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Effectiveness Analysis of Ozonation for Prevention of Corrosion and Precipitation of Crust in Closed System Cooling Towers

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Abstract: A cooling tower is a unit that is used for the disposal process in a cooling system. Thermal. Effectiveness is a very important variable to determine the performance of the cooling tower. The emergence of corrosion, moss, and crustal precipitation can inhibit heat transfer so that it can disrupt the level of thermal effectiveness of the cooling tower. Not only does it reduce thermal effectiveness, but it can also damage the cooling tower. This study aims to determine the effect of ozonation on these inhibiting factors. This ozonation process is expected to reduce the growth of these factors. The method used is with cooling water from the basin circulated with a new system. In the new system water from the basin will be injected with, then the water will return to the basin. Furthermore, water samples will be tested in the laboratory using the AAS, Titrimetric, Gravimetric, Spectrophotometric method to determine water quality. Data obtained from the laboratory are PH, SO4, Electrical Conductivity, Fe, TDS, Ca, Alkalinity, Na, Cl. The data is then entered into the calculation using the Practical Ozone Scaling Index and Langlier Saturation Index method to determine circulating water quality. The results obtained from this study show that the application of ozone can improve water quality because DS and EC in the cycle water used decrease. The amount of safe water cycle concentration is also increased from 2 cycles to 4 cycles.

Keywords: Cooling Towers Closed Systems, Ozone, Corrosion, Precipitation

1. Introduction and background

Cooling Tower is a unit that functions to cooling hot water from the condenser by direct contact with water or air use a big fan[1)]. The coolant works by releasing heat generated from the condensation process of a system and in general water is used as a coolant, it is a heat exchanger fluid to remove heat from various systems[2-3)]. In principle, hot fluid in a system is channeled to the cooling tower and recirculated after dissipating heat into the atmosphere[4)]. Cooling towers are divided into several types based on the cooling system and based on the contact between the hot fluids with cooling air. Based on the cooling system there is a Natural Draft and Mechanical Draft, while based on the type of contact there is directly and indirectly. Several characteristics of cooling tower performances have been reported[5-18)].

Water in the circulation of a cooling tower system plays a very important role as a heat exchanger from the condenser. The quality of water used can affect performance of the cooling tower. This is because in cooling water circulation, the concentration of mineral ions in water continues to increase due to evaporation. If water exposed to high temperatures will cause ionic precipitation calcium and bicarbonate. If it continues to experience precipitation, it will form a hard layer called crust on the tower's heat transfer surface the cooler. A lot of crust will form a layer called fouling. In other side, because of exposure to the surrounding air, the performance of the cooling tower was disrupted by various potential biofouling problems because of microorganisms from surrounding environment[19)]. In addition to crust, due to poor water quality can also cause corrosion.

Corrosion is formed by the interaction of chemical or electrochemical materials with the environment. This is due to the emergence of compounds that can affect chemical processes resulting in an increased corrosion rate process. The emergence of compounds and bacteria will also help the growth of moss. Biofouling from cooling tower water resulted some problems such as reducing efficiency, limiting the capacity of water flow, and helps increase corrosion rates[20)]. Research on water treatment to get good water quality at cooling tower has done a lot. The use of chlorine, iodine, and bromine still having problems with the method. Moreover, the using of chemical, even at trace concentrations, can cause severe risks to living organisms in the aquatic life and the water resources. Finally, it can be dangerous to the entire ecosystem. Therefore, it is important to find a more suitable and efficient wastewater treatment technologies[21].

Other technologies that can be used besides chlorine, iodine, and bromine is to use ozone. Ozone is a strong dioxide widely used in Europe for cooling tower treatment and has been proven effective in controlling bacteria[22]. As a strong biocide, ozone can also be eliminating levels of microorganisms to reduce the concentration of solids organic and minerals in the system. Crust deposits are mineral solids precipitated which is often a serious problem in the industrial world and generally often found in oil and gas industry equipment, desalination process, boiler and chemical industry (Badr and Yassin, 2007; Lestari, 2004)[23-25]. Disruption of fowled and scale formation on the pipe surface will cause a decrease efficiency of heat exchange in the cooling tower system. (Asnawati, 2001)[26].

The use of ozone as a water treatment in this study is expected can be known the effect of ozone on corrosion, bacteria and corals in cooling towers thus increasing the efficiency of the cooling tower performance. Reduce the potential for scaling precipitation which will subsequently improve the thermal performance of the cooling tower. In order to achieve this expectation, the characteristics of the effects of ozonation on the overall thermal fouling resistance of forced draft type - counterflow - closed system cooling towers and the quality of water circulation through the Practical Ozone Scaling Index and Langelier Saturation Index methods must be known first[7].

