27th ABCM International Congress of Mechanical Engineering
December 04-08, 2023, Florianópolis-SC, Brazil

COB-2023-0225
SUSTAINABLE USE OF ALOE VERA OIL AGAINST CORROSION IN COPPER-CONTAINING REFRIGERATION SYSTEMS

Marcos Paulo Simões Barbosa
Carmem Célia Francisco do Nascimento
Intituto Federal do Maranhão, Av. Gettúlio Vargas, 04 – Monte Castelo, São Luís-MA
marcos.barbosa@acad.ifma.edu.br / carmemfn@ifma.edu.br

Ronaldo Silva Paixão
Intituto Federal do Maranhão, Av. Gettúlio Vargas, 04 – Monte Castelo, São Luís-MA
rpaixao@acad.ifma.edu.br

Waldemir Passos Martins
Intituto Federal do Maranhão, Av. Gettúlio Vargas, 04 – Monte Castelo, São Luís-MA
waldemir@ifma.edu.br

Valter Alves de Meneses
Intituto Federal do Maranhão, Av. Gettúlio Vargas, 04 – Monte Castelo, São Luís-MA
valter@ifma.edu.br

Abstract. *The corrosion of air conditioning systems causes numerous issues, such as efficiency reduction, leakage of cooling gases known as green house gases, and increased electricity consumption. While copper is known for its remarkable corrosion resistance, in highly salted environments, the corrosion process is accelerated by the presence of chlorides and by the imperfections in the passivation layer. Therefore, the objective of this study is to evaluate the inhibitory potential of an organic varnish coating with various concentrations of Aloe vera applied to the surface of copper used in air conditioning systems. To achieve this goal, copper tubes were painted with the mixture of organic varnish and the Aloe vera extract at different concentrations. Subsequently, electrochemical impedance spectroscopy and potenciodynamic polarization tests were conducted in an environment containing 3.5% sodium chloride (NaCl) to assess the inhibitory potential and the corrosion rate, respectively. The results demonstrate that the combination of varnish and Aloe vera acts as a highly effective corrosion inhibitor for copper coils in saline environments, reducing the corrosion rate by forming a physical barrier between the metal and the corrosion medium. The highest efficiency was observed with a concentration of 100 ppm, achieving a 99% reduction in corrosion.*

Keywords: *corrosion, copper, air conditioning, Aloe vera, natural extract*

1. INTRODUCTION

Copper is a noble metal that exhibits a reddish color and possesses malleability, ductility, and a crystalline structure similar to silver and gold. Currently, copper is considered one of the most important commercially utilized metals due to its exceptional properties, including excellent thermal and electrical conductivity, corrosion resistance, and remarkable mechanical properties (Cardoso, 2014, Jesus, 2008 and Marques, 2018).

These properties make copper an extremely efficient material for air conditioning applications. Additionally, copper demonstrates resistance to internal pressure at high temperatures, does not release toxic gases or ignite easily, is easy to transport and handle, can be welded, exhibits high plastic deformation, does not readily oxidize, and is weather-resistant and interchangeable (Marques, 2018).

According to Bhatia (2022), corrosion in air conditioning systems can occur in three forms: galvanic, pitting, or general corrosion. Galvanic corrosion arises when two dissimilar materials come into contact in a corrosive environment. Pitting corrosion is caused by chlorides and fluorides present in highly salted environments. Finally, general corrosion refers to the overall degradation of the metal when exposed to a corrosive medium.

The following are the anodic reactions that occur in copper when exposed to a corrosive medium containing sodium chloride (NaCl):

$$Cu \rightarrow Cu^+ + e^- \quad (1)$$
$$Cu^+ + Cl^- \rightarrow CuCl \quad (2)$$
$$CuCl + Cl^- \rightarrow CuCl_2^- \quad (3)$$

The initial reaction, Eq. (1), illustrates the oxidation of copper, leading to the formation of Cu^+ ions. These ions then react with chloride ions (Cl^-) present in the environment, resulting in the formation of an intermediate substance on the metal surface, a soluble layer of CuCl, as shown in Eq. (2). However, this newly formed layer is unstable, allowing it to further react with chloride ions, resulting in the formation of the $CuCl_2^-$ ion complex, as demonstrated in Eq. (3) (Fateh et al., 2020 and Jesus, 2008).

