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Original Research Article

Assessment and Control of Sulfate Reducing Bacteria and Scales Formation in Sea Water Used in Cooling Systems of Abu-Qir and Ataka Power Stations

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Abstract

Microbial biofilm and corrosion in cooling systems either in power stations or in nuclear power plants are most common problems and causing expensive equipment's damage, loss of production and increase maintenance costs. Among anaerobic bacteria, sulphate reducing bacteria (SRB) are most often blamed because it was considered the major bacterial group involved in microbiologically influenced corrosion (MIC). We investigated how to control it chemically and also controlling the scales formed accompanying it in the closed cooling systems in two different power stations: Abu-Qir (Alexandria) station established on Mediterranean Sea and Ataka (Suez) station established on Gulf (Suez). Different categories of biocides Champion (A, B), E.C.C. (A, B) and E.P.R.I. (A, B) were used for controlling SRB growth chemically in cooling water samples. It was found that 500 ppm of Champion biocide type A was enough to make log bacterial count equal to zero recording efficiency 100%, whereas, 600 ppm from Champion type B was needed to reach the same result. For biocide E.C.C. (A, B), 600 ppm are enough for eliminate SRB log count. Also, for the biocide E.P.R.I. type A, 600 ppm was effective 100% whereas type B its efficiency reached 68.42% with the same concentration. The results indicated that Champion biocide - A type - was the most effective biocide of all investigated types for controlling SRB in the Abu-Qir and Ataka water samples. The results shows also that as the concentration of biocide increased, SRB growth decreased in presence or absence of the scales inhibitor but in the presence of the scales inhibitor Gyptron SA860N, the efficiency of the two biocides decreased by small interval values. Three types of scales inhibitors were used in this work with commercial names Gyptron SA860N, Gyptron SD132 and Gyptron SA3480and their effects on scales forming were studied. Gyptron SA860N was found to be the most efficient scales inhibitor for the water samples taken from the two stations. Finally, this study provided methodological support for the responsible for building the conventional and nuclear power stations, aiding in the search for alternatives to prevent possible problems associated with the presence of microorganisms responsible for biocorrosion.

Keywords: *Power Stations, Cooling systems, Sulphate reducing bacteria, Biocides, Scales inhibitors.*

Introduction

Seawater usually used in cooling systems as a heat transfer medium and frequently also as the final point to reject heat into the atmosphere by evaporating inside cooling towers. Depending on the quality of available seawater supply, waterside problems develop in cooling water systems as a result of biological growth as: scaling, corrosion, dirt and dust accumulation. Any of these problems result in costly unscheduled downtime, reduced capacity, increased water usage, high operation and maintenance costs expensive parts replacements and acid cleaning operations which reduce the life of the cooling system**(Baraka** *et. al.,* **2008).** According to recent investigations, damages due to corrosion in United States causes annual costs due to corrosion damage ranged from 1 to 5% of the gross national product (GNP) of each nation **(Widdel and Cypionka, 2003).** (**Prabha** *et. al.,* **2014**) said that corrosion costs the oil industry millions of dollars a year. Corrosion affects every aspect of exploration and production, from offshore rigs to casing, and reviews the role of corrosion agents such as drilling and production fluids. Studying the corrosion reveals that the microbiologically influenced corrosion (MIC) is a very dangerous process, this affects many industries **(Pope and Morris, 1995**). Microbiologically influenced corrosion (MIC) is problematic for the nuclear power plants, paper-making and oil industry. Also it can cause

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considerable damages to water - cooling systems, sewage treatment facilities and underground pipes and ships. The complexity and the environmental dependence of bacterial activities make it difficult to estimate the probability of different processes.

Many types of bacteria including sulphate, iron and CO_2 reducing bacteria, sulphur, iron and manganese-oxidizing bacteria are associated with the MIC of metals and alloys **(Beech and Sunner, 2004; Anandkumar** *et al.,* **2009).** Among MIC, sulphate reducing bacteria sulfate reducing bacteria (SRB) are recognized as a major group involved in anaerobic corrosion. These latter microorganisms can coexist in naturally occurring biofilms with a wide bacterial community, including fermentative bacteria, often forming synergistic communities that are able to influence electrochemical processes through cooperative metabolism **(Beech and Gaylarde, 1999, Manafi** *et al.,* **2013 and Zhao** *et. al.,* **2014)**.

Microbial corrosion by SRB results in severe graphitization of cast iron, leaving a soft surface liable to collapse **(Seth and Edyvean, 2006).** SRB are capable of causing severe corrosion of iron material in a water system because they produce enzymes which have the power to accelerate the reduction of sulphate compounds to the corrosive hydrogen sulphide, thus SRB act as a catalyst in the reduction reaction. A water system may naturally contain sulphate based compounds **(Manafi** *et. al.,* **2013).** The activities of SRB in natural and man-made systems are of great concern to engineers in many different industrial operations **(Gibson, 1990; Odom and Singleton, 1992).** Considerable efforts have been directed toward controlling SRB growth and inhibition of microbial induced corrosion **(Gavrilă,** *et. al.,* **2003).** Inhibition of corrosion is the slowdown of the corrosion rate by using substances which when added in small amounts, they decrease the rate of attack by these bacteria on a metal **(Ash and Ash, 2001).**A number of methods for controlling SRB sulfide production in different industrial facilities including the use of biocides **(Gardner and Stewart, 2002).**Consequently, considerable researches have been devoted to testing various potential micro biocides **(Kumaraswamy** *et al.,* **2010).** Biocides treatments are widely used to decrease biofouling and MIC in steel pipes and in closed systems. The use of corrosion inhibitors to prevent metal dissolution will be inevitable. Corrosion inhibition efficiency of organic compounds is related to their adsorption properties **(Okafor and Zheng, 2009).** The adsorption of these molecules depends mainly on certain physicochemical properties of the inhibitor molecule such as the presence of heteroatoms including: oxygen, sulfur, nitrogen and phosphorus atoms and multiple bonds in the molecule through which they are adsorbed on the metal surface **(Shaban,** *et. al.,* **2013).** In this study we try to investigate methods for evaluation and controlling the most important economic problems resulted from the presence of some microorganisms are known to promote corrosion of metals and/or their mixtures (alloys) in cooling water systems in the different Egyptian industrial fields like power stations, oil fields and also power plants, such corrosion is typed as microbiologically influenced corrosion (MIC). Also, the study aims to find applicable treatment methods for controlling sulphate reducing bacteria (SRB) as one of the important members of microbiologically induced corrosion (MIC) in seawater used in cooling systems of Abu-Qir and Ataka power stations, through reducing the growth and activities, consequently reduce the harmful impact of its presence in different industries as we mentioned before.

