WATER RECYCLE FOR COOLING TOWER IN WATER SHORTAGE AREA

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Abstract

The water is the limited resources in Kalasin, while the replacement and new power plants need to be constructed for ensuring stability of power supply in upper northeast of Thailand. This is the challenge reserving and suppling power generation in water scarcity area. Electricity Generating Authority of Thailand (EGAT) seriously concerns about the limited resources in water shortage area. Thus, water reuse and water recycle are the key for sustain water in scarcity province and resolving water pollution for the large scale.

This study focuses primarily on the sustainable water resources design of the treatment system of make-up water from domestic waste water for the power plant's cooling water. The volume of wastewater was calculated by MIKE Urban 2017 with Ecolab. Recycled water for cooling tower can reduce water replacement of make-up water, but the level of nutrient of water will increase. The important parameters in cooling system are algae, bacteria and other chemicals (chloride, calcium, silica, total hardness). The process of treatment and production for cooling water comprises of coagulation-flocculation, sedimentation, ultrafiltration (UF), and nanofiltration (NF) or reverse osmosis (RO) for chemical control, while chlorine, ozonation and ultrasonic are alternative processes controlling of microorganism in cooling system.

The 78.6 million m^3/year treated municipal wastewater in Kalasin is divided into 47.8 million m^3/year of makeup water process and 30.8 million m^3/year for ecology system preservation. For make-up water system, the proposed treatment processes can save approximately 10.1 to 19.2 percent of cooling tower make-up water by using up to 7 cycles of concentration.

Keywords ; WASTEWATER TREATMENTS, WATER RERECYCLED, COOLING TOWER, SUSTAIN WATER, MAKE-UP WATER

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I. INTRODUCTION

The major problems in Thailand are flood and drought which strongly affect both agriculture and industry every year. The northern region has average rainfall 1,359 mm/year, but the water storage in this area has small capacity and bad soil property (sandstone) in this area (DDPM, 2017). According to Department of Disaster Prevention and Mitigation, around 60 percent of Kalasin area was drought risk in the high level (DDPM, 2017) One of the provinces that confront water shortage is Kalasin. On the other hand, waste water management in the urban area of Kalasin is problematic. In 2017, Kalasin was the top three provinces of water pollution in Thailand (ONPE, 2017). The effect of bad quality of water increase water shortage in Kalasin province, especially during summer.

Not only flood and drought are the major problems in Thailand, the energy becomes important problem in recent year. According to increasing population and economy growth, the estimation of power demand of Thailand increase around 2.67 percent annually from 2014 to 2036. The power demand would be 52,256 MW in 2036, while total power production is only 42,433 MW in 2017. The replacement and added power capacity during 2012 to 2030 will be about 55,130 MW to reserve future demand. Although renewable energy and alternative energy will be used 25 percent instead of fossil fuels for the next 10 years, but combine cycle and thermal power plant are the main power plant as a base load power (EPPO, 2015).

The trend volume of waste water in domestic are is increase as population and economic growth. Water shortage and water pollution can be reduced by water reuse and water reuse (Jhansi et al., 2013). The other way to save water is recycled water for cooling water system. Recycled water increase mineral content which affect to bacteria growth and limit the cycle of concentration (Walter and Duke, 2007).

In this paper focuses on wastewater in Kalasin for make-up water production of cooling tower. Mike Urban with Ecolab is applied to quantify quality and quantity of urban area. The general water treatment process will be considered base on economy, water requirement and environment in Thailand.

2. Water Recycle and Wastewater Treatment

2.1 Study Area

The study area is located near Lam Pow Dam in Kalasin Province. Karasin is far from Bangkok around 519 km. The approximate area of Kalasin is 6,946,746 km2 which is 4.5 percent of the Northeast area (PRD, 2017). According to Department of Disaster Prevention and Mitigation, the northern area is the high level risk of drought during April to July. The monitoring water quality reported that 75 percent of surface rivers in Kalasin were moderest, while other 25 percent was low quality from municipal and agricultural sector (DDPM, 2007). Although Kalasin has wastewater treatment plant in Mueang Kalasin district, wastewater only 650 m3/day is treated (ONPE, 2017).

