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Study of the environmental impacts resulting from using sea water in cooling tower of a nuclear power plant

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Abstract

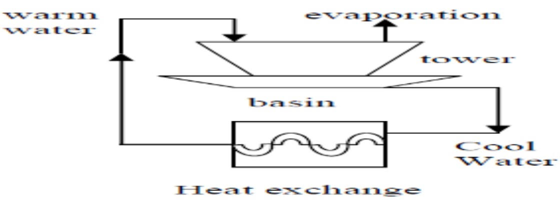
Each cooling system has advantages and disadvantages that need to be balanced before selecting a system. Replacing the once-through system by a cooling tower circuit tremendously reduces both initial investment costs and sea environmental impact of the power plant. A cooling tower is a low cost method of evaporating water and reducing its temperature. When water evaporates, as it does in a cooling system, the dissolved solids are left behind increasing the concentration in the remaining water. Concentrated solids can build up in the form of scale and cause blockages or corrosion to the cooling system materials. Also the growth of algae and other biological matter in cooling tower can lead to corrosion problems. We study the simulating proposal of using mechanical draught cooling tower with 40 meter height in Sidi Abdelrahman region, physicochemical and biological analysis for different parameters such as (temperature, turbidity, pH, total suspended solids, , Total dissolved solids, pH , Total alkalinity, Total hardness, , chlorides, sulfates, total algal count, etc..) had been done during 6 months . The 6 months period were suggested to examine some seasonal variations of the selected region focusing on the effect of different physicochemical parameters which being measured at these suggested cooling tower at the selected region. Statistical analysis had been done to different results. The physicochemical results showed that most of physicochemical parameters are complying with the preferred cooling tower conditions for salt water. Also that there were high significant positive correlation coefficient between silica and Ca^{++} concentrations, which leads to the formation of calcium silicates hard scales inside the suggested cooling *waters cooling tower. The physicochemical results also showed that there were significant positive correlation coefficient between total algal count and alkalinity concentrations, that leads to increasing the probability of scales with bio-fouling formation in the suggested cooling tower at Sidi Abdelrahman area. The simulated study recommended the using of anti-scale formation to control scaling formation if cooling tower material from steel with using 20 mg/l as* PO_4 *as recommended dose. In case of using recycled water in a cooling tower, the system must be designed so that the cooling system recirculating water is treated with chlorine or another biocide to minimize the growth of micro-organisms such as algae.*

Keywords: Sea water, Nuclear power, Cooling tower, Scales formation, Fouling, Corrosion