Materials and Methods

Sampling preparations for detection and enumeration of Sulphate Reducing Bacteria (SRB)

The study was conducted on a conventional water cooling systems of Abu-Qir steam power station located at Alexandria on the coast of the Mediterranean Sea and Ataka thermal power station which located south west of Suez city on the coast of the Gulf (Suez), Egypt. The water samples were collected from both power stations at different points; the inlet, outlet lines and cooling condensers. Samples stored in sterile polypropylene bottles under anaerobic conditions of nitrogen gas filling, then stored in ice tank upon analysis. A liquid Starkey growth medium media **(Starkey, 1948)** used in test methods cover the procedure for the detection and enumeration by the most probable number (MPN) technique for sulphate reducing bacteria in water or water-formed deposits. The contents was dissolved in 1000 ml. of pre-boiled Mediterranean Sea water used in Abu- Qir power station cooling system, pH was adjusted at 7.3, then dispensed at a rate of 9.0 ml broth media per pre-washed and sterilized glass vials, undergo an anaerobic conditions through filling it well with nitrogen gas and then tightly closed with rubber stopper and capped with aluminum caps, autoclaved at 121˚C for 15 minutes. After sterilization, the bottles were classified into sets; each set for one sampling point (inlet, outlet, condensers and sea outlet). We made those sets to apply serial dilution up to 10^{-6} fold dilution for each point. Finally, samples incubated at 33˚C for 21 days. Recording blacking of vial or the black precipitate (sulphide production) indicate the positively presence of sulphate reducing bacteria which are widely distributed in marine and fresh water due to its production through these organisms during dissimilation of sulphate reduction through an incubation period of three weeks. The same steps were repeated for red sea water used in Ataka power station's cooling system. The Enumeration of SRB in all experiments was done using the Most Probable Number (MPN) technique according to (**ASTM designation: D4412-84, 1990**) and (**Videla, 1996**). The MPN count of SRB was compared with the statistical table of Cochran (**Cochran, 1950**).

Differences were considered significant at the 95% confidence interval.

Evaluation of different biocides efficiency on controlling SRB growth

Three different biocides obtained from the Egyptian Petroleum Research Institute: type A (***Aldhydic form***) and type B (***Amine form***) with commercial names ***Champion (A, B), E.C.C. (A, B) and EPRI (A, B)*** were studied. Each biocide was added to a sterilized anaerobic vial containing 100 ml of Sea water sample to reach a final desired concentration of 100 ppm. This step was done to obtained different concentrations (100, 200, 300, 400, 500 and 600ppm) from each biocide used. A vial with the same anaerobic conditions must be left untreated to represent the control vial. In addition, each biocide was kept in contact with seawater containing SRB for two hours at 30^0C. At the end of contact time and by using a sterilized syringe, 1ml of each concentration was inoculated into a Starkey modified medium, incubated at 33°C for three weeks. Enumeration of SRB took place and MPN values were calculated. This experiment was repeated for the cooling Seawater of both stations under study.

Scales formation and scales inhibitors

Solubility of common seawater scales

According to **(Amer B.M. and Abu Azam M.Y., 2009)** for each experiment of common seawater scales, 100ml of each filtered opposite waters was poured into beaker. The mixture heated on hot plate with continuous stirring by magnetic stirrer then the mixture was filtered through 0.45 µm. After filtration, 5ml of the filtrate was pipetted into a 50ml volumetric flask and filled up with distilled water to 50 ml. This instantaneous dilution of the $CaCO_3$, $CaSO_3$ and $SrSO_4$ containing seawater just after filtration was performed in order to prevent their precipitations during the period between filtering and analytical determination of the Ca, Ba and Sr concentrations. The calcium and strontium determinations were calibrated by measuring five standard solutions. Standard solutions were prepared from $CaCl_2$, $SrCl_2$. Calcium and strontium concentrations in the diluted filtrates were determined by atomic absorption spectrometry. After multiplying with the dilution factor, the exact concentrations of calcium and strontium were computed.

Evaluation of the efficiency of some scale inhibitors on scales formation in water cooling systems

Three different scale inhibitors have commercial names ***(Gyptron SA860N, Gyptron SD132 and Gyptron SA3480)*** obtained from the Egyptian Petroleum Research Institute were evaluated. Different concentrations of each Gyptron type were prepared separately; each one was added to a cell test containing 50 ml. of the sulphate containing seawater sample to reach final desired concentrations: 5, 10, 15, 20 and 25 ppm. A blank were prepared by adding 50 ml of sulphate containing seawater sample to the test cell alone without adding any of scales inhibitors. All test cells were capped well and agitate to mix them thoroughly **(NACE Standard T1A0374-90, Item No. 5302, 3 1990)**. All test cells and blanks immerse to 3/4 of their lengths in a water bath at 160°F (71°C) for 24 hours. The test cells removed after the 24 hour exposure and avoid agitation. The test cells cool to 77°F (25°C) and 9°F (5°C) for a time not to exceed two hours. Pipiting 1.0 ml of the test sample to a suitable vial, avoiding transfer of calcium sulfate crystals and dilute with distilled water, deionized water. The calcium ion concentrations were determined by procedures given in **ASTM D 511-88 (2004).**

Evaluating study of the effect of the presence of both biocides and scales inhibitors on SRB growth

Gyptron SA860N was selected as the most effective scales inhibitor that gave the best results in scales inhibition. A solution with a final concentration 10 ppm was prepared in 100 ml of seawater sample present in a sterilized anaerobic vial. This step was prepared before adding the desired biocide by 24 hours (Champion A was chosen due to its high efficiency between all biocides under investigations in controlling SRB growth). Champion A was prepared to achieve the concentration of 100 ppm and was added to the vial. This step was repeated to obtain several concentrations of Champion A (100, 200, 300, 400 and 500 ppm) with a constant (Gyptron SA860N) concentration of 10 ppm. Then the same steps that achieved for evaluation of biocides repeated, log counts of SRB were calculated. Results were recorded for cooling seawater of both power stations under investigations.

