Make-Up Water Utilization Using WWTP Effluent Recycle: A Case Study of Grati Combined Cycle Power Plant, East Java Province, Indonesia

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Abstract
In 2013, average waste water production of Grati Combined Cycle Power Plant is about 3,801 m^3/month within only less than 8% (eight percent) has been reused for reboisation. It requires more effort to recycle effluent of Waste Water Treatment Plant (WWTP) in order to fullfil water conservation program and zero waste water of power plant with emphasis on Environmental Compliance (PROPER) Awarded by Ministry of Environment of Indonesia.

Installation of Brackish Water Reverse Osmosis (BWRO) to process effluent of WWTP can remove chemical and physical impurities in order to reach quality specification of raw water for boiler water. A pilot project BWRO can produce 4 ton/hour service water and reduce specific conductivity effluent of WWTP from 500 microS/cm to less than 20 microS/cm.

We also calculate financial analysis from this innovation, which resulted surplus is about IDR 320,060,578/annum from monthly batch BWRO operation of 160 m^3 within 5 years payback period. There is also non-financial benefit, connected to improvement of environmental management to achieve higher level of PROPER Award. Potential water conservation from this innovation is 1,600 m^3/month or 50% from total waste water by built effluent of WWTP storage pond capacity 300 m^3.

Keywords: Grati Combined Cycle Power Plant, Water Conservation, Environmental Compliance, BWRO

Introduction

PT Indonesia Power Grati Combined Cycle Power Plant (CCPP) produced electricity with installed capacity of 750 MW. It consists of Block I with the pattern of combined cycle operation and Block II with open cycle. Since operating with natural gas fuel in 2009 has been replaced with HSD (High Speed Diesel) fuel, Grati CCPP Block I becoming base load unit with 24 hours of operating hours. Coupled with the operation of CNG (Compressed Natural Gas) as a fuel for GT (Gas Turbine) Block II which able to increase electricity supply at peaker hour as a peaked unit.
Wastewater from the main processes in plants treated at the Waste Water Treatment Plant (WWTP) with the fundamental principle of neutralization and coagulation-flocculation. Treated water or WWTP effluent can be discharged into the stream, taking into account the sea, when the quality is in accordance with the quality standards that determined by Ministry of Environment Regulation under "Peraturan Menteri Lingkungan Hidup" No. 08/2009 [1].
This paper is aim to introduced a utilization of the WWTP effluent production with approach on the quality of domestic raw water or clean water. While the efforts of this recycle, that is reboisation program still not optimal yet. So it takes another attempt to utilize more wastewater.

Purpose and Objectives

This paper described a utilization of WWTP effluent with an addition of Reverse Osmosis so it can be used for service water and increases the national environmental compliance achievement in water efficiency criteria sustainably [3].

Methodology

According to this paper purpose and objective, there are several step of methodology, such as data collection and analysis, design, and examination, which described as follows.

Data Collection

The first step of this study has begun with data collection. It has taken into account in this study consist of WWTP effluent product and waste water quality. One of data collection is then shown in Table 1.

Table 1: Data Collection During 2013

Parameter	Unit	Standard of Quality	Laboratory Result (year of 2013)								
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
pH	-	6 - 9	7.82	8.01	8.9	7.53	7.45	7.54	7.09	6.36	7.85
Total Suspended Solid	mg/l	100	1.2	3.6	3.2	1.6	2.8	4	3.36	2	6.94
Oil and Grease	mg/l	10	< 1.05	< 1.05	<1.05	1.1	<1.05	<2.17	<2.17	<1.05	<2.17
Free Chlorin	mg/l	0.5	<0.004	<0.004	0.02	0.02	<0.004	<0.004	<0.004	<0.004	<0.004
Total Chromium	mg/l	0.5	<0.0269	<0.0269	<0.0269	<0.0269	<0.0269	<0.0269	<0.0269	<0.0269	<0.0269
Copper (Cu)	mg/l	1	<0.0169	<0.0169	<0.0169	<0.0169	<0.0169	<0.0169	0.002	<0.0169	<0.0169
Iron (Fe)	mg/l	3	<0.0413	<0.0413	0.128	0.0538	<0.0413	<0.0413	0.645	<0.0413	0.619
Zink (Zn)	mg/l	1	<0.0157	0.057	0.0806	0.0175	<0.0157	<0.0157	0.283	0.0411	<0.0157
Phosphat (PO4-)	mg/l	10	0.0883	0.554	0.246	0.098	0.037	1.57	0.814	0.04	1.6

Data Analysis

In this paper, the data was analyzed by engineering studies including operations and financial feasibility.