Costa (2013) and Khodakarami et al (2021) present two possible cathodic reactions in this scenario: oxygen reduction and hydrogen evolution, as shown in Eq. (4) and Eq. (5), respectively.

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^- \quad (4)$$
$$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \quad (5)$$

To prevent corrosion in copper, a protective layer can be used. This layer should possess certain properties such as small thickness to avoid altering the thermal properties of the material, impact resistance, flexibility, UV resistance, and water resistance (Bhatia, 2022).

However, many of the commonly used inhibitors are toxic as they are composed of phosphates, chromates, dichromates, vanadates, and arsenates. These substances are pollutants and expensive to produce, leading to an increased search for new products that are environmentally friendly, renewable, and low-cost (Ortega-Ramírez et al., 2021 and Al-asadi et al., 2015).

During the selection of a green inhibitor, several properties need to be considered, including the corrosion mechanisms, the material to be protected, toxicity levels, effects on human health, application conditions (such as temperature, humidity, pH, pressure, geometry, concentration, thermal stability, and solubility), as well as storage, application method, layer thickness, reactivity with the environment, and the system (Ortega-Ramirez et al., 2021 and Umoren et al., 2019).

Aloe vera, a plant well-known for its medicinal properties, is currently being used as a corrosion inhibitor. The main compounds responsible for its inhibitory effect are aloeresin A, aloeresin B, aloins, aloesin, and aloe emodin, which are heterocyclic molecules containing oxygen and nitrogen atoms (Mehdipour et al., 2015).

Numerous studies have demonstrated the effectiveness of Aloe vera as an inhibitor, reducing corrosion in various materials. For example, it has been shown to be effective in carbon steel (Al-Asadi et al., 2015, Espinoza-Vázquez and Gómez, 2017 and Sribharathy et al., 2013), brass B66 (Benzidia et al., 2019), aluminum alloys (Šćepanović et al., 2019 and Bikić et al., 2017), and stainless steel 316L (Putlitz et al., 2019).

Therefore, the objective of this study is to evaluate the inhibitory potential of an organic varnish coating with various concentrations of Aloe vera when applied to the surface of copper used in air conditioning systems in highly salted environments with 3.5% NaCl. Electrochemical methods such as electrochemical impedance spectroscopy and potentiodynamic polarization were employed to characterize the corrosion potential, inhibitory potential, and corrosion rate of the material.

2. EXPERIMENTAL

2.1 Materials and sample preparation

The material used in this study is copper, specifically for air conditioning applications, produced in accordance with NBR 7541 standards. It has a copper content of 99.9% and phosphorus content ranging from 0.015% to 0.040%.

The selected organic varnish is a polymer with a density of 1.02 g/cm^3, a flash point of 100 °C, a pH of 9, and a kinematic viscosity of 404.50 mm^2/s.

The Aloe vera oil, obtained from *Aloe barbadensis* leaves, had a dynamic viscosity of 52.79 mPas, measured using a BROOKFIELD DV III ULTRA viscometer, at a shear rate of 58 s-1 and 200 RPM. Its pH was measured as 5 using pH tape.

To prepare the solution, the varnish was diluted with water at a ratio of 5 parts varnish to 1 part water, following the manufacturer's recommendation. Subsequently, Aloe vera oil was added to achieve concentrations of 50, 100, and 150 ppm, based on the work of Benzidia et al. (2019).

After the solution preparation, electrical conductivity and pH were measured at room temperature (25 °C) using a portable conductometer (CG1400 Gehaka) and a pH meter (PG 2000 Gehaka) respectively. The measured values are presented in Table 1.

The samples used in the study were cut from a 3/8" diameter tubulation with the length of 2.00 cm each and underwent a sanding process using abrasive papers with grit sizes of 320, 400, 600, 800, and 1200. After sanding, they were cleansed with distilled water and dried using compressed air.

Table 1. Electrical conductivity and pH of varnish and solutions with Aloe vera

Sample	pH	ELETRICAL CONDUCTIVITY (mS/cm)
Varnish	8,71	2,27
Varnish+AV50	9,01	2,33
Varnish+AV100	9,10	2,41
Varnish+AV150	9,01	2,40

Once prepared, the samples were painted using a spray method and left to dry for a period of 24 hours. Figure 1 illustrates the appearance of the samples after the painting process. For comparison purposes, one sample was exclusively painted with the varnish, while another sample was left untreated without the protective layer.