Results and Discussion

Detection and enumeration of SRB in water cooling systems of Abu-Qir and Ataka power stations

In this experiment, samples were collected from different points of water cooling systems lines of both Abu-Qir and Ataka power stations in order to detect and enumerate sulphate reducing bacteria (SRB) and consequently to handle the problems they cause. The counts at sea water inlet, outlet, station outlet and the three condensers are given in Table (1).

Results showed that SRB counts differ from point to point, but it was noticed that these counts in Ataka power station water cooling system (Gulf (Suez)) were generally greater than that of Abu-Qir power station water cooling systems (Mediterranean Sea). These results may be remarked that there were appropriate conditions for sulphate reducing bacterial growth among the cooling water systems which support SRB prosperous.

Table (1): Sulphate reducing bacterial counts of Abu-Qir and Ataka stations

Sample Number	Sample Sitting	Sulfate reducing bacteria count (cell/ml)	
		Abu-Qir (Alex.)	*Ataka (Suez)*
Sample A	Condenser 1	2.4×10^5	2.6×10^5
Sample B	Condenser 2	7.5×10^4	9.8×10^4
Sample C	Sea Water Inlet	7.6×10^5	9.4×10^5
Sample E	Condenser 3	1.1×10^5	1.4×10^5
Sample O	Station Outlet	1.5×10^5	1.9×10^5
Sample D	Sea Water Outlet	0.6×10^5	0.8×10^5

Table (2): Sulphate reducing bacteria counts and Champion biocide efficiency change (%)

Biocide Conc., ppm	*Champion Biocide*							
	Abu-Qir (Alexandria)				*Ataka (Suez)*			
	Type A		*Type B*		*Type A*		*Type B*	
	Log Count	*Efficiency %*	*Log Count*	*Efficiency %*	*Log Count*	*Efficiency %*	*Log Count*	*Efficiency %*
Control	5.75	0.00	5.75	0.00	5.90	0.00	5.90	0.00
100	3.85	33.04	4.65	19.13	4.55	22.88	4.75	19.49
200	2.56	55.48	3.82	33.57	3.02	48.81	4.12	30.16
300	2.12	63.13	2.81	51.13	2.45	58.47	3.11	47.28
400	1.30	77.39	1.56	72.87	1.50	74.57	1.83	68.98
500	0.00	100	1.20	79.13	0.00	100	1.36	76.94
600	0.00	100	0.00	100	0.00	100	0.00	100

This data absolutely helped in selecting the most effective biocides and its Minimum inhibitory concentrations, the fact that agree with **(Brözel and Cloete 1993)** who stated that, the minimum inhibitory concentration of different biocides required for a specific killing percentage against a particular organism (biocide fingerprint) can be determined only once the microbial population structure in a system is known. Also enumerating the initial counts will help in pre-determination of the contact time required for a biocide to kill SRB in different sea water samples in all target points.

Effect of different concentrations of Champion biocide with its two types (A and B) on SRB growth

Table (2) and Figure (1,2) summarized the data obtained as a result of applying Champion with its two types A and B and their efficiency percentage on reducing the log count of SRB present in cooling systems for both station under investigations. Generally it was concluded from the obtained data that as the concentration of Champion A or B increased, the log counts decreased and the efficiency changes increased for both types. The data marked that Champion A more efficient than Champion B and that for samples of both stations. Also 500 ppm of Champion A were sufficient for completely inhibit SRB growth effectively by 100 % and that for the two stations. At the same conditions, 600 ppm of Champion B was destroyed SRB growth in both water samples completely. So, it was concluded that the aldhydic biocide champion A was clearly more effective than the amine form (Champion B) as an inhibitor for SRB growth.

This data agrees with what has been achieved by other studies. **(Von Reg and Sand, 1998)** evaluated different biocides efficacy for SRB treatment. The samples were treated with the biocide formaldehyde, tetra methyl ammonium hydroxide, 1,8 di hydroxy anthrax quinone and a commercial biocide named Dilurt at different concentrations. It was found that formaldehyde exhibited the best effect. Only 3% of the original microbial activity remained and reduction in SRB cell numbers of five orders of magnitude.

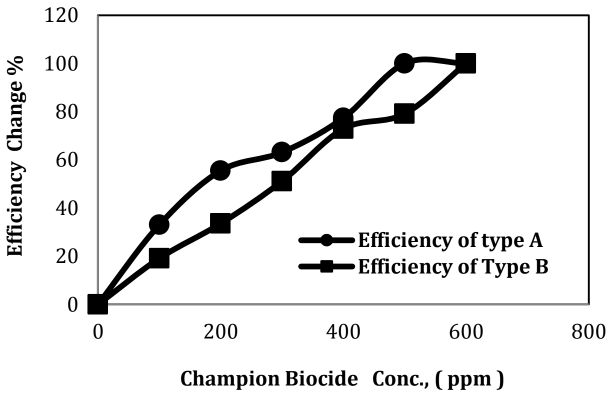

Fig (1): Comparison between efficiency of Champion A and B types for Abu-Qir station

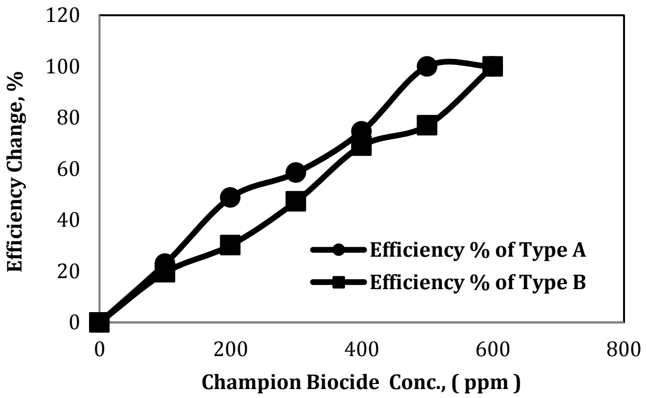

Fig (2): Comparison between the efficiency of Champion A and B types for Ataka station

Table (3): Sulphate reducing bacteria log counts and efficiency change % of biocide E.C.C.

