

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 6, June 2019

Biocidal Inhibition Efficiency of Surfactants on Low Carbon Steel in Neutral Chloride Medium

Dr. Nirmala Baby¹, Dr. K.N. Manonmani², P. Aravindan³

Assistant Professor in Chemistry, Department of Science and Humanities, Christian College of Engineering and
Technology, Oddanchatram, Tamilnadu, India^{1,3}

Associate Professor of Chemistry, Department of Science and Humanities, Sri Subramaniya College of Engineering
and Technology, Palani, Tamilnadu, India²

ABSTRACT: Corrosion is also an outcome of uninhibited microbial escalation. Cooling water structures are tremendously susceptible to microbial contamination. In Microbial Induced Corrosion (MIC), the micro-organisms like bacteria, fungi and algae coalesce with organic compounds to form gelatinous bio films on the surface of the aqueous corrosive medium and then the microbes in that layer have a tendency to liberate metabolic products like CO₂, H₂O and organic acids which are corrosive in nature. Surfactants which are amphiphilic are used as corrosion inhibitors against corrosion of mild steel. This study is apprehensive with the progress of new eco-friendly inhibitor system which functions economically in the presence of biocides for the corrosion control of low carbon steel in cooling water systems. Among the three surfactants used in this study, CTAB is the best biocide for controlling the microbial corrosion of mild steel in the presence of 2-amino 4, 6- dimethyl pyrimidine (ADMP) and Zn²⁺ in neutral chloride medium.

KEYWORDS: Surfactants, carbon steel, microbial corrosion, biocidal efficiency, cooling water systems.

I. INTRODUCTION

A good number of the industries are including inhibitors and biocides at a similar point in cooling water frameworks. The intrusion between biocides and inhibitors are examined and numerous researchers evaluated the task of biocides in the presence of inhibitors [1]. These days, innovative bio-dispersing antifouling compositions are sprouting for the recirculation of cooling water systems [2]. The bio degradation that occurs in the diesel/water boundary in petroleum product pipelines is contemplated by Muthukumar et al [3]. Many reviews of microbial induced corrosion (MIC) have been studied using the biocides and corrosion inhibitors [4].

Surfactants have been used as corrosion inhibitors [5] or in hodgepodge with other compounds like trans-cinnamaldehyde [6] or 1-phenyl-2-propyne-1-ol [6] to get better performance as inhibitors. Relative investigations of the efficacy of dissimilar organic surfactants of inhibiting carbon steel corrosion in a natural geothermal milieu have been reported [7]. Non-ionic surfactants are found to have a discernible inhibiting efficiency on iron in acidic media by adsorption onto its surface [8]. Effects of metallic cations on corrosion inhibition by sodium dodecyl sulphate, an anionic surfactant for low carbon steel in hydrochloric acid have been accounted [9].

Sodium dodecyl sulphate (SDS or NaDS), sodium laurilsulfate or sodium lauryl sulfate (SLS) is an anionic surfactant utilized as a part of many cleaning and sanitation items. It is derived as a part of blends created from economical coconut and palm oils. SDS is a typical segment of numerous household cleaning, individual cleanliness and restorative, pharmaceutical, sustenance items, and additionally of modern and business cleaning and item definitions.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 6, June 2019

The impact of a cationic surfactant N-cetyl-N, N, N-trimethyl ammonium bromide (CTAB) on the calcium gluconate-Zn²⁺ system [10] in managing corrosion of carbon steel in aqueous surroundings has been researched. CTAB is employed as an influential germicide specialist against microscopic organisms and parasites. It is utilized as a buffer for the extraction of DNA. It has been broadly employed as a fraction of amalgamation of gold nanoparticles, mesoporous silica nanoparticles and in hair molding items. CTAB is used as an advancing anticancer operator for head and neck growth. CTAB has risen as the favored decision for organic utilize in light of the fact that it keeps up the uprightness of encouraged DNA amid isolation.