Figure 1. Copper samples.

2.2 Techniques

2.2.1 Potentiodynamic Polarization and EIS tests

Potentiodynamic polarization and EIS measurements were carried out in a AUTOLAB PGSTAT302N. The electrochemical cell consisted of three electrodes: a reference electrode of calomel (Hg|Hg2Cl2|KCl(3M)), a counter electrode of platinum, and a copper working electrode. The working electrode's exposed area to the 3.5% NaCl solution was 0.449 cm^2, and it was secured with an adapted rubber.

The polarization tests were conducted at the sweep rate of 1 mV/s within the range of ± 3 mV from the open circuit potential (V_{OCP}). After stabilizing the open potential circuit for 3600 s, EIS measurements were performed with an amplitude of 10 mV and 10 points per decade. The frequency range varied from 100 kHz down to 1 mHz, adapted from the works of Gonzalez-Rodriguez et al. (2016), Costa (2013) and Mennucci (2011). Data analysis was performed using NOVA 2.1.6, and the resulting curves were plotted using OriginPro 8.5.

By employing Tafel extrapolation on the polarization curves, the corrosion current density (Icorr) was obtained, and inhibition efficiency was calculated using Eq. (6).

$$IE\ (\%) = \left[\frac{I_0 - I_{varnish}}{I_0}\right] x\ 100 \tag{6}$$

where I_0 and $I_{varnish}$ are the corrosion current densities of the copper samples without and with varnish, respectively.

2.2.2 Fourier Transform Infrared – FTIR

FTIR spectra of the varnish and the solutions of varnish and Aloe vera obtained using an IRAffinity-1 Shimadzu FTIR spectrometer equipped with attenuated total reflectance (ATR). The spectra were measured with transmittance (%T) ranging from 4700 to 340 cm^{-1}, with 68 readings at a resolution of 4.0. No baseline correction was required. The obtained data were plotted using Origin 8.5.

3. RESULTS AND DISCUSSION

3.1 Electrochemical Impedance Spectroscopy

Impedance measurements were carried out after stabilizing the open circuit potential. In the experiment, the samples were superficially exposed to a sodium chloride solution, NaCl 3.5%, to simulate a local atmosphere. Figure 2 shows the Nyquist plots for copper samples coated with varnish mixed with Aloe vera at concentrations of 50, 100, and 150 ppm. Additionally, diagrams were plotted for copper samples with and without varnish for comparison.

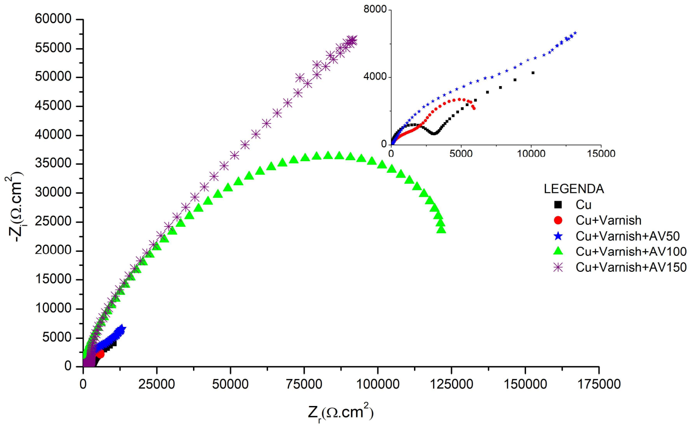
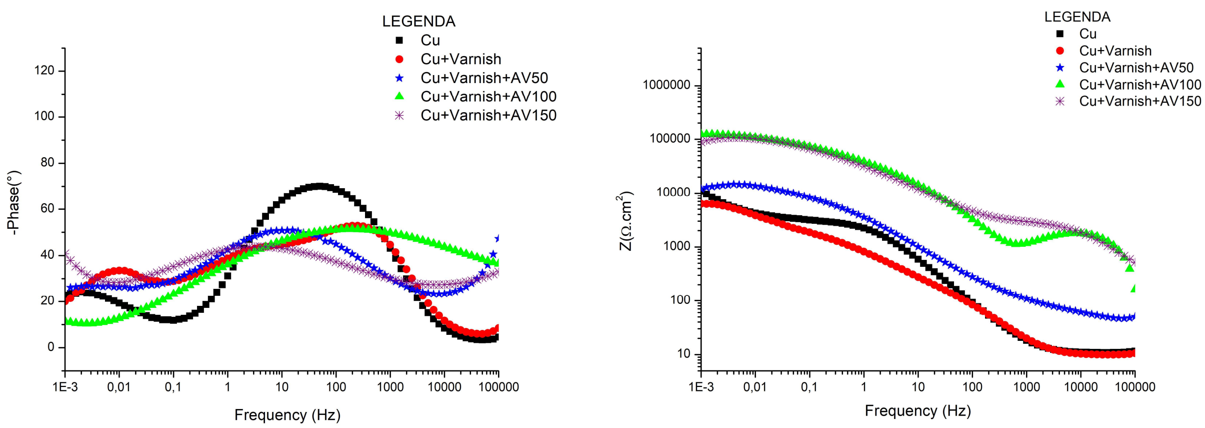


