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High Rate Water Treatment Plant System: Successful Implementation

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Abstract

The High Rate Water Treatment Plant (HR-WTP) system, which is inexpensive, effective and efficient, has been developed to reduce the common operational problems, and also as an alternative for the development of water treatment plant systems capacity in Indonesia. HR-WTP-system is superior to those of conventional WTP-systems in respect to its capacity, performance, as well as operational liability of the system.
Mathematical model of the HR-WTP system had been developed and simulation using the mathematical model as well as field observation had been clarified.
Implementation of HR-WTP-system in up-rating of the Dekeng-WTP system at PDAM Kota Bogor proved successful in increasing the plant capacity from its original of 500 Lps to more than 1200 Lps. Another successful application of HR-WTP-system was experienced in the upgrading and up-rating of the Pedindang-WTP system at PDAM Kota Pangkalpinang where the plant capacity can be increased from its original of 50 Lps to 300 Lps. The performance of the WTP-system was also significantly improved from poor performance to very good performance.

Keywords: conventional system, filtration rate, high rate system, surface loading

1. Introduction

The demand of municipal drinking water in Indonesia is always increasing in direct proportion to population growth and to increasing industrial water demands. However, instead of increased capacities and services, the municipal water supplies are constrained by limited financial factors. The water treatment plant systems in Indonesia have a total capacity of around 100.000 Lps which serve more or less 100.000.000 population equivalent. Only less than 30% of the population is covered by these water treatment plant systems.

Furthermore, there are operational problems of the water treatment plant (WTP) system in some cities in Indonesia (even though they are operated at low to medium loading rate) especially in the sedimentation units, e.g., sludge carry over, flow distribution, temperature effect, density flow, algal growth, scale deposits, wind effect, etc. (Mohajit, 2002). Due to these problems, the filter unit of the water treatment plant systems become inefficient because of its frequent clogging of the filter media. In a normal operation without such a problem the filter unit of the water treatment plant system may work with a backwashing cycles of around 24-48 hours. The more frequent the filter is backwashed the more inefficient the filter unit would be.

If operational problems of the water treatment plant system can be solved and the loading rate of the system can also be increased then the systems will become more efficient and effective therefore the capacity of the water service may be increased and thus the demand of municipal drinking water might be supplied (Mohajit, 2010).

The objective of this work is to find any methods to increase the production and service capacity of the municipal water treatment plant system in order to reach the millennium development goals in water supply sector in Indonesia, where an additional capacity of ca 150,000 Lps should be developed within a 15 years period.

2. Material and Methods

The HR-WTP system had been implemented successfully at Dekeng WTP system at PDAM Kota Bogor and Pedindang WTP system at PDAM Kota Pangkalpinang. The WTP systems were investigated and modified by introducing a new configuration of the systems to increase its capacity (up to double or even three fold) as well as to improve its performance.

Mathematical model of the WTP system had been developed and simulation using the mathematical model as well as field observation had been clarified. The detailed report of the successful application of HR-WTP system for Dekeng and Pedindang WTP system can be found elsewhere (Mohajit, 2010; 2006).

The mathematical model focuses on the sedimentation and filter unit because these two units represent the performance of the WTP-system as the limiting factors. Development and improvement of the sedimentation and the filter unit will significantly affect the WTP-system performance (Mohajit, 2006; Mohajit and Poedjastanto, 2003).

New configuration of the WTP-system was then defined by modifying the design variable of the sedimentation unit as well as the filter unit. The sedimentation unit was provided with the more efficient and effective plate settler and the filter unit was developed by introducing a new filter media with a coarser gradation but still capable to retain a fine flocs with particle size of 50-80 micron as commonly found in the supernatant of the sedimentation unit.

3. Result and Discussion

The Dekeng WTP system of PDAM Kota Bogor was designed for 500 Lps (Liter per second) in capacity with its performance as fair to good performance. The system consists of coagulation unit, flocculation unit, sedimentation unit, filtration unit, and disinfection unit. The system was operated at hydraulic capacity of around 460 Lps and a fair to good performance was reached, and the output of treated water met the drinking water quality standard.

By modification of the system configuration in the sedimentation unit as well as in the filter unit as reported in detailed in Reference (Mohajit, 2010) it was proven that the Dekeng WTP system could be up-rated from its original capacity of 460 Lps with a fair performance to 1200 Lps in capacity with a good performance. The surface loading of the sedimentation unit was increased much higher from the conventional level of 11.56 mph (meter per hour) to a high rate level of 30.48 mph. At this high rate level of loading rate the system is hydraulically still in a laminar and stable condition. No scouring effect on floc particles or sludge washout was observed (Tabel 1).