CPC (Cetylpyridinium Chloride) is a cationic surfactant with solid bactericidal properties and imperviousness to growths. It is utilized as an antibacterial specialist as a part of toothpaste, mouthwash, pre-saturated wipe, throat tablet and the other capsule which altogether needed a high wellbeing. Also, it finds use in an extensive variety of fields, for example, pharmaceuticals, beauty care products and toiletries. Lin et.al [11] used a quaternary ammonium salt and a cationic surfactant as a biocide in personal cleanliness products.

The present study compares the biocidal efficiencies of surfactants in the presence of inhibitor system.

II. MATERIALS AND METHODS

2.1 Preparation of mild steel coupons

For biocidal studies, mild steel coupons of dimensions 1cm × 4 cm × 0.2 cm with a small hole near the upper edge was cleaned mechanically with different evaluations of emery papers from the coarser grade to the finer grade. The cleaned mild steel coupons are washed with distilled water, degreased with acetone, air dried and stored in a dessicator.

2.2 Preparation of Nutrient Agar

28 g of nutrient agar powder is dissolved in 1 litre of distilled water and heated. The dissolved mixture is autoclaved at 121 °C for 15 minutes and cooled. The nutrient agar is poured into plates left on the sterile surface until the agar has solidified. The lid of each petri dish is replaced and stored in a refrigerator.

2.3 Inhibitor solution

A stock solution of the inhibitor 2- amino-4, 6- dimethyl pyrimidine (ADMP) is prepared by dissolving exactly 1g of ADMP in double distilled water and made upto 1000 ml in a standard measuring flask. Hundred fold dilution yields 10 ppm of the solution.

2.4 Calculation of corrosion parameters

The corrosion rate (CR) [12] was calculated by measuring the loss in mass of coupon of known area to a particular environment for specified period using the relation

$$\text{Corrosion rate (CR)} = \frac{\text{Loss in mass (mg)}}{\left(\frac{\text{Surface area of the coupon in dm}^2}{\text{}} \right) \times (\text{Period of Immersion in days})} \text{ mdd}$$

The inhibition efficiency [13] of the inhibitor was calculated using the relation

$$\text{Inhibition efficiency (IE\%)} = \frac{\left(\text{Mass loss in the absence of the inhibitor} \right) - \left(\text{Mass loss in the presence of the inhibitor} \right)}{\text{Mass loss in the absence of the inhibitor}} \times 100$$

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 6, June 2019

2.5 Determination of Biocidal Efficiency

Biocidal efficiency was determined by using CTAB, CPC and SDS surfactants. The formulation containing the inhibitor and zinc ions that offered the best corrosion inhibition efficiency was chosen. The biocidal efficiency of surfactants in the absence and the presence of these formulations are determined. Different concentrations of the various surfactants are added to the inhibitor system. Polished and degreased mild steel coupons are suspended in the sample solutions for 96 hours. After 96 hours, one ml each of test solutions from various environments was pipetted out into sterile petri dishes containing about 20 ml of the sterilized nutrient agar medium kept in a sterilized environment inside the laminar flow system for 48 hours. The total bacterial colonies formed for each ml of the solution (CFU/ml) are counted using bacterial colony counter. The biocidal inhibition efficiency for various concentrations of surfactants is determined similar to mass loss method calculations.

III. RESULTS AND DISCUSSION

3.1 Biocidal efficiency of CTAB, CPC, SDS on mild steel in aqueous medium

The twofold formulation containing 150 ppm of ADMP and 80 ppm of Zn^{2+} ions offered 88.4% IE to the mild steel coupon immersed in 60 ppm of Cl^- ions for a period of 12 hours by mass loss measurements and the CR, IE of the biocides CTAB, CPC and SDS are listed in Table 1.

