



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJIRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 5, May 2021

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.512

9940 572 462

6381 907 438

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Study of Biocorrosion and its Inhibition by a Green Inhibitor on Mild Steel in Cooling Tower Water

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ABSTRACT:Microbial corrosion caused by *Bacillus subtilis* and *Klebsiella pneumoniae* on mild steel (MS) in cooling tower water (CTW) system and its control by a plant inhibitor, *Coriandrum Sativum* was studied by various analysis viz., Weight loss method, Electrochemical Impedance (EIS), Scanning electron Microscope (SEM), and Gas chromatography and mass spectroscopy (GC-MS). Due to the addition of the microbes in cooling tower water, increase in loss of weight was found on MS coupons after a week and gradually increased further which was noted for 3 weeks. The addition of green inhibitor, *Coriandrum Sativum* gradually inhibited the biocorrosion on MS was noticed that 30 μ L was enough to attain more than 70% inhibition efficiency.

KEYWORDS:Biocorrosion; Electrochemical impedance; SEM; green inhibitor

I. INTRODUCTION

Image inpainting is a method for repairing damaged pictures or removing unnecessary elements from pictures. It recovers the missing or corrupted parts of an image so that the reconstructed image looks natural. In real world, many people need a system to recover damaged photographs, designs, drawings, artworks etc. damage may be due to various reasons like scratches, overlaid text or graphics etc.

This system could enhance and return a good looking photograph using a technique called image inpainting. Image inpainting modify and fill the missing area in an image in an undetectable way, by an observer not familiar with the original image. The technique can be used to reconstruct image damage due to dirt, scratches, overlaid text etc.

Some images contain mixed text-picture-graphic regions in which text characters are printed in an image. Detecting and recognizing these characters can be very important, and removing these is important in the context of removing indirect advertisements, and for aesthetic reasons. There are many applications of image inpainting ranging from restoration of photographs, films, removal of occlusions such as text, subtitle, logos, stamps, scratches, red eye removal etc.

Paper is organized as follows. Section II describes automatic text detection using morphological operations, connected component analysis and set of selection or rejection criteria. The flow diagram represents the step of the algorithm. After detection of text, how text region is filled using an Inpainting technique that is given in Section III. Section IV presents experimental results showing results of images tested. Finally, Section V presents conclusion.

II. RELATED WORK

The concept of image inpainting was first introduced by Bertamio et al. [1]. The method was inspired by the real inpainting process of artists. The image smoothness information interpolated by the image Laplacian is propagated along the isophote directions, which are estimated by the gradient of image rotated by 90 degrees. Exemplar Based method proposed by Criminisi et al. [2] used a best exemplar patch to propagate target patch including missing pixels. This technique uses an approach which combine structure propagation with texture synthesis and hence produced very good results. In [3], the authors decompose the image into sum of two functions and then reconstruct each function separately with structure and texture filling-in algorithms. Morphological technique is used to



extract text from the images presented in [4]. In [5], the inpainting technique is combined with the techniques of finding text in images and a simple algorithm that links them. The technique is insensitive to noise, skew and text orientation. The authors in [6] have applied the CCL (connected component labelling) to detect the text and fast marching algorithm is used for Inpainting.

The work in this paper is divided in two stages. 1) Text- Detection 2) Inpainting. Text detection is done by applying morphological open-close and close-open filters and combines the images. Thereafter, gradient is applied to detect the edges followed by thresholding and morphological dilation, erosion operation. Then, connected component labelling is performed to label each object separately. Finally, the set of selection criteria is applied to filter out non text regions. After text detection, text inpainting is accomplished by using exemplar based Inpainting algorithm.

III. METHODOLOGY

Cooling tower water was fetched from Mettur thermal power station, TN, India. MS coupons of 6 x 1 cm were used for weight loss method and 1 cm² area was exposed for EIS. Seeds of Coriandrum Sativum was extracted in the Soxhlet apparatus. The minimum inhibitory concentration was evaluated by well diffusion method .

Weight loss method was made in two different systems: Two separate Bacterial (*B.subtilis* and *K.Pneumoniae* eac) systems contained MS coupon immersed in 400 mL of cooling tower water, 1% Nutrient Broth and the microbes (1 mL) in each system; Green Inhibitor systems contained MS coupon immersed in cooling tower water, Nutrient Broth and the microbes with Coriandrum Sativum (10, 20, 30 and 50 μ L) in each system. Triplicates of each system was monitored. Loss of weight was noticed every week. After three weeks , the copouons were scrapped for corrosion films for SEM analysis.

The electrochemical impedance measurement was made in three different systems: Blank which contained only cooling tower water with MS coupon, Bacterial system and Green inhibitor system (as mentioned in the weight loss method).

IV. EXPERIMENTAL RESULTS

Minimum Inhibitory Concentration

Zone of clear inhibition was shown in fig 1a, 1b.A clear zone of inhibition (12 mm dia) was noticed at 30 μ L of green inhibitor.The fig 1a, 1b shows T1, T2, T3 (10, 30 and 50 μ L) as three different concentrations of plant extract respectively, P as Positive control (amoxyllin) and N as Negative control (Di-methyl sulfoxide (DMSO)).

