Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2021, 8(9):89-94**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Investigation on Microbiologically influenced corrosion on Mild steel inhibited by *Trachyspermum ammi* in Cooling Tower Water

Sharmil Suganya. R[1]*, Stanelybritto Maria Arul Francis[2], T. Venugopal[3]

[1*]Assistant Professor (Bio Engg), Government College of Engineering, Salem – 11, TN
[2]Research Scholar (Chemistry), Government College of Engineering, Salem – 11, TN, India
[3]Assistant Professor (Chemistry), Government College of Engineering, Salem – 11, TN, India
[1*]sweetsharmil@gmail.com

Abstract In this work, Mild steel (MS) was investigated with microbial corrosion by two microorganisms: *Staphylococcus aureus (S. aureus)* and *Bacillus subtilis (B. subtilis*) in Cooling Tower Water (CTW) and is inhibited by a plant extract from *Trachyspermum ammi* for three weeks**.** Every week, weight loss (WL) of MS was examined**.** In the microbial system, thick biofilm was developed and WL increased every week gradually. In the presence of green inhibitor, WL was decreased significantly. This plant inhibitor was found to show more than 60% inhibition efficiency at 30 µL concentration. Electrochemical Impedence studies (EIS), Scanning Electron Microscopic analysis (SEM) images showed biofilm development in the microbial system and its prevention in the inhibitor system. Erythritol, 3-(Methylthio)-1-propanol, Methanamine, N-methoxy were the constituents found in the green inhibitor confirmed by Gas Chormatograpy–Mass spectrometric (GC-MS) analysis which might have been prevented the formation of biofilm to reduce corrosion.

Keywords Microbial corrosion, Plant inhibitor, Electrochemical Studies, Scanning Electron Microscopic, X-ray diffraction analysis

1. Introduction

CTW was obtained from Mettur Thermal Power station for this study. Generally, microbes can be found everywhere around us. MS used in CTW could be attacked by microbes and cause corrosion. This corrosion would lead to the damage of the metals, spread of microbes, human health problems and economic issues. In this study, the naturally obtained, inexpensive plant extract (TA) was extracted by a simple method, soxhlet apparatus and used as green inhibitor. *S. aureus* and *B. subtilis* were innoculated in CTW system containing MS and extract from TA was used to find the inhibition of microbial corrosion. Scanning the review of Literature, many reports and studies are there in the field of biocorrosion but finding a suitable inhibitor for a particular biocorrosion is a challenge. In this paper, a suitable inhibitor is found.

2. Review of Literature

Table 1: Comparison of previous papers

Year	Author	Plant extract	Medium
2009	Ostovari *et al*	*Henna*	HCl
2013	Raja *et al*	*Neolamarckia cadamba*	HCl
2014	P. Slepski *et al*	*Mollasses*	HCl
2014	Kumar *et al*	*Pterolobium hexapetalum and Celosia argentea*	Industrial water
2015	Tuaweri *et al*	*Neem*	Salty water
2016	Singh *et al*	*Aloe vera*	HCl

In the above literature papers, plant extracts were shown to be effective corrosion inhibitors for steel and other metal corrosion with good inhibition efficiency proved in WL and EIS methods. Moreover, it was noticed that increasing green inhibitor concentrations led to increasing inhibition efficiency.

3. Materials and Methods

CTW from Mettur thermal power station, MS coupons of 6 cm x 1 cm and 1 cm^2 were exposed in WL and EIS analysis. TA seeds were obtained from the market, grounded to fine powder and extracted using Soxhlet apparatus.

For Microbial corrosion and EIS analysis, Triplicates of Control systems and plant inhibitor system (separately for each microbes) were used. A system containing CTW, MS, Nutrient Broth (NB) medium and *S. aureus, B. subtilis* each microbes in separate conical flasks was the control system. A system containing CTW, MS, Nutrient Broth (NB) medium and *S. aureus, B. subtilis* each microbes in separate conical flasks, innoculated with TA was the plant inhibitor system.