Biocide Conc., ppm	*E.C.C. Biocide*							
	Abu-Qir (Alexandria)				*Ataka (Suez)*			
	Type A		*Type B*		*Type A*		*Type B*	
	Log Count	*Efficiency %*	*Log Count*	*Efficiency %*	*Log Count*	*Efficiency %*	*Log Count*	*Efficiency %*
Control	5.70	0.00	5.70	0.00	5.90	0.00	5.90	0.00
100	5.02	11.93	5.30	7.018	5.32	9.83	5.55	5.93
200	4.84	15.09	4.88	14.39	5.04	14.57	5.08	13.89
300	3.80	33.33	4.23	25.79	4.20	28.81	4.63	21.52
400	2.32	59.29	3.67	35.61	2.82	52.20	3.85	34.74
500	1.30	77.19	1.60	71.93	1.50	74.57	1.90	67.79
600	0.00	100	0.00	100	0.00	100	0.00	100

On the other hand, tetra methyl ammonium hydroxide had only a slight effect. Microbial activities were reduced only to 20% and the cell numbers did not decrease at all. **Zakaria,** *et. al.,* **2012** stated that the Aldhydic biocides were more effective than the amine type biocides for SRB inhibition.

Effect of different concentrations of E.C.C. biocide (A and B) type on SRB growth

The second biocide under investigation was E.C.C. with its two types Aldhydic type (A) and amine type (B). Table (3) and Fig (3,4) illustrated the data obtained from the relation between log counts of sulphate reducing bacterial and percentage of efficiency change of biocide E.C.C. type A and also for type B for both seawater samples of the two power stations. The data indicated that maximum log counts recorded in control sample and as the concentration of E.C.C. biocide increased the log bacterial counts decreased and the efficiency change increased. Also it was clear that the aldhydic form A was more efficient than the amine form B in inhibition of sulphate reducing bacteria in the samples of both power stations. This agrees with what has been achieved by **Anna Turkiewicz,** *et al.***(2013)**, **Von Reg and Sand (1998)**, **Gardner and Stewart (2002)** and **Zakaria,** *et al.,***(2012)**. The results illustrated also, that by increasing the concentrations of ECC biocide, there were noticeable decreases in log counts of SRB comparing with control and 600 ppm of E.C.C. (A and B) types lead to 100% inhibition of SRB counts in all samples.

Effect of different concentrations of E.P.R.I. (A and B) type on SRB growth

The study was conducting on two another types of selected biocide E.P.R.I. The Aldhydic form was type A and B is the amine form. Table (4) and Figs (5,6) summarized the obtained data of log counts of sulphate reducing bacteria and efficiency change percent of E.P.R.I. type A and type B for seawater sample of Abu-Qir and Ataka power stations. The data indicated that as the concentration of biocide increased from 100 to 600 ppm the bacterial counts decreased gradually comparing to the control. Also, the efficiency change increased with increasing the biocide concentrations and E.P.R.I. type A noticed to be more efficient than E.P.R.I. type B for the samples of two stations. The results agreed with **Anna Turkiewicz**, *et al.***(2013)** and **Zakaria,** *et al.,***(2012)** which marked to those Aldhydic biocides always more effective than amine formed ones.

Maximum inhibition dose of Biocide E.P.R.I. type A recorded at 600 ppm for the investigated samples of the two stations but for type B it was found that 600 ppm was not a sufficient concentration for growth inhibition of sulphate reducing bacterial counts for the

Table (4): Sulphate reducing bacteria log counts and efficiency change % of biocide E.P.R.I.

Biocide Conc., ppm	*E.P.R.I. Biocide*							
	Abu-Qir (Alexandria)				*Ataka (Suez)*			
	Type A		*Type B*		*Type A*		*Type B*	
	Log Count	*Efficiency %*	*Log Count*	*Efficiency %*	*Log Count*	*Efficiency %*	*Log Count*	*Efficiency %*
Control	**5.70**	**0.00**	**5.70**	**0.00**	**5.90**	**0.00**	**5.90**	**0.00**
100	**5.38**	**5.61**	**5.57**	**2.28**	**5.56**	**5.76**	**5.88**	**0.33**
200	**4.54**	**20.35**	**5.12**	**10.18**	**5.45**	**7.62**	**5.42**	**8.13**
300	**3.20**	**43.86**	**4.60**	**19.29**	**4.00**	**32.20**	**4.90**	**16.94**
400	**1.71**	**70.00**	**4.12**	**27.72**	**1.91**	**67.62**	**4.52**	**23.38**
500	**1.00**	**82.46**	**3.20**	**43.86**	**1.40**	**76.27**	**3.12**	**47.11**
600	**0.00**	**100**	**1.80**	**68.42**	**0.00**	**100**	**1.90**	**67.79**

two samples. That mean biocide E.P.R.I. type B was less effective than E.P.R.I. type A, since type B biocide reduced the log SRB counts than the control whereas biocide type A inhibit the growth completely. It must be emphasized that the concentration of a biocide is not related linearly to its activity; a concentration power is involved in the relationship.

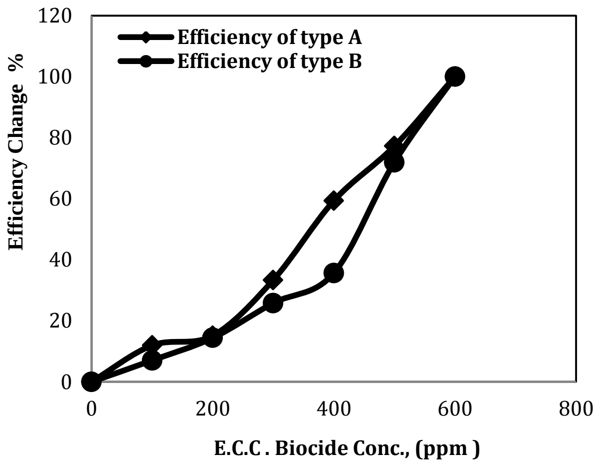

Fig (3): Comparison between efficiency of E.C.C.A and B types for Abu-Qir station