2. Method and experimental setup

First, created auxiliary channels which has a function as a place for injecting ozone into the water flow in the cooling tower.

The supporting components are then installed in the water channel of the closed system. These components include bypasses, valves, flow meters, a mazei injector, UV rays and ozone generators.

After installation, the water flow from the cooling tower basin to the auxiliary water channels in the closed-circuit cooling tower system must be checked to ensure that there are no leaks and blockages in the pipes.

Before the operation starts, all the equipment used must be checked first. Equipment that uses electrical energy such as ozone generators, UV light, and water pumps must be checked in the off-switch position before connecting to the power supply. After checking, turn on the water pump to start circulation through the auxiliary water channel.

The ozone generator and UV light are then turned on. The ozone generator is set up by time, so that it will automatically turn off after 2 hours. After 2 hours of operation the ozone generator needs a 1-hour break before beginning another 2 hours cycle. This is done continuously for 8 hours.

Once all the necessary tools are working either the solubility of the ozone in the flow or the amount of flow in the water channel may take a little time to stabilize.

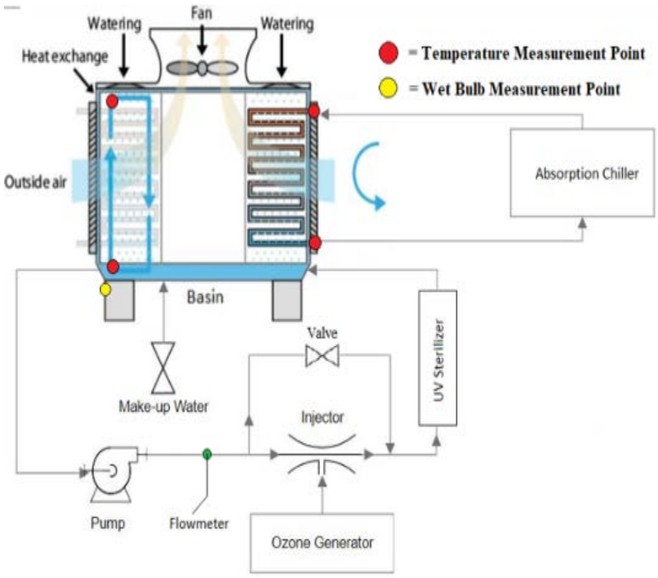

Fig. 1: Schematic Experimental Setup.

Data collection was carried out in 2 phases, the first was before being injected with ozone and the second was after being inject with ozone. This division aims to see the differences that occur in the closed system cooling tower before ozone injection and after ozone injection.

3. Results and Discussion

3.1. LSI Method

The Langelier Saturation Index (LSI), is a parameter measure of the ability of a solution to dissolve or precipitate calcium carbonate, often used as a water corrosion indicator[27-28]. To calculate the Langlier Saturation Index (LSI), several are used parameters include TDS (Total Dissolve Solid), temperature, Ca Hardness, and total alkalinity in a closed cooling tower basin water system at DTM FTUI. Parameter- these parameters are obtained using a measuring instrument and with a water quality test in the laboratory. Comparison of Langlier Saturation Index (LSI) values before and after the process ozonation can be seen in **Fig. 2**.

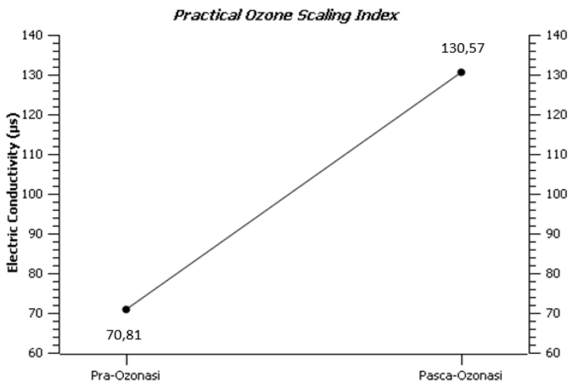

Fig. 2: Comparison of LSI values

Can be seen in **Fig. 2**, that the value of the Langlier Saturation Index (LSI) on pre-ozonation water is -0.98 and in post-ozonation water is -1.11. If seen in saturation index evaluation table, the LSI values of the two samples are included in the indication that water is slightly corrosive but does not cause crust. However, with the amount of the LSI value, water is considered aggressive. This is based on Table 1.

