International Journal of Latest Research in Science and Technology **ISSN (Online):2278-5299**
Volume 3, Issue 6: Page No.1-5 (2014)
https://www.mnkjournals.com/journal/ijlrst/index.php

COMMON SAGE EXTRACT AS AN INHIBITOR OF STEEL CORROSION IN 3% NaCl

[1]M. Tomić, [1]V. Mićić, [2]Lj. Mlađenović, [3]R. Godec, [1]M. Pavlović, [4] Đ. Vaštag
[1]University of East Sarajevo, Faculty of Technology, Zvornik, Bosnia and Herzegovina
[2]Municipality of Milići, Republic of Srpska, Bosnia and Herzegovina
[3]University of Maribor, Faculty of Chemistry and Chemical Engineering, Slovenia
[4] University of Novi Sad, Faculty of Sciences, Serbia

Received : 04 November 2014; Accepted : 24 November 2014 ; Published : 31 December 2014
Copyright © 2014 M. TomiÄ‡ et al. This is an open access article distributed under the Creative Commons Attribution 4.0 International (CC BY 4.0) license which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract- **Research on corrosion protection of steel was carried out by processing corrosive environment applying various concentrations of common sage extract 0.5 g/dm^3, 1 g/dm^3 and 1.5 g/dm^3, as a green inhibitor, in 3 % NaCl solution. Measurements were conducted using the gravimetric method, as well as electrochemical methods (Tafel extrapolation method and electrochemical impedance spectroscopy). The highest level of protection was achieved in 3% NaCl, at concentrations of common sage 1.5 g/dm^3, over a period of 6h and is z = 97.5 % . Concentrations of common sage 1.0 g/dm^3 and 1.5 g/dm^3 in 3% NaCl show very good inhibitory effect, since the average protective factor is $\bar{z}$ = 78.5% and $\bar{z}$ =95.3% respectively. These results recommend the common sage as a possible inhibitor in 3 % NaCl solutions. Results obtained by electrochemical impedance spectroscopy are consistent with the results of gravimetric measurements of corrosion indicators in 3% NaCl. This confirms that the electrochemical impedance spectroscopy can be used for rapid corrosion tests as a reliable method. Determination of corrosion rate and the degree of protection using Tafel's diagrams, calculated on the basis of current corrosion, do not provide reliable results. The obtained results differ from those obtained by gravimetric method and electrochemical impedance spectroscopy (EIS) .**

Keywords - Common sage extracts, steel, inhibitor, corrosion, protective factor

I. INTRODUCTION

The toxicity of commercial inhibitors coupled with the rising strictness of environmental standards have boosted intensive research into the existing or novel substances as potential inhibitors of corrosion. These factors have shifted the focus of research to non-toxic,"green" inhibitors of corrosion. Green inhibitors include substances that protect metal(s) from corrosion without having negative effects on the environment and life forms. This also lead to the idea to investigate the possibilities of using tincutres and extracts of medicinal herbs as potential green inhibitors [1-13].

According to the estimations of world experts in this field, corrosion of iron and its alloys in the world during a period of one year "eats" one third of the total annual world production of iron and steel [1-5]. It is easy to see the importnace of knowing every possible detail of this phenomenon and constantly developing novel, more efficient measures and methods of protection from corrosion.

Corrosion inhibitors can be classified into organic and inorganic depending on their chemical composition. According to the mechanism of their action on the process of corrosion, they are classified as anodic, cathodic and mixed. Inhibitors are nowdays used for protection of metals against abrasion, in oil production and refining, in heat exchangers, power stations, machinery maintenance, rocket technology, machine building and other branches of industry. Research shows that a quarter of corrosion damage can be prevented by using modern technologies of protection from corrosion [6-19].

The aim of this paper is to investigate corrosion stability of steel, as the most important construction material, in non-inhibited and inhibited 3% NaCl solutions, depending on time. Different concentrations of common sage extracts were used for the treatment of the corrosion area and its effect on the rate of corrosion process was investigated. Moreover, the aim is to determine the optimal concentration of common sage as the corrosion inhibitor in the given environment.

