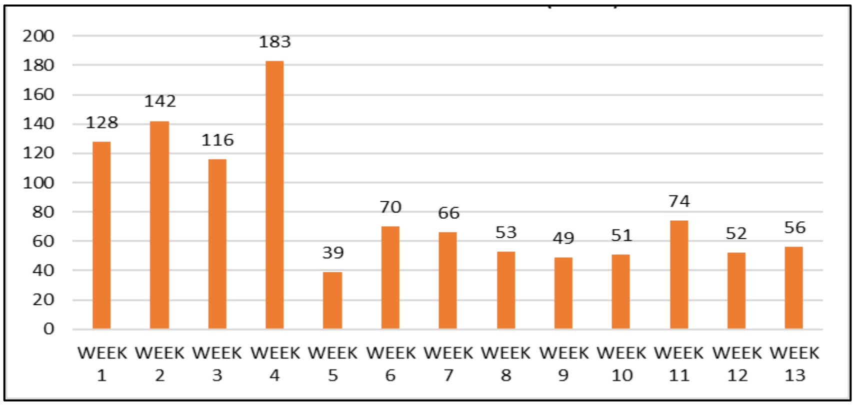

Figure 1. Graph of Average Raw Water Turbidity Level

From the graph above, it shows that the average level of raw water turbidity per week is at most 183 NTU (Nephelometric Turbidity Unit) which is measured using a turbidimeter. The Y axis indicates the level of turbidity of the water and the X axis indicates the length of measurement time.

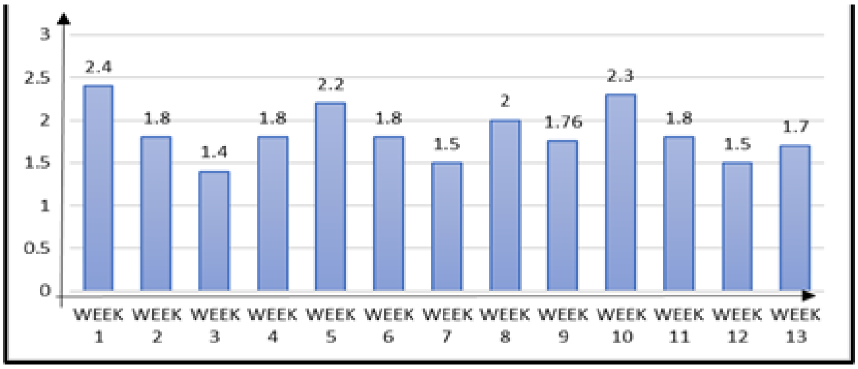

Figure 2. Graph of Average Clean Water Turbidity Rate

From the graph above, it shows that the average level of turbidity of clean water per week is at most 2.4 NTU which is measured using a turbidimeter. The Y axis indicates the level of turbidity of the water and the X axis indicates the measurement time.

Based on the problems that exist in the Tirtajaya area, consumers often complain that the quality of water is not clean and not fit for drinking due to the lack of optimal water production process at the Water Treatment Facility (IPA). And another problem is also in the name of the company, namely the drinking water company, in fact the water produced is not suitable for drinking but is suitable for daily use. IPA is a Water Treatment Plant, Water treatment plant is one way to process raw water from rivers, reservoirs or other underground sources into safe drinking water for consumption. The process used to process raw water into drinking water is the coagulation and flocculation process [6], [12]. It is a system or means that functions to treat water from contaminated raw water quality (influent) to get the desired water quality treatment according to quality standards or ready for consumption. This means or system is important to produce clean and healthy water for consumption. Usually, the building or construction consists of 5 processes, namely coagulation, flocculation, sedimentation, filtration, and disinfection [13], [14], [15].

Water Treatment System Clarifier generally functions to lower the level of Total Suspended Solids (TSS), such as particles and sediments. The main applications of clarifier systems are in river water treatment and wastewater treatment [16], [17], [18], [19]. Therefore, production employees must be agile to maximize efforts when the raw water is cloudy. One of the main processes carried out to reduce the turbidity of raw water to clean water is the coagulation process, which is included in the chemical treatment method [20], [21], [22]. In general, the process used to treat raw water is the coagulation and flocculation process .