Figure 2. Nyquist plots for copper samples with and without varnish and Aloe vera oil at concentrations of 50, 100 e 150 ppm

Firstly, it is observed that the sample coated with varnish and Aloe vera at a concentration of 100 ppm exhibited the best performance, very close to the sample with varnish and Aloe vera at 150 ppm. According to Gonzalez-Rodriguez et al. (2016), a larger semicircle diameter in a Nyquist plot indicates a greater impedance variation and, consequently, better inhibitory properties. Furthermore, it can be noted from the curve shapes that the corrosion mechanism differs for each sample.

In addition, the sample without coating shows a nearly linear region in the second region, indicating that the metal undergoes passivation. This behavior in the low-frequency region suggests that the corrosion process is controlled by diffusion (Özyilmaz et al., 2005; Gonzalez-Rodriguez et al., 2016).

To gain a better understanding of the corrosion process from impedance data, it is necessary to analyze the Bode plots shown in Figure 3.



(a) (b)

Figure 3. Bode (a) phase and (b) impedance plots for copper samples with and without varnish and Aloe vera oil at concentrations of 50, 100 e 150 ppm

The impedance plot confirms that samples with Aloe vera at concentrations of 100 and 150 ppm demonstrated greater efficiency in inhibiting corrosion in copper tubes. Additionally, from Figure 3a, it can be observed that all samples exhibited a high-frequency time constant, indicating that the coating provided resistance to corrosion. However, there was dispersion of data in the low-frequency region, suggesting the presence of a diffusion process, as discussed by Cardoso (2014) and Porcayo-Calderon et al. (2016).

In Figure 3b, no impedance plateau was formed in the high-frequency region for any of the samples, and the impedance remained frequency dependent. According to Porcayo-Calderon et al. (2016), this behavior is a consequence of the adsorption of the coating to the metal surface, acting as a barrier to corrosion.

3.2 Potentiodynamic Polarization

Figure 4 displays polarization curves for copper samples with the following coatings: varnish mixed with Aloe vera at concentrations of 50, 100, and 150 ppm, as well as copper samples with and without varnish coating.

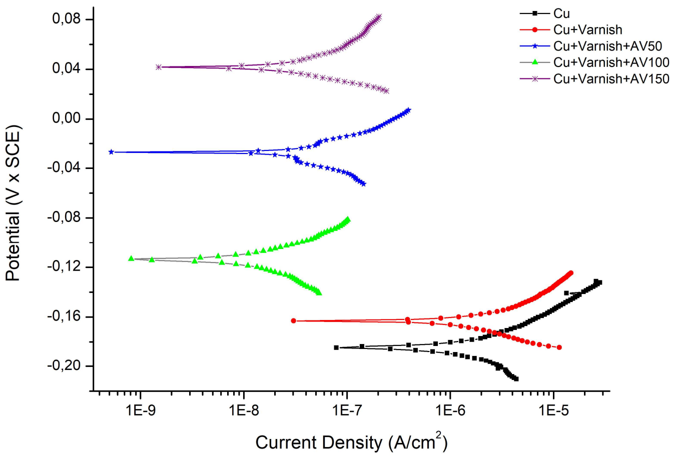


Figure 4. Polarization curves for copper samples with and without varnish and Aloe vera oil at concentrations of 50, 100 e 150 ppm

