The Model of Optimization for Parameter in the Mixing Process of Water Treatment

Mastiadi Tamjidillah
Pratikto
Mechanical Engineering Department of Brawijaya University, 65145 Malang-Indonesia

Purnomo Budi Santoso
Sugiono
Industrial Engineering Department of Brawijaya University, 65145, Malang-Indonesia

ABSTRACT

This research aims to determine the optimized model of raw water mixing process having a high turbidity level, alum or Poly Aluminium Chloride (PAC) and pump stroke to input the raw water taken from river. It is to obtain the proportional composition and the optimized model for the setting of parameter with the experimental design of Taguchi method in which the process of mixing water such as 5lt/sec, 10lt/sec, and 15lt/sec and % of alum water 5 ppm, 10 ppm, and 15 ppm with the installations of pump stroke that are of 15 %, 20 % and 25 %. The dominant factor which influences the average response is beneficial to choose the level of factor producing quality of clean water and optimal mixing model. Model produced from this process can be used as basis to find out the characteristic of raw water supply, and design the mixing process of optimal alum dosage and the behavior of floating particles (flock). The particles were later processed in SEM (Scanning Electron Microscope) to uncover the microstructure content of sedimentation result of the mixing process. With the finding of proportional setting for parameter of raw water supply, it thus results clean water which is proportional to the quality standard.

Keywords: *Model, Clean Water, Optimization, Mixing, Water Quality*

ISSN 1823-5514, eISSN 2550-164X

Received for review: 2016-05-30
Accepted for publication: 2017-04-02
Published: 2017-06-01

Introduction

The existence of clean water either it is in urban and rural area is very important because many activities in a dynamic community life require the availability of sufficient clean water that meets health standard. Since three-quarter part of earth is water and human has 55% - 78% part of his body composed of water, water becomes a very natural resource that is highly vital for human life and development. Its existence cannot be replaced with other materials in the world.

A regional company of clean water, Intan Banjar, currently served the Banjarbaru city and Banjar district until the end of 2015 with a total consumer of 62.205 million people. Customers with service coverage of about 52% below the national target of 68% and the MDGs (millennium development goals) UN 80% with an average of NRW (non revenue water) of 29% and sedimentation resulted in the form of small particles of water and mud with every day 15m^3/day wasted a result of the production process of a capacity of 250 lt/sec. By looking at the conditions above, it is necessary to increase the production and service for customers to minimize wastage in the production process.

In this study, a regional company of clean water, Water Treatment Plant (WTP), which supplies the water needs of more than 62 hundred inhabitants and is operated by a regional company of clean water at Banjarbaru, South Kalimantan was selected as the sampling source. It receives raw water from Martapura river, which is the sub-Barito river. It is one of the largest water treatment plants in South Kalimantan and has an average treated water production of about 250,000 litre per second (m^3/sec). The WTP was designed to produce quality water complying with drinking water standard. The water treatment processes performed in WTP are coagulation, flocculation, sedimentation, filtration, chlorination as shown in Figure 1.

According to [1], a research was done on the relation of parameter for the quality of raw water, chlorine need, and the content of disinfectant in drinking water. The proportional use of chlorine will minimize the disinfectant in Malaysia. The model obtained for the condition of clean water processing in Malaysia showed that there was a relation on alum need and its optimization which influences the setting of parameter [2, 3]. The content of raw water also affects the result of the final which is also known as clean water product and requires treatment in the processing part.

