Jurnal Teknologi

Full Paper

INHIBITIVE EFFECT OF *COCON NUCIFERA L.* (COCONUT PULP) EXTRACT ON MILD STEEL ACID CORROSION

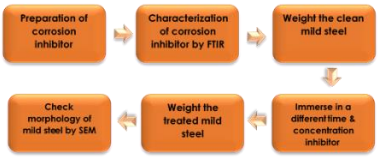
S. Sobri[a,b*], N. Rahim[a]

[a]Department of Chemical and Environmental Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[b]Institute of Advanced Technology, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

Article history
Received
16 October 2016
Received in revised form
4 May 2016
Accepted
8 May 2016

*Corresponding author
shafreeza@upm.edu.my

Graphical abstract



Abstract

In recent years, industrial sectors are concerned with the corrosion of metal and alloys and they also received huge attention from researcher to overcome these problems. To decelerate the rate of corrosion or to stop the corrosion to occur, one of the common methods to deal with this problems is using green inhibitor. The use of local wastes which are organic in nature for the production of green corrosion inhibitor is no doubt the trend of the day. To arrive at an inexpensive non-toxic, eco-friendly inhibitor formulation, the present study on the use of coconut pulp waste extract of *Cocon Nucifera L*. has been carried out by the weight loss method. The aim of this project is to study the inhibitive effect in terms of time and concentration of the coconut pulp waste extract on the acid corrosion of mild steel in 1.0 M HCL solution. Result showed that the inhibition efficiency was found to increase with increasing inhibitor concentration up to maximum 94.52% for 10 %v/v at 48 hours immersion time. Examination on the extract by Fourier transform infrared spectroscopy (FTIR) confirms that the extract contains functional group of N-H, O-H, C-H, C≡C, C=O, C=C, C-F and C-O that good for corrosion inhibitor while scanning electron microscopy (SEM) studies showed that the deposition of coconut pulp extract on the metal surface. The results of all studies confirmed that the extract of coconut pulp has great potential to prevent the corrosion of mild steel in acidic environment with highest % IE is 94.52 % and the corrosion rate is 3.6919 x10-5.

Keywords: Mild steel, coconut pulp extract, acid corrosion, weight loss, corrosion inhibition

1.0 INTRODUCTION

Acids such as HCl and H_2SO_4 are extensively used in several industries as pickling, descaling and cleaning agents to remove the unwanted oxide films and corrosion products (Bothi Raja and Sethuraman, 2009a). In many industries, mild steel (MS) is the material of choice in the fabrication of reaction vessels, storage tanks etc., which get corroded easily in the presence of acids (Bothi Raja and Sethuraman, 2009b). Among the different corrosion protection strategies, utilization of inhibitors is an effective technique to lessen consumption of metals, particularly in corrosive media.

The huge number of organic compounds having hetero-molecules, for example, N, O, S atoms and p-electrons were accounted for as the proficient corrosion inhibitors under aggressive environments, for example acidic or basic mediums etc. (de Souza and Sinelli, 2009; Fekry and Mohamed, 2010; Lyon, 2004; Fu *et al*., 2010; Sheng *et al.,* 2007). In perspective of the disadvantages of the compounds of synthetic origin, there has been an upsurge in screening of compounds of natural origin for their corrosion inhibition impact

(Bothi Raja and Sethuraman, 2008). Furthermore, corrosion inhibitors from plant extracts are biodegradable and do not contain heavy metals or other toxic compounds (Eddy and Odoemelam, 2009). In the present study, waste from coconut pulp of Cocon Nucifera L is examined for its potential to inhibit corrosion of mild steel in 1M HCL using weight loss method. The aims of the present work are to investigate the active compounds of coconut pulp waste and its inhibitive effect on mild steel acid corrosion.

2.0 METHODOLOGY

2.1 Materials

Mild steel of compositions (wt %) Mn (0.75), P (0.04), Cu (0.2), C (0.26) S (0.05) and Fe (99.00) was used for the study. Samples were mechanically cut into 5 cm × 1.5 cm × 0.5 cm. The exposed area was mechanically abraded with a series of emery papers of variable grades, starting with a coarse one (600) and proceeding in steps to the finest (1000) grade. The sample was then washed thoroughly with double distilled water, rinsed with ethanol, dried in acetone and stored in a desiccator.

