Multi-Criteria Analysis In Selecting Coagulation And Flocculation Of Bojong Renged Water Treatment Plant, Tangerang

Tazkiaturrizki, Winarni, Rifa Adriany

Abstract: The aims of study to analyze aspects that must be considered in the selection of coagulation and flocculation unit in water treatment plant based on multi-criteria analysis methods. Drinking water treatment plant consists of coagulation, flocculation, sedimentation, filtration, and disinfection units. There are several types of coagulation and flocculation units based on their operational methods, therefore, an appropriate type of unit is needed in selecting process. There are several aspects considered in the selection of processing units, specifically technical, economic and environmental aspects. The method that will be carried out in determining the processing units is a scoring method by giving a percentage to each aspect and the index value in the alternative units. Mechanical and hydraulic type of unit will be the comparison to determine the right coagulation and flocculation units that will be used in the next drinking water treatment plant. Based on the scoring results, the type of coagulation is the hydraulic jump unit has a score of 4.85 and the flocculation unit selected score 4.75 is hydraulic flocculation. The selected unit that will be used in the next plant is coagulation, flocculation, sedimentation, and filtration

Index Terms: drinking water, water treatment plant, bojong renged, multi-criteria analysis, coagulation, flocculation

1 INTRODUCTION

The drinking water treatment plant (WTP) aims to treat raw water into safe drinking water to meet the community demands and quality requirements. The design of a treatment system represents a decision about the efforts made to achieve certain goals by utilizing limited resources using several considerations, namely technical, economic and environmental aspects [1], [2]. Environmental decisions are cover multidisciplinary knowledge bases which include of natural, physical social sciences, politics, and ethics [3]. Multi-criteria analysis is one of the methods that can be used as a complex problem-solving solution, therefore it can parse the problem clearly more easily managed [4]. Minister of Public Works Regulation No.18/PRT/M/2007 provides some aspects that must be considered in the design of a water treatment plant, which consists of, 1) technical aspects, namely, i) removal efficiency in processing; ii) flexibility of the processing system against quality fluctuations; iii) construction; iv) operations and maintenance (O & M); v) availability of material for the WTP unit; vi) Possible damage. 2) Economic aspects consist of, i) Land requirement; ii) operation and maintenance costs; iii) construction costs, as well as 3) environmental aspects in the form of ecologically balanced, environmental carrying capacity, and land use. Water supply enterprise Tirtakerta Raharja (TR) has an existing 50 L/sec conventional WTP includes hydraulic coagulation-flocculation unit, tube settler sedimentation, rapid sand filtration, and disinfection. The TR plan to build 100 L/sec WTP that treat the Cisadane River water, in order to increase the production capacity of TR. The quality of the Cisadane River can be seen in Table 1.

TABLE 1

RAW WATER QUALITY OF CISADANE RIVER 2018

Parameter	Sampling Time		Permenkes RI
	14 Mei	26 Juni	No. 492/2010
Mikrobiologi			
E. Coli	12000 /100 ml	22000 /100 ml	0 /100 ml
Total coliform	15000 /100 ml	28000 /100 ml	0 /100 ml
Anorganic Chemical Matters			
Arsenic	<0.005 mg/L	<0.005 mg/L	0.01 mg/L
Flouride	0.5 mg/L	<0.01 mg/L	1.5 mg/L
Total Chromium	0.05 mg/L	<0.01 mg/L	0.05 mg/L
Cadmium	0.01mg/L	<0.002 mg/L	0.003 mg/L
Nitrite (NO_2-)	0.09 mg/L	0.04 mg/L	3 mg/L
Nitrate (NO_3-)	0.4 mg/L	0.4 mg/L	50 mg/L
Cyanide	<0.005 mg/L	<0.005 mg/L	0.07 mg/L
Selenium	<0.002 mg/L	<0.002 mg/L	0.01 mg/L
Organic Chemical Matters			
BOD	6 mg/L	14 mg/L	-
COD	30 mg/L	43 mg/L	-
Physics			
Total Disolved Solids (TDS)	76 mg/L	58 mg/L	500 mg/L
Turbidity	11.56 NTU	93.7 NTU	5 NTU
Chemical			
Iron	0.2 mg/L	0.2 mg/L	0.3 mg/L
Chloride	8 mg/L	6 mg/L	350 mg/L
Mangan	0.2 mg/L	0.01 mg/L	0.4 mg/L
pH	8	7	6.5 – 8.5
Zinc	<0.008 mg/L	0.01 mg/L	-
Sulfate	12 mg/L	11 mg/L	250 mg/L
Copper	<0.009 mg/L	<0.009 mg/L	2 mg/L
Amoniac	<0.01 mg/L	<0.01 mg/L	1.5 mg/L
Lead	<0.004 mg/L	<0.004 mg/L	0.01 mg/L