Table 1 Corrosion rates of mild steel in ADMP- Zn^{2+} system in neutral chloride media for various concentrations of surfactants
Immersion Period: 12 Hrs

Conc.of binary Inhibitor system	Conc.of Biocides (ppm)	CTAB		CPC		SDS	
		CR (mdd)	IE (%)	CR (mdd)	IE (%)	CR (mdd)	IE (%)
Blank	0	26	-	26	-	26	-
150 ppm ADMP + 80 ppm Zn^{2+}	0	3	88.4	3	88.4	3	88.4
	50	5	80.7	7	73.0	5	80.7
	100	2	92.3	5	80.7	8	69.2
	150	2.5	90.3	7.5	71.1	10	61.5
	200	3.5	86.5	9	65.3	11.5	55.7
	250	4	84.6	11	57.6	16	38.4
	300	4.5	82.6	15	42.3	19	26.9

mdd-milligram/decimeter²/day

Inspection of Table 1 reveals that the inhibition efficiency (IE) increases with concentration, interestingly at 100 ppm of CTAB and CPC shows maximum IE of 92.3 % and 80.7 % respectively. However for SDS at low concentration of 50 ppm itself maximum IE of 80.7 % is observed. After 50, 100 ppm for SDS and CTAB, CPC, IE decreases with concentration. Hence 50 ppm of anionic surfactant (SDS) and 100 ppm of cationic surfactants (CTAB, CPC) have effectively destroyed [14] corrosion causing bacteria/ micro-organisms in aqueous medium.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 6, June 2019

The interference of biocides with ADMP-Zn²⁺ inhibitors form complexes with iron which are effectively adsorbed on the mild steel surface by blocking the pits and corroding spots caused by aggressive chloride ions and microbes. Therefore maximum inhibition efficiency on mild steel in presence of the inhibitor and biocides is noticed in this study and the corresponding concentrations of surfactants are selected for further biocidal studies. The plot of IE and CR as a function of concentration of all the biocides is depicted in Figs. 1 and 2.

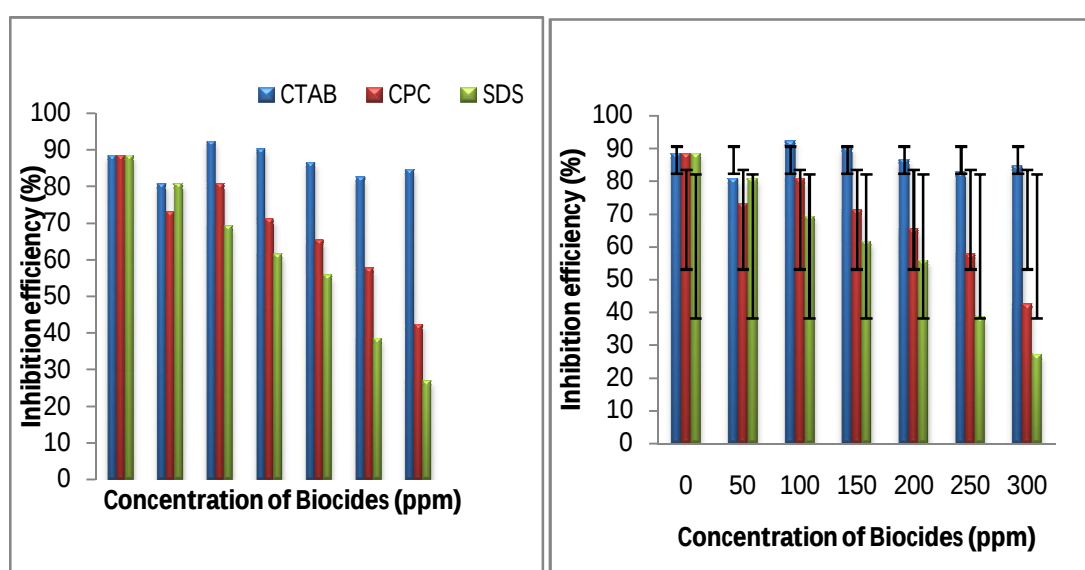


Fig.1 Concentration of Biocides as a function of Inhibition efficiency on ADMP-Zn²⁺ system and error bar diagram