INTRODUCTION

The design of a cooling system is site and process specific. Key factors that influence the design include: Cooling requirements of the process, in relation to process efficiency; Availability and temperature of water that can be used for cooling; environmental considerations; Economics; Regulatory or permitting constraints; Geography of the site [(1)]. When selecting a wet cooling tower, there are many factors to consider. The weighting for the selection criteria for a cooling tower application are always depend on the local conditions and preferences of the end user. The considered factors at selecting appropriate wet cooling tower might include: a) Technical factors: cooling tower performance over a range of ambient conditions, flexibility of operation and maintenance of desired water temperatures, space requirement including provision for air inlets and shape; b)Economic factors: capital cost, operating costs, lifetime cost and reliability; c) Environmental factors: noise, plume generation, visual impact. At cooling tower applications there are some terms frequently used and therefore some explanation is needed. Wet bulb air temperature is the minimum temperature which may be achieved by purely evaporative cooling of a water-wetted, ventilated surface. Dry bulb air temperature is the temperature of air measured by a thermometer freely exposed to the air but shielded from radiation and moisture; Range indicates the difference between the hot and cold circulating water temperatures, while approach indicates the difference between the wet bulb and cold water temperatures. Heat load is the amount of the heat that the cooling tower is required to dissipate [2].Cooling towers fall into two main categories: Natural draft and Mechanical draft. Natural draft towers use very large concrete chimneys to introduce air through the media. Due to the large size of these towers, they are generally used for water flow rates above 45,000m3/hr. These types of towers are used only by utility power stations. Mechanical draft towers utilize large fans to force or suck air through circulated water. The water falls downward over fill surfaces, which help increase the contact time between the water and the air - this helps maximize heat transfer between the two. Cooling rates of Mechanical draft towers depend upon their fan diameter and speed of operation. Since, the mechanical draft cooling towers are much more widely used. Natural Draught hyperbolic cooling towers are the characterizing land marks of power station. They contribute both to an efficient energy output & to a careful balance with our environment. These structures are most efficient measures for cooling thermal power plants by minimizing the need of water & avoiding thermal pollution of water bodies hyperbolic cooling towers are colossal, thin shell reinforced solid structures which contribute to vitality era execution, unwavering quality and tonatural wellbeing. Hyperbolic supported solid cooling towers are effectively utilized for cooling gigantic amounts of water in warm power stations, [3]**.** What differentiates seawater cooling towers from fresh water towers is the existence of dissolved minerals (salts) in the cooling water [4]. Therefore, establishing the impact of salts in the cooling water is the single most important technical feasibility concern. The areas of concern were identified as thermal performance, salts concentration, salts emission (Drift) and environmental impacts. Salt in the water has four basic effects on its use as a coolant, only one of which is major. Salt lowers the vapor pressure of water, thus the water does not evaporate as readily. This makes it less as effective coolant and reduces tower performance[4]**.** Increasing the design wet bulb temperature by 0.055^{o}C per 4,000 ppm TDS was a satisfactory compensation for the salt effect on cooling tower performance. Cooling tower vendors recommend degrading the tower performance by approximately 1.1% for every 10,000 ppm of salts in the cooling water. In practice, most engineering contractors specify a 0.55-1.1^{o}C margin on the wet bulb temperature to account for salts in the cooling water[(2)]. Salts also increase density and surface tension, while decreasing specific heat capacity. The increase in density has small positive effects on performance, while lower heat capacity and the higher surface tension have a negative effect. The net impact is a small negative effect. Therefore, the heat capacity decreases more than the density increases. Since heat transfer is proportional to the product of density and specific heat capacity, the net effect is slightly less heat absorbing capacity of seawater as compared with fresh water. However, this effect is minor as compared with the vapor pressure effect. It follows that the net impact of salts in the cooling water is that it reduces the effective “Approach” (defined as the difference between wet bulb temperature and cold water temperature). For design purposes, a maximum value of 1.1^{o}C reduction in Approach would be used. This impact the tower size required to achieve the same cold water temperature. Consequently, the tower size could be up to 20% higher i.e. the worst practical impact of salts in the cooling water is to require 20% more tower size (20% more cells). In practice, the actual impact depends on the TDS in the seawater source and the concentration cycle (factor by which that water is permitted to concentrate) [(4)]. The presence of dissolved salts and organic material in cooling tower will tend to decrease the rate of droplet evaporation. A standard condenser will have many hundreds of tubes and the heat transfer efficiency is vital to the overall performance of the power plant. It is usual practice today to have screen openings one-third of the condenser tube internal diameter that is 6-8 mm. In almost all of the screens in current UK power stations, nuclear or conventional, the mesh installed on the band screen or the drum screen is between 5 and 10 mm.[(3)]. Public concern over cooling towers mainly stems from the visual impact of these large structures, In order of visual impact, natural draught cooling towers are the most offensive, typically being 100 m tall or higher and invariably with a visible plume, followed by mechanical draught and hybrid mechanical draught and dry cooling towers (all around 40 m in height)[(2)].

Fig (1) open recirculating loop [3]



Salts in the cooling water provide the potential for scaling i.e. deposition of salts in the cooling system. The potential for scaling increases with salts concentration and is affected by the composition of the salts and the water chemistry. Water treatment can reduce the impact of the solids and biological matter, however, after a certain point impurities become too concentrated and solids and biological matter must be removed from the system to avoid serious damage [3].