The parameters of chemical, physical, and biological characteristics of water should be checked, generally in terms of suitability for a particular -or designated [5]. Depending on the quality of the raw water, the extent of pollution and the regulations for safeguarding of public health, drinking water is treated by various methods before it reaches the consumer [4], and compare to Quality Standard of Minister of Health Indonesia No. 492/2010. In determining the right processing unit must be considered to make cost effective decisions in water quality management of factors such as social, economic, and environment [6]. To choose the best unit with considering factors can be use the multi-criteria decision analysis (MCDA). MDCA offers a lot of methods to support analysis decision making structured and to combine multiple criteria to an overall assessment and find the best option [7], [8]. This study aims to analyze aspects that must be considered in the selection of coagulation and flocculation unit

- *Tazkiaturrizki(*), Environmental Engineering, Faculty of Architecture Landscape and Environmental Technology, PH-6285720195537. Corresponding Author. E-mail: tazkiaturrizki13@trisakti.ac.id*
- *Winarni, Environmental Engineering, Faculty of Architecture Landscape and Environmental Technology, PH-628161386579. E-mail: winarni@trisakti.ac.id*
- *Rifa Adriany, Environmental Engineering, Faculty of Architecture Landscape and Environmental Technology, PH-628116643096. E-mail: riifa_adriany@yahoo.co.id*

in water treatment plant using the multi-criteria analysis method.

2 METHODS

The Minister of Public Works criteria is weighted, in the selection of the units to be used, a comparison is made between the two available unit alternatives by looking at the differences in each unit type and scoring. The first step decide the concept and the scope of the decision. This includes a technical, economic and environment the decision making process of alternative unit of coagulation and flocculation. Scoring is done in accordance with the criteria contained in the determined aspects [1], [9]. The procedure to choose the best type of coagulation and flocculation corresponding to a multi-criteria analysis with several criteria [10]. The multi-criteria analysis and results defined as standard procedure by compare the analytic hierarchy process [11]. In the next step, classified the aspect of multi-criteria and put the score base on design. The score that will be given is in numbers 1 to 5, number 5 shows the biggest score and number 1 is the smallest score. The higher the score obtained in the alternative unit, the unit that will be selected as the processing unit to be used [12]. The method is carried out as seen in Fig.1.

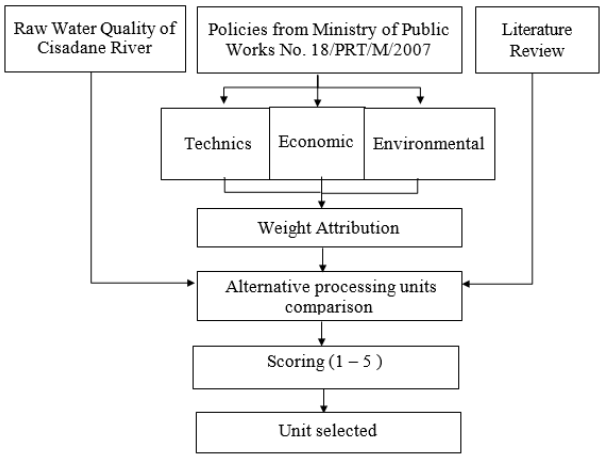

***Fig. 1**. Unit selection methods*

The decision point of analysis is as follows: (1) define evaluation criteria appropriate to the alternative, (2) assign a relative weight to each criterion (using AHP), (3) create appropriate alternatives, (4) evaluate each alternative against the criteria, (5) rank all alternatives using scoring and (6) analyze the result [13]. Hierarchy of achieving the water supply design at least equity, protection, supply of water, social, and cost consider. . A systematic methodology must explain the quantitative and qualitative inputs from scientific or engineering studies of risk, cost, and benefit [14]. Table 2 shows the rationale that used in providing the weight attribute to each criteria in order to select the appropriate type of unit process, i.e. 70% of technical aspect, 25% of economics aspects and 5% of environmental aspects