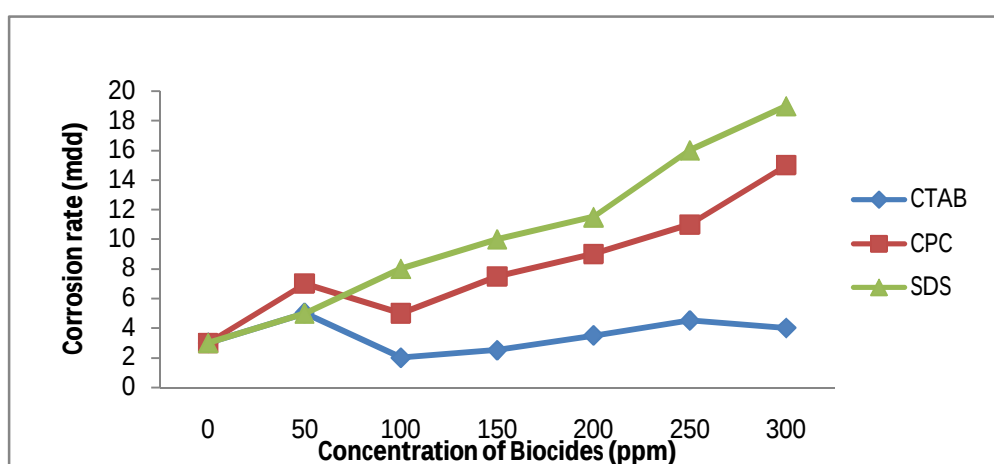


Fig. 2 Concentration of Biocides as a function of Corrosion rate on ADMP-Zn²⁺ system

3.2 Biocidal efficiency of CTAB, CPC, SDS on mild steel in aqueous medium

The biocidal efficiency (BE) of CTAB[15], CPC [11] and SDS [16] in the absence and presence of ADMP-Zn²⁺ system after immersing the metal coupon for 12 hours is studied by using nutrient agar medium and the data are tabulated in Table 2, 3 and 4 respectively. The visuals of the bacterial colonies formed in the corrosive medium in the absence and presence of the inhibitor system along with the surfactants are shown in Fig 3, 4 and 5 respectively.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 6, June 2019

It is noticed from the Table 2 that in the absence of binary inhibitor ADMP-Zn²⁺ formulation 100ppm of CTAB showed 100% BE individually.

Table 2 Biocidal Efficiencies of CTAB in the presence and absence of ADMP-Zn²⁺ system in neutral aqueous medium containing 60 ppm of Cl⁻ ions

Concentration of ADMP (ppm)	Concentration of Zn ²⁺ (ppm)	Concentration of CTAB (ppm)	Colony Forming Units/ml	Biocidal Efficiency (%)
0	0	0	143	-
0	0	10	11	92.3
0	0	50	1	99.3
0	0	100	0	100
150	80	0	6	95.8
150	80	10	5	96.5
150	80	50	4	97.2
150	80	100	0	100
150	80	150	0	100

Similarly the same concentration of CTAB with 150 ppm ADMP, 80 ppm Zn²⁺ offered 100% BE. But in the absence of CTAB, the ADMP-Zn²⁺ system offers only 95.8% BE. This is due to the anti inhibition ability of the inhibitor and the biocidal ability of CTAB. The ternary formulation consisting of CTAB- ADMP-Zn²⁺ system shown in Fig. 3(e) contains no colony forming units which may cause microbial corrosion.

