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Analyzing corrosion rate and its reduction in a microbiologically contaminated cooling water

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Abstract : Microbial contamination and corrosion rate of a cooling water system were analyzed three times in April, July, and October 2014. Microbial analyses and Biocide efficacy test were performed according to NACE standard TM 0194 and ASTM E645 standard, respectively. Weight loss measurements were performed to determine the corrosion rate of simple carbon steel in water samples. General heterotrophic bacteria (GHB) and sulfate-reducing bacteria (SRB) were observed in all water samples. Highest microbial contamination was observed in July which GHB and SRB counts were 10^6 and 10^2 per milliliter of water, respectively. Corrosion rate of April, July, and October samples were 3.5, 15, and 4.1 mpy that reduced to 1.7, 5.3, and 2.5 mpy respectively, after biocide application. The July sample required at least 30 ppm biocide, while the April and October samples, required 20 ppm biocide for effective results. The results not only demonstrated the importance of microbiologically influenced corrosion in the studied cooling water system but also revealed the importance of monthly biocide optimization in a particular system.

Keywords : Cooling water; Corrosion rate; General heterotrophic bacteria (GHB); Microbiologically influenced corrosion (MIC); Sulfate-reducing bacteria (SRB).

INTRODUCTION

Corrosion creates many problems in different environments and industries and often is associated with devastating consequences and extensive economic loss. Many factors can cause corrosion, one of the most important ones are microorganisms. Microorganisms have various and different role on the planet earth. They have vital roles in organic matter decomposition and nutrient cycles. By binding to different surfaces and biofilm formation, microorganisms damage substratum materials causing corrosion[1,2]. Corrosion due to the presence and/or activity of microorganisms is called microbiologically influenced corrosion (MIC)[3,4]. In various studies, the proportion of MIC in total corrosion is estimated in varying amounts. Commonly, MIC is estimated to accounts for about 20 percent of the total corrosion[5].

In most industries and organizations one of the most important equipments are cooling water systems. These systems increase water contact with the air, causing rapid cooling of the water and consequently related equipment(s). Most cooling water systems are made of a closed circuit which the water absorbs unwanted heat from process and transfer and excrete it to the air. The proper functioning of the cooling water systems is critical for appropriate process efficacy. Cooling water systems suffer many forms of problems including corrosion and failure due to its physical, chemical, and biological conditions[6].

Cooling water systems are suitable environments for microbial growth[7]. In this regard, MIC is very important and emerging as a serious problem in these systems[8]. Many studies investigated MIC and its control in different cooling water systems[9-14]. It should be noted that each system has its unique features. A MIC control program (such as biocide application) that is appropriate in one system may not be suitable in another system. For example, study of Minnos *et al.* [15], showed the importance of biocide concentration optimization for each cooling water system.

Since MIC can reduce the efficiency of the cooling water systems and increase the cost of maintenance, in this study microbial contamination and corrosion rate of a cooling water system were analyzed. Furthermore, the corrosion rate was evaluated after biocide application.

EXPERIMENTAL

Water sampling procedure

Water samples collected in glass bottles according to APHA 9060 A[16] from a cooling water system in Tehran, Iran. Bottles sterilized in 121 °C for 15 minutes. $Na_2S_2O_3$ and disodium salt of ethylenediaminetetraacetic acid (Na_2EDTA), were added to the bottles for neutralizing residual chlorine and reducing toxicity of heavy metals, respectively. Sampling was performed three times in April, July, and October 2014.

Detection and enumeration of microorganisms

Detection and culturing of general heterotrophic bacteria (GHB) and sulfate-reducing bacteria (SRB), two main group of microorganisms related to MIC, were performed according to NACE standard TM 0194[17]. Standard bacteriological nutrient broth was used for cultivation of GHB. Composition of this medium was: beef extract, 3.0 g; peptone, 5.0 g; and distilled water 1,000 mL. Composition of SRB medium was (g/l): sodium lactate solution, 4.0 mL; yeast extract, 1.0 g; ascorbic acid, 0.1 g; $MgSO_4.7H2O$, 0.2 g; K_2HPO_4, 0.01 g; $Fe(SO_4)_2(NH_4)_2.6H_2O$, 0.2 g; NaCl, 10.0 g; and distilled water 1,000 mL. Bacterial number enumerated according to NACE standard TM 0194[17] by serial dilution.

Water sample analysis

Water sample parameters were analyzed using standard methods. These parameters were: nitrate, nitrite, sulphate, and sulphite, TDS, Mg, Ca and Na.

Corrosion rate measurements

In order to find the corrosively of water samples and testing efficiency of biocide, weight loss measurements were carried out using carbon steel coupons. Coupon chemical composition (TABLE 1) analyzed according to ASTM E415[18]. Coupons with 2×70×14 mm dimensions dipped in 500 ml of water samples at room temperature for 30 days. Before each experiment, coupons were abraded with wet SiC paper (grades 600-1200), polished with emery paper to mirror surface, washed with double distilled water, degreased with acetone, sterilized in ethanol 70 % for 1 hour, dried and then weighted.