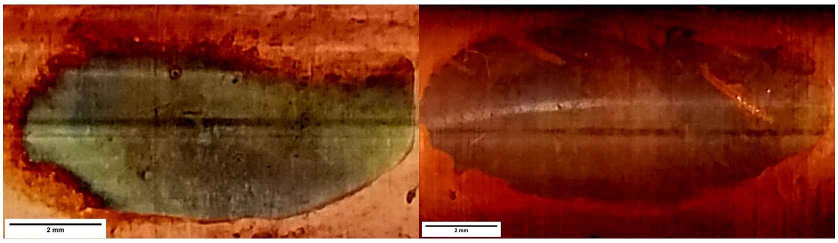
From Figure 4, it can be observed that the addition of varnish coating with Aloe vera shifted the curves to the left, indicating a reduction in copper dissolution and an increase in corrosion inhibition. Furthermore, changes in the Tafel slopes of both the anodic and cathodic curves confirm that Aloe vera acts as a mixed-type inhibitor, simultaneously reducing the anodic reaction of copper and the cathodic reaction of oxygen, as stated by Mehdipour et al., (2015) and Mashooque et al., (2022). However, there is a shift of the curves towards the cathodic region, as observed by Benzidia et al. (2019), indicating that the varnish with Aloe vera has a significant influence on controlling the cathodic reduction of oxygen.

Table 2 presents the results of the Tafel analysis, including the corrosion current density, corrosion potential, and slopes of the anodic and cathodic curves. The sample coated with varnish and Aloe vera at a concentration of 100 ppm exhibited the highest inhibition efficiency of 99.26%, followed by the varnish with Aloe vera at 150 ppm with 99.02%. Figure 5 illustrates the corrosion areas in all samples.

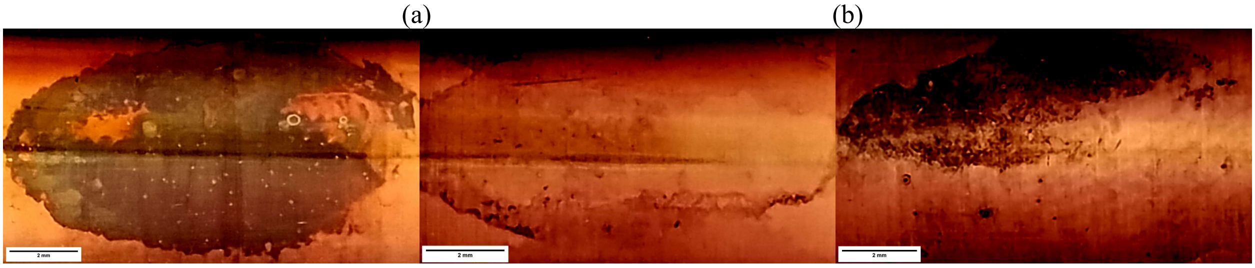
Figure 5a shows copper without any coating after corrosion. The corroded area exhibits a greenish color, indicating the formation of copper oxide on the metal surface as a corrosion product. Figures 5b and 5c show a large dark area formed by corrosion, indicating the formation of oxide beneath the varnish film. Figure 5e of the 150 ppm Aloe vera sample displays a corrosion region with a different color, which can be associated with the formation of other corrosion products. Figure 5d depicts the 100 ppm Aloe vera sample with minimal corrosion compared to the other samples, confirming the results of electrochemical tests that indicated this concentration had the best performance in reducing corrosion in copper.

3.3 Fourier Transform Infrared – FTIR

Figure 6 displays the infrared spectra of varnish and solutions containing varnish and Aloe vera. Upon comparing the data, notable changes can be observed at peaks 2956 and 2874 cm^{-1}, which are associated with the vibration modes of C-H bonds present in CH_2 and CH_3 molecules as mentioned by Santos et al., (2016). According to Mohamed et al., (2017), the variation in peaks at 2361 and 2342 cm^{-1} indicates an increase in C≡C bond. The changes observed in the peak at 1728 cm^{-1} are related to the vibration modes of carbon double bonds (C=C) and double bonds between carbon and oxygen (C=O), as described by Abbasi et al., (2020). Additionally, variations in peaks below 1500 cm^{-1} correspond to the vibrational modes of simple bonds such as phenolic -OH, C-H, C-O-C and C-O-H as discussed by Mashooque et al., (2022) and Zhang et al. (2020).