MATERIAL AND METHODS

We study the simulating proposal of using mechanical draught cooling tower with 40 meter height to be a cooling water system in nuclear power plant, in a suggested selected region as Sidi Abdelrahman, physicochemical and biological analysis for different parameters such as (temperature, turbidity, total suspended solids, , Total Dissolved solids, pH , Total alkalinity, Total hardness, Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Cl^{-} ,SO^{4--}, total algal count) had been done during six months , due to stander methods for water and wastewater examination[5] , showing the different impacts which may be resulted from using sea water in the proposed selected cooling tower . The 6 months period used to examine some seasonal variations of the selected region focusing on the effect of temperature inlet and outlet on different physicochemical parameters which being measured at the selected region. Statistical analysis had been done to different results. The permissible concentration of salts in the cooling water is determined from the results of the water chemical and physical analysis.

RESULTS AND DISCUSSION

Table (1) mean average value of physicochemical and biological parameters measured at Sidi Abdelrahman region during the period from 21/6/2016-11/11/2016

Parameter	Mean average value
Temperature	25^{0}C
Turbidity	2 NTU
Total suspended solids	25 mg/l
Total dissolved solids	37,000 mg/l
*pH	8.3
Total alkalinity	140 mg/l as CaCO3
Total hardness	6650 mg/l as as CaCO3
Ca++_	470 mg/l
Mg++_	1450 mg/l
Na+_	11000 mg/l
K+_	450 mg/l
Cl $^-$	21000 mg/l
SO_4^{--}	3000 mg/l
Silica	158 mg/l
Ammonia	3.0 mg/l
Residual chlorine	2.0 free residual mg/l
Total algal count	12378 0 cell/L

***pH is not a mean average value**

Figure (2) Correlation between Silica and Ca^{++} concentrations measured at Sidi Abdelrahaman region during the period 21/6/2016-11/11/2016

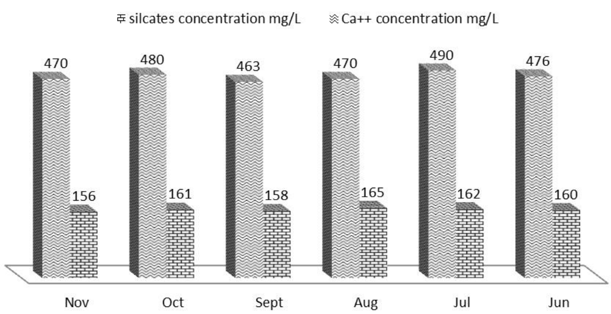


Table (1) Showed that the average mean value of water intake temperature, turbidity at Sidi Abdlerahman site were 25^{0}C and 2 NTU respectively that complying with the preferred cooling tower conditions for salt water [(6)]. In case of total suspended solids TSS, consist of un-dissolved material such as silt, sand, fine clay, and vegetation, can enter the system with makeup water and can be generated in the system from corrosion and scale byproducts or from air/water contact. Suspended solids can adhere to biofilms and cause under-deposit corrosion. TSS can be controlled through pretreatment, side stream filtration or through use of deposit control agents. Table (1) showed that the mean average value of TSS which was 25 mg/l complying with the preferred cooling tower conditions for salt water [(6)]. On the Other hand Alkalinity was an important means of predicting calcium carbonate scale potential, table (1) showed that the mean average value of alkalinity which was 140 mg/l complying with the preferred cooling tower conditions for salt water. Hardness was also contribute to scale formation, table (1) showed that the mean average value of hardness which was 6650 mg/l complying with the preferred cooling tower conditions for salt water [(6)]. Table (1) also showed that silica mean average concentration was 158 mg/l, it was reported that a pretreatment or side stream filtration is often required if the silica levels are above 150 ppm (as SiO2) in cooling tower system, as producing hard scale deposits[(6)]. Figure (2) also showed that there are high significant positive correlation coefficient (0.366) at $p<0.001$ between silica and Ca^{++} concentrations, which leads to the formation of calcium silicates hard scales inside the suggested cooling water. Chlorides were also corrosive to most metals. Limit concentrations to 300 ppm for stainless steel: up to 1,000 ppm for other metals Table (1) also showed that chlorides mean average concentration was 21000 mg/l which lead to corrosion impact to the cooling tower selected material. Ammonia Promotes biofilm development in the heat exchangers and cooling tower fill, which is being corrosive to copper alloys at concentrations as low as 2.0 ppm. Table (1) showed that mean average value of ammonia in selected site was 3.0 mg/l which may cause corrosion effect on cooling tower material.