Table 1. Saturation index evaluation

Evaluation Saturation Index	Indication
2.0	Scale formation but not corrosive
0.5	There is little scale formation but is not corrosive
0.02	The conditions are balanced but there is very little chance of being corrosive
-0.5	Slightly corrosive but no scale formation
-2.0	Corrosive

3.2. POSI Method

Pryor and Fisher (1993)[27] have proven that conventional indices (for example, LSI) are used to forecast calcium carbonate precipitation in the waters of conventionally treated cooling towers, rather than as precise indicators of potential scale in the ozonized system. The use of conventional indices cannot accurately predict how many cycles can be operated before scale concentration begins to build up in the ozonated cooling system[7]. Using a practical approach, Practical Ozone Scaling Index (POSI), the POSI equation predicts the upper limit of conductivity operations in other ozonated systems[28].

Practical Ozone Scaling Index (POSI) value is an index determine the maximum value of electrical conductivity in water so that water can circulate safely. With the POSI value obtained, it can determine the value concentration cycle or commonly called the Cycle of Concentration (CoC) in the tower the cooler. To calculate the POSI value, several parameters are needed electrical conductivity, pH, Ca Hardness, Mg Hardness, Na, Cl, temperature, and total alkalinity.

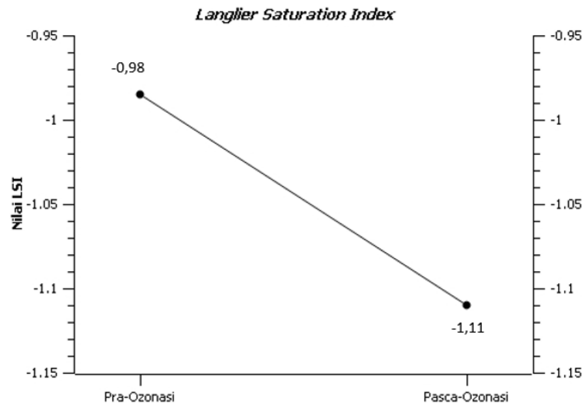

Fig.3: Comparison of POSI values

Can be seen a comparison of the value of POSI obtained in **Fig. 3** contained increase in POSI value during pre-ozonation and post ozonation. During pre-ozonation, obtained a POSI value of 70.81. Whereas the value of POSI post ozonation is at 130.57.

With the POSI value obtained, then used to Cycles of Concentration calculation. At the time of pre-ozonation, the Cycles of value is obtained Concentration of 1.73. Whereas after ozonation, the value of Cycles of Concentration of 3.8. Can be seen in Graph 4.3. This indicates the value the maximum concentration cycle of the cooling tower circulation water rises to two times fold after ozonation process., can be seen in **Fig. 4**.

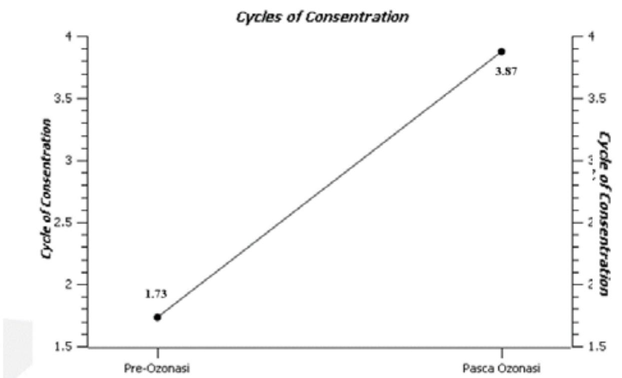

Fig.4: Estimated Cycles of Concentration based on POSI.

It can be concluded that the ozonation process in the cooling tower can be increase the number of cycles of water concentration that can be used safely, without rustic preparation due to excessive ionic concentration.

3.3. Analysis of Electrical Conductivity Value (Electric Conductivity)

The value of electrical conductivity is the value of water quality that illustrates how well the water can conduct electricity. Water that can conduct electricity means it has a metal solid contained therein, so that it can cause deposits that will reduce the performance of the cooling tower. Therefore, we want to reduce the value of electrical conductivity in water.

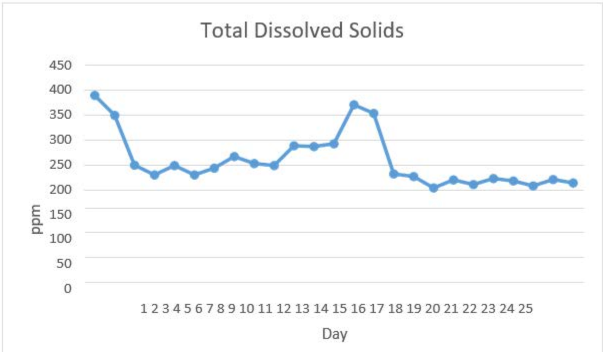

Fig. 5: Value of electrical conductivity per day.