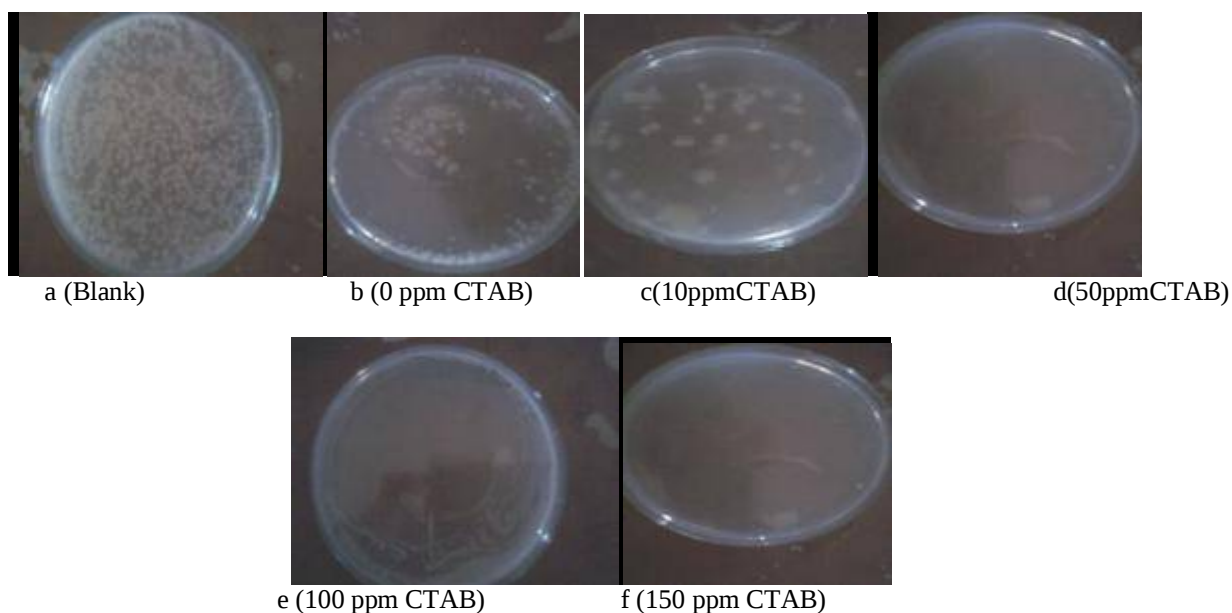


Fig. 3 Bacterial colonies formed in the presence of CTAB

The analysis of Table 3 showed that in the absence of the binary inhibitor formulation, 150 ppm of CPC showed 100% BE and in the absence of CPC, the ADMP-Zn²⁺ system offered 90.2% BE.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 6, June 2019

Table 3 Biocidal Efficiencies of CPC in the presence and absence of ADMP-Zn²⁺ in neutral aqueous medium containing 60 ppm of Cl⁻ ions

Concentration of ADMP (ppm)	Concentration of Zn ²⁺ (ppm)	Concentration of CPC (ppm)	Colony Forming Units/ml	Biocidal Efficiency (%)
0	0	0	143	-
0	0	10	53	62.9
0	0	50	17	88.1
0	0	100	3	97.9
0	0	150	0	100
150	80	0	14	90.2
150	80	10	8	94.4
150	80	50	6	95.8
150	80	100	2	98.6
150	80	150	0	100
150	80	200	0	100

When CPC is increased in small amounts, the BE also increased and the total number of colony forming units per ml also decreased. The ternary formulation consisting of 150ppm of ADMP, 80 ppm of Zn²⁺ and 150 ppm of CPC showed 100% BE which is evidenced by the absence of colony forming unit as shown in Fig 4 (f).