2.2 Previous Studies

Mike Urban is used as a tool to calculate volume of wastewater and wastewater properties. The model consists of surface run off, water quality and sediment transportation. Hampton Roads Sanitation District found that Mike Urban was able to evaluate water collection and drainage system (stormwater and wastewater) in term of volume and quality of water (DHI, 2013).

In 2007, Walters and Duke report that use recycled water replacing fresh water consumption in cooling tower. However, the mineral concentration which effect on material service life of water cooling system increase around 17-50 percent of the water if water recycle around 2 – 6 cycles of concentration (Walter and Duke, 2007).

The concentration of dissolved minerals cause the limit cycles of concentration. Although water cooling system save fresh water by increasing cycles of concentration, the high level of minerals concentration of water will lead to scaling, corrosion, algae and bacteria (FEMP, 2011). The important chemicals for scaling and corrosion are chloride, calcium, silica, total hardness.

2.3 Domestic Waste Water

The combined drainage system is used in Thailand. The main sources of waste water are agricultural sector and domestic sector. According to Office of Natural Resources and Environmental policy and Planning (ONPE), the average dissolved oxygen (DO) was 8.25 mg/l before treating, while the value of dissolved oxygen after treated was 3.75 mg/l in 2017 (ONPE, 2017). The new sewerage system for the power plant is showed in Figure 1.

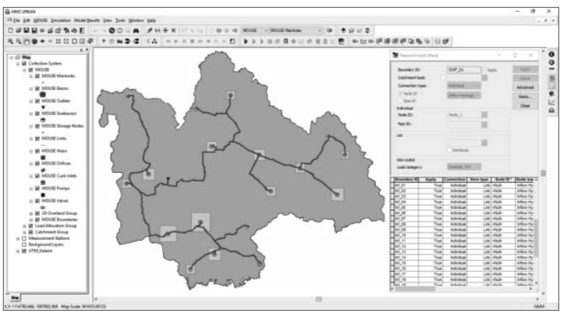

Figure 1. Waste Water System in Kalasin

2.4 Data and Sources

Mike Urban required various sources to calculation of quality and quantity of waste water for collected waste water system. The weather data such as rainfall, temperature and humidity from Thai Meteorological Department (TMD) during 1987 to 2017 is applied in the model. The data of geology and land use are collected from Digital elevation model (DEM) which was version 4.1 and Land Development Department (LDD), respectively. The data of water supply and population in Kalasin used data from Land Development Department (LDD) year 2006 to 2015. For the condition of pipe, HDPE pipe was used in the combined drainage system which mixes stormwater in urban area only.

2.5 Water Treatment Process

The waste water is collected by combined drainage system to wastewater treatment plant in Kalasin. The general system of water treatment that use in Kalasin is activated sludge (AS). The AS was suggested due to its reliability, effectiveness, and easy to control as well as capability to received fluctuated wastewater characteristics. Also, this process can be easily adjusted or combined with advanced treatment processes (PRD, 2017). According to the effective of wastewater treatment process in Kalasin, a biological process was selected in this project. The wastewater treatment plant in this project should consist of aerobic tank, anoxic tank, and aeration tank. The most of effluent after treating will be sent to the cooling tower, while 5 dry-weather-flow (DWF) flows to environment.

2.6 Make-up Water for Cooling Towers

Cooling tower is a device to decrease heat of waste to the atmosphere. Wet cooling tower is wildly use in power plant of Thailand. The Figure 2 showed a function of cooling tower. In the future plan, power plant at Kalasin require water make up around 93,212 m3/day for wet cooling towers of power plant 1,180 MW. The wastewater treatment plant removes water pollution from influent as raw water of make-up water, but the influent need to improve some characteristics for cooling water. The make-up water for cooling water in Thailand doesn't have standard. However, the quality of make-up water for cooling water was set by Japan Refrigeration and Air Conditioning Industry Association (JRA GL02-1994). According to JRA, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Kjeldahl Nitrogen (TKN) and Total Phosphorus (TP) are parameters considering for waste water treatment.

other way to save fresh water, but the high level of mineral content affect the cost of operation and maintenance of cooling tower system (Walters and Duke, 2007). EGAT concentrate on chloride, calcium, silica and total hardness cause these affects to service life of cooling tower for power plant. Alternative method of make-up water treatment will be considered base on suitable cycle of concentration to preventing corrosion, scaling and fouling. The widely process are used to desalinate are microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO) (Alman et, al.). There are 3 types of treatment process to consider in this study which showed in Figure 3.