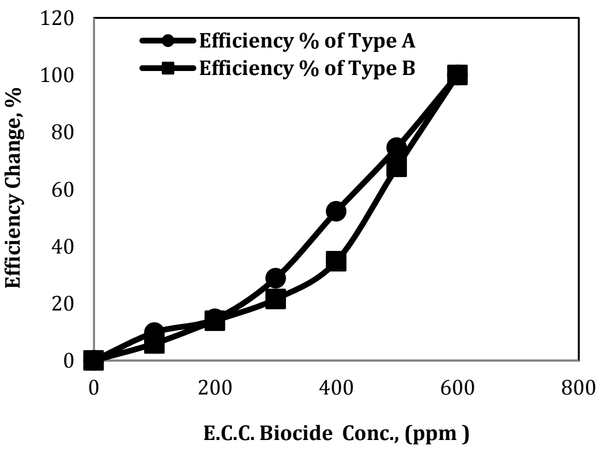

Fig (4): Comparison between efficiency of E.C.C. A and B types for Ataka station

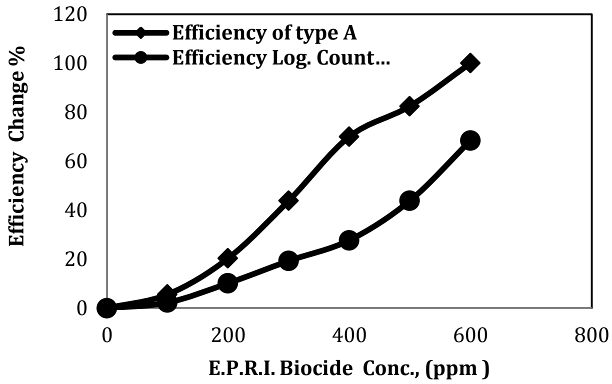

Fig (5): Comparison of efficiency of biocide E.P.R.I. A and B types for Abu-Qir station

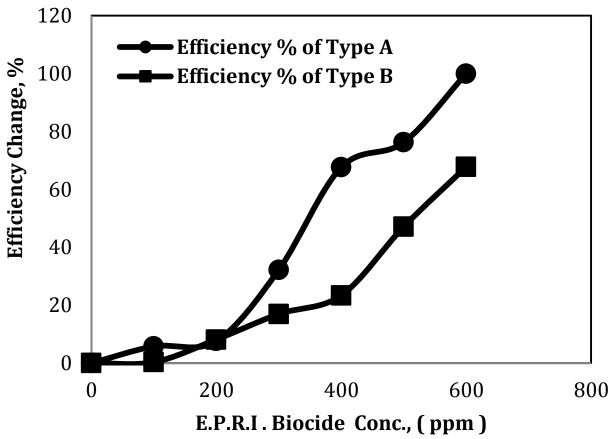

Fig (6): Comparison of efficiency of biocide E.P.R.I. A and B types for Ataka station

Using biocides to control sulphate reducing bacteria is acceptable and commonly used in practice. Although biocides are used to reduce bacterial counts, they do not necessarily reduce the fouling rates. It is essential to apply the correct biocide concentration at the correct frequency. Wrong use of biocides gives poor results and is expensive. For more effective biocide selection, a comparative study between the efficiency of the three aldhydic forms of the evaluated biocides and that for Abu-Qir and Ataka power stations sea water samples as shown in Figs. (7,8). The results indicated that Champion A biocide was the more effective, the evaluated efficiency change sequence was as follow: **Champion A > E.P.R.I. A > E.C.C. A**. When comparing between the effects of the three amine forms of biocides concentrations under investigations and the efficiency change for Abu-Qir power station Sea water samples as represented in Figs. (9,10). The data indicated that Champion B is the most efficient amine form biocide and the evaluated efficiency change sequence was as follow: **Champion B > E.C.C. B > E.P.R.I. B.**

Finally from what has been mentioned, the results clarified that Aldhydic biocide Champion A is the most powerful biocide among the others that had been tested. As at all its concentrations, it exhibited the highest efficiency for reducing SRB log counts than others evaluated biocides. Also it recorded the lowest minimal inhibitory concentration for growth inhibition at the lowest concentrations. So it will be selected as the most efficient biocide among the others.

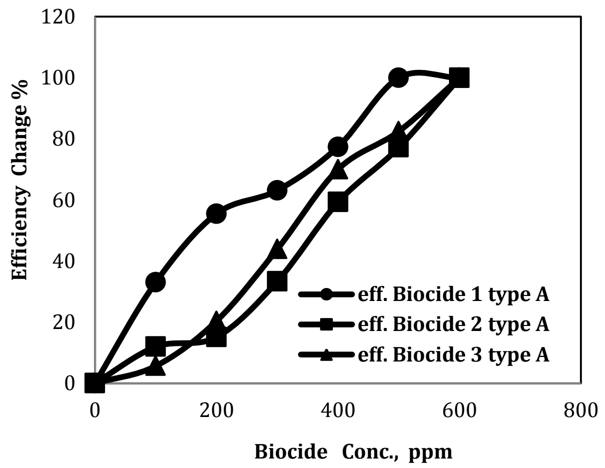

Fig (7): Comparative study of efficiency of three biocides A type for Abu-Qir station

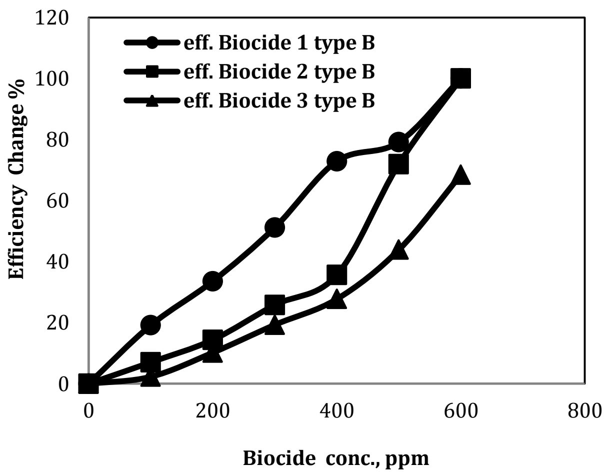

Fig (8): Comparative study of efficiency of three biocides B type for Abu-Qir station

