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Research Article

ROLE OF SDS AS CORROSION INHIBITOR AND BIOCIDE IN POLYMERS - Zn^{2+} SYSTEM IN AQUEOUS SOLUTION

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ABSTRACT

The purpose of the present investigation is to (i) examine the influence the biocide on the inhibition efficiencies of polymer systems such as CMC and PVA with Zn2+ in chloride ion solution (ii) assess the biocidal efficiency of SDS in chloride ion solution in the presence and absence of the inhibitor systems. The corrosion rates of carbon steel in the presence and absence of the inhibitor systems such as CMC and PVA with Zn2+ and also in the presence and absence of the biocide–sodium dodecyl sulphate in aqueous chloride solution were determined. The biocidal efficiencies of the biocides in the presence and absence of the inhibitor formulations are also studied. The inhibitor formulation PVA–Zn2+ in the absence of SDS does not control the bacterial growth at all. Nevertheless, the addition of SDS completely kills the microbes and 100% biocidal efficiency is achieved. Even though SDS has biocidal effect with PVA + Zn2+ system, as the IE is drastically reduced on the addition of SDS, it is not suitable biocide for PVA + Zn2+ system. But the inhibitor formulation CMC–Zn2+ gives 42% biocidal efficiency in the absence of SDS. But the addition of SDS to this inhibitor formulation completely eradicates the microbes. Interestingly, the same formulation with SDS offers a maximum inhibition efficiency of 98%. Therefore CMC–SDS–Zn2+ system is ideal for cooling water system for the control corrosion as well as microbial growth.

Keywords: SDS, Corrosion inhibitor, Biocidal efficiency.

INTRODUCTION

Cooling water systems are extremely vulnerable to microbial contamination. Problems occur when microbes begin to proliferate and attach to system surfaces. Microbes can easily congest the system, restricting water flow and, ultimately, reduce heat exchange. The result is increased operating costs in the form of poor heat dissipation, overall system inefficiency, and system clean up, including any downtime that may be necessary. Corrosion can also result from unchecked microbial growth. The microbes produce products of metabolism that are corrosive in nature. The result is pitting and corrosion of metal components. To eliminate the threat of such potential problems and achieve optimum system efficiency, microbiological activity within a system must be properly controlled by the addition of suitable biocides. A biocide must successfully control a broad spectrum of microbial contamination, provide cost-effective performance and prove compatible with other system components, while at the same time meeting stringent environmental, health and safety standards. Most industries add inhibitors and biocides at the same point in cooling water systems. The interference between biocides and inhibitors were studied in detail and many researchers evaluated the role of biocides in corrosion in the presence of inhibitors [1]. Many studies have also been done for preparation of corrosion inhibitors having biocide properties. Once a biofilm forms, the local environment at the metal/biofilm interface undergoes drastic changes in terms of pH, dissolved oxygen content and concentration of the ionic species. Many studies are in progress with the development of new biodispersing, antifouling compositions for recirculating cooling water system [2]. Microbiologically influenced corrosion is emerging as a serious problem in cooling systems. Literature survey has exposed a number of biocides used along with corrosion inhibitors. Rajendran et al. [3,4] have studied the influence of CTAB on the corrosion inhibition of mild steel by ATMP-Zn^{2+} system, and also the biocidal efficiency of CTAB in the presence of various phosphonic- Zn^{2+} system and reported that CTAB acts as an excellent biocide as monomer and also as micelle. It is reported that most of the biofilms are sensitive to the detergent biocide SDS [5,6]. Iwalokun et al. [7] have suggested to use urea and SDS in the laboratory to reduce the risk of infection with virulent proteus strains. Richard et al. [8] have investigated the effect of the surfactants such as alcohol ethoxylates, amine ethoxylates, amine oxide and SDS on bacterial cell membranes using EPR spectroscopy.

The purpose of the present investigation is (i) to assess the biocidal efficiency of SDS in chloride ion solution in the presence and absence of the inhibitor systems. (ii) to examine the influence the biocide on the inhibition efficiency of inhibitor systems such as CMC–Zn2|+ and PVA–Zn2|+.

Carbon steel specimens (compositions 0.1% C, 0.026% S, 0.06% P, 0.4% Mn and balance Fe) of dimensions 1.0 × 4.0 × 0.2 cm were polished to mirror finish, degreased with trichloroethylene and used for mass-loss studies. Carbon steel specimens in duplicate were immersed in 100 ml of the solutions containing various concentrations of the inhibitor systems in the absence and presence of SDS for one day. The weight of the specimens before and after immersion were determined, using a ACCULAB Electronic top loading balance, with readability/sensitivity of 0.1 mg in 210 g range. The IE was then calculated.