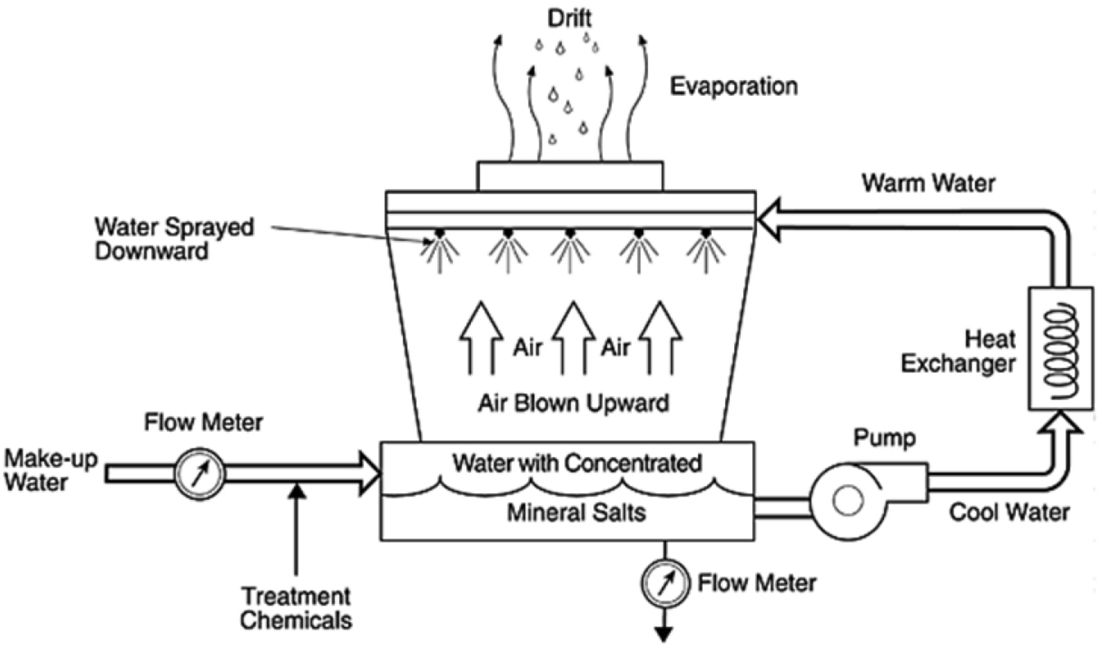

Figure 2. Typical Cooling Tower Operation (Federal Energy Management Program, 1995)

In water cycling process, cooling tower evaporate and blow down water in system, while some water leak and loss by wind. The level of minerals is left behide during recycled water of cooling water process. Using recycled water is

The factors of biofilm are based on algae and bacteria. Microbial control in water cooling system is a good way to improve efficiency of water consumption in cooling tower. In Thailand, adding chemical such as chlorine compounds is