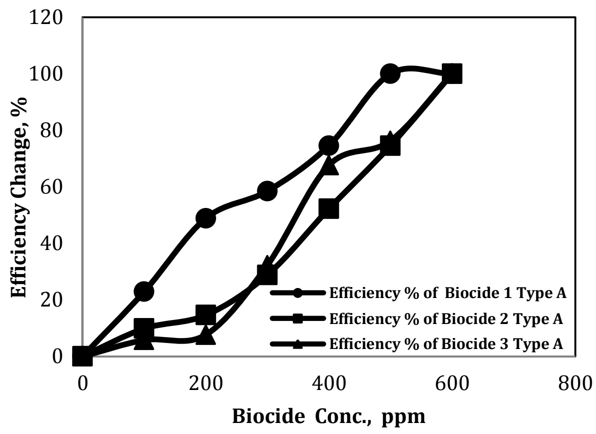

Fig (9): Comparative study of efficiency of three biocides A type for Ataka station

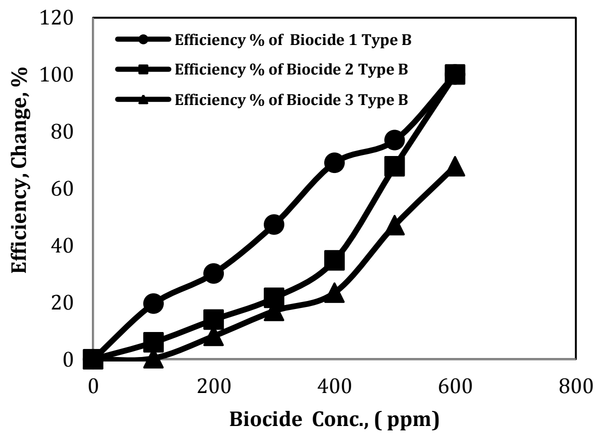

Fig (10): Comparative study of efficiency of three biocides B type for Ataka station

Scales formation and scales inhibitors

Seawater mostly contains alkaline earth metal cations such as magnesium, calcium, barium and anions such as carbonate, bicarbonate, sulfate, silicate, oxalate, phosphate, etc. This part of research is a trial to find an applicable method for prevention of biodeterioration of industrial materials, thereby preserving their structures and prolong their usage as long as possible so as to reduce the costs which is very important gigantic industrial projects, like nuclear power plants and oil industries. Deterioration may be a result of scales formation and also biofilm formation results from SRB activities.

Solubility analyses of common scales forming salts in Mediterranean and Gulf (Suez) seawater were summarized in Tables (5,6) and Fig. (11,12). Results show that the relation between the concentrations of the common salts $CaCO_3$, $CaSO_4$ and $SrSO_4$ change at different temperatures. The data indicated that by increasing the temperature the solubility of $CaCO_3$, $CaSO_4$ and $SrSO_4$ decreased at various temperatures. The expected trend in this temperature range is a decrease of $CaSO_4$ and $SrSO_4$ solubility's with increasing temperature.

Table (5): Solubility of scales in Mediterranean seawater

Temp. ⁰C	*Temp. ⁰F*	*$CaCO_3$, mg/L*	*$CaSO_4$, mg/L*	*$SrSO_4$, mg/L*
25	***77***	***3019.25***	***4283.74***	***492.24***
50	***122***	***1876.63***	***2113.52***	***241.51***
100	***212***	***998.08***	***1214.91***	***145.58***
150	***302***	***830.12***	***530.07***	***87.44***
200	***392***	***770.33***	***140.53***	***66.65***

Table (6): Solubility of scales in Gulf (Suez) seawater

Temp. ⁰C	*Temp. ⁰F*	*$CaCO_3$, mg/L*	*$CaSO_4$, mg/L*	*$SrSO_4$, mg/L*
25	***77***	***3019.25***	***4283.74***	***492.24***
50	***122***	***1876.63***	***2113.52***	***241.51***
100	***212***	***998.08***	***1214.91***	***145.58***
150	***302***	***830.12***	***530.07***	***87.44***
200	***392***	***770.33***	***140.53***	***66.65***

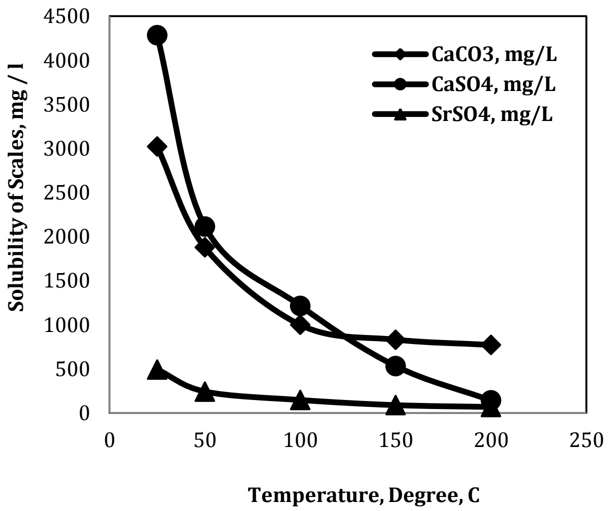

Fig (11): Solubility of common scales in Mediterranean seawater

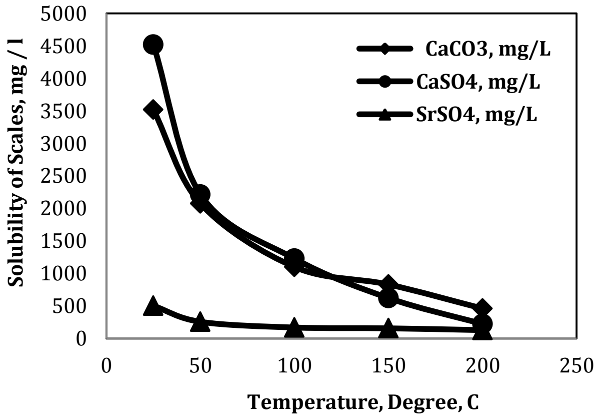

Fig (12): Solubility of common scales in Gulf (Suez) seawater

The solubility of $CaSO_4$ and $SrSO_4$ decrease with increasing temperature because of dissociation of $CaSO_4$ and $SrSO_4$ which are exothermic reaction so, the deposition of the common scales increased by increasing temperature reached maximum at 200⁰C.