TABLE 2
MULTI-CRITERIA PERCENTAGE CLASSIFICATION

No	*Criteria*	*%*	*Description*
Technical aspects			
1.	*Removal efficiency*	*20%*	*This aspect has an effect because the higher of processing efficiency, the better and efficiency achieved.*
2.	*Flexibility against the quality fluctuation*	*5%*	*This aspect is not very influential, because the treated water discharge has been adjusted to the provisions of the planned discharge, and the quality of the Cisadane river is not that fluctuatve.*
3.	*Construction*	*5%*	*This aspect is not too influential because the construction is seen from the level of ease. The easier the unit construction is done the better.*
4.	*Operational and Maintenance (O & M)*	*25%*	*Operational and maintenance procedures are very influential because they will have an impact on costs that will be incurred.*
5.	*Material availability*	*10%*	*This aspect is quite influential because the material needed affects the construction.*
6.	*Damage possibility*	*5%*	*The effect on this aspect is that if a planned unit has the possibility of greater damage it will have an impact on maintenance costs.*
Economic aspects			
7.	*Land requirement*	*0%*	*The WTP building will be made on the location and land has been provided, the planned unit to be used must be adjusted to the land.*
8	*Operation and maintenance cost*	*15%*	*This aspect needs to be considered because these costs will be incurred as long as the unit operates. These costs include energy costs incurred, costs for chemicals used, processing fees for processing residues and employee/labor salaries.*
9.	*Capital/construction cost*	*10%*	*This aspect is taken into consideration because construction costs are only issued at the time of initial construction.*
Environmental aspects			
10.	*Ecological balance, environmental carrying capacity, and land use*	*5%*	*This aspect does not need to be considered in choosing a drinking water treatment unit, because any residue produced will be reprocessed so that it is safely received by the environment, and the less energy use will be better. The thing that addresses this aspect is the use of energy in the processing unit.*

3 RESULTS AND DISCUSSIONS

Based on the raw water quality found in Table 1, there are several parameters that exceed drinking water quality standards, namely, E. coli, total coliform, and turbidity. The processing that can be done so that the raw water can meet drinking water standards is coagulation, flocculation, sedimentation, rapid sand filtration and followed by disinfection in accordance with the treatment process at the existing Bojong Renged WTP. The raw water treatment process can be seen in Fig.2. Alternative units that will be compared using the scoring method are coagulation and flocculation.

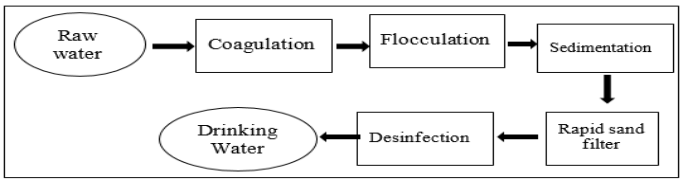

Fig. 2. *Unit processes in the Bojong Renged WTP*

3.1 Analysis Multi-criteria of Coagulation Unit

For the considerations, the best treatment strategy have to be necessarily based on multi-criteria aspect as mentioned on Table 2 were treatment cost, treatment efficiency and environmental preservation benefit being the main considered factors [16]. Another possible selection criterion may be based on treatment target changing based on the adopted treatment train. More specifically, removal target performances should vary if coagulation/flocculation reactor is used for pre-treatment or as the main treatment unit. The alternative coagulation units to be used are mechanical coagulation and hydraulic coagulation, i.e., Mechanical mixer; 2) In-line static mixer; 3) Hydraulic jump. The differences of alternative units in Table 3 [15], based on these differences can be obtained by the score x weights in Table 4. The decision procedure using multi-criteria analysis of coagulation unit as follows according to Table 2.