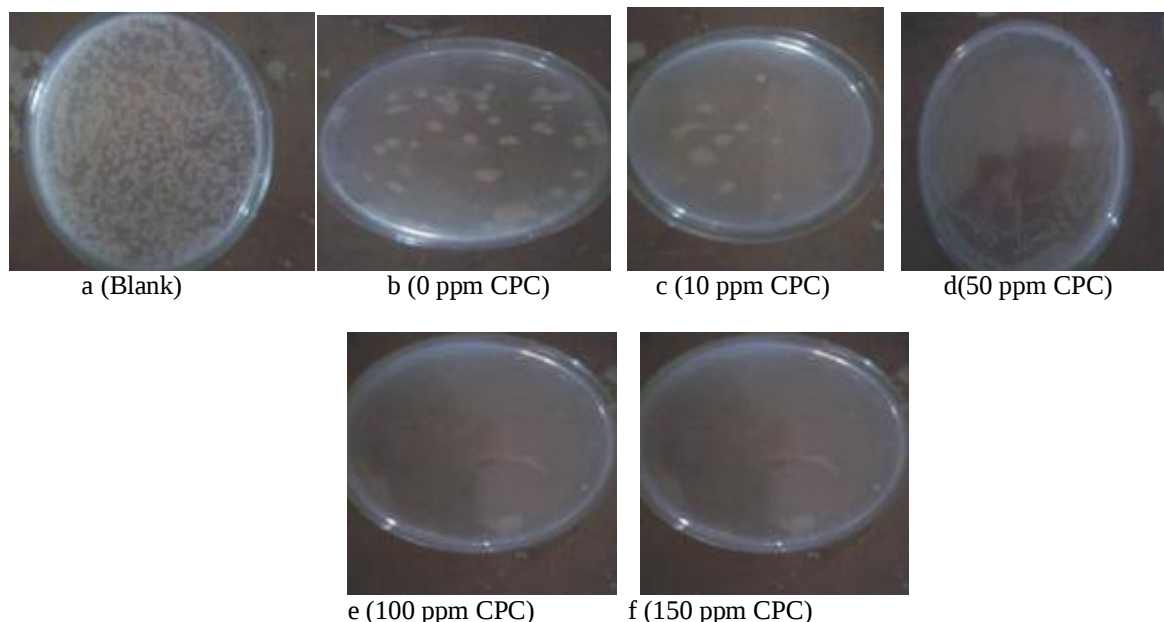


Fig. 4 Bacterial colonies formed in the presence of CPC

From Table 4 it is analyzed that 150 ppm of SDS alone showed 100% BE and the number of bacterial colony forming unit is zero.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 6, June 2019

Table 4 Biocidal Efficiencies of SDS in the presence and absence of ADMP-Zn²⁺ system in neutral aqueous medium containing 60 ppm of Cl⁻ ions

Concentration of ADMP (ppm)	Concentration of Zn ²⁺ (ppm)	Concentration of SDS (ppm)	Colony Forming Units/ml	Biocidal Efficiency (%)
0	0	0	143	-
0	0	10	45	68.5
0	0	50	22	84.6
0	0	100	9	93.7
0	0	150	3	97.9
0	0	200	0	100
150	80	0	13	90.9
150	80	10	11	92.3
150	80	50	9	93.7
150	80	100	5	96.5
150	80	150	2	98.6
150	80	200	0	100
150	80	300	0	100

The absence of microbial colony forming units is visualized in Fig. 5(f). The inhibitive tendency of 150 ppm of ADMP- 80 ppm of Zn²⁺ system is enhanced by the addition of 150 ppm of the biocide SDS which offers 100% BE is due to the killing of bio-corrosion inducing micro-organisms in aqueous medium.