The antibacterial assay was examined using 2 gram – positive bacterial culture. Well diffusion method was used to evaluate minimum inhibitory concentration of plant extract. Bacterial culture was spread on the sterilized agar medium in petri plates, then wells were made into the medium and filled with TA of the different concentrations. The plates were incubated for one day at 37 ºC. After 24 hours, the zone of inhibition was measured.

4. Results and Discussion

4.1. Minimum Inhibitory Concentration

On the Nutrient agar medium, both microbes showed clear zone of inhibition. On the plates bearing agar medium swapped with *S. aureus*, the diameters of zone of inhibition were measured as 11, 13, 11, 12, 13 mm for negative, positive controls, 10, 30 and 50 ppm of inhibitor respectively. On the plates bearing agar medium swapped with *B. subtilis*, the diameters of zone of inhibition were measured as 10, 11, 10, 11, 12 mm for negative, positive controls, 10, 30 and 50 ppm of inhibitor respectively. TA showed inhibition of microbial at 30 µL itself whose zone of inhibition was measured as 11 mm dia on an average.

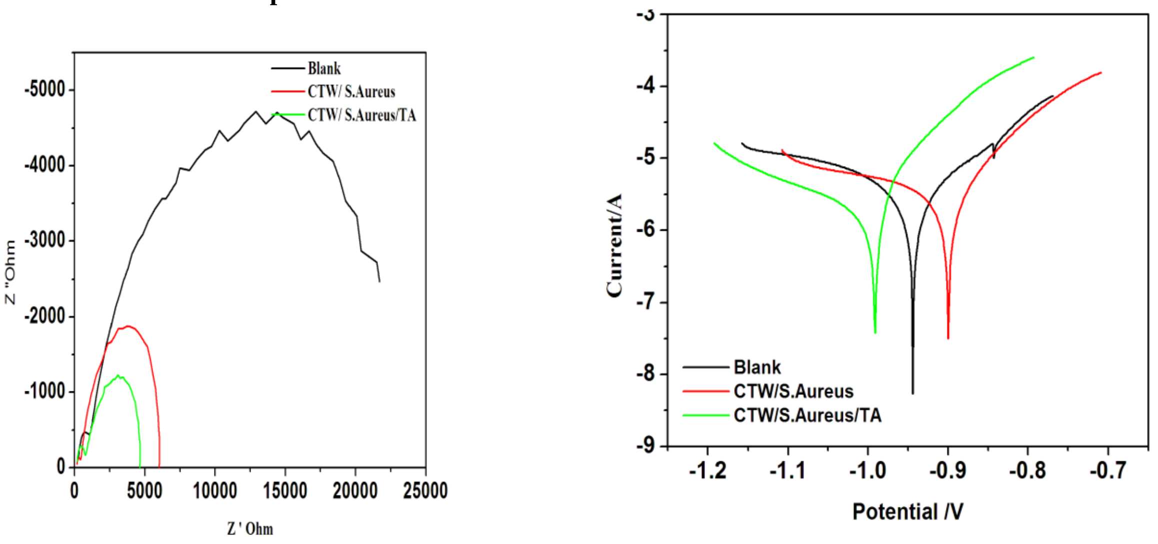
4.2. Weight Loss Method

The mean weight loss of the blank system containing *S. aureus* was 0.078, 0.0803, 0.0897 g for weeks 1, 2, 3 respectively. The corrosion rates were 16.63, 17.12, 19.12 mm/year respectively. This showed that the weight loss and the corrosion rate of the blank system increased slowly every week due to the biofilm development on the MS. The mean weight loss of the inhibitor system containing *S. aureus* with 30 ppm of TA was 0.0304, 0.0316, 0.0326 g for weeks 1, 2, 3 respectively. The corrosion rates were 6.48, 6.73, 6.95 mm/year respectively. The inhibition efficiencies were 61, 61, 64 % respectively. This showed that there was reduction in the corrosion rate than the blank system.