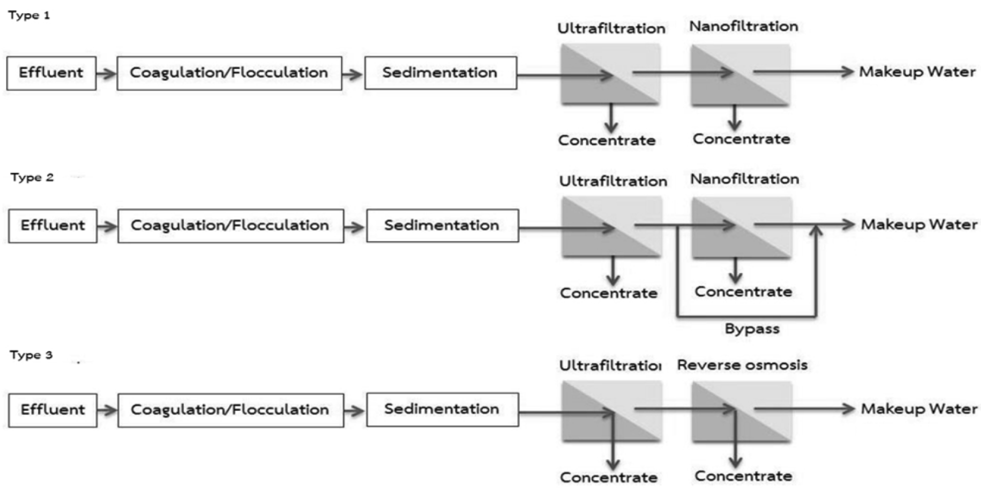

Figure 3. Type of Cooling Water Treatment

generally use for water supply and cooling water system, but it affect to fouling and corrosion. Typically, contaminants and microorganisms in cooling water must be eliminated by chemical process to avoid problems in a cooling system, such as residual chemicals, scaling, and corrosion (WQPN, 2007). Although there are other method such as ozonation and ultrasonic for enhance the efficiency of cooling water usage. From the corrosion test according to ASTM D4778-05, ozonation cause much more corrosion of low carbon steel than chlorination. However, the corrosion of copper was similar in the usage of both ozonation and chlorination (ASTM, 2008). The study in this project aims to focus on adding chemical (chlorine compound) for controlling microorganisms in cooling water instead of chlorination.

3. Results

Volume of wastewater of urban area at Kalasin is estimated base on 80 percent water consumption by domestics sector. According to population, estimation of minimum waste water at Kalasin is 35,853 m^3/day in 2035 and 39,904 m^3/day in 2095. Waste water drainage system was collected around 64.0 million m^3/year to waste water treatment plan. Treated water 47.8 million m^3/year (14.6 million m^3/year for waste water and 33.2 million m^3/year for stormwater) will be used for make-up water.

The make-up water of type 1 consists coagulation-flocculation, sedimentation, ultrafiltration and nanofiltration with two stages NF with 2:1 arrays. This type can recycle water in cooling water system 10 cycles of concentration. In primary stage, ultrafiltration had recovery rate of water 95 percent of initial water, while the second stage returned water to process 60 percent of initial water. The main water loss was nanofiltration process around 40 percent. To increasing water recovery rate 84 percent, nanofiltration was set two stages with 2:1 arrays. Thus, the replacement reduced from 93,000 m^3/day to 82,668 m^3/day. In the other word, The water balance of Type 1 is showed in Figure 4.

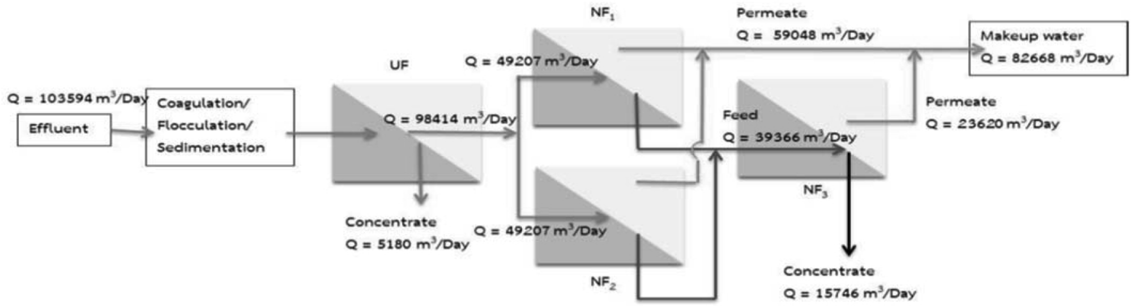

Figure 4. Water Balance of Make-up Water Treatment Type 1

Coagulation-flocculation, sedimentation and ultrafiltration combine with nanofiltration were used in alternative type 2 of make-up water process. Ultrafiltration had recovery water rate same as type 1 (95 percent of initial water) and the second state also returned the same rate as type 1(84 percent of initial water). The fresh water reduced 11.11 percent by recycled water 10 cycles of concentrate. According to Table 1, the ratio between NF and UF that was the most effective cycle of concentration was 0.7:0.3which was 10 cycles of concentration The water balance of Type 1 is showed in Figure 5.