2.2 Preparation of Coconut Pulp Extract

Coconut pulp wastes were collected from a coconut milk shop at the fresh market in Kajang, Selangor. The waste were then dried, grinded and sieved to a powder form. Stock solution of the plant was prepared by refluxing weighed amount (50gm) of dried powder of coconut pulp for 6 hours in 200 ml of 1.0 M HCL solution. The refluxed solution was allowed to stand for 12 hours, filtered and stored. The filtrate was diluted with the appropriate quantity of 1 M HCL solution to obtain concentration of 2, 4, 6, 8, ad 10 v/v %.

2.3 FTIR Spectroscop

The extract of coconut pulp was characterized using Thermo Nicolet 6700 FTIR spectroscopy. The extract was analysed in mode of transmittance. Several functional groups were observed in the range of 500 - 4000 cm-1 wavenumbers and these peaks are distinguished by comparing with the standard peak of the group.

2.4 Weight Loss Method

The mechanically polished and pre-weighed mild steel specimens of uniform size were suspended in 100 ml test solutions with and without coconut pulp extract at different concentrations of 2, 4, 6, 8, and 10 v/v % for different immersion times of 6, 12, 18, 24 and 48 hours at 298K. The specimens were then washed, dried and weighed. From the weight loss data, the inhibition efficiency (IE) of the inhibitor, degree of surface coverage (θ) and corrosion rates (CR) were calculated as follows (Bothi Raja and Sethuraman, 2009a). The Inhibition efficiency (IE) is the weight loss value in the absence of inhibitor minus the weight loss value in the presence of inhibitor over the weight loss value of the absence of the inhibitor as given in equation (1). The rate of corrosion can be defined as the ratio of the loss in weight of the sample ΔW to its area A and the time length over which the test was attempted as given in equation (3)

$$\mathrm{IE}(\%) = \frac{W_0 - W_i}{W_0} \times 100 \quad (1)$$

$$\theta = \frac{IE(\%)}{100} \quad (2)$$

$$C_r(gm^{-2}h^{-1}) = \frac{\Delta W}{At} \quad (3)$$

2.5 SEM Images

Microscopy images were obtained using Hitachi S-3400 N SEM. Mild steel specimens were immersed in the 1.0 M HCL solution and 10 % v/v concentration of the extract which is the optimum concentration of the inhibitor for a period of 48 hours. After 48 hours, the specimens were remove to rinse and dried. The nature of the surface film formed on the surface of the mild steel specimen was observed.

3.0 RESULTS AND DISCUSSION

3.1 FTIR of Coconut Pulp Extract

FTIR spectroscopy of the coconut pulp extract is shown in Figure 1. A small peak at 3473.26 cm^{-1} is assigned to stretching vibration of N-H. Combination of two band at peaks 2920.85 and 2854.87 cm^{-1} were observed for O-H group that form carboxylic acid. Each peaks are also assigned to the C-H stretching vibration. A band at 2120.48 cm^{-1} indicates C≡C stretching vibration. The C=O stretching vibration is found at 1740.71 cm^{-1} while a peak at 1457.16 cm^{-1} is assigned to ring C=C stretching vibration. C-H bending vibration is found at 1370.66 cm^{-1}. A peak at 1156.80 cm^{-1} corresponds to C-F stretching vibration and while at 1107.27 cm^{-1} is due to the C-O stretching vibration. The absorption bands below 1000 cm^{-1} correspond to the aliphatic C-H group (Li *et al*., 2012a, b; Deng and Li 2012). This result confirms that the extract contains functional group of N-H, O-H, C-H, C≡C, C=O, C=C, C-F and C-O. These results are found to be similar to the previous study such as in the Litchi peel extract (Ramananda Singh, Gupta, & Gupta, 2015) and *Musa paradisica* peel extract (Ji, Anjum, Sundaram, & Prakash, 2015).