II. EXPERIMENTALS

The experimental part of the research involved using (30x30x1) mm samples of steel whose composition is known. Gravimetric and electrochemical methods in 3% NaCl solutions were used to investigate inhibiting properites of common sage on corrosion. All the samples underwent chemical preparation, after which they were investigated as to the rate of corrosion in inhibited and non-inhibited solutions. The experiments were conducted in a confined area/indoors at room temperature. The steel samples had been prepared identically before they were immersed in corrosion solutions: degreasing using a detergent, rinsing with free-flowing water and distilled water, chemical degreasing for 20 minute at the temperature 80-90^{o}C in the solution

($c(NaOH)$ = 30– 40 g/dm^3; $c(Na_2CO_3)$ = 40–50 g/dm^3; $c(Na_3PO_4$ x $10H_2O)$ = 3–5 g/dm^3). The samples were again rinsed with free-flowing and distilled water and immersed in abrasion solution (20% H_2SO_4) for the period of τ =1 min at the temperature of 60-70°C. After abrasion, the samples were rinsed with free-flowing and distilled water. The next operation is drying. In order to obtain a faster drying rate, the samples were previously rinsed in alcohol (96% ethanol). The samples were dried for 5 min using a fan heater, after which they were measured. The measured mass represents the starting mass of the sample before corrosion.

After measuring, the surface of the sample was activated in 20% H_2SO_4 at t = 60 – 70°C and τ = 2 s. The sample was then rinsed with free-flowing and distilled water and immersed in non-inhibited and inhibited solutions.

Chemical composition of the investigated steel:

Steel	C	Si	Mn	P	S	Al
% mas	0.04	0.004	0.192	0.01	0.008	0.038

Common sage extract was obtained by extracting common sage with alcohol (96% CH_3-CH_2-OH).
The following items were used for extraction:

1. Dried common sage,
2. Alcohol 96% ethanol,
3. Extraction vessel,
4. A 1000 cm^3 glass vessel with a lid,
5. Funnel,
6. Filter paper.

The obtained extract (expressed in dry weight) was added into 3% NaCl in different concentrations; in this way the following solutions were prepared for steel corrosion tests:

- *Solution 1.* 3% NaCl;
- *Solution 2.* 3% NaCl + 0,5 g/dm^3 of common sage
- *Solution 3.* 3% NaCl + 1,0 g/dm^3 of common sage;
- *Solution 4.* 3% NaCl + 1,5 g/dm^3 of common sage;

Based on the mass loss in steel samples for the time spent in prepared solutions, we calculated negative mass indices of corrosion K_{m}^{-}, crevice corrosion index π, degree of efficiency (degree of protection of the inhibitor) z. Moreover, their mean values were also calculated for all the samples, $\bar{K}_{m}^{-}$, $\bar{\pi}$, $\bar{z}$.
Electrochemical measuremens were conducted using a potentiostat/galvanostat/ZRA Gamry Series G™.

III. RESULTS AND DISCUSSION

Table 1. shows the values of steel corrosion indices in solutions 1-4.

Table 1. Steel Corrosion Indices in Solutions 1-4.

Corrosion indices	Solution 1 3 % NaCl without inhibitor				Solution 2 3% NaCl+ 0,5g/dm^3 of sage				Solution 3 3% NaCl+ 1g/dm^3 of sage				Solution 4 3% NaCl+ 1,5g/dm^3 of sage			
τ(h)	2	4	6	24	2	4	6	24	2	4	6	24	2	4	6	24
Δm(g)	0.0016	0.003	0.0020	0.0044	0.0009	0.0028	0.0009	0.0043	0.0009	0.0016	0.001	0.0043	0,0008	0.0020	0.0006	0.0033
K_{m}^{-} (g/m^{2}h)	0.41666	0.78125	0.52083	1.14533	0.11718	0.36458	0.23437	0.55989	0.078125	0.13888	0.08680	0.37326	0.01736	0.04340	0.01302	0.07161
$\bar{K}_{m}^{-}$ (g/m^{2}h)	0.71601				0.31900				0.16926				0.03634			
z(%)	0	0	0	0	71.8	53.3	55	51.1	81.2	82.2	83.3	67.41	95.8	94.4	97.5	93.7
$\bar{z}$ (%)	0				57.8				78.5				95.3			
π(mm/year)	0.51122	0.95850	0.63900	1.40519	0.14377	0.44730	0.28754	0.68692	0.09585	0.17039	0.10649	0.45794	0.02122	0.05324	0.01597	0.08785

$\bar{\pi}$ (mm/year)	0.87847	0.39138	0.20766	0.04457

The efficiency of common sage, as an inhibitor was investigated by electrochemical methods. Corrosion rate was measured by extrapolation method (Tafel diagrams were recorded) which was used to calculate corrosion potential and corrosion current. Nyquist curves were also recorded using electrochemical impedance spectroscopy (EIS).
Figure 1 shows crevice corrosion index in steel depending on the time the samples were exposed to corrosion environment in solutions.