Three types of scales inhibitors with commercial names ***Gyptron SA860N, Gyptron SA3480 and Gyptron SD132*** were studied to evaluate their efficiency. Generally the scales inhibitors are chemically based on three types of compounds, phosphate esters, phosphonates and polymers. Previous studies indicated that the polymeric based scales inhibitors are particularly preferred, that they can be made by any conventional polymerization method of an anionic monomer that carrying a group (may be carboxylic group) capable of providing a negative charge on the resulting polymeric chain. The scales inhibitors are always commercially available.

Evaluation of some scales inhibitors on scales formation in water cooling systems of Abu-Qir and Ataka power stations

The effect of different concentrations of three types of scales inhibitors on the scales formed in Sea water samples of Abu-Qir (Alexandria) station and Ataka (Suez) station summarized in Tables (7,8). Figs. (13,14) is a comparison study between the efficiency of the three types of the scale inhibitors. The results indicated that ***Gyptron SA860N*** is the most significant scale inhibitor between the three types tested. Their efficiency is taking the order: ***Gyptron SA860N >Gyptron SA3480 >Gyptron SD132.***Scales inhibitors such as phosphonates or polyacrylic acid, show very strong inhibitory effects to prevent mineral scales formation in the oil and gas production system. It has been observed that many aspects of the brine composition and operation condition may affect the performance of the inhibitors. An understanding of the inhibition mechanism is needed in order to predict how these operational variations affect inhibition.

Table (7): The effect of scales inhibitors concentrations on scale forming for Abu-Qir station

Scale Inhibitor Dose, ppm	*Gyptron SA860N*		*Gyptron SD132*		*Gyptron SA3480*	
	Scale formed	*Efficiency*	*Scale formed*	*Efficiency*	*Scale formed*	*Efficiency*
0.0	**12692.3**	**0.00**	**12692.3**	**0.00**	**12692.3**	**0.00**
5.0	**10737.69**	**15.4**	**11346.92**	**10.59**	**11143.84**	**12.19**
10.0	**8839.226**	**30.35**	**10699.61**	**15.69**	**9529.226**	**24.92**
15.0	**7508.995**	**40.84**	**10014.22**	**21.1**	**8328.841**	**34.37**
20.0	**7410.687**	**41.61**	**10006.92**	**21.16**	**8237.76**	**35.09**
25.0	**7405.3**	**41.65**	**9998.97**	**21.22**	**8126.38**	**35.97**

Table (8): The effect of scales inhibitors concentration on scale forming for Ataka(Suez) station

Scale Inhibitor Dose, ppm	*Gyptron SA860N*		*Gyptron SD132*		*Gyptron SA3480*	
	Scale formed	*Efficiency*	*Scale formed*	*Efficiency*	*Scale formed*	*Efficiency*
0.00	**1606.65**	**0.00**	**1606.65**	**0.00**	**1606.65**	**0.00**
5.00	**1346.37**	**16.20**	**1400.99**	**12.80**	**1386.53**	**13.70**
10.0	**1193.74**	**25.70**	**1322.27**	**17.70**	**1245.92**	**22.45**
15.0	**1041.11**	**35.19**	**1229.08**	**23.50**	**1143.93**	**28.80**
20.0	**1040.74**	**35.22**	**1227.14**	**23.62**	**1135.51**	**29.32**
25.0	**1039.86**	**35.27**	**1226.97**	**23.63**	**1133.90**	**29.42**

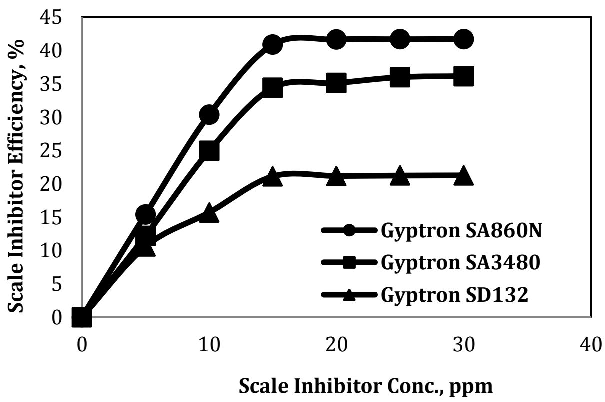

Fig (13): The effect of scale inhibitors concentrations on scale forming for Abu-Qir station

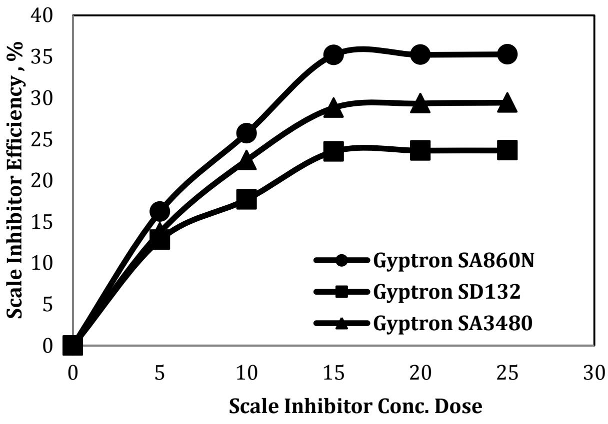

Fig (14): The effect of scale inhibitors concentrations on scale forming for Ataka (Suez) station

The effect of the most efficient scales inhibitors Gyptron SA860N on biocides efficiency and consequently, to SRB counts

Corrosion, scaling and biofouling, three fetal problems that affect the performance of the recirculation cooling water system, an important component in most industries. Most of the industries are adding biocides and scales inhibitors at the same place in cooling water systems. Inhibitors are added continuously and biocides may added once weekly or once in fifteen days. The inhibition efficiency increases with circulation velocity rise and resisted to immersion time. Moreover, the inhibition efficiency was circa temperature-independent and retained its performance on a surface covered by corrosion products and though in very aggressive media such as 3% NaCl. The study explored the influence of the presence of the most efficient scales inhibitors, as indicated from the results, Gyptron SA860N on the log SRB counts in the presence or absence of the most effective biocides independently Champion (A,B) as represented in Table (9) and Figs (15-18). The data reflected that, as the concentration of biocide increased SRB growth decreased in presence or absence of the scales inhibitor but in the presence of scales inhibitor the efficiency of the two biocides decreased and Champion A more effective than Champion B in presence or absence of (Gyptron SA860N). This result parallel to what has been achieved by **Maruthamthu,** *et. al.,***(2000)**, they used Morpholine phosphate as biocide and they stated that, Morpholine phosphate when used alone acts as a good biocide, but when