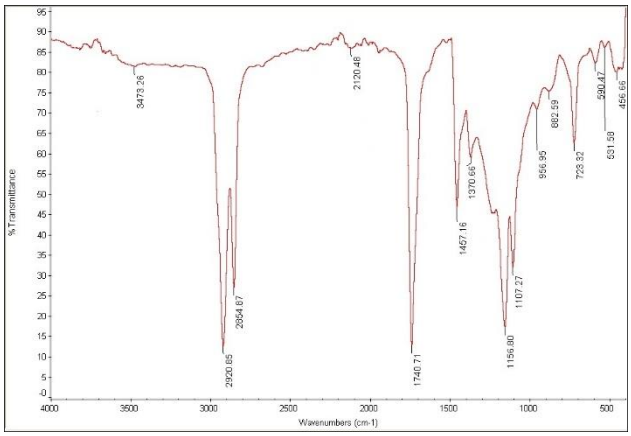


Figure 1 FTIR spectra of coconut pulp extract

3.2 Weight Loss Method

Table 1 shows Corrosion rate and inhibition efficiency for mild steel in 1 M HCL in the absence and presence of Coconut pulp extract. From Table 1, it was found that the inhibition efficiency of coconut pulp extract increased up to 94.52% at higher concentration which is 10 v/v % at 48 hours immersion time. The inhibition efficiency of coconut pulp extract at 6 hours immersion time is 90.06% and decreases to 87.78 % at 12 hours before increases up to 88.9% and 92.36 % at 18 hours and 24 hours. As the time of immersion increases, the adsorbed molecules on the surface increases and it was found to be 94.52% at 10v/v% concentration for 48 hours. Therefore, it can be concluded that the inhibition efficiency increased with increasing of immersion of time due to the stability of the adsorbed layer on mild steel surface.

Table 1 Corrosion rate and inhibition efficiency for mild steel in 1 M HCL in the absence and presence of Coconut Pulp extract

Concentration of the inhibitor v/v %	Time (Hours)	Corrosion rate gm. cm^{-2} h^{-1}	% IE
0	6	4.2093×10^{-4}	
	12	4.4419×10^{-4}	
	18	4.0052×10^{-4}	
	24	4.6415×10^{-4}	
	48	6.7355×10^{-4}	
2	6	6.2016×10^{-5}	85.27
	12	1.0039×10^{-5}	77.40
	18	6.2532×10^{-5}	84.39
	24	5.1357×10^{-5}	88.94
	48	6.0659×10^{-5}	90.99
4	6	5.7364×10^{-5}	86.37
	12	8.3333×10^{-5}	81.24
	18	5.9432×10^{-5}	85.16
	24	4.9419×10^{-5}	89.35
	48	5.8043×10^{-5}	91.38
6	6	5.1938×10^{-5}	87.66
	12	7.4031×10^{-5}	83.33
	18	5.5297×10^{-5}	86.19
	24	4.3023×10^{-5}	90.73
	48	5.1647×10^{-5}	92.33
8	6	4.9612×10^{-5}	88.21
	12	5.9690×10^{-5}	86.56
	18	4.6512×10^{-5}	88.39
	24	3.6047×10^{-5}	92.23
	48	4.9128×10^{-5}	92.70
10	6	4.1860×10^{-5}	90.06
	12	5.4264×10^{-5}	87.78
	18	$4.4444x \times 10^{-5}$	88.90
	24	3.5464×10^{-5}	92.36
	48	3.6919×10^{-5}	94.52