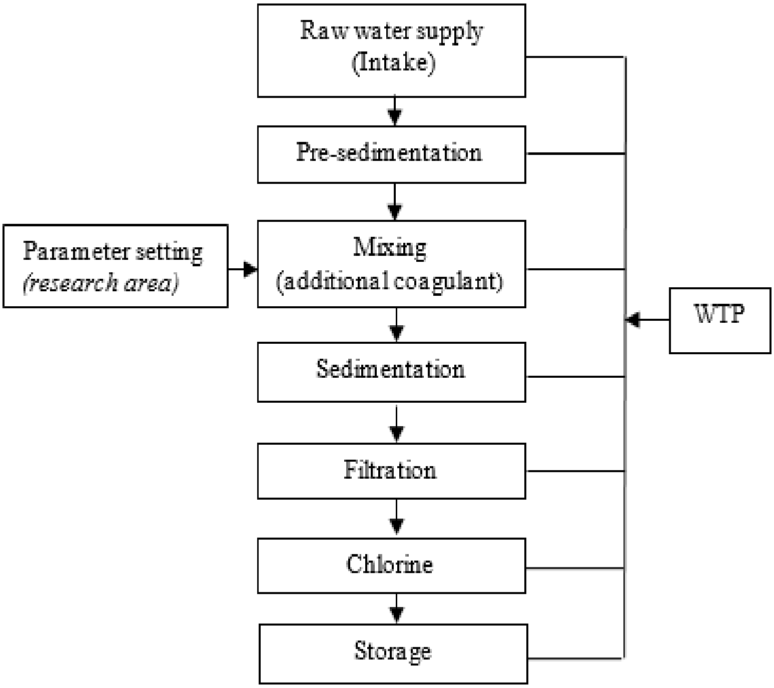


Figure 1: The schema of WTP processes in a regional company of clean water

Methodology

The quality of clean water becomes very important to be designed from the beginning until its final stage: ready to consume clean water to produce the product. The process of producing clean water at WTP started from the intake of raw material until the reservoir of water container as in Figure 1. Green Taguchi method is used to analyze the setting of parameter in the mixing part with the function to mix the alum with raw water. Green Taguchi Method is used to set the optimized parameter which is good for environment by minimizing the waste in the mixing process of % alum water and the pump stroke in the instalation of mixing pump.

Coagulant PAC (Poly Aluminium Chloride) or alum will benefit the coagulation process by shortening the time of precipitation and hardening the flock formed. Thus, the definition of coagulant is secondary coagulant added after the primary or main coagulant which aims to fasten the precipitation, formation and flock ossification. The type of coagulant used in this research is PAC and the other important compound for coagulation that is of Al is PAC, $Al_n(OH)_mCl_{3n-m}$. Some ways have been patented to create PAC produced from partial hydrolysis of aluminium chloride, as shown in the following reaction:

$$n\, AlCl_3 + m\, OH^- . m\, Na^+ \rightarrow Al_n (OH)_m Cl_{3n-m} + m\, Na^+ + m\, Cl^-$$

This compound is made in various ways to produce a rather stable PAC solution. PAC is a complex inorganic compound, hydroxyl ion and aluminum with a different level of chlorination as the former of poly nuclear having a general formula that is of $Al_m(OH)_nCl_{(3m-n)}$. The PAC with the brand of PRIMAPAC was produced by PT Amaniaga Internusa as the admixture or coagulant with chemical formula of Al_2S0_4 11 H_2O or 14 H_2O or 18 H_2O, while raw water was taken from a river containing physics and chemical compound with a certain level of turbidity used as coagulant forming flock that binds floating granule found in the water turbidity. The installation for experimental design is shown below.

1) Reservoir is used to provide a place for raw water.
2) Mixer pump is used to stir the raw water with PAC to obtain a proportional ratio and a homogenous mixture.
3) Pipe for the fitting process in the installation to set the speed of mixing process.
4) Reservoir is used to measure how many liters of PAC liquid required.
5) Mixing pump is used to drain the homogenous mixture to the reservoir of raw water.
6) Installation of mixing pump is used to drain the homogenous mixture to the reservoir 5lt/sec, 10lt/sec, 15lt/sec.
7) Turbidimetry is used to measure the water turbidity.
8) Conductivitimetry is used to measure TDS and electrical conductivity.
9) Spectrofotometry is used to test the color, dissolved iron and mangan.

Experimental design using Taguchi method

Engineering design optimization method that has been extensively used is Taguchi technique [4, 5]. Taguchi method consists of the procedures for system design, parameter design and tolerance design aims to attain a convincing process and result for good quality product [6, 7]. The application of parameter design is the most principal trustworthiness of Taguchi's techniques [8]. It is an engineering method for production process which targets the decision of factor parameter settings producing the perfect levels of quality characteristics accomplishment with a minimum variation.