TABLE 3

PARAMETERS OF COAGULATION UNITS

Criteria	*Mechanical mixer*	*In-line Static Mixer*	*Hydraulic Jump*
Efficiency	*Removal efficency is up to 90%*	*Removal efficency is up to 90%*	*Removal efficency is up to 90%*
Flexibility	*Flexible against the quality fluctuation*	*Not flexible*	*Not flexible*
Constructions	*Materials used for construction such as stirrer motors cannot be easily obtained.*	*The construction is easier to do.*	*The construction is easier to do and material are easily obtained.*
Operational and maintenance	*Maintenance is not easy to do, personnel who are experts in operating the unit is needed.*	*Operations and maintenance are not as easy as hydraulic types and require skilled personnel*	*Operational and maintenance is easier to do.*
Damage Possibility	*Has a greater damage possibility*	*It has small damage possibility because this type of a static mixer.*	*Has a less damage possibility amongst all the other alternative.*
Land requirement	*Does not require large land area*	*Does not require large land area.*	*Requires a large area.*
Costs	*Requires greater costs in terms of operations and maintenance and construction.*	*Requires a great costs but it is not as great as mechanical mixer costs.*	*Not require great costs on construction, operational, and maintenance process.*

TABLE 4

SCORE ANALYSIS OF COAGULATION ALTERNATIVE UNITS

Criteria	*(%)*	*Type of Coagulation Units*					
		Mechanical mixer		*In-line Static Mixer*		*Hydraulic Jump*	
		index	*score*	*index*	*score*	*index*	*score*
Technical aspects							
1	*20%*	*5*	*1*	*5*	*1*	*5*	*1*
2	*5%*	*5*	*0.25*	*3*	*0.15*	*3*	*0.15*
3	*5%*	*2*	*0.1*	*5*	*0.25*	*4*	*0.2*
4	*25%*	*3*	*0.75*	*3*	*0.75*	*5*	*1.25*
5	*10%*	*3*	*0.3*	*3*	*0.3*	*5*	*0.5*
6	*5%*	*2*	*0.1*	*4*	*0.2*	*5*	*0.25*
Economic aspects							
7	*0%*	*3*	*0*	*5*	*0*	*3*	*0*
8	*15%*	*2*	*0.3*	*3*	*0.45*	*5*	*0.75*
9	*10%*	*2*	*0.2*	*3*	*0.2*	*5*	*0.5*
Environmental aspects							
10	*5%*	*5*	*0.25*	*5*	*0.25*	*5*	*0.25*
Total	*100 %*	*3.25*		*3.65*		*4.85*	

Based on the scoring results, the type of mechanical mixer coagulation unit has a score of 3.25, for this type of in-line static mixer unit has a score of 3.65 while the hydraulic jump unit type has a score of 4.85. The selected coagulation unit based on the scoring results is coagulation using the hydraulic jump. An appropriate estimation of costs must include and consider to the construction and operation of the system [13]. Efficiency of coagulation process become an important aspect because it deals with COD in the primary sedimentation [16]. Increasing costs by controlling primary sludge volume, coagulant dose and cost as well as an economic analysis aspect.

3.2 Analysis Multi-criteria of Flocculation Unit

Analysis of coagulation cannot despite of flocculation process because they are used together and have interconnected as floc and settlement of clarification. Therefore, optimizing only the coagulant could be not enough [10]. However, it need to manage the different kind of flocculation unit by multi-criteria analysis. The alternative flocculation units to be used are mechanical flocculation and hydraulic flocculation, i.e., 1) Horizontal Shaft with Paddle; 2) Vertical Shaft with Turbine; 3) Hydraulic Flocculation. The differences of each alternative units can be seen in Table 5 [10]. Based on the comparison of each alternative flocculation units can be obtained the results of the score x weight found in Table 6.

TABLE 5

PARAMETERS OF FLOCCULATION UNITS

Criteria	*Horizontal Shaft With Paddle*	*Vertical Shaft With Turbine*	*Hydraulic Flocculation*
Efficiency	*Removal efficency is up to 90%*	*Removal efficency is up to 90%*	*Removal efficency is up to 90%*
Flexibility	*Flexible against the quality*	*Flexible against the*	*Not flexible*

	fluctuation	*quality fluctuation*	
Constructions	*Construction is quite complicated because the distribution of compartments is difficult.*	*It is difficult to determine the right impeller and motor to use.*	*Construction is easy because it only uses hydraulic power as a stirrer*
Operational and maintenance	*Maintenance and removal of the floculator is done when the unit/tub is closed.*	*Maintenance and removal of floculators can be carried out without tub/unit closure.*	*More effective and practical.*
Damage Possibility	*The shaft can be damaged due to the initial playback of the unit.*	*The possibility of damage is quite large because using a drive motor*	*Less possible damage.*
Land requirement	*Does not require large land area.*	*Does not require large land area.*	*Requires large land area.*
Costs	*Requires a greater cost because The using of drive motors.*	*Requires a greater cost because of the use of a driving motor.*	*Does not require a large costs.*