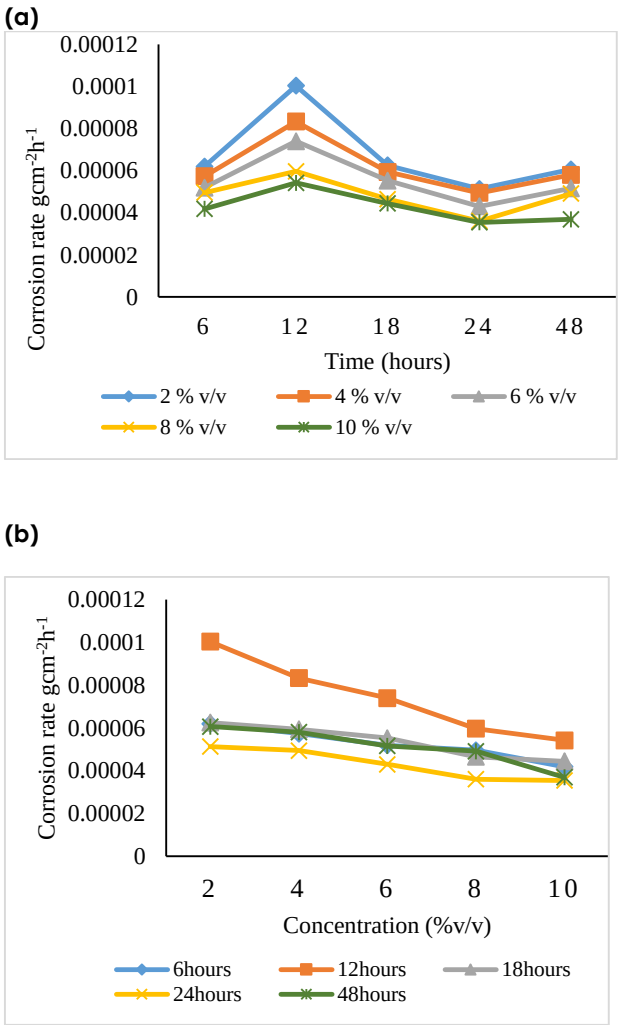


Figure 2 Graph of corrosion rate against (a) time at different concentration interval, (b) concentration at different time interval

The corrosion rate for mild steel in 1.0 M HCl solutions at different concentrations of coconut pulp extract and immersion time is presented in Figure 2. From the Figure 2, it was found that the corrosion rates decreased with the increase in concentration of coconut pulp extract. These proved that the coconut pulp extract shows a significant inhibitive effect on mild steel acid corrosion. This can be seen at the 48 hours of immersion time, the corrosion rate for concentration of the inhibitor 0 %v/v is 6.7355 x10^{-4} which is higher compare to the corrosion rate for concentration of the inhibitor 10 %v/v which is 3.6919 x10^{-5}. The decreasing of the index number from -4 at the absence of the inhibitor to -5 at the higher concentration inhibitor shows a significant inhibitive effect on mild steel in acid corrosion. From Figure 3, it is observed that the inhibition efficiencies increase with increase in coconut pulp extract concentration. This shows that the active organic components of the extracts are adsorbed onto the mild steel surface resulting in the blocking of the reaction sites and protection of the mild steel surface from the attack of the corrosion active ions in the acid medium (Zhang and Hua, 2009).This is due to the presence of hetero atoms like nitrogen and oxygen, and the aromatic rings. Surface coverage, θ for different concentrations of inhibitors in 1.0 M HCl was calculated and it was found that coconut pulp extract proficiently cover the surface of mild carbon steel.