Taguchi method applies an orthogonal array for its experimental design and a signal to noise (S/N) ratio for its quality assessment. In this study, three controllable factors of process were examined, namely:

PAC/alum, raw water supply and pump stroke. The mixing time denoted respectively the assigned three levels for each controllable factor. An L9 orthogonal array was developed. The levels in Table 1 indicate that they were 5, 10, and 15 for water supply with the debit of 5, 10, 15 and pump stroke of 15, 20, 25. With the L9 array, only 9 tests run instead of full experiment conducted for three controllable factors on each level. The details of the L9 experiment are shown in Table 2 on the section of optimization and condition. In Taguchi method, quality characteristics are categorized into the larger-the better, nominal-the-best, and smaller-the-better types [9]. The goal of this study is to optimum parameter setting. Table 1 shows the orthogonal array sheet in which there are three control factors (% concentration alum, raw water supply, pump stroke). There are nine experiments that will take place on different parameter.

The time for product development cycle can be greatly reduced for both design and production through Taguchi techniques. Hence, industries are saving costs and increasing profit. The three-step approach; system design, parameter design, and tolerance design engineering optimization of a process or product; should be carried out using Taguchi method. To produce a basic functional prototype design, an engineer should apply scientific and engineering knowledge through system design. The design objective is to optimize the values of the process parameter and its settings for the improvement of performance characteristics and the product parameter values are identified by using the optimum parameters of process [9].

Table 1: Level factor

Parameter	**Code**	**Level 1**	**Level 2**	**Level 3**
Conc. Alum (% ppm)	A	5	10	15
Raw Water Supply (lt/sec)	B	5	10	15
Pump Stroke (%)	C	15	20	25

Table 2: The basic Taguchi L9 orthogonal array

RUN	**Control factor and levels**		
	A	**B**	**C**
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 3: Mixing process in Taguchi L9 orthogonal matrix

Conc. alum (% ppm)	**Raw water supply (lt/sec)**	**Pump stroke (%)**
5	5	15
5	5	15
5	5	15
10	10	20
10	10	20
10	10	20
15	15	25
15	15	25
15	15	25

Result and Discussion

Research on the use of alum as admixture material to purify the water is ongoing. PAC is often used for river water having composition that influences the setting of parameter to produce the qualified drinking water. The result of water supply turbidity affects the characteristic of clean water quality [10] as shown in Figure 2. Somehow, for the mixing in a freshwater, the regional company of river gets a model which is appropriate for its region [11, 12]. Figure 2 presents the data of water supplied from river on its average of turbidity value for the parameter of water quality measurement as shown in the graphic and the optimization of model for parameter setting based on the formula found.

$$ppm = \frac{(lt)hourX56250\,ppm)}{8\,lt/\sec X3600\,sec/hour} \quad (1)$$

Finally, several manufacturing systems were modeled and measured the relationship alum, raw water and pump stroke. Model selections were analyzed using statistical software package MiniTAB®.

The mixing process of setting for parameter can be seen in Figure 3 as shown below. It is done with a camera magnification of 1000 times to observe the behavior of mixing process and microstructure obtained and to gather the characteristic of every mixture setting.