Table 1. Simulation of Sedimentation Unit for High Rate WTP-system

Mathematical Model for Sedimentation Unit of Water Treatment Plant Systems			
Conventional sedimentation unit		***High rate sedimentation unit***	
Type (conventional, plate, tube) ?	**plate**	Type of settler (plate or tube)	**plate**
Shape (circular or rectangular) ?	**rectangular**	Shape (circular or rectangular) ?	**rectangular**
Total flow rate (L/s)	**460**	Total up-rated flow rate (L/s)	**1200**
Number of the basin (unit)	**3**	Number of the basin (unit)	**3**
Width of the basin (m)	**4.8**	Width of the basin (m)	**4.8**
Length of the basin (m)	**10.5**	Length of the basin (m)	**10.5**
Depth of the basin (m)	**5.0**	Depth of the basin (m)	**5.0**
Length of effluent weir (m)	**88.9**	Minimum length of effluent weir (m)	89
Surface area (m2)	143	Efective surface area (m2)	142
Accelaration due to gravity (m/s2)	**9.81**	Accelaration due to gravity (m/s2)	9.81
Kinetics viscousity (m2/s)	8.000E-07	Kinetics viscousity (m2/s)	8.000E-07
Temperature (°C)	**30**	**Data input :**	**OK**
Demension of plate settler or tube settler		***Modification of sedimentation unit***	
Distance between settler (cm)	**9.0**	System configuration (1, 2, ..., 24)	**sp**
Thickness of settler (cm)	**0.5**	Thickness of settler (cm)	**0.2**
Length of settler (m)	**3**	Degree of up-rating	261%
Inclined angle of settler (°)	**60**	Recommendation	recommended
Vertical height of settler (m)	2.60	Comment	much better
Performance of sedimentation unit		***Performance of high rate sedimentation unit***	
Settleable Settling velocity (m/h)	0.79	Settleable Settling velocity (m/h)	0.70
Particulate removal	fair/normal	Particulate removal	good
Reynould number	209	Reynould number	183
Freuode number	3.11E-05	Freuode number	6.49E-04
Flow characteristics	laminar flow	Flow characteristics	laminar flow
Flow stability	stable flow	Flow stability	stable flow
Scouring effect	moderate: none	Scouring effect	moderate: none
Current effect	none	Current effect	none
Surface loading (m/h)	11.56	Surface loading (m/h)	30.48
Detention time (minutes)	13.5	Detention time (minutes)	5.1
Streamliner ratio	?	Streamliner ratio	≥ 2,5

Further more by modification of the filter unit with a coarser gradation of the media it can be achieved that the filter unit could be up-rated from its original capacity of 460 Lps with a good performance to 1200 Lps in capacity with a similar performance.

The filtration rate was increased much higher from a conventional level of 6.4 mph to high rate level of 16.7 mph. At this high level of filtration rate the system was still under condition of good performance where the in-plant water losses are less than 5%. This is acceptable in accordance with the design standard (Table 2). The filtrate of treated water has less than 0.5 NTU of turbidity, and this is much better than the prevailing drinking water standard of 5 NTU.

Table 2. Simulation of Filter Unit for High Rate WTP-system

Mathematical Model for Filter Unit of WTP Systems						
Filter media analysis				*Design parameter*		
ASTM Sieve Number	Grain size (mm)	Cummulative weight (%) Conventional media	Cummulative weight (%) High rate media	Water temperature (°C) =	25	
				Kinematic viscosity, ν (m2/s) =	8.93E-07	
				Gravitational acceleration, g (m/s2) =	9.81	
200				Recommended filter runs (h) =	24	
170	0.083	0	0	Practical factors constant =	1.96	
140	0.098	0	0	Filter run factor =	0.85	
120	0.116	0	0	Required efective size, ES (mm) =	0.9	0.9
100	0.138	0	0	Required uniformity coefficient (UC) =	1.5	1.5
80	0.165	0	0	Filter media to be used (1, 2) =	1	silica sand
70	0.196	0	0	Is medium gradation equal ? (yes, no)	no	Check aX-b !
60	0.231	1	0	Approximated Vs ?	OK	OK
50	0.275	1	0		*Silica sand*	*Synthetic media*
45	0.328	2	0	Porosity of filter bed, *f* =	0.45	0.50
40	0.390	3	0	Filter media shape factor, φ =	0.82	1.00
35	0.463	6	0	Specific weight of filter media =	2.65	1.3
30	0.550	10	0		*Conventional*	*High Rate*
25	0.655	16	0		*System*	*System*
20	0.780	32	0	Code number (1,..., 5) =	5	5
18	0.925	60	13	Performance of sedimentation unit =	excellent	excellent
16	1.090	80	31	Filter capacity (L/s) =	460.0	1200.0
14	1.290	94	53	Number of filters (unit) =	6	6
12	1.550	100	82	Surface area of filter unit (m2) =	43.2	43.2
10	1.850	100	100	Depth of filter bed (m) =	0.80	0.80
8	2.180	100	100	Available filter head (m) =	1.50	1.50
7	2.580	100	100	Backwashing time (minutes) =	15	15
6	3.075	100	100	Backwash rate, *v* (m/h) =	40	40
5	3.675	100	100	Filtration rate, *v* (m/h) =	6.4	16.7
4	4.375	100	100	Initial head loss; Rose (m) =	0.58	0.51
				Approximated Filter Run (h) =	66	20
				Backwashing head loss (m) =	0.73	0.73
				Expanded bed (m) =	1.07	1.07
				Expansion (%) =	134%	134%
				Approximated in-plant losses (± 5%) =	2.4%	3.0%
				Water production required for backwashing =	104%	40%
				Actual filter head (m) =	0.92	0.99
				Comment :	**high rate system is recommended !**	
				Estimated In-plant Water Losses for Filter Backwashing :		
				Actual filter run (h) =	66	
				Water tariff (Rp./m3) =	2500	2500
				Unaccounted for water =	30%	30%
				Annual in-plant losses/benefit (Rp.) =	667,300,000	1,327,800,000
				Cross check ! :	**reconfirm actual filter run !**	