Previous research was conducted by Fitriadi "Water Quality Control in the Tirta Meulaboh Regional Drinking Water Company to Improve Services to the Community". Which states that: Water quality control can be carried out by measuring various variables that affect it by using the taguchi method which is carried out by designing parameters of a product or process that can be controlled so that it can improve water services to the community. Quality in manufacturing and service companies has an important role in efforts to increase, maintain, and regain market share in the Company [15]. Because of good quality and in accordance with what the community needs, it can dominate the market.

Based on the problems from previous research conducted by Fitriadi regarding the failure of the water production process, namely the addition of Aluminum Sulfate (Alum) with the causative factors, namely raw water, alum application, rapid stirring, long stirring and sedimentation.

The purpose of this research is to find out several factors that are obstacles or obstacles in the production process, namely, identifying production problems that cause water quality to decline and obtaining an experimental design of solutions in an effort to control water quality using the taguchi method.

Research Methods

This research is included in the type of analytical descriptive research, which is a type of research that aims to describe the problems faced as well as find solutions for their solutions. Through this research, it is hoped that the right solutions to the problems and challenges that are being faced can be obtained. The data used is secondary data sourced from the company [6], [12], [23].

The method used in this study is the Taguchi Method, which is a Design of Experiment approach which is a key element in achieving high quality goods at minimum cost [16]. Design of Experiment is a systematic activity by providing treatment to an object to determine the effect of the treatment on other factors under controlled conditions [17]. This method aims to improve the quality of products and production processes [18]. In particular, the Taguchi method helps to improve process capabilities and reduce the causes of variability in production [3], [4], [24], [25].

To simplify the calculation process, Minitab software is used. In general, Minitab is widely used for data processing purposes, such as more in-depth data analysis, regression analysis, and table and graph creation.

This research was conducted at the Tirta Tarum Regional Drinking Water Public Company (PERUMDAM) Tirtajaya Branch, which is located in Batujaya District, Karawang Regency. The data collection process is carried out in stages, following a research implementation model that can be adjusted and developed according to needs [1], [2], [5], [26].

This study uses data from the Water Treatment Plant (IPA) of PERUMDAM Tirta Tarum Tirtajaya Branch. The data used is sourced from monthly water quality reports for three months, namely April, May, and June. This data is considered sufficient to be used in the water quality control process at the IPA of PDAM Tirta Tarum Tirtajaya Branch [27], [28], [29].

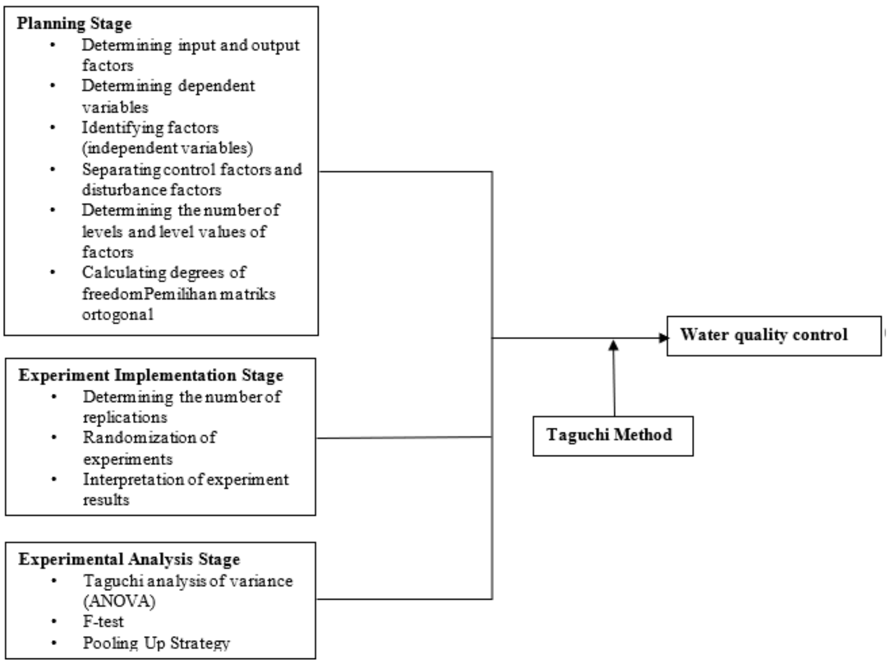

Figure 3. Conceptual Model of Quality Control

The conceptual model combines the calculation process using the taguchi method which aims to improve the quality and get *a design of experiment* in solving the problem that occurs, the following are the steps of the taguchi experiment carried out [30], [31], [32], [33]:

1. Problem Formulation.
2. Defining the Purpose of the Experiment

3. Determining the Factors Influencing the Object of Research.
4. Separating the *Noise Factor* and the Control Factor

The control factor is a variable that can be controlled by the researcher, the *Noise* Factor is a variable whose value cannot be controlled, The determination of these factors can be done through *the brainstorming* method.