TABLE 1 : The chemical composition of carbon steel coupons

Element	C	Si	Mn	P	S	Cr	Mo	Ni	Al
(%)	0.15	0.11	0.48	0.02	0.016	0.06	0.01	0.01	0.038
Element	Co	Cu	Nb	Ti	V	W	Sn	As	Fe
(%)	0.015	0.04	<0.005	<0.002	<0.005	<0. 02	<0.005	<0.002	Base

After completion of the test, coupons were washed and cleaned using water and smooth brush. Weights of dried coupons were measured and corrosion rate calculated as mpy.

Biocide efficacy test

Based on water analysis, economic assessment, and previous experience an imidazoline-based biocide selected for efficacy test. Biocide efficacy evaluated according to ASTM standard E 645[19] at 10 to 100 ppm concentration. The cooling water samples were used as received. All tests performed in duplicate.

RESULT AND DISCUSSION

GHB and SRB, which involved in MIC, were observed in the cooling water samples at different times (TABLE 2). Highest microbial contamination was observed in July. In this month GHB and SRB counts were 10^6 and 10^2 per milliliter of water, respectively. Monthly variations of microbial count in cooling water systems have been reported by other investigations[20,21]. Water chemical analysis (TABLE 3) indicated that the cooling water had enough nutrients for microbial growth. The higher amount of sulphate was observed in July that was correlated with SRB count. Sulphate stimulates SRB growth and utilizes as terminal electron acceptor by this group of bacteria under anaerobic conditions[22]. Sulphate content of the cooling water samples were between 235 to 310 mg/l which were approximately similar to sulphate content of the SRB medium of NACE standard TM 0194[17]. Accordingly, the amount of sulphate was sufficient for SRB growth. SRB are the most well known bacterial group in MIC and are present in most MIC cases[23]. It is well known that SRB are important causative agent in most microbiologically influenced corrosion of cooling water systems[6]. So, their occurrences increase the risk of MIC in this industrial cooling water system and it must be managed properly.

Biocide efficacy tests were performed using April, July, and October samples. As shown in TABLE 4, the used biocide efficiently killed bacteria in all water samples. However, efficient concentrations were different according to the sampling date. The water sample with higher bacterial count required higher biocide concentration. In this regard, the July sample required at least 30 ppm biocide for effective killing of GHB, while the April and October samples, that have lower bacterial counts, required 20 ppm biocide for effective results. Similar to Minnos *et al.*,[15] these results demonstrated the importance of biocide concentration optimization for each cooling water system.

Corrosion rate of the water samples are given in TABLE 5. Maximum corrosion rate was related to the July sample and significantly reduced after biocide application which demonstrating usefulness of

TABLE 2 : GHB and SRB counts per ml of water samples

General Heterotrophic Bacteria (GHB)/ml			Sulfate-Reducing Bacteria (SRB)/ml		
April	July	October	April	July	October
10^4	10^6	10^4	10^1	10^2	10^1

TABLE 3 : Water samples chemical analysis (data represented as mg/l)

Chemical	Quantity (mg/l)			Analysis Method
	April	July	October	
sulphate	253	310	235	ASTM D516
sulphite	3.7	4	3.2	APHA 4500-SO_3
nitrate	224	250	234	APHA 4500-NO_3
nitrite	0.02	0.01	0.01	ASTM D1254
TDS	1637	1795	1648	APHA 2540 C
Mg	12	15	13	APHA 2340 C
Ca	25	22	19	APHA 2340 C
Na	510	537	525	APHA 3111 B

TABLE 4 : Biocide efficacy test results, (+): effective, (-): ineffective

Biocide concentration (ppm)	Sample date					
	April		July		October	
	GHB	SRB	GHB	SRB	GHB	SRB
10	-	-	-	-	-	-
20	+	+	-	+	+	+
30	+	+	+	+	+	+
40	+	+	+	+	+	+
50	+	+	+	+	+	+
75	+	+	+	+	+	+
100	+	+	+	+	+	+

TABLE 5 : Corrosion rate of water samples with and without biocide application measured by weight loss method

Water sample	Corrosion rate (mpy)	
	Without biocide	With biocide
April	3.5	1.7
July	15	5.3
October	4.1	2.5

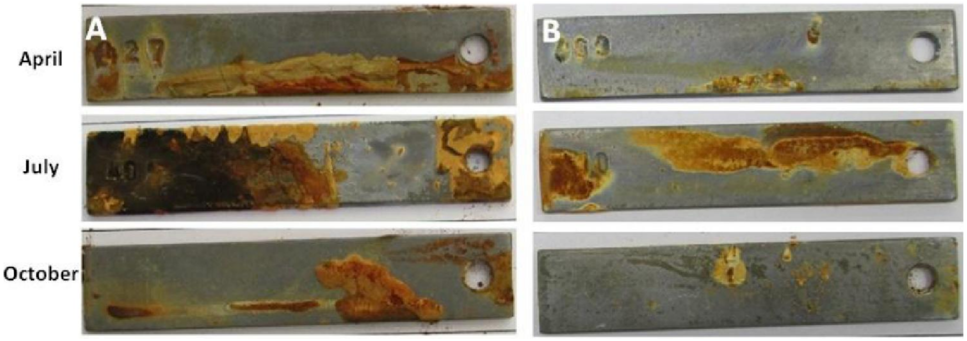

Figure 1 : The surface of carbon steel coupons before (A) and after (B) biocide application in different months