Another successful application of HR-WTP system was experienced at Pedindang WTP system where the system was designed for 75 Lps in capacity with its performance as expected fair to good performance. The WTP system was a typical pulsator system which consists of coagulation unit, flocculation unit, sedimentation unit, filtration unit, and disinfection unit. The system was actually operated at hydraulic capacity of around 50 Lps and a poor to fair performance was resulted. Table III shows a comparable result in the application of HR-WTP for up-rating and upgrading Dekeng- and Pedindang WTP system.

It can be seen from the Table III that uprating of Dekeng WTP-system is characterized by a higher surface loading rate of the Sedimentation Unit, i.e., 30.48 mph as compared to the uprating of Pedindang WTP-system (the surface loading rate of the Sedimentation Unit is 26.84 mph).

On the other hands, the uprating of Pedindang WTP-system is characterized by a higher filtration rate, i.e., 28.7 mph as compared to the uprating of Dekeng WTP-system (the filtration rate is only 16.7 mph).

This clearly shows that application of a surface loading as high as 30 mph for Sedimentation Unit and a filtration rate as high as 30 mph are likely feasible and implementable.

Table 3. The performance of HR WTP system application

Sedimentation Unit		Dekeng WTP System	Pedindang WTP System
1	Uprating Capacity (L/s)	460 - 1200	50 - 300
2	Surface Loading (m/h)	30.48	26.84
3	Settleable Settling Velocity (m/h)	0.70	0.64
4	Reynould Number - Laminar Flow	183	135
5	Freuode Number, Stable Flow	6.49E-04	6.04E-04
6	Scouring Effect	Not Found	Not Found
7	Current Effect	Not Found	Not Found
8	Particulate Removal	Very Good Performance	Good Performance
9	Turbidity of the Supernatant		
	• Minimum	1.3 NTU	2.33 NTU
	• Maximum	2.5 NTU	4.87 NTU
	• Average	2 NTU	3.76 NTU
Filter Unit		**Dekeng WTP System**	**Pedindang WTP System**
1	Uprating Capacity (L/s)	460 - 1200	50 - 300
2	Filtration Rate (m/h)	16.7	28.7
3	Filter Media	Silica Sand	Silica Sand
4	Media Particle Size	Mesh No. 8-20	Mesh No. 8-12
5	Depth of Media (cm)	70-80	40-60
6	Filter Run (h)	21	9.75
7	Backwash Rate (m/h)	40	40
8	In-plant Water Losses (Approximated)	3% < 5%	3.8% < 5%
9	Turbidity of Filtrate		
	• Minimum	0.2 NTU	0.26 NTU
	• Maximum	0.5 NTU	0.93 NTU
	• Average	0.4 NTU	0.61 NTU

4. Conclussion

The HR-WTP system, which is inexpensive, effective and efficient, has been developed to reduce the common operational problems, and also as an alternative for the development of water treatment plant systems capacity in Indonesia.

Implementation of HR-WTP system in up-rating of the Dekeng-WTP system at PDAM Kota Bogor proved successful in increasing the plant capacity from its original of 460 Lps to more than 1200 Lps. Another successful application of HR-WTP system was experienced in the upgrading and up-rating of the Pedindang-WTP system at PDAM Kota Pangkalpinang where the plant capacity can be increased from its original of 50 Lps to 300 Lps.

This new approach might be an innovative solution to the challenge of Millennium Development Goals in Water Supply Sector in Indonesia, where an additional capacity of ca 150,000 Lps should be developed within a 15 years period with an estimated budget of US $1.5 billions.

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