In the same way, the mean weight loss of the blank system containing *B. subtilis* was 0.0832, 0.0848, 0.0852 g for weeks 1, 2, 3 respectively. The corrosion rates were 17.73, 18.08, 18.16 mm/year respectively. This also showed that the weight loss and the corrosion rate of the blank system increased slowly every week due to the biofilm development on the MS. The mean weight loss of the inhibitor system containing *B. subtilis* with 30 ppm of TA was 0.0327, 0.0365, 0.0377 g for weeks 1, 2, 3 respectively. The corrosion rates were 6.97, 7.78, 8.03 mm/year respectively. The inhibition efficiencies were 61, 61, 60 % respectively. This showed that there was reduction in the corrosion rate than the blank system.

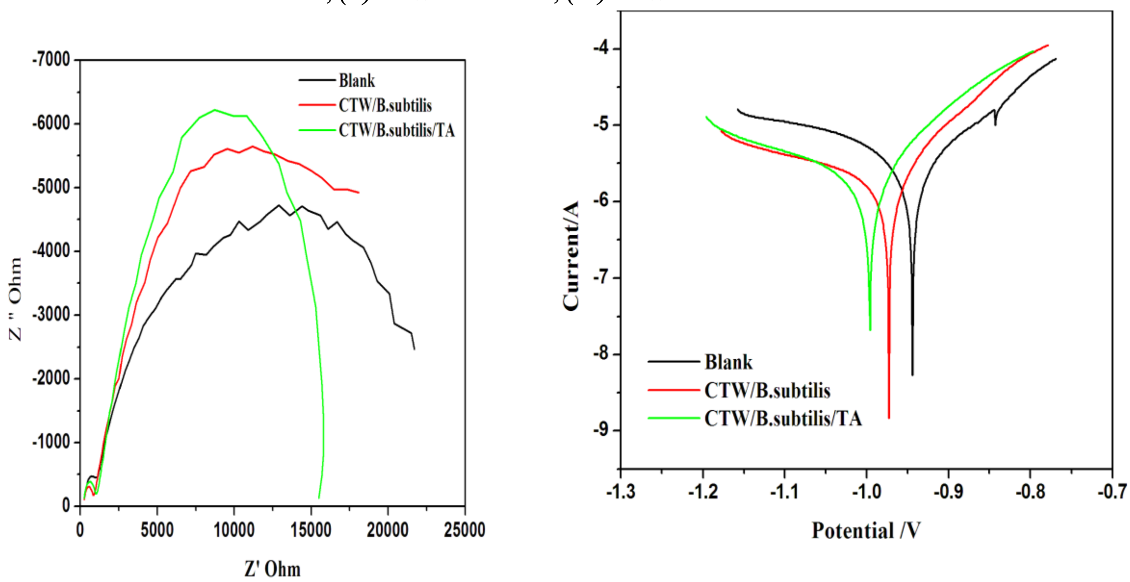
Comparing the inhibitor systems of both microbes, more than 60% of Inhibition efficiency has been attained at 30 µL of TA with inhibition efficiencies increased on an average as 84 and 79 % at the end of third week respectively.

4.3. Electrochemical Impedence



(a) (b)

Figure 1: (a) Impedence and (b) TAFEL plots of MS in three systems after 12 days of immersion in CTW: (i) Blank, (ii) CTW / S. aureus, (iii) CTW / S. aureus/TA



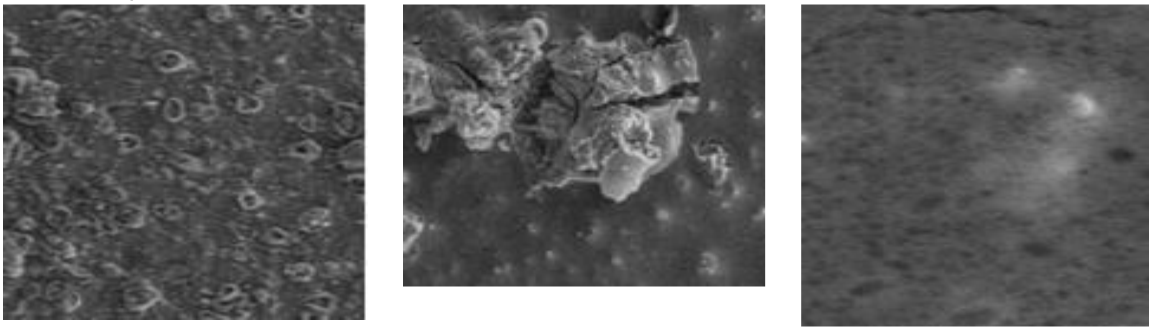
(c) (d)