(a) (b)



(c) (d) (e)

Figure 5. Samples after corrosion tests. (a) copper (b) copper with varnish and copper with varnish and Aloe vera at (c) 50 ppm, (d) 100 ppm and (e) 150 ppm.

Table 2. Electrochemical parameters from polarization tests after Taffel analysis

	Cu	***Cu+Varnish***	***Cu+Varnish+ AV50***	***Cu+Varnish + AV 100***	***Cu+Varnish + AV 150***
Ecorr, Obs (V)	-0,1844	-0,1630	-0,0273	-0,1138	0,0416
jcorr (A/cm²)	1,92E-06	9,56E-07	7,80E-08	1,42E-08	1,88E-08
|ba| (V/dec)	0,0432	0,0160	0,0502	0,0354	0,0218
|bc| (V/dec)	0,0700	0,0222	0,0935	0,0469	0,0164
Inhibition Efficiency (%)		50,27%	95,94%	99,26%	99,02%

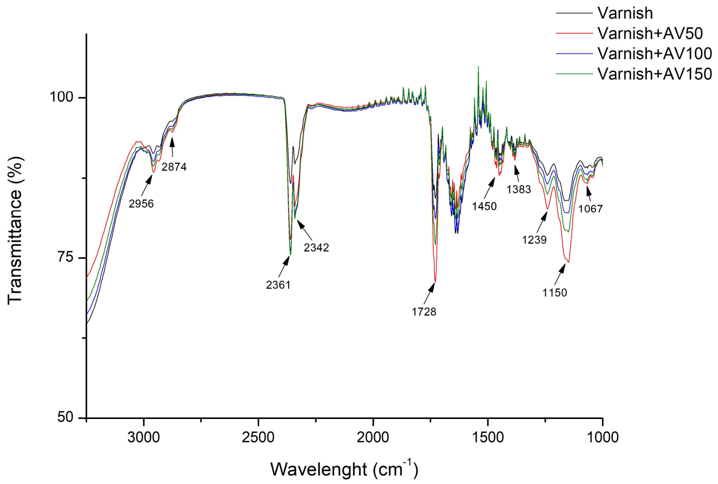


Figure 6. FTIR spectrum of varnish without and with Aloe vera at 50, 100 and 150 ppm concentrations.

The observed peak changes can be attributed to the presence of Aloe vera components such as aloeresin A, aloeresin B, aloins, aloesin, and aloe emodin. These components contain aromatic rings, phenolic-OH bonds, double bonds C=O,

CH_3 molecules and C-O-C bonds. The presence of these molecular structures on metal surface increases electron density and forms a protective film, retarding corrosion effect as discussed by Ortega-Ramirez et al. (2021), Zhang et al. (2020), Haris et al. (2019), Sribharathy et al. (2013), Mehripour et al., (2015), Mashooque et al., (2022), and Abiola and James (2010).

4. CONCLUSION

Based on the investigation of the inhibition performance of Aloe vera added to varnish for copper in 3.5% NaCl, the following conclusions can be drawn:

- Impedance plots demonstrated an increased resistance to corrosion for samples coated with varnish and Aloe vera compared to samples without varnish and those with only varnish. This indicates that the Aloe vera oil acts as a mixed-type inhibitor, with predominance of the cathodic inhibition mechanism.
- Potentiodynamic tests revealed a reduction in the corrosion current density for the sample with varnish and Aloe vera. The sample with 100 ppm Aloe vera exhibited the highest inhibition efficiency, reaching 99.26%.
- The observed inhibitory effect can be attributed to the molecular composition of Aloe vera, particularly the presence of phenolic -OH bonds, double carbon bonds in aromatic rings, double bonds C=O, CH_3 molecules, and C-O-C present in components such as aloeresin A, aloeresin B, aloins, aloesin, and aloe emodin. These components contribute to the delay of corrosion processes in copper exposed to 3.5% NaCl solution.

5. ACKNOWLEDGEMENTS

We thank Federal Institute of Maranhão, particularly the Mechanical and Materials Department and Chemical Department, for providing the necessary equipment for conducting the tests and analyses in this study. The FTIR experiments were conducted at the LACAT (Catalysis and Metal Oxides Synthesis Laboratory).