5. Determining Quality Characteristics

Quality characteristics are the essential thing of a product or process. These characteristics must be determined from the beginning of the design of the experiment. In this study, the "*Smaller is Better*" characteristic is used, where the smaller the value of a characteristic (or closer to zero), the better. Examples: waste, defective products, noise, and waste [34], [35], [36], [37], [38].

6. Determining the number of levels and factor levels
7. Calculating degrees of freedom degrees of freedom indicates the minimum number of experiments required.
8. Selection of *orthogonal array* (OA) tables
9. Filling in Factor and Interaction Columns into an *Orthogonal Matrix*
10. Run experiments
11. Obtaining and Analyzing the results of the taguchi variance analysis experiment
    - Create a variable data table
    - Calculate the average for each experiment
    - Create a bidirectional ANOVA table as follows [39], [40], [41], [42], [43]:

Table 1. Response Influence Factors

Source of Variation	SS	DOF	MS	F-Ratio	SS'	Rho %	F-table
Factor A	SS A	DOF A	MS A	FA	MSA/MSE	SS'A / SST	Fα (DOF A; DOF Total)
Factor B	SS B	DOF B	MS B	FB	MSB/MSE	SS'B / SST	Fα (DOF B; DOF Total)
Factor X	SS X	DOF X	MS X	FX	MSX/MSE	SS'X / SST	Fα (DOF X; DOF Total)
Error	SSE	DOFE	MSE	–	SS'E	SS'E / SST	–
Total	SST	DOFT	–	–	SST	100%	–

12. Interpretation of Experimental Results

Things to consider in the interpretation of the results of the taguchi experiment:

a. Percent Contribution, which is the percentage of significance of factors and factor interactions to the total variance of observed objects [44], [45], [46], [47], [48].

13. Confirmation Experiment

A confirmation experiment as a validation step is successful when:

a. There was an improvement after the taguchi experiment was carried out.

b. The results of the confirmation experiment are close to the predicted value

The planning of the experiment that will be carried out using the taguchi method is as follows [49], [50], [51], [52], [53].

1. Determination of Non-Independent Variables

   The non-free variable is the one used in this study, which is *smaller the better* which means that the less the number of defective products, the better the quality.

2. Determination of Independent Variables

   The Free Variable in this study is a factor that greatly affects water quality which results in the product being defective. Some of the factors are as follows [54], [55], [56], [57], [58], [59], [60]:
   a. Raw Water (River Water).
   b. Affixing of Aluminum Sulfate (Alum).
   c. Quick stirring.
   d. Fast stirring time.
   e. Slow Stirring.
   f. Slow stirring time.
   g. Sedimentation/Sedimentation.

3. Determination of Number of Levels

The determination of this level can be seen in the following table.

Table 2. Determination of Number of Levels and Level Value Factor

Code	Factors	Level 1	Level 2	Units
A	Raw Water (River Water)	Cloudy	A bit cloudy	-
B	Alum Affixing	1,0	2,5	Ppm
C	Fast stirring	100	110	rpm
D	Slow stirring	30	40	rpm
E	Sedimentation	20	30	Minutes
F	Fast stirring time	60	70	Seconds
G	Slow stirring time	15	20	Minutes

4. Selection of Orthogonal Array
   The number of degrees of freedom is 7 the number of levels b=2 levels so that the orthogonal matrix used is L8(2^7) where the number of experiments is a=8 experiments [61], [62], [63].

Results and Discussion

Input variables

Table 3. Amount of Raw Water

Amount of Raw Water		
April (m3)	May (m3)	June (m3)
151.230	146.570	131.250

Meanwhile, the amount of alum used during the 3 months is as follows;

Table 4. Number of Alum Uses

Number of Alum		
April (kg)	May (kg)	June (kg)
5110	4760	4640

Variable *Output*

The *output variable* in this study is the water quality requirements that have been set out in the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2023 concerning Guidelines for the Implementation of Environmental Health.