Figure 2: (c) Impedence and (d) TAFEL plots of MS in three systems after 12 days of immersion in CTW: (i) Blank, (ii) CTW / B. subtilis, (iii) CTW / B. subtilis /TA

The fig 1 (a, b) shows the Impedence and TAFEL curves of MS coupons in three different systems: (i) Blank contained MS in CTW, (ii) CTW / *S. aureus* – this system contained MS in CTW innoculated with *S. aureus*, (iii) CTW / *S. aureus/TA* – this is the inhibitor system which contained MS in CTW, *S. aureus* innoculated with TA. The fig 2 (c, d) shows the Impedence and TAFEL curves of MS coupons in three different systems: (i) Blank contained MS in CTW, (ii) CTW / *B. subtilis* – this system contained MS in CTW innoculated with *B. subtilis*, (iii) CTW / *B. subtilis /TA* – this is the inhibitor system which contained MS in CTW, *B. subtilis* innoculated with TA.

Increase in corrosion rate and current density was found in the presence of microbes as the impedence curves showed a huge, defined capacitive loops (Fig 1a, 2c), whereas, in the presence of green inhibitor, they decreased significantly (Fig 1b, 2d).

4.4. SEM Analysis



(a) Blank (b) Biofilm (c) with Inhibitor

Figure 3: SEM - MS in CTW (a) Blank system; (b) with B. subtilis; (c) Plant inhibitor

Fig 3 shows (a) the Blank system containing MS in CTW, (b) MS immersed in CTW innoculated with *B. subtilis*, (c) MS immersed in CTW innoculated with *B. subtilis* and TA. The Blank system showed slight corrosion on MS (Fig 3a). The bacterial system showed biofilm development (Fig 3b). The Inhibitor system showed that TA was a good inhibitor (Fig 3c).

4.5. GC-MS Analysis

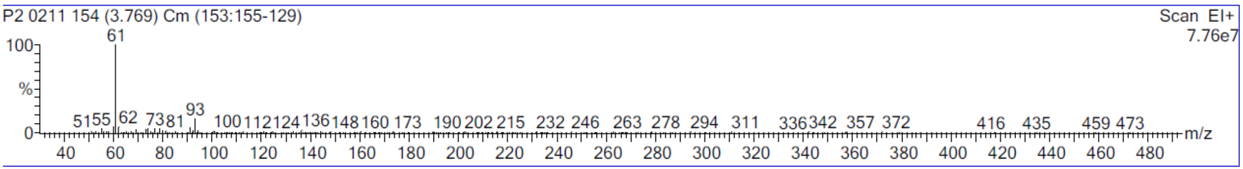


Figure 4: *GC-MS showing constituents in TA*

The constituents present in TA was shown in Fig 4. In TA, Erythritol, 3-(Methylthio)-1-propanol, Methanamine, N-methoxy were found as anti corrosive compounds preventing corrosion on MS.