Weight loss method

The Mean Weight loss, corrosion rate and inhibition efficiency of MS coupons were calculated It was found that the average weight loss of the systems; bacterial system containing *B.Subtilis* was around 0.0832g at first week and increased to around 0.0852g at the end of third week, the bacterial system containing *K.Pneumoniae* was around 0.0812g at first week and increased to around 0.0864g at the end of third week. This might be due to the development of a thick biofilm layer on the MS coupons.

In the presence of the green inhibitor (30 μ L) with *B.Subtilis*, the weight loss, corrosion rate and inhibition efficiency were 0.0378 g, 8.05 mm/year and 78%, respectively and in the inhibitor with *K.Pneumoniae*, the weight loss, corrosion rate and inhibition efficiency were 0.0111 g, 2.36 mm/year and 87%, respectively (after three weeks). This showed that the corrosion rate has highly decreased when compared to the bacterial system and more than 70% of corrosion inhibition efficiency was obtained at 30 ppm of *Coriandrum Sativum*.

Electrochemical Impedence

From fig 2a, it was inferred that the inhibition efficiency for the concentrations of plant extract viz., 10, 20, 30 and 50 μ L with respect to *B.subtilis* in Polarization plot were 37, 50, 65 and 80 % and Nyquist plot were 38, 50, 66 and 79%. Increase in corrosion current led to the formation of biofilm. The fig 2a shows the bar diagram with respect to different Concentrations of green inhibitor and the percentage of Inhibition efficiency in MS coupons due to the corrosion current with respect to *B.subtilis*. From fig 2b, it was inferred that the inhibition efficiency for the concentrations of plant extract viz., 10, 20, 30 and 50 μ L with respect to *K.pneumoniae* in Polarization plot were 37, 47, 62 and 86 % and Nyquist plot were 38, 48, 62 and 87%. Increase in corrosion current led to the formation of biofilm.



The fig 2b shows the bar diagram with respect to different Concentrations of green inhibitor and the percentage of Inhibition efficiency in MS coupons due to the corrosion current with respect to *K.pneumoniae*.

SEM Analysis

In Fig 3a, before exposure to microbes, corrosion was not shown. In fig 3b, 3c biofilm development causing corrosion was shown on the MS due to *B.subtilis* and *K.Pneumoniae* respectively. In fig 3d, 3e inhibition of the biofilm was shown due to the presence of green inhibitor.

GC-MS Analysis

From these results, the green inhibitor was noticed to contain certain constituents viz, Cyclopentanone, 2-methyl-, (2-Mercaptoethyl)guanidine, 1,2-Diethylhydrazine, ζ -Terpinene as corrosion inhibiting compounds (shown in fig 4).

Figures and graphs



Fig 1(a) Zone of inhibition in B.subtilis



Fig 1 (b) Zone of inhibition in K.Pneumoniae

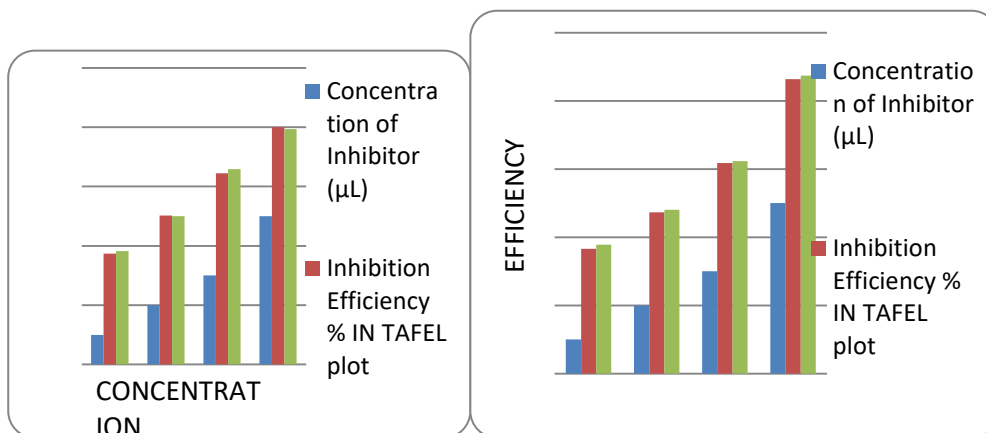


Fig 2ADifferent Concentrations of green in system with *B.subtilis* Vs Inhibition efficiency of MS coupons due to the corrosion current
 Fig. 2BDifferent Concentrations of green inhibitor in system with *K.pneumoniae* Vs Inhibition efficiency of MS coupons due to the corrosion current