Stock solutions of sodium chloride, carboxy methyl cellulose (CMC), poly vinyl alcohol (PVA) were prepared by dissolving 1 g of the respective compounds in double distilled water and made up to 100 ml. Zinc sulphate solution is prepared by dissolving 1.1 g in double distilled water and made up to 250 ml in a 250 ml standard measuring flask. Zobell medium was prepared by dissolving 5 g of peptone, 1 g of yeast extract, 0.1 g of potassium dihydrogen phosphate and 15 g of agar–agar in 1 litre of double distilled water. The medium was sterilized by applying 15 pounds per square inch for 15 minutes in an autoclave.

The biocidal efficiencies of SDS at various concentrations in the presence and absence of the inhibitor systems 1 (CMC–Zn^{2+}) and 2 (PVA–Zn^{2+}) were determined after immersing the specimens for one day in 120 ppm chloride solution. Polymer systems such as CMC–Zn^{2+} and PVA–Zn^{2+} formulations that offered the best corrosion inhibition efficiency were selected. After one day, 1 ml each of test solutions from the environments was pipetted out into sterile petri dishes each containing about 20 ml of the sterilized Zobell medium. The petri dishes were then kept in a sterilized environment inside the laminar flow system fabricated and supplied by CEERI-Pilani, for 48 h. The total viable heterotropic bacterial colonies were counted using a bacterial colony counter.

It is noted from Table 1 that increase in the concentration of Zn^{2+} alone, increases the IE for the corrosion of carbon steel in 120 ppm Cl^- ion solution and it is found that 100 ppm of Zn^{2+} offers 40% inhibition efficiency. It is also noted that CMC itself is a very poor inhibitor and 250 ppm of CMC gives a maximum of 6% IE. Perusal of the table reveals that a combination of Zn^{2+} and CMC shows a better IE. For example, 100 ppm of Zn^{2+} gives an IE of 40% and 250 ppm of CMC gives 6%, but their combination offers an IE of 97%, which is found to be the maximum IE offered by the system. This suggests the existence of synergistic effect between Zn^{2+} and CMC. The synergism may be due to the formation of complex between Zn^{2+} and CMC. Due to the complex formation the inhibitor molecules are readily transported from the bulk to the metal surface.

Table 2 points out that the IE of carbon steel immersed in Zn^{2+} increases with an increase in the concentration of Zn^{2+} ions and offers 40% IE for 100 ppm of Zn^{2+}. It is clear from the table that the IE of 50 ppm PVA is 16% and the IE is found to increase marginally with the increase in the concentration of PVA and reaches a maximum of 22%. However, perusal of Table 2 reveals that the combination of both shows a better IE. For example, carbon steel immersed in 300 ppm of PVA offers 22% IE and 75 ppm of Zn^{2+} solution gives 30% while the combination of 300 ppm of PVA and 75 ppm of Zn^{2+} gives 80%. This is found to be the maximum IE offered by the system. This clearly suggests that Zn^{2+} and PVA mutually enhance the inhibition efficiency of

Table 1: The corrosion rates [CR] of carbon steel immersed in 120 ppm chloride solution in the presence and absence of various concentrations of sodium salt of carboxy methyl cellulose (CMC) and Zn2+.

Zn^{2+} →	0		25		50		75		100	
CMC↓	CR (mdd)	IE (%)	CR (mdd)	IE (%)	CR (mdd)	IE (%)	CR (mdd)	IE (%)	CR (mdd)	IE (%)
0	39.00	--	31.61	19	28.85	26	27.32	30	23.44	40
50	40.13	-3	41.85	-7	28.12	28	24.49	37	19.02	51
100	38.53	1	40.91	-5	25.48	35	24.23	38	13.47	65
150	38.45	1	32.84	16	21.54	45	19.82	49	10.03	74
200	37.44	4	29.53	24	24.74	37	17.96	54	5.19	87
250	36.74	6	25.37	35	25.00	36	15.51	60	1.17	97
300	37.15	5	30.76	21	30.27	22	16.68	57	1.16	97

Table 2: The corrosion rates [CR] of carbon steel immersed in 120 ppm of chloride solution in the presence and absence of various concentrations of polyvinyl alcohol (PVA) and Zn2+.

Zn^{2+} →	0		25		50		75		100	
PVA ↓	CR (mdd)	IE (%)	CR (mdd)	IE (%)	CR (mdd)	IE (%)	CR (mdd)	IE (%)	CR (mdd)	IE (%)
0	39.00	--	31.61	19	28.85	26	27.32	30	23.44	40
50	32.95	16	26.52	32	21.72	44	19.23	51	22.0	44
100	32.41	17	24.45	37	19.77	49	17.32	56	19.00	51
150	32.33	17.	23.01	41	18.84	52	14.70	62	16.89	57
200	31.82	18.	20.59	47	16.30	58	11.60	70	14.70	62
250	30.58	22	17.90	54	14.08	64	9.09	77	12.40	68
300	30.34	22.	15.72	60	12.48	68	7.80	80	11.35	71