Based on the chart above, it can be seen that the value of the electrical conductivity increases at the time before the injected ozone in which it indicates the increase in the number of ions of metal that is dissolved which have the characteristics of natural as a conductor of electricity. While the electrical conductivity has decreased after ozone injection (starting from day to14) and experience a stagnation or a value that tends to remain on day 18 with a slight fluctuation until the 25th day. It can be concluded that ozone injection for 15 days can reduce the value of the electrical conductivity of water from the cooling tower.

3.4. Analysis of the pH value of water

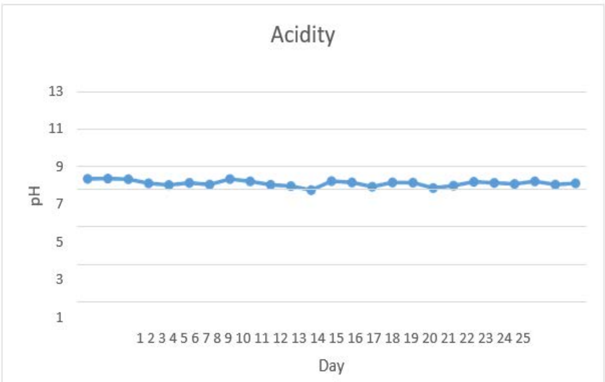

Fig. 6: Graph of pH values per day.

Based on the graph above, the data obtained on the acidity value of water quality from the cooling tower experiences fluctuating values in the pH 8 range both before and after ozone injection. This illustrates that the acidity of the water at the time of the study less in accordance with what we expect that a pH value of 8. This value is desirable in research this is the value of pH 7 for ozone will work with optimum at pH 7 as shown on the basic theory.

3.5. TDS (Total Dissolved Solids) Analysis

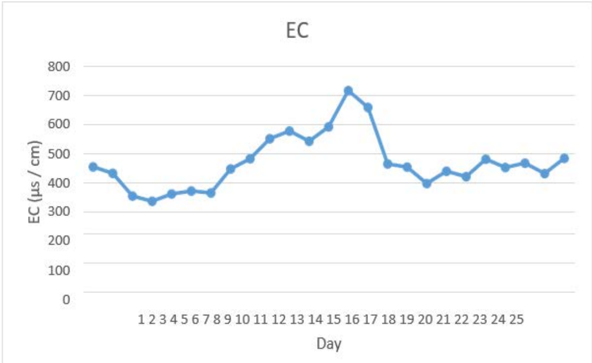

Fig. 7: Graph of TDS values per day.

Based on the graph above, the value of TDS before the ozone injection (the first day to the 14th) experiences an upward trend. Once injected ozone in the day to 14, the value of TDS decreased until day 18 and stagnated until day 25. This illustrates that the injection of ozone can reduce the number of dissolved solids in the cooling tower water due to the trend of the graph above that tend to go down.

4. Conclusions

Based on the graph data obtained in this study, it can be concluded as follows:

1. The Langlier Saturation Index (LSI) method shows that there is improvement of circulating water quality in the cooling tower after the ozonation process is carried out. Potential for crust preparation in water cooling tower circulation decreases but injection of ozone levels Excessive water can cause corrosive circulation.
2. The Practical Ozone Scaling Index (POSI) method shows that with do the ozonation process on the cooling tower water circulation can increase the number of concentration cycles without crust preparation which results from excessive concentration of water.
3. The water quality test shows the relative value of TDS and EC decreases after ozonation process is carried out. This can identify the reduction potential for scale formation by cooling tower water circulation.
4. Water quality testing shows a relatively stable pH value. This shows that ozone is less effective in dealing with pH problems.

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Nomenclature

COP	coefficient of performance (–)
c_p	specific heat capacity (J kg^{-1} K^{-1})
P	power (W)
$\dot{E}$	exergy rate (W)
h	specific enthalpy (J kg^{-1})
s_0	specific enthalpy of the dead state (J kg^{-1} K^{-1})

Greek symbols

δ	exergy defect (–)
η	efficiency (–)

Subscripts

2^{nd}	Second Law
Carnot	Carnot
Dis	discharge
e	Exit

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