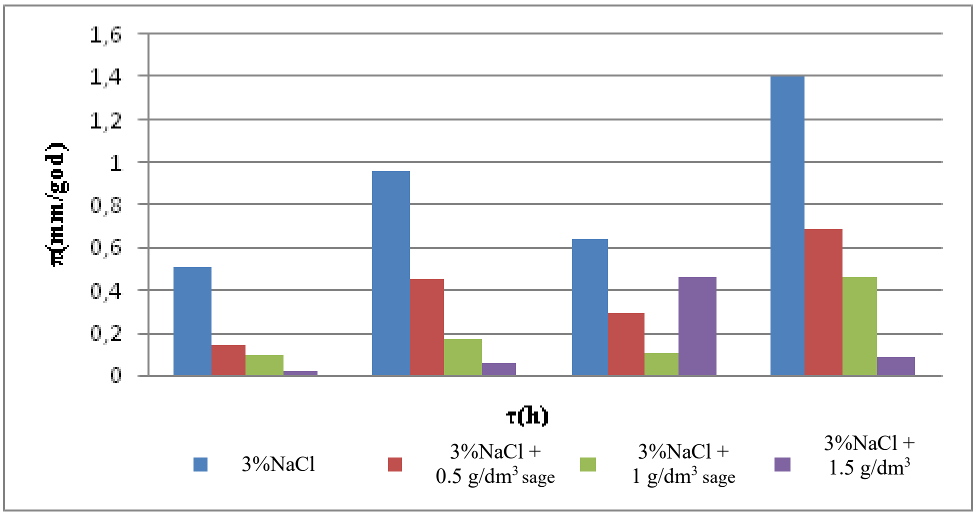

Figure 1. Diagram of steel crevice corrosion index in solutions 5-8 depending on time

Figure 1 clearly shows that there is a decrease in the value of crevice corrosion index with time. The lowest value of crevice corrosion index is π =0.01597 mm/year in 3% NaCl + 1,5 g/dm^3 of common sage for the time of 6 hours.

Figure 2 gives a diagram of the dependence between protection factor and the time the samples were exposed to corrosion in solutions 1-4.