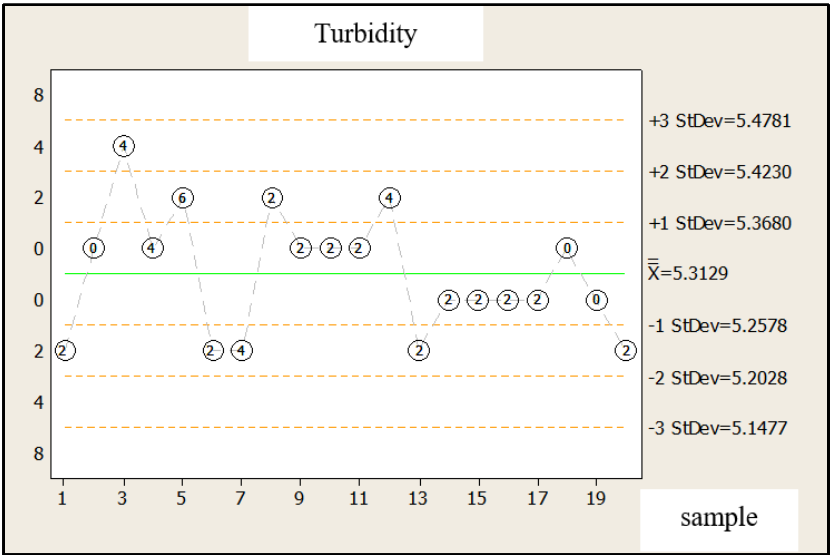
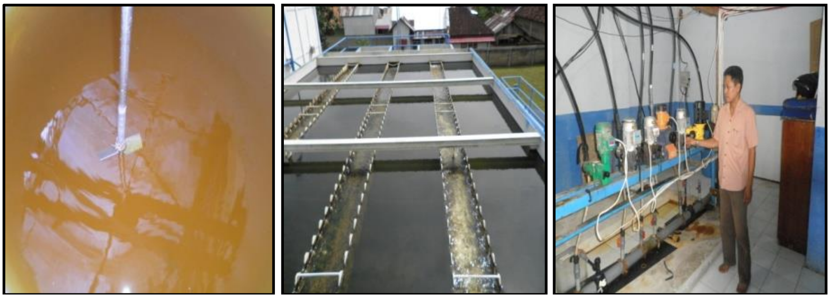
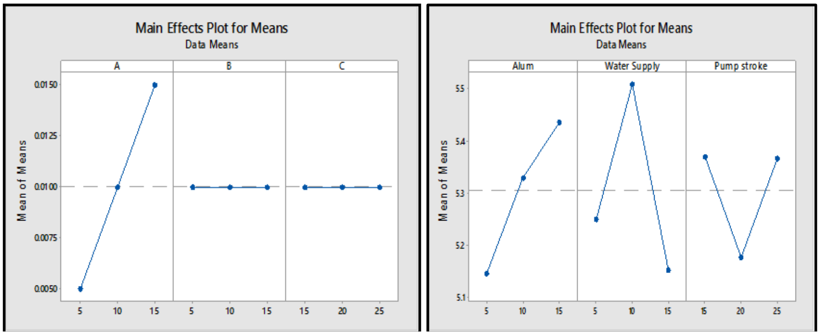


Figure 2: Turbidity value of water



(a) (b) (c)

Figure 3: (a) Water supplied from river (turbidity), (b) Mixing section (adding coagulant), (c) Author in the section of pump installation to set the additional coagulant alum



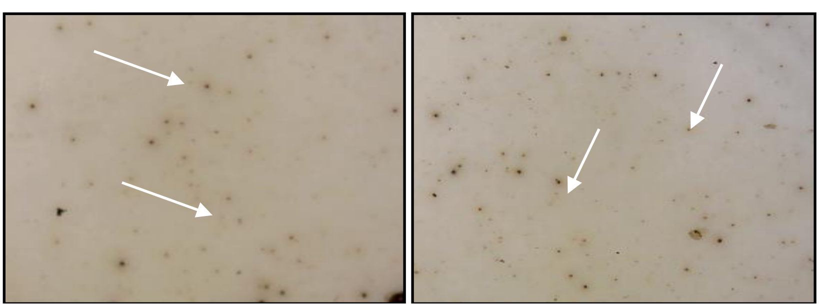
(a) (b)

Response Table for Means			
Level	Alum	Water Supply	Pump stroke
1	5.147	5.250	5.370
2	5.330	5.510	5.177
3	5.437	5.153	5.367
Delta	0.290	0.357	0.193
Rank	2	1	3

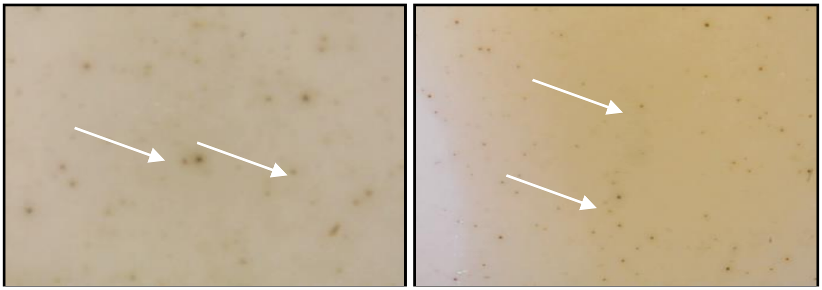
(c)

