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Environmental Impact Assessment of Algae on Nuclear Power Plant Cooling System

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Abstract

The quality of the cooling water intake and the amount of algae in that water affects the operation and performance of the condenser and therefore the thermal performance of the typical steam plant and nuclear power plant. In this study a model to determine the suitable time to kill algal bio-fouling when using different chlorine doses at different temperature had been used. The samples were collected at depth 1-10 m throughout each site. Different parameters (pH, salinity, DO and total Phytoplankton count) had been measured. The results of the study had showed that using 0.3 ppm chlorine dose which considered as suitable dose to kill algae, at different temperatures of the different selected suggested intake cooling sites. The study also showed that Al- Alamin region has high probability of algae fouling formation than other selected sites. While the AlamAlroom site has the lowest probability of algae fouling formation than other selected sites. Results also showed that AlamAlroom site has taken the lowest time to kill algae fouling than the other selected sites.

Key words: Algae, Bio-fouling, chlorine dose, cooling water

INTRODUCTION

Fouling of cooling water systems by aquatic organisms is a problem of considerable economic significance to many power plants. The number of studies on bio-fouling of coastal electrical power plants is few and most of these studies relate to problems encountered in temperate

waters. Moreover, detailed studies on the community structure of bio-fouling assemblages and other ecological parameters such as growth rate and settlement are lacking [(1)]. Fouling of cooling water systems by aquatic organisms is a problem of considerable economic significance to many power plants. Bio-fouling-induced problems in power plants roughly fall under four categories: (1) blockage of free flow of water in the cooling conduits and consequent mechanical damage to pumps; (2) clogging of condenser tubes; (3) reduction in heat transfer efficiency across heat exchanger surfaces and (4) acceleration of corrosion. The fouling also has potential to affect raw water systems including backup cooling loops provided for safety-related cooling systems in nuclear power plants. Several incidents of plant shutdown due to fouling have been reported from various parts of the world Plant. Fouling usually occurs where there is available sunlight, i.e. around the water line and a few meters below. Slime fouling on submerged surfaces is attributable to the accumulation of unicellular algae (diatoms), difficult to control, slime has a very low surface profile. The most common means to control fouling is through the use of antifouling[(2)]. Environmental parameters such as fluid velocity, temperature, pH value, nutrient levels, salinity, cell count, help in demonstrating the degree of fouling algae problems in sea water cooling power plants .From the analyzed data, a visible change in phytoplankton community with regard to numerical abundance and species composition was evident among beaches and in the seasonal cycle. Salinity, dissolved oxygen, temperature and pH may be responsible for the variations in phytoplankton and zooplankton community structure and hence control the plant bio-fouling formation[(3)]. Seawater intake, concentrate the drifting and floating plankton near to the site of pumping and creates situations of great bio-fouling potential. The cost of fouling has been found to be enormous and despite worldwide efforts on bio-fouling control, the solution remains still elusive. Condenser tubes were seen to be choked with marine shells. Bacteria and diatoms were two of the most significant groups entering the plant structures through the feed seawater [(4)]. The coastal zone of Egypt, including several beaches, has been exposed to various environmental problems. Estimates of water quality based on physicochemical properties give us a clear picture to the suitable source of cooling water which can be used [(5)]. There are many methods to identify directly or indirectly the level of microbial

fouling in cooling water systems the simplest (and the most used) method are based on the measurement of the total number of microorganisms (algae) in cooling water[6]. This study was carried out to determine the algae impact as bio-fouling factor at some selected sites at Alexandria costal line and to study their impacts on suggested intake water system of a nuclear power plant

MATERIAL AND METHODS

The proposal of the suggested nuclear power station at study uses 44 m^3 s^{-1} of seawater for cooling. It was assumed that the thermal discharge of a proposed pressurized water reactor nuclear power plant is modified by the addition of antifouling biocides of residual chlorine measured in the outlet region to maintain the efficiency of flow and heat transfer across the condensers. So that samples were collected at different sites by, as shown in the map (Sidi kerir, Al-alamine, and Alam Alrom). The samples were collected at depth 1-10 m throughout each site. Mortality of microorganisms is related to different parameters as:- dose, exposure, time, temperature, pH, biomass and sensitivity of organisms . For common fouling organisms of temperature water, using an empirical equation of toxic response would be used in that study. In this study the model will be used at different temperatures to determine the suitable time to kill algae biofouling at suggested TRO 0.2 to 0.5 mg/l[6,7,8]. For fouling algae the empirical model: log D = a-b (T^0C) - c log TRO was used, where : D time to kill in days, is related to a constant (a= 2.99), b: the water temperature (0.006*T^0C) and C constant and total residual oxidant TRO (chlorine) (0.80 Log TRO), so the empirical model will be :

$$Log\ D= 2.99- (0.006*T^0C) - (0.80\ Log\ TRO)^{(9)}$$

Hence at log (TRO<1mg/l) temperature exerts a greater influences and at low temperature < 20 ^0C) the time for complete mortality is very long so the effective practice at once through costal power stations is to chlorinate at a rate of 0.2 to 0.5 mg/l at condenser inlets rather than to kill the microorganisms when ambient temperature is ≥ 10 ^0C[8]. On the other hand, some chlorination experiments showed that a chlorine concentration of 0.2 ppm greatly suppressed phytoplankton productivity, regardless of whether the water temperature was elevated or not. However, algae productivity was

little influenced by a chlorine concentration of 0.5 ppm[9]. Adverse effects have been most apparent with phytoplankton, perhaps due to the ease of measuring productivity Reports of Zooplankton biocide entrainment damage include 50% kill in the presence of 0.25- 0.75 ppt chlorine residue. This has led to the development of specific antifouling measures for power plants.