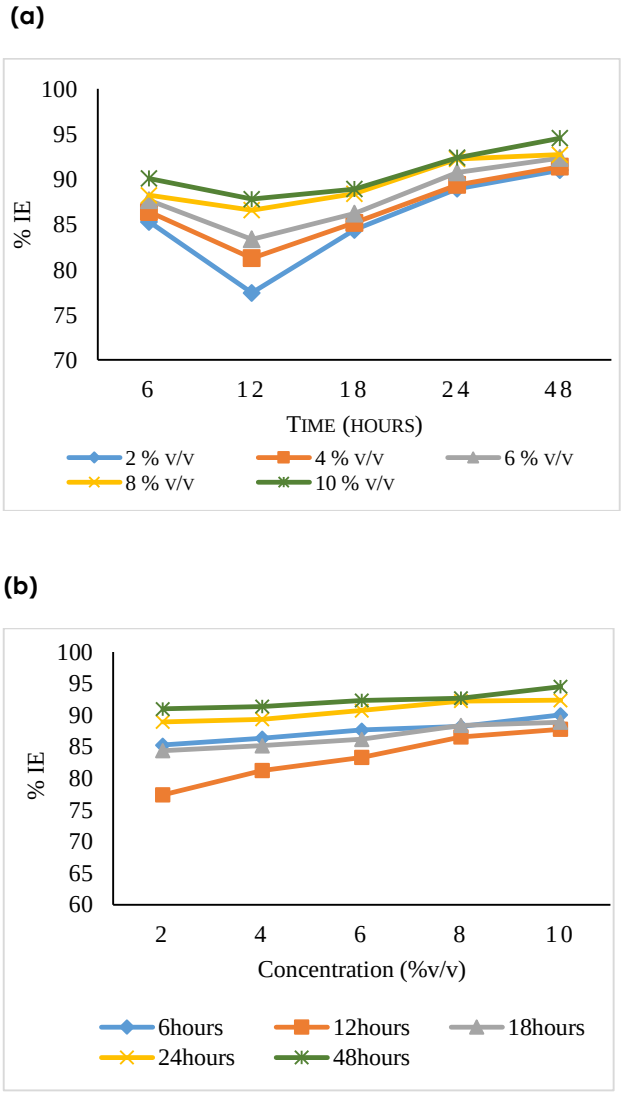


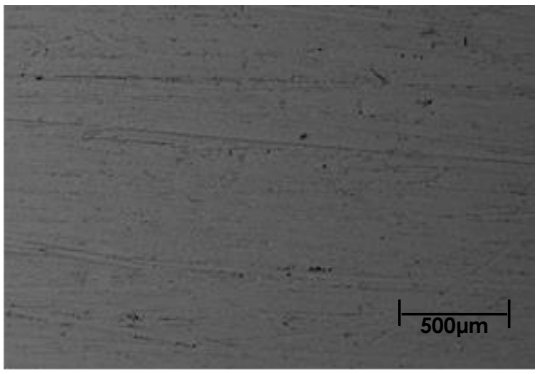
Figure 3 Graph of inhibition efficiency against (a) time at different concentrations, (b) concentration at different immersion time

3.3 Scanning Electron Microscopy

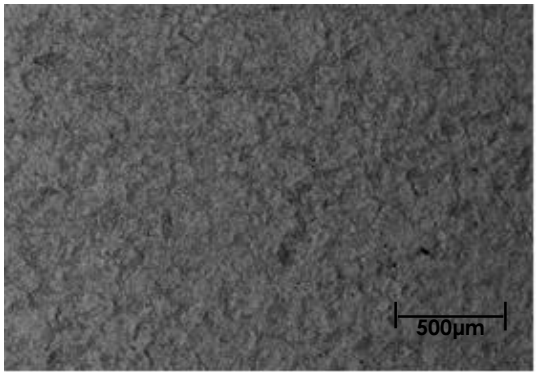
SEM images of mild steel specimens in acid media in the absence and presence of coconut pulp extract are shown in Figure 4. Figure 4a shows clean and smooth surface of mild steel because there are no reaction present on it. In Figure 4b, it can be seen that the mild steel surface was damaged and have rough surface when immersed in 1.0 M HCL. Figure 4c shows a smooth surface because inhibitor extract containing 10 %v/v

concentration of coconut pulp extract is deposited on the mild steel (Bothi Raja and Sethuraman, 2008; Al-Turkustani *et al*., 2011; Hazwan Hussin and Jain Hassin, 2011; Garai *et al*., 2012; Ramananda Singh, 2013). The smooth surface was observed due to the formation of an adsorbed film of coconut pulp extract on the surface of mild steel that a protective organic layer (Prabhu, Venkatesha and Shanbhag, 2009)

(a)



(b)



(c)

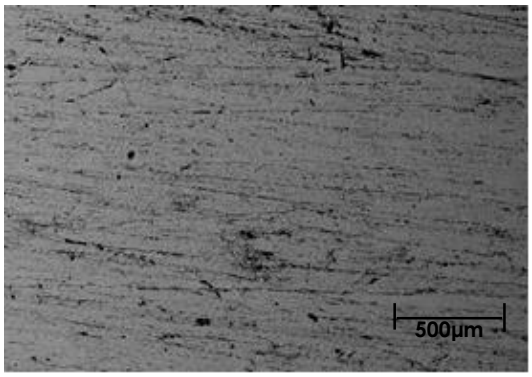


Figure 4 SEM images of (a) mild steel specimens b) mild steel specimens in 1.0 M HCl, c) mild steel specimens in 10 %v/v concentration of inhibitor