Water Quality Inspection Results

The results of the raw water quality inspection at PERUMDAM Tirta Tarum Tirtajaya Branch which is sourced from the Citarum River are as follows

Table 5. Results of Raw Water Inspection

Yes	Parameters	Units	Maximum Requirements	Test Results
	Physics			
1	Temperature	C	Air Temperature (32) ± 3	29
2	Turbidity	NTU	25	31
3	Taste and Smell	-		Odorless
	Chemistry			
1	Salinity	-	0,1	0,1
2	pH	-	6,5 – 9	7,3
	Bacteriologist			
1	E.Coli	Y/100 ml	0	0

Table 6. Results of Clean Water Inspection

Yes	Parameters	Units	Maximum Requirements	Test Results
	Physics			
1	Temperature	C	Air Temperature (31) ± 3	28
2	Turbidity	NTU	<3	4,9
3	Taste and Smell	-		Odorless

	Chemistry			
1	Salinity	-	0,1	0,1
2	pH	-	6,5 – 8,5	7,2
	Bacteriologist			
1	E.Coli	Y/100 ml	0	0

Determination of Non-Independent Variables

The non-free variable used in this study is *smaller the better* which means that the less the number of defective products, the better the quality of the product.

Determination of Independent Variables

Some of the free variables in this study are factors that greatly affect water quality which results in the product being defective. Some of the factors are:

A. Raw Water (River Water)
B. Aluminum Sulfate *(Alum)* Plating
C. Quick stirring
D. Slow stirring
E. Sedimentation
F. Fast stirring time
G. Slow stirring time

Determination of Number of Levels and Level Value Factor

Next determines the number of levels and number factors.

Table 7. Determination of Number of Levels and Factors

Code	Factors	Lv 1	Lv 2	Units
A	Raw Water	Cloudy	A bit cloudy	-
B	Sulfate Fixing	1,0	2,5	Ppm
C	Quick stirring	100	110	rpm
D	Slow stirring	30	40	rpm
E	Sedimentation	20	30	Minutes
F	Fast stirring time	60	70	Seconds
G	Slow stirring time	15	20	Minutes

Calculation of Degrees of Freedom

Based on the results of the calculation, the degree of freedom of each factor is 1 degree of freedom so that because there are 7 factors, the total of all degrees of freedom is 7 degrees of freedom.

Selection of *Orthogonal Matrix*

The calculation of the degree of freedom obtained is 7, many levels b = 2 levels, where many experiments a = 8 experiments. so that the orthogonal matrix used is L8(27).

Placement of Factor and Interaction Columns

The following is the placement of the factors and interaction columns and the calculation of the results of the experiment.

Determination of columns for factors and interactions into *orthogonal matrices* as listed in the following table.

Table 8. Placement of Factor and Interaction Columns

Factors	Columns
Raw Water (River Water) (A)	1
Aluminum Sulfate (Alum) Plating (B)	2
Quick stirring (C)	3
Slow stirring (D)	4
Sedimentation/Sedimentation (E)	5
Fast stirring time (F)	6
Slow stirring time (g)	7

Implementation of the Taguchi Experiment

Based on the results of the experiments that have been carried out, the results are as listed in the following table.

Table 9. OA L8(27)

Experiments	A	B	C	D	E	e	e
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

Calculation of Experimental Results

Based on the results of the calculation, the average response from the influence of water quality factors can be seen in the following table.

Table 10. Experimental Results

Ex.	A	B	C	D	E	e	e	R1	R2	R3	Quantity	Red	SNR
1	1	1	1	1	1	1	1	3.4	3.8	3.5	10.7	3.566667	-11.0551
2	1	1	1	2	2	2	2	3.6	3.9	3.7	11.2	3.733333	-11.4468
3	1	2	2	1	1	2	2	1.9	2.2	2	6.1	2.033333	-6.18048
4	1	2	2	2	2	1	1	1.7	2	1.8	5.5	1.833333	-5.28488
5	2	1	2	1	2	1	2	1.9	2.2	2	6.1	2.033333	-6.18048
6	2	1	2	2	1	2	1	2.4	2.9	2.7	8	2.666667	-8.54508
7	2	2	1	1	2	2	1	1.2	1.6	1.4	4.2	1.4	-2.98125
8	2	2	1	2	1	1	2	1.5	1.9	1.7	5.1	1.7	-4.64887

The following are the results of the influence of levels and factors from the signal to noise ratios obtained from the minitab application with the variation used, namely the smaller the better.