4.6. XRD Analysis

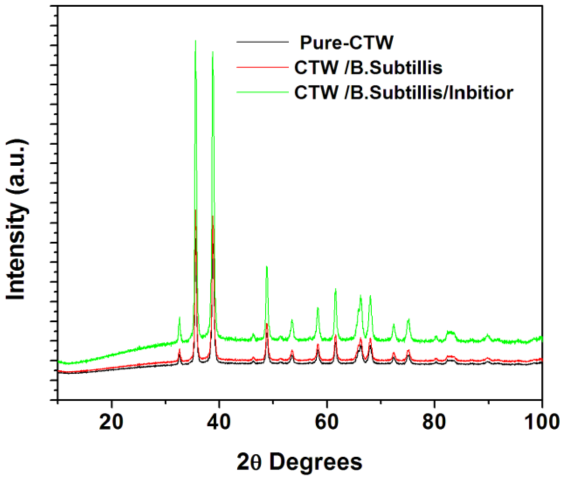


Figure 5: XRD - corrosion product of MS in 3 systems

Fig 5 shows the XRD spectrum depicting MS in three systems: (a) Pure – CTW, (b) CTW / *B. subtilis*, (c) CTW / *B. subtilis* / Inhibitor. Pure – CTW was the blank system that contained MS immersed in CTW, CTW / *B. subtilis* was the system that contained MS in CTW innocultaed with *B. subtilis* and CTW / *B. subtilis* / Inhibitor was the system that contained MS in CTW innocultaed with *B. subtilis* and TA. From the XRD data, it was clear that the corrosion inhibition on MS by TA was mainly due to the increased charge transfer resistance in the inner layer of MS. XRD data was used to find the oxides in the corrosion products. Also, it pointed out the ferric and other inorganic chemical species that the microbes accelerated the formation of ferric and other complex products.

5. Conclusion

In this study, 30 ppm of the extract was sufficient to attain more than 60 % inhibition efficiency and thereby, increasing the concentration of inhibitor lead to increase in the inhibition efficiency. All the analytical data showed that the microbes were the main cause for corrosion on MS and could be inhibited by the green inhibitor at 30 μL of TA itself.

Conflicts of Interest

I herewith declare that there are no conflicts of interests.

Acknowledgements

I sincerely thank our Principal, Government College of Engineering, Salem for granting permission to do my entire Research works in the same institution. My heartfelt gratitude to my Supervisor, Dr. T. Venugopal, Assistant Professor, Department of Chemistry, Government College of Engineering, Salem for his full support in my lab work and grammar check to complete this manuscript. Also, I thank whole heartedly the other Research scholars who have helped me in my practical work and shaping this manuscript.

References

[1]. Kumar, CPP & Mohana, KN 2014, ‘Phytochemical screening & corrosion inhibitive behavior of *Pterolobium hexapetalum* & *Celosia argentea* plant extracts on mild steel in industrial water medium’, Egyptian Journal of Petroleum, vol. 23, no. 2, pp. 201-211.

[2]. Ostovari, A et al, Corrosion inhibition of mild steel in 1 M HCl solution by henna extract: A comparative study of the inhibition by henna and its constituents (Lawsone, Gallic acid, -d-Glucose and Tannic acid). Corros. Sci. 2009, 51, 1935–1949.

[3]. Raja, P, B et al, *Neolamarckia cadamba* alkaloids as eco-friendly corrosion inhibitors for mild steel in 1 M HCl media. Corros. Sci. 2013, 69, 292–301.

[4]. Rajasekar Aruliah & Yen-Peng Ting, ‘Characterization of Corrosive Bacterial Consortia Isolated from Water in a Cooling Tower’, Hindawi Publishing Corporation ISRN Corrosion, vol. 2014, pp. 11.

[5]. Rawia Sadek, F, Hala Farrag, A, Shimaa Abdelsalam, M, ZMH Keiralla, Amany Raafat, I & Eman Araby 2019, ‘A Powerful Nanocomposite Polymer Prepared From Metal Oxide Nanoparticles Synthesized *via* Brown Algae as Anti-corrosion & Anti-biofilm’, Front. Mater, https://doi.org/10.3389/fmats.2019.00140

[6]. Rexin Thusnavis, G & Vinod Kumar, KP 2014, ‘Green Corrosion Inhibitor for Steel in Acid Medium’, Application No. 6278 /CHE/2014 A.

[7]. Reza Javaherdashti 2019, ‘Microbial corrosion’, Elsevier, 1st edition, ISBN: 9780128184486, 1st Nov 2019, pp. 208.

[8]. Rongjun Zuo 2007, ‘Biofilm: strategies for metal corrosion inhibition employing microorganisms’, Appl Microbiol Biotechnol, vol. 76, pp. 1245-1253.