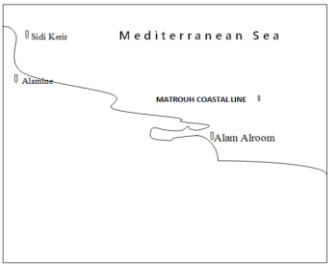

Figure (1): Map showing sampling sites of north costal line

RESULTS AND DISCUSSION

Table (1): The average physicochemical parameters had been measured during summer 2016 and for six months at the selected sites

Selected Site	DO	Salinity	Water temperature	pH	Total plankton count cell/l
Sidi kerir	7.09	38.56	29	8.21	12812
El -Alamin	7.68	38.35	28	8.24	14560
Alam Alrom	8.37	38.58	27	8.49	11457

Phytoplankton community along Alexandria coast comprised 207 species, dominated by diatoms(105 species) and dinoflagellates (53 species), Numerous fresh water assemblages were found including cyanophyceae (10 species) chlorophyceae (29 species) and Euglenophyceae (9 species)[2]. A total of 207 phytoplankton species were quantified through the analysis of the samples collected by oceanographic and fishers department from three beaches (Sidi kerir, Alamin, Alam Alrom) during summer 2015[6] . The most diverse genus was *Nitzschia* (9 species).

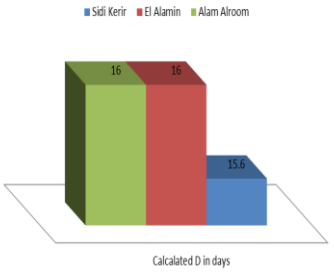

Figure (2) The calculated time for fouling mortality in days of different selected sites

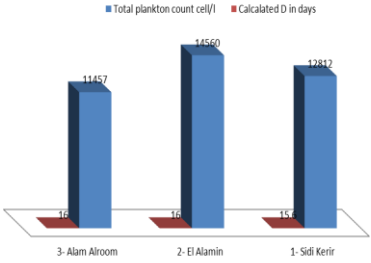

Figure (3) total planktone count and the calculated time required for fouling mortality with different TRO

So as shown in table (1) and figure (2) that using chlorine dose to kill algae bio-fouling at different TRO mg/l and at different temperature of the different selected sites of the suggested intake cooling structures, had showed that the suitable TRO used for complete algae mortality is 0.3 ppm at different temperatures (29, 28, 27 ^{0}C) of the selected sites by using the previous empirical model equation[8]. Our results, also appears that most entrained organisms are adversely affected by concentrations in excess of 0.3 ppm residual chlorine. As shown in table (1) and when some Measured environmental parameters such as salinity, DO, pH and total plankaton count at different selected sites (sidi kerir, Alamin and Alam Alrom) have a certain impact on heat exchanger of Nuclear power station , as the increase of salinity concentration at these selected areas specially sidi kerrir, Alamin and Alam Alrom (38.56,38.36,38.58‰) with other environmental parameters as Total plankton count (12812,14560,11457 cell/L) and temperature (29,28 and 27 ^{0}C) will lead to flow blockage of suggested tubular heat exchangers. Figure (3) had showed that the most increase in algae count located at Al Alamin 14560 count /cell then SidiKerir 12812 count per cell then

Alam Alroom 11457 count per cell while the Calculated D in days are (16,15and 16) respectively ,so the site of Alamin is the most site with low algae fouling formation than other selected sites. Design characteristics of once-through systems of a suggested NPP may allow or even increase the rate of fouling by promoting conditions that are conducive to sedimentation, macrofoulants and corrosion. Intake structures of once-through systems vary from plant to plant depending on environmental considerations and flow requirements. Most of the flow-through systems comprise of an offshore intake system (bored tunnel or a buried culvert), which conveys the water to a pump(10). Once-through systems typically have high flow velocities and mass flow rates for minimizing temperature effects on receiving waters. A typical 500 MW(e) unit would have a flow of 30 $m^3 s^{-1}$ at an average velocity of 3 $m^3 s^{-1}$ in the cooling water circuits.

Conclusion

1- Study the environmental water characteristics of the selected sites (Sidi kerir, Alamin, Alam Alrom) as salinity, total plankton count and temperature will help to evaluate the probability of flow blockage of suggested tubular heat exchangers in the suggested costal Nuclear power station.
2- Using 0.3 ppm chlorine dose which calculated in the previous empirical model which considered as suitable dose to kill algae, at different temperatures of the different selected sites of the suggested intake cooling structure
3- The site of Alamin has high probability of algae fouling formation than other selected sites. While the Almalroom site has the lowest probability of algae fouling formation
4- Using of chock dose of chlorine for complete and effective mortality, as what has been done in other conventional thermal power plant (Sidi kerir and Abou-Qir).

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