Table (9): Effect of Gyptron SA860N on biocides efficiency and SRB log counts

Biocide Conc., ppm	*Log Sulphate Reducing Bacteria count*							
	Abu-Qir (Alexandria)				*Ataka (Suez)*			
	Without Gyptron SA860N		*With 10 ppm Gyptron SA860N*		*Without Gyptron SA860N*		*With 10 ppm Gyptron SA860N*	
	Champion A	*Champion B*	*Champion A*	*Champion B*	*Champion A*	*Champio n B*	*Champion A*	*Champion B*
Control	5.8	5.8	5.8	5.8	5.93	5.93	5.93	5.93
100	4.3	4.6	5.23	5.45	4.46	5.36	5.13	5.82
200	2.5	3.47	3.31	4.42	2.78	4.57	3.87	4.75
300	1.6	2.4	2.2	2.98	2.54	2.83	2.8	3.28
400	1.08	1.51	1.94	2.58	2.33	2.56	2.62	2.84
500	0.00	1.2	0.00	1.62	0.00	1.36	0.00	1.75
600	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

combined with scale inhibitors, the killing efficiency was nil. Results suggest that bacteria should be killed first and inhibitors should be added later for getting higher efficiency and for avoiding the interference between biocides and scale inhibitors. An interaction process might occur among the scales inhibitors and biocide when added together to the seawater cooling system. The synergistic or combined effect of adding these chemicals to the seawater system might affect their effectiveness in maintaining the water quality of the system.

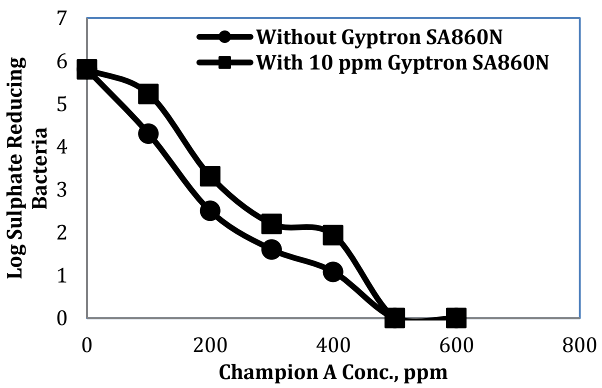

Fig (15): The effect of Champion A biocide on SRB counts with and without Gyptron SA860N scale inhibitor for Abu-Qir station

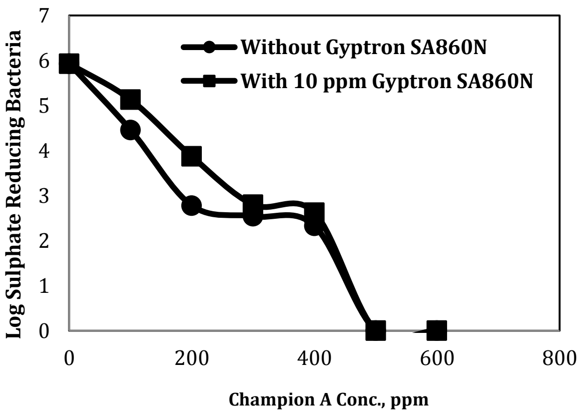

Fig (16): The effect of Champion A biocide on SRB log counts with and without GyptronA860N scales inhibitor for Ataka station

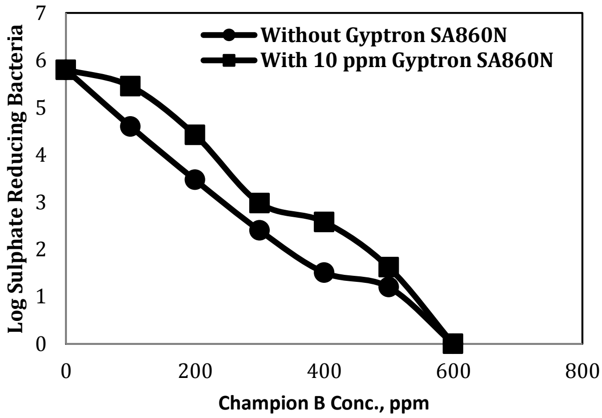

Fig (17): The effect of Champion B biocide on SRB log counts with and without Gyptron SA860N scales inhibitor for Abu-Qir station

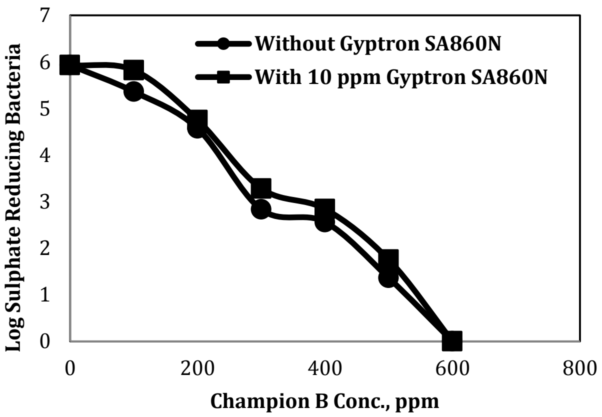

Fig (18): The effect of Champion B biocide on SRB log counts with and without Gyptron SA860N scales inhibitor for Ataka station

Conclusion

This study investigated detection and controlling of sulphate reducing bacteria (SRB) in cooling systems of Abu-Qir and Ataka power stations. The results indicated that the Aldhydic biocide *Champion A* was the most effective biocide of all investigated types for controlling SRB in samples collected from Abu-Qir and Ataka power stations. As the concentrations of biocide increased, SRB growth decreased in presence or absence of Gyptron SA860N. The early detection of SRB could be employed for preventing the damages on metal surfaces before the installation of corrosion processes. Strategies for reducing the time spent on SRB isolation and identification could be auxiliary tools for controlling the corrosion of materials. This study provided methodological support for those who are responsible for building the conventional and nuclear power stations, aiding in the search for alternatives to prevent possible common problems associated with the presence of microorganisms responsible for biocorrosion. Although corrosion is a natural process, the presence of SRB accelerates the corrosion rate; therefore, alternatives to prevent and detect the potential problems could be employed in attempt to reduce the economic losses.

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