Analysis of Problems

In order to utilize WWTP effluent, discussions were made with Engineering Department with several options to be considered, such as:

1. Laboratory analysis WWTP effluent quality on November 16, 2010, the results meet Standard Healthy Regulation (Peraturan Menteri Kesehatan Republik Indonesia) 416/1990 as clean water [2].

2. Utilization of Effluent WWTP for domestic water; As part of problem analysis, there is also numerous of fundamental considerations, such as:
a. Splitting water tank for domestic and service water demand
b. Potential residual chemicals
c. Required pipeline facilities to the halls and/or buildings
d. Low investment cost of USD 23,077
e. Required Sand Filter and Chlorine Injection Facility
f. Conductivity product shall not changed

3. Utilization WWTP effluent to water service with Reverse Osmosis, with consideration that consist of:
   a. No need to manufacture additional tank
   b. The recycle water for use as water enhancer
   c. Low potential residual chemicals (mixed with desalination plant product water)
   d. The investment cost of USD 57,692
   e. Conductivity product decrease to be lower than 20 μS/cm

Operation Feasibility

Based on the alternatives above, the following step taken into account operations feasibility study to determine the best of it. Each alternative is assessed and calculated its feasibility as shown in Table 2.

Table 2: Operational Feasibility Study to Determine the Best Alternatives

No	Criteria	Weight (%)	Alternative 1			Alternative 2		
			Filtration Unit			Reverse Osmosis Unit		
			Remarks	Value	Score	Remarks	Value	Score
1	Cost	30	Cheaper	8	2.4	Expensive	4	1.2
2	Additional Investment	25	Tank and pipeline	3	0.75	-	9	4.25
3	Operation & Maintenance	25	Easy	8	4	complicated	6	1.5
4	Risk	20	High risk for human	4	0.8	Low risk for human	8	1.6
	Total Score	100			7.95			8.55

Financial Feasibility

Besides conducting data analysis and technical feasibility, financial perspective of feasibility is also considered. It used technical economy approach to determine tangible and intangible benefit.

Design

Based on the design point of view, this study also performed design and capacity plant.

Monitoring and Evaluation

This study also monitored the quality and quantity of Reverse Osmosis product at commissioning and normal operation condition periodically.

Results and Discussions

This study discussed about implementation of the program and its beneficial impact, which consist of financial benefit. This study also implemented as water conservation program, which contributed to the national government program on environmental compliance and beyond.

Implementation

This study has filing process that started in 2012 to Reverse Osmosis unit normal operation in October 2013. Unit Reverse Osmosis (RO) in Grati CCPP consists of two systems, namely the pretreatment system and RO system. Pretreatment system consists of the Multi Media Filter (MMF) and Chemical Treatment, while the RO membrane system consists of modules and cleaning facilities. The schematic diagram of flow process is then depicted in Figure 1. As an example, permeate quality at commissioning of program is also shown in Table 3.