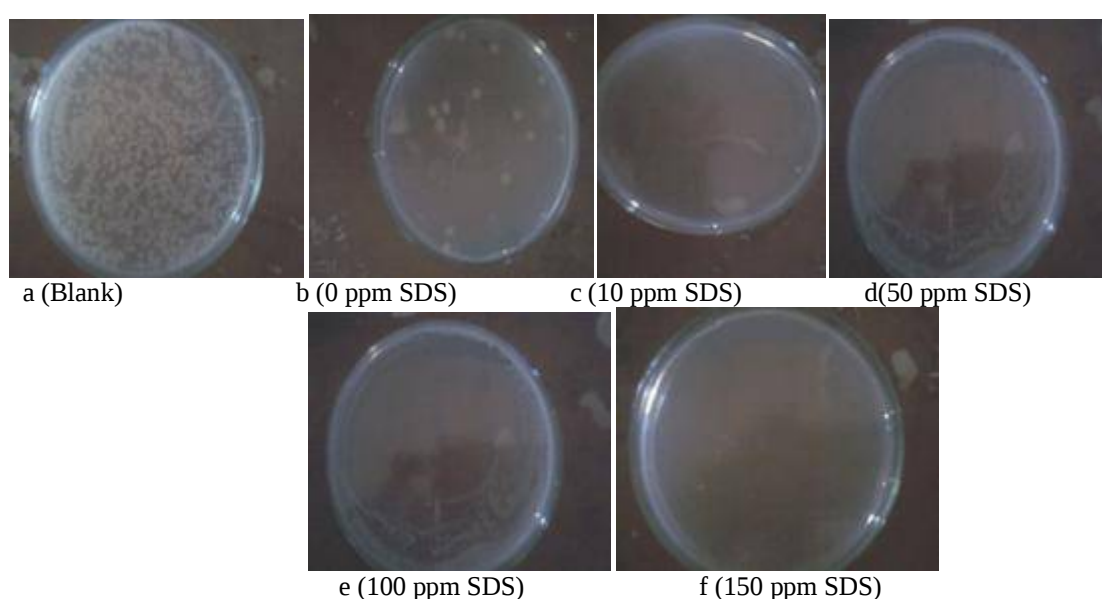


Fig. 5 Bacterial colonies formed in the presence of SDS

The number of Colony Forming Units /ml (CFU/ml) as a function of the concentration of the three biocides namely CTAB, CPC and SDS is depicted in Fig. 6.

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 8, Issue 6, June 2019

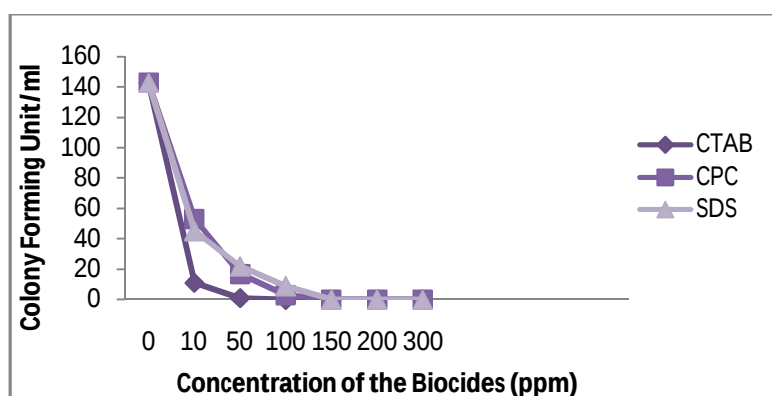


Fig. 6 Number of colony forming units as a function of concentration

IV. CONCLUSION

The comparative examination of the biocidal ability of CTAB, CPC and SDS illustrates the increasing order of IE as follows: SDS < CPC < CTAB. The lowest concentration of CTAB (50 ppm) shows the maximum IE of 92.3 %. Hence it is concluded that among the three biocides, CTAB is the best biocide for controlling the microbial corrosion of mild steel in the presence of ADMP and Zn^{2+} in neutral chloride medium. However all the three biocides presents 100% biocidal efficiency as reported by earlier researchers [19] and thus these biocides may be applied as excellent promising biocides in cooling water systems to control MIC.