[9]. Sabulal, B 2012, ‘Chemical composition & antimicrobial properties of essential oils from India. In: L. Valgimigli (Ed.), Essential oils as natural food additives. Composition, applications, antioxidant & antimicrobial properties’, Nova Science Publishing, New York, pp. 173-265.

[10]. Saeed, S & Tariq P, 2007, ‘Antimicrobial activities of *Emblica officinalis* & *Coriandrum sativum* against Gram-positive bacteria & *Candida albicans*’, Pak J Bot, vol. 39, pp. 913-917.

[11]. Samba Murty AVSS & Subrahmanyam NS 1989, ‘A textbook of economic botany’, Wiley Eastern Limited, New Delhi, pp. 416-419.

[12]. San Deigo County Water authority 2009, ‘Technical information for cooling towers using recycled water’.

[13]. Sathish, JVV, Ram Mohan Reddy, K & Sujith Pavan 2017, 'Tube adherence test as a screening tool for detection of biofilm formation among Staphylococcus', Indian J Microbiol Res, vol. 4, no. 1, pp. 44-47.
[14]. Singh, A, K et al, "Corrosion inhibition effect of Aloe vera gel: gravimetric and electrochemical study," Journal of Industrial and Engineering Chemistry, vol. 33, pp. 288– 297, 2016.
[15]. Sivashankar, A & Arulgandhi, G 2015, 'Performance Analysis & Efficiency Improvement in 210 MW LMW Turbines at METTUR Thermal Power Station', International Journal for Research in Applied Science & Engineering Technology (IJRASET), vol. 3 no. III.
[16]. Siyanbola, TO, Sasidhar, K, Anjaneyulu, B, Kumar, KP, Rao, BVSK, Ramanuj Narayan, Olaofe, O, Akintayo, ET & Raju, KVSN 2013, 'Anti-microbial & anti-corrosive poly (ester amide urethane) siloxane modified ZnO hybrid coatings from Thevetia peruviana seed oil', J Mater Sci, vol. 48, pp. 8215-8227 DOI 10.1007/s10853-013-7633-x.
[17]. Slepski, P 2014, 'Simultaneous impedance & vol. tric studies & additionally potentiodynamic polarization measurements of molasses as a carbon steel corrosion inhibitor in 1M hydrochloric acid solution', Construction & Building Materials, vol. 52, pp. 482-487.
[18]. Tuaweri, T, J et al, "Corrosion inhibition of heat treated mild steel with neem leave extract in a chloride medium," International Journal of Research in Engineering and Technology, vol. 4, no. 6, pp. 404–409, 2015.
[19]. Waanders, FB, Vorster, SW & Geldenhuys, AJ 2002, 'Biopolymer Corrosion Inhibition of Mild Steel: Electrochemical/Mössbauer Results', Kluwer Academic Publishers, Printed in the Netherlands Hyperfine Interactions, vol. 139/140, pp. 133-139.
[20]. Xiao Lei Li, Jayaraman Narenkumar, Aruliah Rajasekar & Yen-Peng Ting 2018, 'Biocorrosion of mild steel & copper used in cooling tower water & its control', Biotech, vol. 3, no. 8, pp. 178-188.
[21]. Xu, D & Gu, T 2011, 'Bioenergetics explains when & why more severe MIC pitting by SRB can occur', Corrosion, Paper No 11426. NACE International, Houston, TX.
[22]. Zargari, A 1996, 'Medicinal plants', Tehran University Press, Tehran, (Iran).
[23]. Zulfareen, N, Kannan, K, Venugopal, T & Gnanavel, S 2016, 'Adsorption & Quantum chemical studies on the inhibition potential of Mannich base for the corrosion of Brass in Acid Medium', Arabian Journal for science & Engineering, DOI 10.1007/s13369-016-2088-4.
[24]. Zwenger, S & Basu, C 2008, 'Plant terpenoids: applications & potentials', Biotechnology & Molecular Biology Reviews; vol. 3, pp. 001-007.