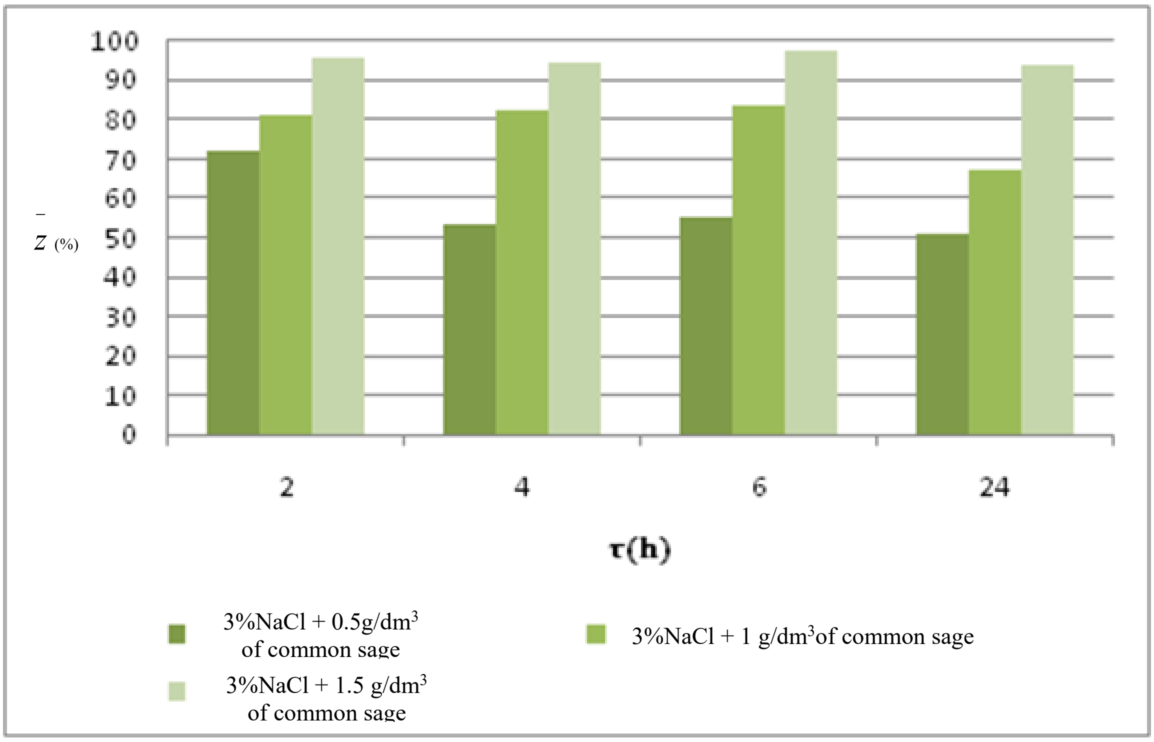

Figure 2. Diagram of dependence between protective factor and the time the samples were exposed to corrosion in solutions 1-4.

Figure 2 shows that with sage concentration of 1.5 g/dm^3 (solution 4 *),* protective factor ranges from 93.7 to 97.5% for every length of time. This fact shows that common sage with the concentration of 1.5 g/dm^3 in 3% NaCl, is a very efficient corrosion inhibitor.

Figure 3 presents Tafel diagrams which show dependence between potential (E) and current logarithm (log I) in 3% NaCl with different commmon sage concentrations.

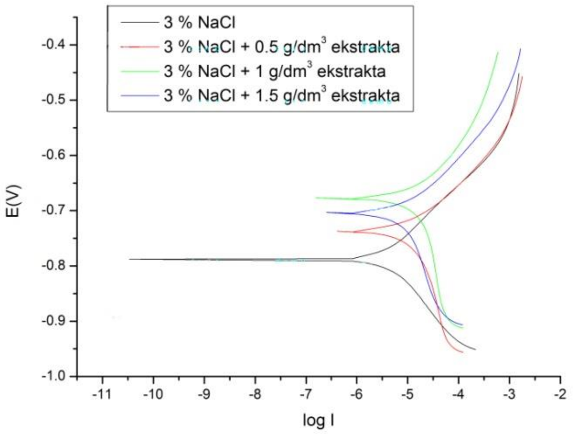

Figure 3. Tafel extrapolation diagrams for steel in 3% NaCl with different concentrations of common sage

It can be seen from Figure 3 that recorded Tafel curves for steel differ markedly in 3% NaCl solutions.Table 2 shows the results of corrosion current and corroson potential which were calculated from recorded Tafel curves using a software identically as descibed in the previous part.

Table2. Calculated values of corrosion potential and current from recorded Tafel diagrams for steel in solutions 1-4.

	Steel	
Solution	**E_{kor}(mV)**	**I_{kor}(μA)**
Solution 1. 3% NaCl	-787.3	10.87
Solution 2. 3% NaCl + 0.5 $g/dm^3$of common sage	-736.9	23.3
Solution 3. 3% NaCl + 1.0 $g/dm^3$of common sage	-676.8	28.71
Solution 4. 3% NaCl + 1.5 $g/dm^3$of common sage	-703.5	15.80

Measured values of corrosion current and potential do not indicate that common sage has inhibiting properties in 3% NaCl, which is not consistent with gravimetric measurements of corrosion indices.

Figure 4 shows – Z_{imag} from Z_{real} (Nyquist curves) recorded using electrochemical impedance spectroscopy (EIS) in solutions 1-4 for the steel used.

Figure 4 shows that steel has maximum stability in 3% NaCl + 1.5 g/dm^3 of common sage (*Solution 4*).The results obtained are consistent with those from gravimetric corrosion indices in 3% NaCl. This confirms that electrochemical impedance spectroscopy can be used for rapid corrosion tests as a very reliable method, since the results obtained comply with gravimetric measurements. Calculation of corrosion rate and degree of protection through recorded Tafel diagrams based on determined corrosion current does not give reliable results. This can be concluded from the fact that the obtained results differ from those obtained by gravimetric method and electrochemical impedance spectroscopy (EIS).