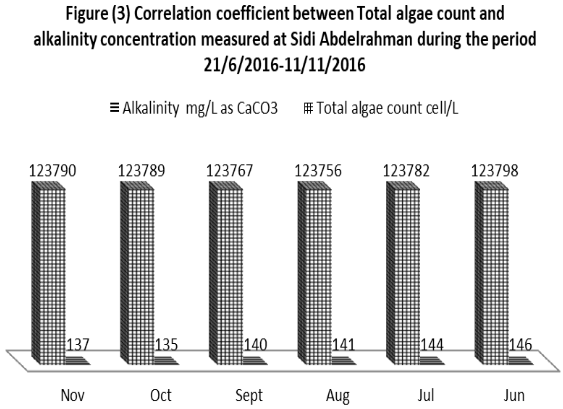


Table (1) also showed that the mean average value of total algal count was 12378 0 cell/L which may lead to fouling formation in the cooling tower. Figure (3) also showed that that there are a significant positive correlation coefficient (0.048) at $p<0.001$ between total algal count in cell /L and alkalinity concentration in mg/L as $CaCO_3$, this correlation leads to increasing the probability of scales- fouling formation in cooling tower. Related to previous measured results in table (1) the using conditioning chemicals will be necessary, that the using of orthophosphates to control scaling formation if cooling tower material from steel with 20 mg/l as PO4 as recommended dose [(7)]. When recycled water is used in a cooling tower, the system must be designed so that the cooling system recirculating water is treated with chlorine or another biocide to minimize the growth of micro-organisms [(7)]. In order to limit the noise level, actions can be taken at three level:1) at the source with low noise fans and mechanical devices 2) at the emission area with louvers, baffles, 3)motor enclosures, special casing type, 4) between the noise source and the reception point with screens, walls or embankments[(7)].

CONCLUSION

- The physicochemical results showed that most of physicochemical parameters are complying with the preferred cooling tower conditions for salt water.
- The physicochemical results showed that silica mean average concentration value was 158 mg/l, it was reported that a pretreatment or side stream filtration is often required if the silica

levels are above 150 ppm (as SiO2) in cooling tower system. Also that there were high significant positive correlation coefficient (0.366) at $p<0.001$ between silica and Ca^{++} concentrations, which leads to the formation of calcium silicates hard scales inside the suggested cooling waters cooling tower.

- The physicochemical and biological results showed that the mean average value of total algal count is 123780 cell/L which may lead to fouling formation in the cooling tower also the results showed that there were a significant positive correlation coefficient (0.048) at $p<0.001$ between total algal count and alkalinity concentration, this correlation leads to increasing the probability of scales-fouling formation in the suggested cooling tower at Sidi Abdelrahman area.
- The physicochemical and biological results supported that, the using of orthophosphates to control scaling formation if cooling tower material from steel with using 20 mg/l as PO_4 as recommended dose . In case of using recycled water in a cooling tower, the system must be designed so that the cooling system recirculating water is treated with chlorine or another biocide to minimize the growth of micro-organisms such as algae.
- In order to limit the noise level, actions can be taken as follow :1) at the source with low noise fans and mechanical devices 2) at the emission area with louvers, baffles, 3) motor enclosures, special casing type, 4) between the noise source and the reception point with screens, walls or embankments.

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