imidazoline-based biocide in such systems. Corrosion rate of treated water samples from April, July, and October were 51, 65, and 39% lower than untreated samples, respectively. Correlation of corrosion rate with bacterial count and its significant reduction after biocide application indicated active role of bacteria in corrosion of the studied cooling water system. Despite the active role of microorganisms in corrosion occurrence in the system, corrosion was observed on coupons even after proper biocide application. This indicates that in addition to MIC, there are other types of corrosion in water samples. Consequently, other chemicals such as corrosion inhibitors also should be used in order to minimize the corrosion rate. Figure1 shows the surface of carbon steel coupons before and after biocide application in different months.

Taken together, the results not only demonstrated the importance of microbiologically influenced corrosion in the studied cooling water system but also revealed the importance of monthly biocide optimization in a particular system.

REFERENCES

[1] J.D.Gu, T.E.Ford, R.Mitchell; Microbial degradation of materials; general process, In: Uhlig's Corrosion Handbook, 3rd Edition, R.Winston Revie (Ed); John Wiley & Sons Inc., New Jersy, 351-352 **(2011)**.

[2] K.Li, M.Whitûeld, K.J.Van Vliet, Corros Rev; **31**, 73–84 **(2013)**.

[3] B.J.Little, J.S.Lee; Microbiologically influenced corrosion, 1st Edition, R.Winston Revie (Ed); John Wiley & Sons Inc., New Jersy, **(2007)**.

[4] K.A.Zarasvand, V.R.Rai; Int Biodeterior Biodegr,

87, 66–74 **(2014)**.
[5] R.Javaherdashti; Anti Corros Method M, **46(3)**, 173–180 **(1999)**.
[6] H.M.Herro, R.D.Port; The Nalco guide to cooling water system failure analysis, 1st Edition, McGraw-Hill; Inc., New York, **(1993)**.
[7] P.Xu, Z.Xu, J.Wang, Y.Zhang, L.Zhang; J Water Resour Prot, **4**, 203-206 **(2012)**.
[8] S.G.Choudhary; Hydrocarb.Process, May, 91-102 **(1998)**.
[9] R.Aruliah, Y.P.Ting; ISRN Corrosion., Article ID 803219, http://dx.doi.org/10.1155/2014/803219, **(2014)**.
[10] A.Rochdi, O.Kassou, N.Dkhireche, R.Touir, M.El Bakri, M.E.Touhami, M.Sfaira, B.Mernari, B.Hammouti, Corros Sci., **80**, 442–452 **(2014)**.
[11] W.Su, Y.Tian, S.Peng; Appl.Surf.Sci., **315**, 95–1031 **(2014)**.
[12] M.R.Viera, P.S.Guiamet, M.F.L.de Mele, H.A.Videla; Int Biodeterior Biodegr, **44(4)**, 201–207 **(1999)**.
[13] E.Ilhan-Sungur, A.Cotuk; Environ Monit Assess, **104**, 211–219 **(2005)**.
[14] E.Ilhan-Sungur, A.Cotuk; Corros Sci., **52**, 161–171 **(2010)**.
[15] B.Minnoş, E.Ilhan-Sungur, A.Çotuk, N.D.Güngör, N.Cansever; Biofouling, **29(3)**, 223–235 **(2013)**.
[16] APHA 9060 A, Samples, In: Standard methods for the examination of water and wastewater, 21st Edition, American Public Health Association, Washington, **(2005)**.
[17] NACE Standard TM0194, Field monitoring of bacterial growth in oil and gas systems, National Association of Corrosion Engineers, Houston, **(2004)**.
[18] ASTM standard E415, Standard test method for analysis of carbon and low-alloy steel by spark atomic emission spectrometry, American Society for Testing and Materials, Pennsylvania, **(2008)**.
[19] ASTM standard E645, Standard practice for evaluation of microbicides used in cooling water systems, American Society for Testing and Materials, Pennsylvania, **(2007)**.
[20] E.Nebot, J.F.Casanueva, T.Casanueva, M.M.Fernandez-Baston, D.Sales; Appl.Therm.Eng., **26**, 1893–1900 **(2006)**.
[21] N.Wéry, V.Bru-Adan1, C.Minervini, J.P.Delgénes, L.Garrelly, J.J.Godon; Appl.Environ.Microbiol., **74(10)**, 3030-3037 **(2008)**.
[22] J.M.Akagi; Respiratory sulfate reduction, In: sulfate-reducing bacteria, 1st Edition, L.L.Barton (ed.), Plenum Press, New York, 89–111 **(1995)**.
[23] D.Enning, J.Garrelfs; Appl Environ Microbiol, **80(4)**, 1226-1236 **(2014)**.