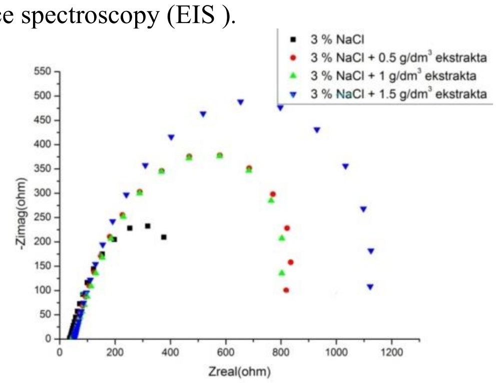

Figure 4. Nyquist diagram for steel in solutions1-4.

IV. CONCLUSION

In order to investigate the effect of protection using inhibitors it is necessary to prepare the surface of a metal correctly. The highest degree of protection in 3% NaCl, z=97.5%, is achieved at the concentration of 1.5 g/dm^3 of common sage for the time interval of 6h. Common sage concentrations of 0.5 g/dm^3 and 1.0 g/dm^3 in 3% NaCl exhibit very good inhibitory properties, since mean protective factor is $\bar{z}$ = *57.8%* and $\bar{z}$ = *78.5%,* respectively.These results show that common sage is a recommend able inhibitor in solutions 3% NaCl. Gravimetric measurements are consistent with the results obtained form electrochemical impedance spectroscopy (EIS) in 3% NaCl, which shows that electrochemical impedance spectroscopy can be used as a very reliable method for rapid corrosion tests. Calculation of corrosion rate and degree of protection through recorded Tafel diagrams based on determined corrosion current does not give reliable results.This can be concluded from the fact that the obtained results different from those obtained by gravimetric method and electrochemical impedance spectroscopy (EIS).

REFERENCES

[1] M.G. Pavlović, D. Stanojević, S. Mladenović, *Korozija i zaštita materijala,* Tehnološki fakultet, Zvornik, 2012.

[2] M. Antonijević, M.G. Pavlović, Č. Lančnjevac, S. Mladenović, *Korozija i zaštita čelika*, Beograd 1998.

[3] S. Mladenović, *Korozija materijala*, Izd. TMF Beograd, 1990.

[4] M. Maksimović, S. Mladenović, I. Vučković, *Korozija i zaštita,* Tehnička knjiga,Beograd, 1996.

[5] http:// peskiranje.com/sta_je_korozija.html;

[6] V.S.Sastri, *Green corrosion of inhibitors, theory and practice,* Published by John Wiley & Sons, Inc., Hoboken, New Jersey 2011.

[7] M.V. Tomić, R. Fuchs Godec, Lj. Vasiljević, M. G. Pavlović, *Zaštita materijala,* 53 (2012) 3.

[8] M. Sangeetha, S. Rajendran, T.S. Muthumegala, A. Krishnaveni, *Zaštita materijala,* 52(2011)1.

[9] Jagoda Radošević, *Zaštita materijala,* 53 (2012) 313-323.

[10] I. Esih, *Osnove površinske zaštite*, Fakultet strojarstva i brodogradnje, Zagreb, 2003.

[11] I.Esih, Z.Dugi, *Tehnologija zaštite od korozije*, Školska knjiga, Zagreb, 1990.

[12] http://corrosion.ksc.nasa.gov/corr_forms.htm.

[13] http://www.cdcorrosion.com/mode_corrosion/stress_corrosion_cracking.htm.

[14] O. Avwiri, F.O. Igho, *Mat. Lett.* 57 (2003)3705

[15] R. Fuchs-Godec, M.G. Pavlović, M.V. Tomić, *Ind. Eng. Chem. Res.*51 (2012) 274-284.

[16] R. Fuchs-Godec, M.G. Pavlović, *Corrosion Science,* 58(2012) 192-201.

[17] R. Fuchs Godec, M.G. Pavlović, M.V. Tomić, Proceedings, *XIV YUCORR,* CD, Tara 2012, 155-161.

[18] M.V. Tomić, M.G. Pavlović, M. Jotanović, R. Fuchs Godec, *Quality of Life 1*,(1) 2010, 72-89

[19] M.V. Tomić, M.G. Pavlović, R. Fuchs Godec, *Drugi međunarodni simpozijum o koroziji i zaštiti materijala i životnoj sredini,* Knjiga radova, p. 64-68. Bar, 17. do 20. oktobra 2012.