REFERENCES

- [1] George, R.P., Muraleedaran, P., Parvathavarthini, N., Khatak, H. S., Newman, R. C., "Microbial Corrosion", *Eur. Fed. Corros. Publ.*, Vol. 29, pp. 116 – 139, 2000.
- [2] Georgescu, O. D, Niculescu, M. M, Stoica, M., Tepor, A, Romanian Patent, Vol.114, p.724,1999.
- [3] Muthukumar. N., Maruthamuthu. S., Ilangoan, A., Palaniswamy. N., "Impact of micelles on the biocidal efficiency in a diesel–water interface", *Surface and interface analysis*, Vol. 39, pp. 533 – 541, 2007.
- [4] Meena. B. V., Noreen Anthony, Mangayarkarasi. K, Jayaram. P, Rajendran. S., Proc. Of 10th National Congress on Corr. Control, Madurai, organized by NCC of India, CECRI, 6 – 8 Sep (2000), pp. 241 – 247.
- [5] Abdel Fattal, A.A., Atia, K.M., Ahemed, F.S., Roushady, M.I., "Evaluation of some polyoxyethylene adducts as corrosion inhibitors for mild steel" *Corros. Prev. Control*, Vol. 33, 67-69, 1986.
- [6] Growcock, F.B., Lopp, N.R., Jasinski, R., "Corrosion Protection of Oilfield Steel with 1-Phenyl-2-Propyn-1-Ol", *J. Electrochem. Soc.*, Vol. 135, 823-827, 1988.
- [7] Amalhay, M., Ignatradis, I., Proc. 8th Europ. Symp. on Corros Inhibitors, Ferrara, Italy, pp.135, 1995..
- [8] Jian, C.J., Shon C.J., Proc.6th Europ. Symp. on Corros. Inhibitors, Ferrara, Italy, p.257,1985.
- [9] Mu, G.N., Zhao, T.P., Liu, M., Gu, T., "Effect of Metallic Cations on Corrosion Inhibition of an Anionic Surfactant for Mild Steel", *Corrosion*, Vol. 2, pp.853-856,1996.
- [10] Rajendren, S., Apparao, B.V., Palaniswamy, N., "Corrosion inhibition by phosphonic acid–Zn²⁺ systems for mild steel in chloride medium.", *Anti-Corros. Methods Mater.*, 47, 11pp. 359-365,2000.
- [11] Lin, G.H.Y., Voss, K.A., Davidson, T.J., "Acute inhalation toxicity of cetylpyridinium chloride", *Food and Chemical Toxicology*, Vol. 29(12), pp. 851-854, 1991.
- [12] Dharmalingam, V., Arockia Sahayaraj, P., John Amalraj, A., Angelin Prema, A., "Poly(Acrylic Acid) and Potassium Sodium Tartrate as Effective Corrosion Inhibitors for Mild Steel in Aqueous Environment", *J. of Advanced Electrochemistry*, Vol. 2(1), pp. 37–41, 2016.
- [13] Loto, C.A., "Inhibition effect of Tea (Camellia Sinensis) extract on the corrosion of mild steel in dilute sulphuric acid", *J. of Material & Environmental science*, Vol. 2(4), pp. 335-344, 2011.
- [14] Ramesh, S., Rajeswari, S., Maruthamuthu, S., "Effect of inhibitors and biocide on corrosion control of mild steel in natural aqueous environment", *Materials Letters*, Vol. 57, pp. 4547 – 4554, 2003.
- [15] Denyer, S.P., "Mechanisms of action of biocides", *Int. Biodeterioration*, Vol. 26, p. 8, 19909.
- [16] Dawies, G.G., Parsek, M.R., Pearson, J.P., "The Involvement of Cell-to-Cell Signals in the Development of a Bacterial Biofilm" *Science*, Vol. 280, 295-298,1998.
- [17] Santana Rodriguez, J.J., Santana Hernandez, F.J., Gonzalez Gonzalez, J.E., "XRD and SEM studies of the layer of corrosion products for carbon steel in various different environments in the province of Las Palmas (The Canary Islands, Spain)", *Corros. Sci.*, Vol. 44, pp. 2425-2438, 2002.