Figure 4: Effect plot for mean of clean water (a) before (b) after the mixing process and (c) the average response for the rank and level

This plot shows that the Code A (alum) is the main factor in the mixing process of getting the clean water at every level set. Thus, more emphasis must be put on this parameter at every experimental. Many combinations of the parameter alum, raw water and pump stroke have been explored in producing qualified clean water esignated to produce qualified clean water. See microstructure for % concentration ppm of alum.



(a) (b)



(c) (d)

Figure 5: SEM image of flock (arrow sign) sedimentation after being mixed with coagulant (*PAC*) (a) 5% ppm, (b) 10% ppm, (c) 15% ppm, (d) 20% ppm

Conclusion

In the mixing process, the parameter for the quality of clean water affected by turbidity in the intake pipeline was measured for its level of turbidity. Effect plots indicate that the % of alum is the main contributing factor, but the main reason of effect is due to the variation of raw water quality. Thus, the data of turbidity remains very important in the production process because the quality of clean water affects the consumers. During the process of sample gathering within a year, based on monthly, daily and hourly interval, it is observed that the turbidity factor is the most influencing factor in the optional setting model if the source of raw water comes from different rivers. But, if it is for the water supplied from a specific river with some intrusion of swamp water, then its turbidity becomes the most influencing factor in the optimal setting of model. However, the setting of parameter in the mixing process should be done more thoroughly to obtain the best quality standard of water.

Acknowledgement

The authors are grateful to the financial support from the DP2M, BPPS foundation from DIKTI, and Lambung Mangkurat University at Indonesia

References

[1] Md. Pauzi Abdullah, Lim Fang Yee, Sadia Ata, Abass Abdullah, Basar Ishak, Khairul Nidzam Zainal Abidin, 2009. *The study of interrelationship between raw water quality parameters, chlorine demand and the formation of disinfectant by products*. Physics and Chemistry of the Earth, p 806-811

[2] Braglia, M., Frosolini, M., & Montanari, R. (2003). Fuzzy TOPSIS approach for failure mode, effects and criticality analysis. Quality and Reliability Engineering International, 19, 425–443.

[3] Gauri, S. K., Chakravorty, R., & Chakraborty, S. (2011). Optimization of correlated multiple responses of ultrasonic machining (USM) process. International Journal of Advanced Manufacturing Technology, 53, 1115–1127.

[4] P.J Ross, Taguchi techniques for quality engineering: loss function, orthogonal experiments, Parameter and Tolerance Design - 2nd edition, McGraw-Hill, New York: 1999.

[5] M.S. Phadke, Quality engineering using robust design, Prentice Hall, Englewood Cliffs, New Jersey: 1989.

[6] G. Taguchi, System of experimental design, Unipub/Kraus, International Publication, White Plains, New York: 1987.

[7] G. Taguchi, Taguchi on robust technology development - bringing quality engineering upstream, American Society of Mechanical Engineers Press, New York: 1993.

[8] Ealey Lance, Quality by design taguchi methods and US industry. 2nd edition, Irwin professional publishing and ASI Press, Sidney: 1994, pp. 189–207

[9] Shaik Shafee A., B. Balu Naikb, K. Sammaiah (2015). Resistance Spot Weld Quality Characteristics Improvement by Taguchi Method, Materials Today: Proceedings 2 (2015). 2595 – 2604

[10] Tamjidillah M. (2015). Quality Characteristic Fresh Water In Optimum On Process Mixing Poly Aluminium Chloride And Water Supply At Pump Installation In Regional Company Fresh Water. Higher education ministry

[11] Tamjidillah M. (2015). Analysis Out Of Control and Performance Water Supply in Regional Company Fresh Water with Control Chart Variable. Proceeding Saintek, Engineering Faculty, Brawijaya University Malang.

[12] Tamjidillah M. (2016). Study of Performance of Fresh Water on Control Chart to Minimize Waste in Loss Function. Proceeding, Engineering Faculty, ITN Malang.