4.0 CONCLUSION

This study has shown that coconut pulp extract can be used as corrosion inhibitor. As the concentration of inhibitor increases, the corrosion rate decreases and the inhibitor has an optimum efficiency of about 95%. FTIR analysis shows that the coconut pulp extract contain active compounds that suitable for inhibition in acid medium. SEM images confirmed the formation of a protective layer by inhibitor molecules over the surface of mild steel. The results of all studies confirmed that the extract of coconut pulp has great potential to prevent the corrosion of mild steel in acidic environment.

Acknowledgement

We wish to thank Department of Chemical and Environmental Engineering, Universiti Putra Malaysia and Institute of Advanced Technology, Universiti Putra Malaysia for the facilities. We are also grateful for the funding from Ministry of Higher Education Malaysia under Fundamental Research Grant Scheme (FRGS).

References

[1] A. Ostovari, S. M. Hoseinieh, M. Peikari, S. R. Shadizadeh, S. J. Hashemi. 2009. Corrosion Inhibition of Mild Steel in 1M HCl Solution by Henna Extract: A Comparative Study of the Inhibition by Henna and Its Constituents (Lawsone, Gallic Acid, a-d-Glucose and Tannic Acid. *Corros. Sci*. 51: 935.

[2] Al-Turkustani, A. M., Arab, S. T., Al-Qarni, L. S. S. 2011. Medicago Sative Plant as Safe Inhibitor on the Corrosion of Steel in 2.0M H_2SO_4 Solution. *J. Saudi Chem. Soc*. 15(1): 73-82.

[3] Bothi Raja, P., Sethuraman, M. G. 2009a. Inhibition of Corrosion of Mild Steel in Sulphuric Acid Medium by Calotropis Procera. *Pig. Res. Tech*. 38: 33-37.

[4] Bothi Raja, P., Sethuraman, M. G. 2008. Natural Products as Corrosion Inhibitors for Metals in Corrosive Media–A Review. *Mater. Lett*. 62: 113-116.

[5] Bothi Raja, P., Sethuraman, M. G. 2009b. Strychnos Nux-vomica–An Eco-Friendly Corrosion Inhibitor for Mild Steel in 1M Sulfuric Acid Medium. *Mater. Corros*. 59: 22-28.

[6] Bothi Raja, Pandian, Sethuraman, Mathur Gopalakrishnan. 2008. Inhibitive Effect of Black Pepper Extract on the Sulphuric Acid Corrosion of Mild Steel. *Mater. Lett*. 62: 2977-2979.

[7] De Souza, F. S., Sinelli, A. 2009. Caffeic Acid as a Green Corrosion Inhibitor for Mild Steel. *Corros Sci*. 51: 642-649.

[8] Fekry, A. M., Mohamed, Riham R. 2010. Acetyl Thiourea Chitosan as an Eco-Friendly Inhibitor for Mild Steel in Sulphuric Acid Medium. *Electrochem Acta*. 55: 1933-1939.

[9] Fomin, M. N., Zhigalova, K. A. 1986. Methods of Corrosion Testing of Metals. *Metallurgiya*. Moscow. 11-18.

[10] Fu, Jia-jun, Li, Su-Ning, Wang, Ying, Cao, Lin-Hua, Lu, Lu-De. 2010. Computational and Electrochemical Studies of Some Amino Acid Compounds as Corrosion Inhibitors for Mild Steel in HCL Solution. *J. Mater.* Sci. 45: 6255-6265.

[11] G. Avci. 2008. Corrosion Inhibition of Indole 3-Acetic Acid on Mild Steel in 0.5 M HCl. *Colloids Surf*. A. 317: 730-736.