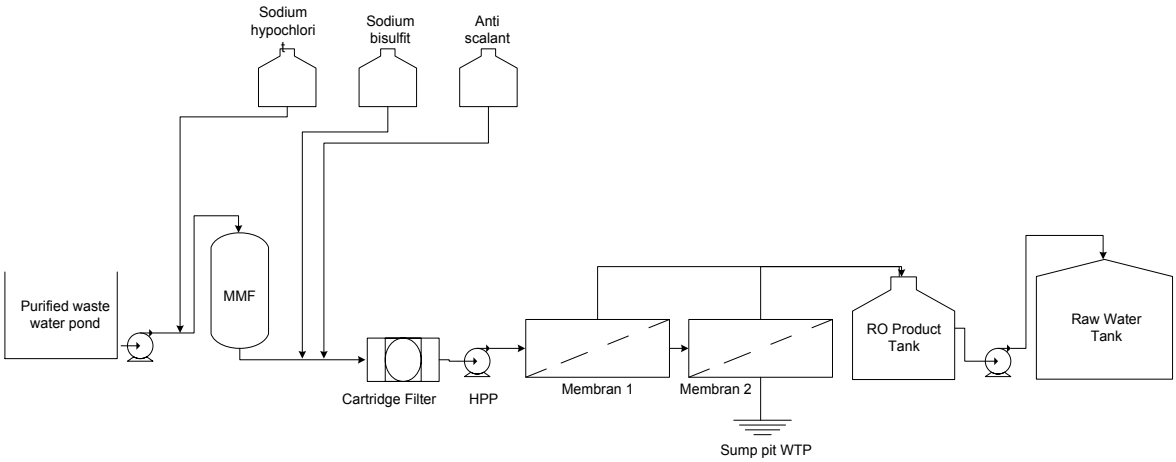

Figure 1: Schematic Diagram of WWTP Effluent Utilization with Reverse Osmosis Facilities

Table 3: Permeate Quality at Commissioning

4-Oct-13	pH	Conductivity (µS/cm)	Turbidity	Flow (LPM)
14.3	7.31	16.8	0.12	75
15.3	7.27	15.5	0.12	74
17	6.81	16.1	0.13	66
18	7.1	14.7	0.1	65
19	7.1	14.5	0.11	65
20	6.95	14.6	0.1	65
21.3	7.04	14.4	0.16	63
22.3	6.63	14.1	0.24	63
0.15	6.86	13.6	0.16	65
1	7.1	13.1	0.11	65

The increasing of WWTP effluent utilization is shown in Table 4 and Table 5. WWTP effluent used as raw material of RO unit and within this program, the amount of WWTP effluent utilized in 2014 has known significantly increase compared to the year of 2013.

Table 4: Utilization of WWTP Effluent before RO Program

Year	Month	Amount of Process Wastewater (m^3/month)	Amount of Utilized Wastewater for Watering (m^3/month)	Amount of Utilized Wastewater for RO (m^3/month)	Total of Utilized Wastewater	% Utilization for Watering	% Utilization for RO	Total (%)
2013	Jan	4010.60	405.00	0.00	405.00	10.10%	0.00%	10.10%
	Feb	4687.20	369.00	0.00	369.00	7.87%	0.00%	7.87%
	Mar	4435.60	207.00	0.00	207.00	4.67%	0.00%	4.67%
	Apr	4177.50	315.00	0.00	315.00	7.54%	0.00%	7.54%
	May	2847.60	351.00	0.00	351.00	12.33%	0.00%	12.33%
	Jun	3157.80	378.00	0.00	378.00	11.97%	0.00%	11.97%
	Jul	4261.60	342.00	0.00	342.00	8.03%	0.00%	8.03%
	Aug	4905.80	180.00	0.00	180.00	3.67%	0.00%	3.67%
	Sep	1107.90	450.00	7.92	457.92	40.62%	0.71%	41.33%
	Oct	3677.10	342.00	61.11	403.11	9.30%	1.66%	10.96%
	Nov	4127.40	153.00	101.15	254.15	3.71%	2.45%	6.16%
	Dec	4216.20	108.00	40.50	148.50	2.56%	0.96%	3.52%
Average		3801.03	300.00	17.56	317.56	10.20%	0.48%	10.68%