The type 3 was applied coagulation-flocculation, sedimentation, ultrafiltration and reverse osmosis with two stages RO with 2:1 arrays for make-up water treatment. The water balance of Type 3 is showed in Figure 6. This type had the highest cycle of water. The fresh water for replacement decreased from 93,000 m^3/day to 75,153 m^3/day. In the other words, the replacement water safe 19.19 percent in 100 cycles of concentration.

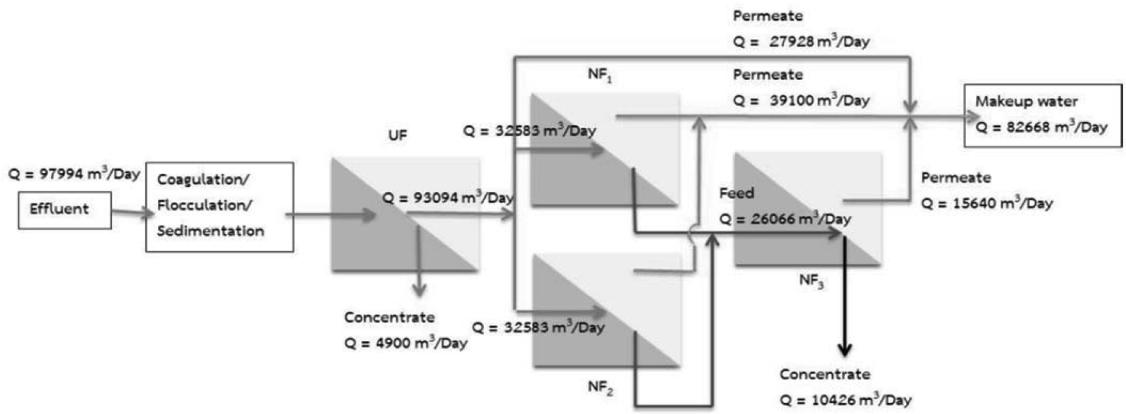

Figure 5. Water Balance of Make-up Water Treatment Type 2

Table 1. Cycle of Concentration of Ultrafiltration Combine with Nanofiltration

Ratio		Cycle of Concentration					Control Parameter	Limited Cycle of Concentration
NF	UF	Total Hardness	Ca	SiO2	Cl	TDS		
1.0	0.0	12.5	12.5	41.7	10.0	16.0	Cl	10
0.9	0.1	11.6	11.8	34.0	10.1	16.0	Cl	10
0.8	0.2	10.9	11.2	28.7	10.2	15.9	Cl	10
0.7	0.3	10.2	10.6	24.9	10.3	15.8	Cl	10
0.6	0.4	9.6	10.1	21.9	10.4	15.7	Total Hardness	9
0.5	0.5	9.1	9.7	19.6	10.5	15.6	Total Hardness	9
0.4	0.6	8.6	9.3	17.7	10.6	15.5	Total Hardness	8
0.3	0.7	8.2	8.9	16.2	10.8	15.4	Total Hardness	8
0.2	0.8	7.8	8.5	14.9	10.9	15.3	Total Hardness	7
0.1	0.9	7.5	8.2	13.8	11.0	15.2	Total Hardness	7
0.0	0.0	7.1	7.9	12.8	11.1	15.1	Total Hardness	7