TABLE 6

SCORE ANALYSIS OF FLOCCULATION ALTERNATIVE UNITS

Criteria	*(%)*	*Type of Flocculation Units*					
		Horizontal Shaft With Paddle		*Vertical Shaft With Turbine*		*Hydraulic Flocculation*	
		index	*score*	*index*	*score*	*index*	*score*
Technical aspects							
1	*20%*	*5*	*1*	*5*	*1*	*5*	*1*
2	*5%*	*5*	*0.25*	*5*	*0.25*	*3*	*0.15*
3	*5%*	*3*	*0.15*	*3*	*0.15*	*4*	*0.2*
4	*25%*	*3*	*0.75*	*3*	*0.75*	*5*	*1.25*
5	*5%*	*5*	*0.25*	*5*	*0.25*	*5*	*0.25*
6	*10%*	*3*	*0.3*	*3*	*0.3*	*5*	*0.5*
Economic aspects							
7	*0%*	*3*	*0*	*3*	*0*	*3*	*0*
8	*15%*	*3*	*0.45*	*3*	*0.45*	*5*	*0.75*
9	*10%*	*3*	*0.3*	*3*	*0.3*	*4*	*0.4*
Environmental aspects							
10	*5%*	*5*	*0.25*	*5*	*0.25*	*5*	*0.25*
Total	*100 %*	*3.80*		*3.80*		*4.75*	

The scoring results between three types of flocculation units, horizontal shaft with paddle type have a score of 3.80, flocculation type vertical shaft with a turbine has a score of 3.80, while hydraulic flocculation has a score 4.75. The flocculation unit selected and will be used in the planned WTP based on the scoring results is hydraulic flocculation. This analysis for decision-making process help people to set the optimum condition and make the best decision when both qualitative and quantitative aspects of a decision need to be considered [11], [17].

3.4 Sedimentation Unit

The sedimentation unit that will be used is high rate sedimentation, which is the type of sedimentation using trays in the form of a tube or plate in the deposition section. The cross section is useful in increasing speed and increasing container load in sedimentation tanks.

3.5 Filtration Unit

Rapid sand filtration is used in the WTP plan because the plan processing consists of coagulation, flocculation, and sedimentation. After going through the filtration unit, the raw water will be disinfected and flowed towards the reservoir.

4 CONCLUSION

Multi-criteria analysis is a method that can be used to systematically compile and plan especially in unit selection because it is viewed from several complex aspects. Based on the scoring results, the type of coagulation is the hydraulic jump unit has a score of 4.85 and the flocculation unit selected score 4.75 is hydraulic flocculation that will be used in planning of Bojong Renged WTP with a capacity of 100 L / sec. The hydraulic coagulation-flocculation unit will be followed by a subsequent processing unit consisting of high rate sedimentation, fast sand filtration, then disinfection will be stored in the reservoir. Based on the selected processing unit, the unit used in the planned WTP is the same type of unit as the type of unit used in the existing Bojong Renged WTP.

5 REFERENCES

[1] A.R Karimi, N. Mehrdadi, S. J. Hashemian, G. R. N Bidhendi, and R. T. Moghaddam. “Selection of Wastewater Treatment Procces Based on the Analytical Hierarchy Process and Fuzzy Analytical Hirarchy Process Methods.” Int. J. Environ. Sci. Tech 8, pp. 267-280, 2011.