Table 5: Utilization of WWTP Effluent after RO Program

Year	Month	Amount of Process Wastewater (m^3/month)	Amount of Utilized Wastewater for Watering (m^3/month)	Amount of Utilized Wastewater for RO (m^3/month)	Total of Utilized Wastewater	% Utilization for Watering	% Utilization for RO	Total (%)
2014	Jan	4305.10	81.00	157.82	238.82	1.88%	3.67%	5.55%
	Feb	4240.50	94.50	309.32	403.82	2.23%	7.29%	9.52%
	Mar	-	90.00	244.41	334.41	-	-	-
	Apr	2211.30	99.00	180.02	279.02	4.48%	8.14%	12.62%
	May	2850.30	90.00	141.53	231.53	3.16%	4.97%	8.12%
	Jun	2013.20	126.00	174.78	300.78	6.26%	8.68%	14.94%
	Jul	1991.60	162.00	229.95	391.95	8.13%	11.55%	19.68%
	Aug	1678.80	126.00	55.73	181.73	7.51%	3.32%	10.82%
	Sep	4226.60	144.00	480.21	624.21	3.41%	11.36%	14.77%
	Oct	3648.70	135.00	261.21	396.21	3.70%	7.16%	10.86%
	Nov	1602.30	162.00	407.91	569.91	10.11%	25.46%	35.57%
	Dec	3911.10	132.75	470.65	603.40	3.39%	12.03%	15.43%
Average		2970.86	120.19	259.46	379.65	4.93%	9.42%	14.35%

Based on Table 4 and Table 5 above, it can be seen that there is a significant in total utilization of wastewater about 10.68 % in 2013 to 14.35 % in 2014. It has significantly increase effluent utilization as it shown in Figure 2.

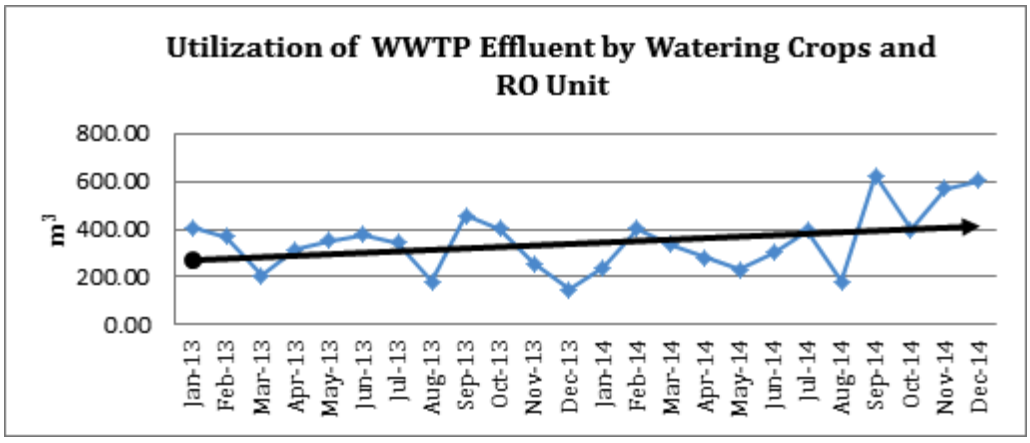

Figure 2: Wastewater Effluent Utilization for Watering Crops and Reverse Osmosis Unit

After the program has successfully implemented in the field, the amount of wastewater recycled to service water using Reverse Osmosis unit is about 259.46 m^3/month with total percentage of 9.42 percent (%).

Financial Benefit

The utilization of Reverse Osmosis unit to re-process WWTP effluent into water service recognized to be quite efficient. At this condition, technical and financial benefits are calculated as follows.

1. Reduce distillate water consumption = 259.46 m^3 per month
   Financial benefit = 867.2 USD per month
2. Reduce steam demand of Desalination Plant (DP) = 0.65 m^3 per hour
   Financial benefit = 1,184.5 USD per month
3. Calculation of Payback Period (PBP)

PV Cash Out (Investment)	= 57,692.31 USD
PV Cash In	= 67,608.53 USD
Net Present Value (NPV)	= 9,916.22 USD
IRR	= 13.22%
Payback Period (PBP)	= Year 5
Discounted Payback Period	= Year 5
Conclusion	= Decent

Conclusions and Recommendations

This study has several conclusions and recommendations which consist of:

- In 2013, the average production of wastewater in Grati Combined Cycle Power Plant monthly recorded about 3,801.03 m^3.
- As an additional effort to improve the efficiency of water consumption, Reverse Osmosis (RO) units significantly viable to utilize the WWTP effluent.
- Reverse Osmosis units can improve the utilization rate of wastewater ranging from 10.68 % in 2013 to 14.35 % in 2014.
- With Reverse Osmosis program, it has been calculated that financial benefit gained USD 24,620 annually and achieve payback period after five years period.

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