Table 11. Results Influence of levels and factors

Level	A	B	C	D	E
1	2.792	3.000	2.600	2.258	2.492
2	1.950	1.742	2.142	2.483	2.250
Differences	0.842	1.258	0.458	0.225	0.242
Ranking	2	1	3	5	4

It was obtained from the results of the calculation of the influence of level and factor, namely factor B with a difference of 1,258.

Variance Analysis

The calculation of *variance analysis* will be carried out starting from the calculation of the average value of all experiments to the calculation of the percentage contribution of each experiment. Table 11 shows the results of *the variance* analysis.

Table 12. Results of Variance Analysis

Factors	DF	SS	MS	F	P
A	1	16.8535	16.8535	62.92	0.016
B	1	41.0960	41.0960	153.42	0.006
C	1	1.9415	1.9415	7.25	0.115
D	1	1.5561	1.5561	5.81	0.138
E	1	2.5721	2.5721	9.60	0.090
Error	2	0.5357	0.2679	1	
Total	7	64.5550			

From the results of the variance analysis calculation, the result was 64.55.

Pooling Up Strategy

The pooling up strategy is a combination of factors with the lowest significance as *an error*. The purpose of *pooling up* is to avoid excessive estimation and also to minimize errors in the experiments carried out.

Table 13. Pooling Up Strategy 1

Factors	*Pooled*	DF	SS	MS	Phrase	SS'	Ratio%
A		1	16.8535	16.8535	24.1731211	16.1563	25,02
B		1	41.096	41.096	58.9443488	58.24714882	90,23
C		1	1.9415	1.9415	2.78471027	1.2443	1,93
D	Y		1.556	1.556			
E		1	2.5721	2.5721	9.60097051	1.8749	2,9
Error	Y		0.5357	0.2679			
Pooled		3	2.0918	0.6972	1	-12.9678488	-20,08
SSt		7	64.5548	10.7145		64.5548	100
Red		1	134.9004				
SSTotal		8	64.555				

For the factor with the lowest significance, namely factor D, it is used as an *error.* In Table 13, *Pooling Up* 2 is carried out with the aim of obtaining more significant results on product quality and determining *error factors.*

Table 14. Pooling Up Strategy 2

Factors	*Pooled*	DF	SS	MS	Phrase	SS'	Ratio%
A		1	16.8535	16.8535	12.757172	15.5324	24,06
B		1	41.096	41.096	31.10741	29.7863105	46,14
C	Y		1.9415	1.9415			
D	Y		1.556	1.556			
E	Y		2.5721	2.5721			
Error	Y		0.5357	0.2679			
Pooled		5	6.6053	1.3211	1	19.2360895	29,8
SSt		7	64.5548	10.7145		64.5548	100
Red		1	134.9004				
SSTotal		8	64.555				

For the factors with the lowest significance, namely factor C, Factor D and Factor E so that it is used as an *error.* In table 14, the results of *the pooling up* calculation obtained a significant value for factor A of 24.06%, Factor B 46.14%, and *Error* of 29.8%.

Table 15. Pooling Up Finish Strategy

Factors	Pooled	DF	SS	MS	Phrase	SS'	Ratio%
A		1	16.8535	16.8535	12.7575583	15.53244	24,06
B		1	41.096	41.096	31.1083524	29.78729238	46,14
Pooled		5	6.6053	1.32106	1	19.23506762	29,8
SSt		7	64.5548	19.75685		64.5548	100
Red		1	134.9004				
SSTotal		8	64.555				

Based on the Pooling Up Strategy that has been carried out, significant results have been obtained, namely in factor A with a ratio value of 24.06% and factor B with a ratio value of 46.14.

The following is the result of the value response from *the signal to noise ratios* obtained from the minitab application with the variation used, namely *smaller the better*.

Table 16. SNR Value Response

Level	A	B	C	D	E
1	-8.492	-9.307	-7.533	-6.599	-7.607
2	-5.589	-4.774	-6.548	-7.481	-6.473
Differences	2.903	4.533	0.985	0.882	1.134
Ranking	2	1	4	5	3

It was obtained from the results of the calculation of the Signal To noise Ratio level and factor, namely factor B with a difference of 4.533.