Table 3: The corrosion rates [CR] of carbon steel immersed in 120 ppm chloride solution containing CMC + Zn2+ (250 ppm of sodium salt of carboxy methyl cellulose and 100 ppm of Zn2+) and also PVA + Zn2+ (300 ppm of PVA and 75 ppm of Zn2+) in the presence and absence of the biocide sodium dodecyl sulphate (SDS) and inhibition efficiencies [IE]

SDS (ppm)	CMC + Zn^{2+} Zn^{2+} = 100 ppm CMC = 250 ppm,		PVA + Zn^{2+} Zn^{2+} = 75 ppm PVA = 300 ppm	
	CR (mdd)	IE (%)	CR (mdd)	IE (%)
0	1.17	97	7.80	80
50	8.40	78	19.49	50
100	3.80	90	15.99	59
150	0.78	98	13.17	66
200	5.70	85	18.72	52
250	5.80	85	22.00	44
300	5.90	85	21.84	44

Table 4: Biocidal efficiencies of SDS in 120 ppm of chloride ion solution

SDS	Colony forming units/ml	Biocidal efficiency (%)
0	1474	--
10	1200	19
50	3	99.80
100	0	100
300	0	100

Table 5: Biocidal efficiencies of SDS in 120 ppm of chloride ion solution in the presence and absence of the inhibitor system.

SDS (ppm)	Inhibitor formulation-1 CMC + Zn^{2+} Zn^{2+} = 100 ppm, CMC= 250 ppm		Inhibitor formulation-2 PVA + Zn^{2+} Zn^{2+} = 75 ppm PVA = 300 ppm	
	Colony forming (units/ml)	Biocidal efficiency (%)	Colony forming (units/ml)	Biocidal efficiency (%)
0	854	42	3942	-167
25	847	43	1200	18.59
50	1	99.93	4	99.73
100	1	99.93	1	99.93
150	0	100	0	100

each other in controlling the corrosion of carbon steel.

Table 3 shows that IE of the inhibitor formulation 1 (CMC + Zn2+) slightly decreases on the addition of 50 ppm of SDS. However, further addition of SDS increases the IE of the system and at 150 ppm of SDS, a maximum IE of 98% is achieved. The decrease in IE at lower concentration of SDS may be due to the competition between SDS and CMC for Zn2+ ions. As CMC + Zn2+ is a better inhibitor formulation than SDS + Zn2+ that is evident from Table 1, the IE of the CMC + Zn2+ system decreases for want of Zn2+ ions. However, at higher concentration of SDS, synergistic behaviour is noticed. This may be due to the co-participation of both CMC and SDS in complex formation with Zn2+ that enhances the IE. Hence it is concluded that the lower concentration of SDS exhibits antagonistic behavior and higher concentrations of SDS shows synergistic behavior with CMC + Zn2+ system. For the formulation 2 (PVA-Zn2+ system) the addition of SDS decreases the IE tremendously. This proves that both SDS and PVA mutually exhibit antagonistic effect with each other.

The biocidal efficiencies of SDS in the presence and absence of the inhibitor formulations 1 and 2 in chloride ion solution after suspending the metal pieces for 24 hours are given in Tables 4 and 5.

The inhibitor formulation 1 gives 42% BE in the absence of SDS. The formulation consisting of 250 ppm of CMC, 100 ppm of Zn2+ ions, and 150 ppm of SDS gives 100% BE. Therefore, a minimum of 150 ppm of SDS is required for the complete eradication of microbes. Interestingly, the same formulation offers a maximum inhibition efficiency of 98%. As the combination of 250 ppm of CMC, 100 ppm of Zn2+ions and 150 ppm of SDS offer 100% BE and 98% IE, it is ideal to use this combination for cooling water system to control corrosion as well as microbial growth. The inhibitor formulation-2 in the absence of SDS does not control the bacterial growth at all and on adding 25 ppm of SDS nearly 19% BE is achieved, Nevertheless, the addition of 150 ppm of SDS completely kills the microbes and 100% BE is achieved. The inhibitor formulation consisting of 300 ppm of PVA, 75 ppm of Zn2+ ions, and 150 ppm of SDS is required for the complete eradication of microbes. Even though SDS has biocidal effect with PVA + Zn2+ system, the IE is drastically reducedon the addition of SDS. Hence SDS is not a suitable for PVA + Zn2+ system.

CONCLUSION

The inhibitor formulation PVA–Zn2+ in the absence of SDS does not control the bacterial growth at all. Nevertheless, the addition of SDS completely kills the microbes and 100%

biocidal efficiency is achieved. Even though SDS has biocidal effect with PVA + Zn2+ system, as the IE is drastically reduced on the addition of SDS, it is not suitable biocide for PVA + Zn2+ system. But the inhibitor formulation CMC- Zn2+ gives 42% biocidal efficiency in the absence of SDS. But the addition of SDS to this inhibitor formulation completely eradicates the microbes. Interestingly, the same formulation with SDS offers a maximum inhibition efficiency of 98%. Therefore CMC-SDS-Zn2+ system is ideal for cooling water system for the control corrosion as well as microbial growth.

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