[2] K.C Li, dan E. M. Wu, “Application of Stochastic NLP Model On The Optimal Design Of Water Treatment Facilities.” J. Water Supply 6: 137, 1988

[3] I.B Huang, J. Keisler, and I. Linkov, “Multi-criteria decision analysis in environmental sciences: Ten years of applications and trends”, Science of the Total Environment, vol. 409, pp. 3578–3594, 2011. doi:10.1016/j.scitotenv.2011.06.022

[4] P, Reichert., SD, Langhans., J, Lienert., N, Schuwirth. “The Conceptual Foundarion of Environmental Decision Support.” Journal of Environmental Management. pp. 154: 316 – 320, 2015

[5] Tilahun, Misgina., Zenebe, Haftom., Hishe, Gebremedhin., Berhe, Desta., Gebreyohans, Abadi., Sahu, Omprakash. “Design of Drinking Water Treatment Plant for Mekelle City.” J. Environ. Treat. Tech, pp.3: 88 – 89, 2015

[6] N. Schuwirth, M. Honti, I Logar and C. Stamm, “Multi-criteria decision analysis for integrated water quality assessment and management support,” Water Research X, vol.1, 2018. https://doi.org/10.1016/j.wroa.2018.100010

[7] V. Belton, T. Stewart, “Multiple Criteria Decision Analysis: an Integrated Approach.” Springer Science & Business Media: Springer US. 2002. doi: 10.1007/978-1-4615-1495-4

[8] R. Gregory, L. Failing, M. Harstone, G. Long, T McDaniels, and D. Ohlson, Structured Decision Making: A Practical Guide to Environmental Management Choices, John Wiley & Sons: US, 2012.

[9] Sjostrand, Karin. , Lindhe, Andreas. , Soderqvist, Tore. , Resen, Lars. “Sustainability Assessments of Regional Water Supply Interventions-Combininh cost-benefit and Multi-criteria decision analyses.” Journal of Environmental Management. pp.225: 313 – 324, 2018

[10] Feo, Giovanni., De Gisi, Sabino., Galasso, Maurizio. “Definition of a Practical Multi-criteria Procedure for Selecting The Best Coagulant in Chemicallly Assisted Primary Sedimentation Process for the Treatment of Urban

Wastewater." Desalination, Italy: Department of Civil Engineering, University of Salerno.pp 230: 229 – 23, 2008.
[11] T.L. Saaty, Theory and Applications of the Analytic Network Process. Decision Making with Benefits, Opportunities, Costs, and Risks. RWS, Pittsburgh, 2005.
[12] L. Scholtena, N. Schuwirtha, P. Reicherta, and J. Lienerta, " Tackling uncertainty in multi-criteria decision analysis– Anapplication to water supply infrastructure planning", European Journal of Operational Research , vol. 242, pp.243–260, 2015. http://dx.doi.org/10.1016/j.ejor.2014.09.044
[13] G.A. Kiker, T.S. Bridges, A. Varghese, T. P. Seager, and I. Linkovjj, "Application of Multicriteria Decision Analysis in Environmental Decision Making", Integrated Environmental Assessment and Management, vol.1 (2), pp. 95–108, 2005.
[14] E.S Chung, and K.S Lee. "Prioritization of water management for sustainability using hydrologic simulation model and multicriteria decision making techniques," Journal of Environmental Management , vol.90, pp.1502–1511, 2009. doi:10.1016/j.jenvman.2008.10.008
[15] Kawamura, S., Integrated Design of Water Treatment Facilities. New York: John Willey and Sons, Inc, 2000.
[16] G. Di Bella, M.G. Giustra, and G. Freni, "Optimization of coagulation/flocculation for pre-treatment of high strength and saline wastewater: performance analysis with different coagulant doses", Chemical Engineering Journal, Accepted Manuscript, May 2014. http://dx.doi.org/10.1016/j.cej.2014.05.115
[17] T.L Saaty, "Decision making with the analytic hierarchy process", Int. J. Services Sciences, vol. 1, No. 1, pp.83–98. 2008
[18] H.A -Daza, C. Sergio, S. Raquel and J. Saldarriaga, "A New Multi-Criteria Decision Analysis Methodology for the Selection of New Water Supply Infrastructure", Water, vol.11, page.805. doi:10.3390/w11040805
[19] Geza, Mengistu., Ma, Guanyu., Kim, Hyung., Cath, Tzahi Y., Xu, Pei. "iDST: An integrated decision support tool for treatment and beneficial use of non-traditional water supplies – Part I. Methodology." Journal of Environmental Management. pp.25: 236 – 246, 2018.
[20] Vigneswaran, S, and C Saravanamuthu, Water Treatment Process : Simple Options. New York: CRC Press, 1995.