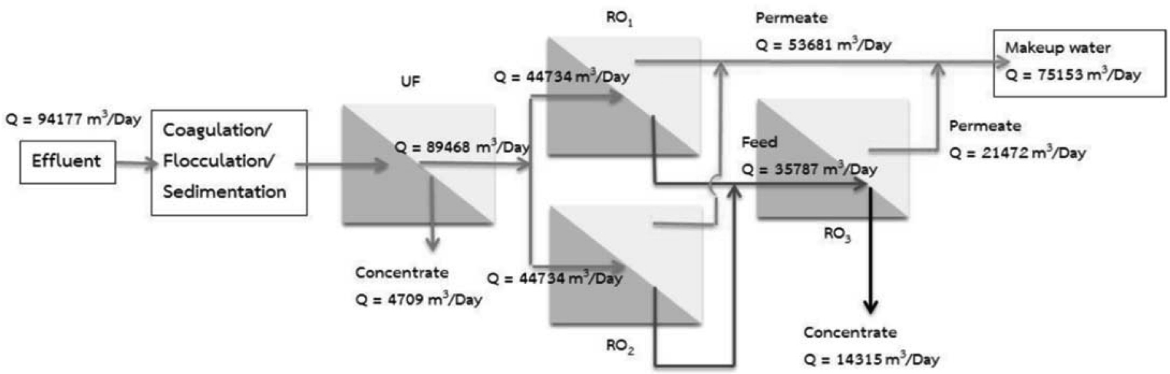

Figure 6. Water Balance of Make-up Water Treatment Type 3

The type 1 had the most volume of blow down 20,926 m3/day, while type 2 and type 3 release water 15,326 and 19,024 m3/day, respectively. According to blow down conflict, TDS is the important indicator that mostly over standard. Most potable water in Thailand can be rang 500 to 1,300 mg/l, while the allowable waste water blow down standard must not exceed 3,000 mg/l. For this study, TDS concentration of type 1, 2 and 3 were 245, 252 and 457, respectively. The Table 2 showed the summary results of alternative types of cooling water treatment process.

Table 2. Summary Results of Alternative Types of Cooling Water Treatment Process

Parameters	Type 1		Type 2		Type 3	
Process	UF	NF	UF	NF	UF	RO
Initial Water	103,594		97,994		94,177	
Water Replacement	82,668		82,668		75,153	
Saving Water Replacement (%)	11.11		11.11		19.19	
Cycle of Concentration (Cycles)	10		10		100	
Concentrate (m^3/day)	5,180	5,746	4,900	10,426	4,709	14,315
Total Concentrate (m3/day)	20,926		15,326		19,024	
TDS (mg/l)	306	224	306	227	306	529
Average TDS	245		252		457	

Adding chemical such as chlorine compounds is generally use for water supply and cooling water system because of low cost of operation and easy use. However, adding chlorine compound for controlling microorganisms in cooling water system increase residual chlorine in system. The experiment analyzed the growth rate of algae in 6 days of water cooling system, and also analysis of the initial and final bacteria content. The Figure 7 showed that chlorine compound inhibited the growth of algae during 6 days. The initial dry weight method was 4.8 mg/l. the dry weight method decreased continually to 3.9 mg/l until 4 days. The concentration of dry weight was constant until day 6 of experiment. In addition, chorine compound was able to reduce amount of bacteria (Spread plate technique) from 500,000 CFU/ml to 500 CFU/ml by contact time 30 minutes and 1 mg/l chlorine residue.

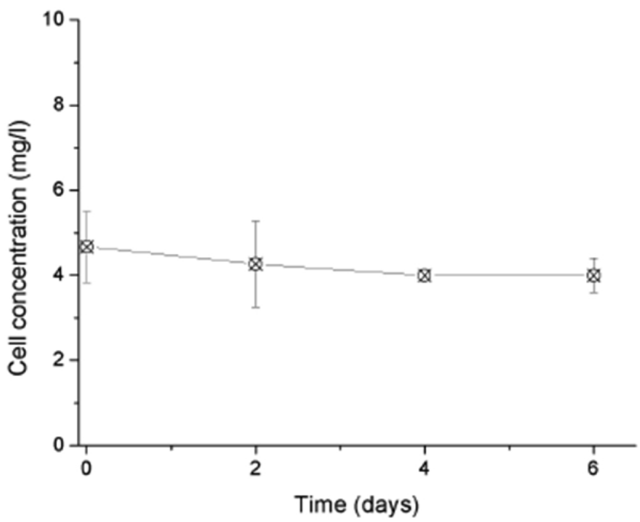

Figure 7. Effects of Chlorine Compounds on Algae in Water Cooling System

For make-up water 93,000 m^3/day, sodium hypochlorite should be added approximately 325 kg/hour (7.8 tons/day). The effect of sodium hypochlorite increased water in water cooling process chloride ion concentration (Cl-) 2.1 mg/l and TDS values increased 3.5 mg/l. The reduction of cycle of concentration after using chlorine compounds in water cooling system showed in Figure 3. Total hardness and silica were the main factors that limited cycle of concentration.