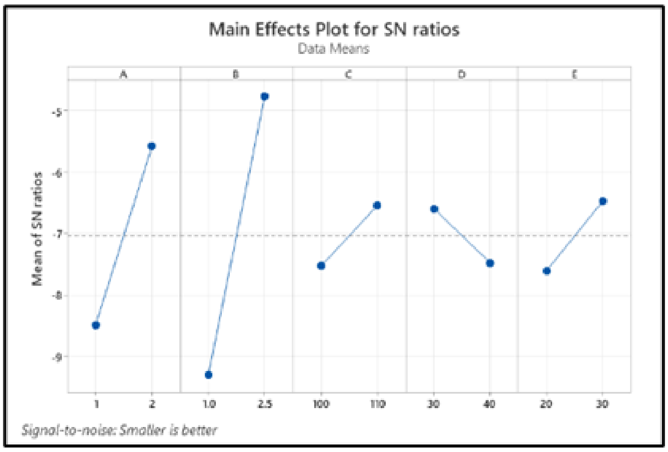

Figure 4. Value Response Results (Smaller The Better)

From the above value response chart, it can be concluded that the factors and levels with the variations used, namely smaller the better as A1, B1, C1, D2, and E1.

Selection of Optimal Factor Level Combinations

Selection of optimal combination of factor levels to improve product quality. Table 17 explains the determination of the optimal level setting according to the calculations that have been made. Based on table 17, it can be seen that the optimal level combination obtained is A1, B1, C1, D2, and E1. Determination of the initial setting and optimal level setting at the following quality;

Table 17. Setting Initial Settings

Factors	Level	Units
Raw Water (River Water)	A bit cloudy	-
Sulfate Fixing	2,5	Ppm
Fast stirring	110	rpm
Slow stirring	30	rpm
Sedimentation	20	Minutes
Fast stirring time	60	Seconds
Slow stirring time	15	Minutes

For this setting, the results are obtained as stated in table 6. The results of the clean water inspection have been carried out at PERUMDAM Tirta Tarum Tirtajaya Branch.

Table 18. Setting the Optimal Level

Factors	Level	Units
Raw Water (River Water)	Cloudy	-
Sulfate Fixing	1,0	Ppm
Quick stirring	100	rpm
Slow stirring	40	rpm
Sedimentation	20	Minutes
Fast stirring time	60	Seconds
Slow stirring time	15	Minutes

And for the results of determining the optimal level setting and factors after doing the calculation so that this setting is obtained and the following test results.

Table 19. Results of Setting Levels and Optimal Factors

Yes	Parameters	Units	Maximum Requirements	Test Results
	Physics			
1	Temperature	C	Air Temperature (31) ± 3	28
2	Turbidity	NTU	5	1,4
3	Taste and Smell	-		Odorless
	Chemistry			
1	Salinity	-	0,1	0,1
2	pH	-	6,5 – 9	7,3
	Bacteriologist			
1	E.Coli	Y/100 ml	0	0

Based on the setting level and optimal factors, the results of clean water tests were obtained which showed a turbidity level of 1.4 NTU, which for this turbidity level can be classified as drinking water but apart from that there are several other factors that must be tested whether this water is suitable for drinking.

Conclusion

Based on the results and analysis that has been carried out in this study, it can be concluded that several things cause failure, namely factor B (sulfate affixing) with a percentage contribution of 46.14%, and there are several factors that are used as *error* factors including factor F and factor G to make it easier to determine significant results in *pooling up.* The experimental design was at a combination of factors and optimal levels, namely A1 (raw water at turbid level), B1 (aluminum *sulfate* application of 1.0 ppm per 1000 ml of water), C1 (rapid stirring 100 RPM), D2 (slow stirring 40 RPM), and E1 (settling time of 20 minutes). With this setting, the turbidity level of clean water is 1.4 NTU, and pH is 7.3. So with results like this, it is hoped that clean water is ready to drink after cooking. The implication of this study is that water quality control recommendations with treatments that can provide results that meet the standards of clean water for drinking after cooking, so that water quality control can be carried out effectively and efficiently. It is hoped that after this research is carried out, there will always be further research so that there will always be updates in accordance with the latest Minister of Health so that the water quality is maintained clean and safe for direct consumption considering that currently the raw water sources obtained have begun to be polluted by a lot of waste from factories and households which results in a decrease in water quality.

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