[12] Garai, Subhadra, Garai, Saraswati, Jaisankar, Parasuraman, Sing, J. K., Elango, Adirajan. 2012. A Comprehensive Study on Crude Methanolic Extract of Artemisia Pallen (Asteraceae) and Its Active Components as Effective Corrosion Inhibitors of Mild Steel in Acid Solution. *Corros Sci*. 60: 193-204.
[13] Hazwan Hussin, M., Jain Hassin, M. 2011. The Corrosion Inhibition and Adsorption Behaviour of Uncaria Gambir Extract on Mild Steel in 1.0 M HCL. *Mater. Chem. Phys.* 125: 461-468.
[14] Ji, G., Anjum, S., Sundaram, S., & Prakash, R. 2015. Musa Paradisica Peel Extract as Green Corrosion Inhibitor for Mild Steel in HCl Solution. *Corrosion Science*. 90: 107-117.
[15] Li, Lingjie, Zhang, Xueping, Lei, Jinglei, He, Jianxin, Zhang, Shengtao, Pan, Fusheng. 2012a. Adsorption and Corrosion Inhibition of Osmanthus Fragran Leaves Extract on Carbon Steel. *Corros. Sci*. 63: 82-90.
[16] Li, X., Deng, S., Fu, H., Mu, G. 2009. Inhibition Effect of 6-Benzylaminopurine on the Corrosion of Cold Rolled Steel in H_2SO_4 Solution. *Corros. Sci.* 51: 620-634.
[17] Li, Xianghong, Deng, Shuduan, Fu, Hui, 2012b. Inhibition of the Corrosion of Steel in HCL, H_2SO_4 Solution by Bamboo Leaf Extract. *Corros Sci*. 62: 163-175.
[18] Lyon, Stuart, 2004. A Natural Solution to Corrosion. *Nature*. 427: 406-407.
[19] M. Behpour, S.M. Ghoreishi, M. Khayatkashani, and N. Soltani. 2011. The Effect of Two Oleo-cum Resin Exudate from Ferula Assa-Foetida and Dorema Ammoniacum on Mild Steel Corrosion in Acid Media. *Corros. Sci*. 53: 2489-2501.
[20] N. O. Eddy and S. A. Odoemelam. 2009. Inhibition of the Corrosion of Mild Steel in H2SO4 by Ethanol Extract of Aloe Vera. *Resin & Pigment Technology*. 38(2): 111-115.
[21] Ostovari, A., Hoseinieh, S. M., Peikari, M., Shadizadeh, S. R., Hashemi, S. J. 2009. Corrosion Inhibition of Mild Steel in 1M HCL Solution by Henna Extract: A Comparative Study of the Inhibition by Henna and Its Constituents (Lawsone, Gallic Acid, @a-d-Glucose And Tannic Acid). *Corrosion Science*. 51(9): 1935-1949.
[22] Prabhu, R. A., Venkatesha, T. V., Shanbhag, A. V. 2009. Carmine and Fast Green as Corrosion Inhibitors for Mild Steel in Hydrochloric Acid Solution. *J. Iran. Chem. Soc*. 6(2): 353-363.
[23] Ramananda Singh, M. 2013. A Green Approach: A Corrosion Inhibition of Mild Steel by Adhatoda Vasica Plant Extract in 0.5 M H_2SO_4. *J. Mater. Environ. Sci*. 4(1): 119-126.
[24] Ramananda Singh, M., Gupta, P., & Gupta, K. 2015. The Litchi (Litchi Chinensis) Peels Extract as a Potential Green Inhibitor in Prevention of Corrosion of Mild Steel in 0.5M H_2SO_4 Solution. *Arabian Journal of Chemistry*. 0-6.
[25] Sheng, Xiaoxia, Ting, Yeng-Peng, Pehkonen, Simo Olavi. 2007. Evaluation of an Organic Corrosion Inhibitor on Abiotic Corrosion Microbiologically Influenced Corrosion of Mild Steel. *Ind. Eng. Chem. Res.* 46: 7117-7125.
[26] U. M. Eduok, S. A. Umoren, and A. P. Udoh. 2012. Synergistic Inhibition Effect between Leaves and Stem Extract of Sida acuta and Iodide Ion for Mild Steel Corrosion in 1M H_2SO_4 Solutions, *Arabian. J. Chem*. 5: 325-337.