Table 4 showed comparison corrosion rate between adding chlorine compound and ozonation in different materials. This result was the same trend as Seneviratne's research in 2006. The research reported that corrosion of different materials by using ozonation were 0.02057 inch/year for low carbon steel and 0.00025 inch/year for copper (Seneviratne, 2006).

Table 3. Reduction of Cycle of Concentration after Using Chlorine Compounds in Water Cooling System

Parameters	Cycles of Concentration			
	Domestic Water of Kalasin	Type 1	Type 2	Type 3
Chloride ion (mg/l)	3	11 → 9	10 → 9	500 → 80
Total hardness (mg/l as CaCO3)	2	6 → 6	12 → 12	625 → 625
Calcium hardness (mg/l)	5	7 → 7	12 →12	625 → 625
Ionized Silica (mg/l)	2	4 → 4	41→41	100 →100
Total Dissolved Solids (mg/l)	5	15→14	16→16	1300→371

Table 4. Comparison Corrosion Rate between Adding Chlorine Compound and Ozonation in different materials

Parameters	Corrosion Rate (inch/year)	
	Carbon Steel	Copper
Control	0.007	0.000147
Chlorine	0.032	0.000210
Ozonation	0.015	0.000220

4. Conclusion and Discussion

According to estimation of waste water by Arithmetic Progressing, the maximum waste water (14.60 million m^3/year) and stormwater (64.0 million m^3/year) will be collect to waste water treatment plant. The volume of excess water is considered to drain to environment 30.8 million m^3/year (5 DWF) from wastewater system preserving ecosystem. On the other words, there is water recycle for cooling water in scarcity area 47.8 million m^3/year and reducing water pollution to rivers 78.6 million m^3/year. The water cooling process configuration can generate concentrate after treatment accounted as the water loss of approximately 15% of inlet water. In other words, the water volume of 109,670 m^3/day is required to produce the makeup water amount that meets the design of EGAT of 93,212 m^3/day. However, the waste water requirement for cooling water with of using recycle water is 109,670 m^3/day, while the total waste water in system over 110,000 m^3/day only 204 days. Power plant need water storage to manage water of cooling system during October to April (161 days) which has the average of waste water around 58,000 m^3/day. Treated water can be used in cooling tower, but the collected drainage system in urban area of Kalasin shall be improved.

Type 1 and type 2 increase cycle of concentration from 5 to 10 cycles that decrease water replacement from 93,000 m^3/day to 82,668 m^3/day, while type 3 increase cycle of concentration from 5 to 100 which reduce water replacement 17,847 m^3/day. The amounts of water concentration were 20,926, 15,326 and 19,024 m^3/day, respectively. However, the Reverse Osmosis (RO) with Electrochemical Deionization (EDI), which increases the cycle of concentration for RO, shall be studied to quantify the best alternative of make-up water treatment in the future.

Although the adding chemical had residual chlorine in the system, it was few amount of residual to effect on cycle of concentration. Efficiency enhancement of cooling water usage by adding chlorine compounds was not reduced cycle of concentration (Silica and total hardness) from water treated by UF and NF method and UF and RO method. Adding chlorine compounds can be control growth of algae and bacteria in water cooling cycle. Ozonation can be used to reduce the chemical consumption but are still unable to replace chlorination. In addition, the application of ozonation in microorganisms control could result in corrosion of a cooling tower. For the corrosion test base on ASTM D4778-05, chlorination cause much more corrosion of low carbon steel. For the future study, other method such as ozonation and ultraviolet shall be study to reducing cost and corrosion rate to replace using chemical.

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