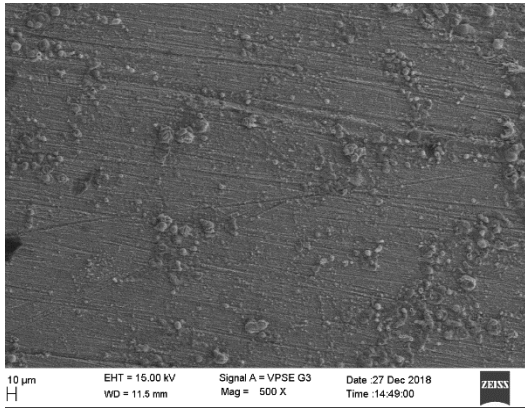


Fig. 3aSEMImage - Control system

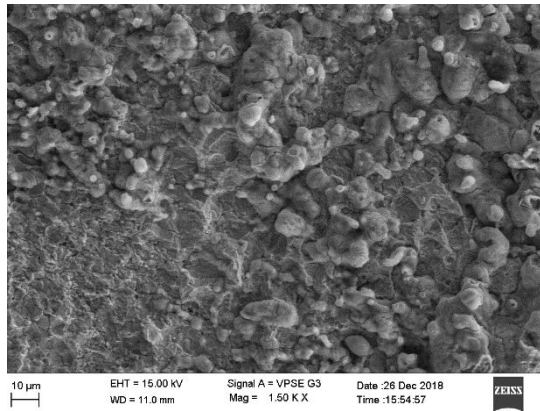


Fig. 3bSEMImage - system with *B.Subtilis*

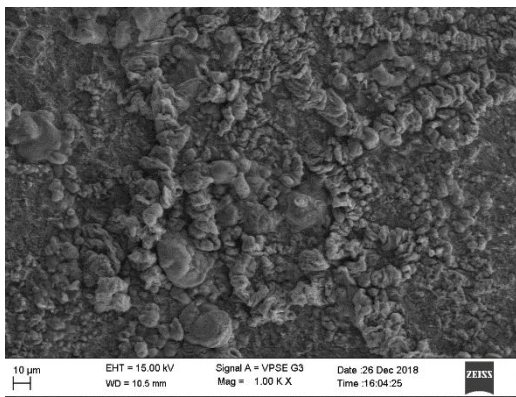


Fig. 3cSEM image- system with *K.Pneumoniae*

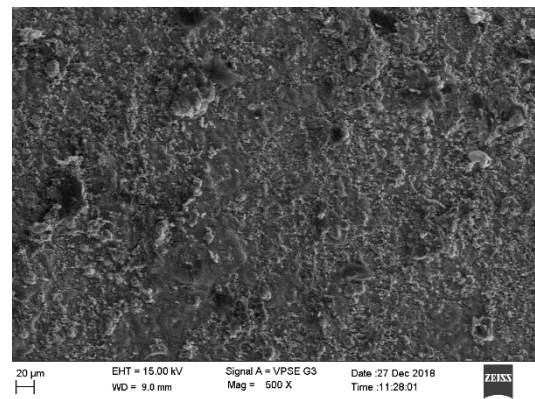


Fig. 3dSEM image - green inhibitor system with *B.Subtilis*

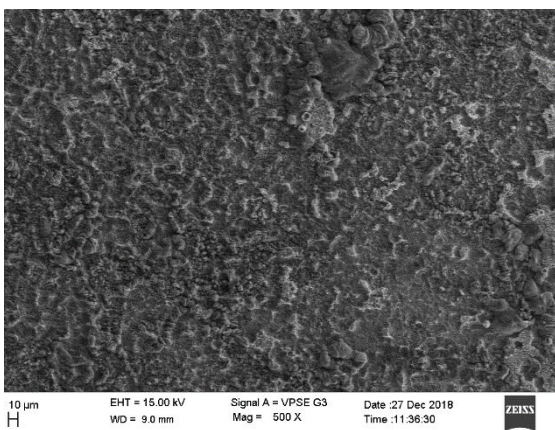


Fig. 3eSEM image - green inhibitor system with *K.Pneumoniae*

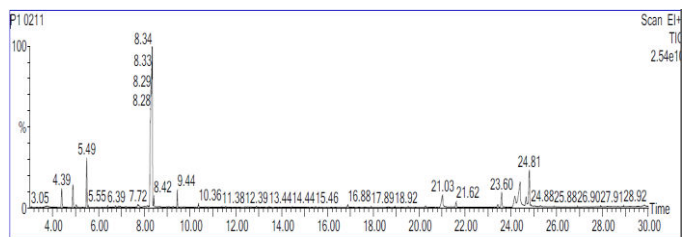


Fig. 4 GC-MS spectrum - Constituents in plant extract



V. CONCLUSION

In the proposed work, MS was used in this study as it is not expensive and has minimal corrosion resistance and some cooling towers are composed of this metal. Also, this present study aimed on inhibition of biocorrosion on MS using green inhibitor.

In this study, *B.subtilis* and *K.Pneumoniae* were inoculated in the cooling tower water system to notice biocorrosion (biofilm development) and the plant extract from *Coriandrum Sativum* was used as green inhibitor in various concentration viz. 10, 20, 30, 50 μ L. At 30 μ L of extract, more than 70% of corrosion inhibition efficiency was noticed. Moreover, the constituents present in the green inhibitor viz., Cyclopentanone, 2-methyl-, (2-Mercaptoethyl)guanidine, 1,2-Diethylhydrazine, ζ -Terpinene acted as the major cause for corrosion inhibition.

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