6. REFERENCES

Abbasi, M.S.A., Tahir, M.A. and Meer, S., 2020. FTIR Spectroscopic Study of Aloe vera barbadensis Mill Buds. *Asian Journal Of Chemical Sciences*, p. 1-6.

Abiola, O.K. and James, A.O., 2010. The effects of Aloe vera extract on corrosion and kinetics of corrosion process of zinc in HCl solution. *Corrosion Science*, v. 52, n. 2, p. 661-664.

Al–asadi, A.A., Abdullah, A.S., Khaled, N.I. and Alkhafaja, R.J.M., 2015. Effect of an Aloe Vera As a Natural Inhibitor on The Corrosion of Mild Steel in 1 wt. % NaCl. *International Research Journal Of Engineering And Technology*, v. 02, n. 06, p. 604-607.

Benzidia, B., Hammouch, H., Dermaj, A., Benassaoui, H., Abbout, S. and Hajjaji, N., 2019. Investigation of Green Corrosion Inhibitor Based on Aloe vera (L.) Burm. F. for the Protection of Bronze B66 in 3% NaCl. *Analytical & Bioanalytical Electrochemistry*, v. 11, n. 2, p. 165-177.

Bhatia, A. *HVAC Design Considerations for Corrosive Environments*. 2022. Disponível em: https://www.cedengineering.com/userfiles/HVAC%20Design%20Considerations%20for%20Corrosive%20Env%20R1.pdf. Acessed 11 May 2022.

Bikić, F., Kasapović, D., Delijić, K. and Radonjić, D., 2017. Application of Aloe Vera as Green Corrosion Inhibitor for Aluminum Alloy Types AA8011 and AA8006 in 3,5% NaCl. *Bulletin Of The Chemists And Technologists Of Bosnia And Herzegovina*, n. 48, p. 35-40.

Cardoso, E.S.F., 2014. *TEOS - GPTMS conversion layer and hybrid films additives with cerium ions as pre-protective treatments against copper corrosion (in Portuguese)*. Master's thesis – Graduate Program in Chemistry, Federal University of Grande Dourados, Dourados.

Costa, J.F., 2013. *Evaluation of amino acids as corrosion inhibitors for copper in artificial seawater media (in Portuguese)*. Master's thesis – Graduate Program in Chemistry Engineering, State University of Rio de Janeiro, Rio de Janeiro.

Espinoza-Vásquez, A. and Gómez, F.J. R., 2017. "Evaluación electroquímica de la Aloína como inhibidor de la corrosión en el acero AISI 1018". In: Mexican Chemistry Congress, 2017, Puerto Vallarta.

Fateh, A., Aliofkhazraei, M. and Rezvanian, A.R.., 2020. Review of corrosive environments for copper and its corrosion inhibitors. *Arabian Journal Of Chemistry*, v. 13, n. 1, p. 481-544.

Gonzalez-Rodriguez, J G., 2019. Use of a Palm Oil-Based Imidazoline as Corrsion Inhibitor for Copper in 3.5% NaCl Solution. *International Journal Of Electrochemical Science*, p. 8132-8144.

Haris, N.I.N., Sobri, S., Yusof, Y.A. and Kassim, N., 2019. Oil palm empty fruit bunch extract and powder as an eco-friendly corrosion inhibitor for mild steel: a comparison study. *Materials And Corrosion*, v. 70, n. 12, p. 2326-2333.

Jesus, A.C.N., 2008. *Study of parameters: NaCl content and surface finish in resistance to pitting corrosion in copper tubes (in Portuguese)*. Master's thesis – Graduate Program in Science, University of São Paulo, São Paulo.

Khodakarami, S., Zhao, H., Rabbi, K.F. and Miljikovic, N., 2021. Scalable Corrosion-Resistant Coatings for Thermal Applications. *Acs Applied Materials & Interfaces*, Washington, v. 13, p. 4519-4534.

Marques, J.J.A., 2018. *Good practices in the use of copper for refrigeration and air conditioning (in Portuguese).* São Paulo: SENAI-SP.

Mashooque, S., Kumar, M., Unar, I.N., 2022. Effect of Aloe Vera Extract as Green Corrosion Inhibitor on Medium Carbon Steel in SulphuricAcid Environment. *Pakistan Journal Of Analytical & Environmental Chemistry*, v. 23, n. 1, p. 70-78.

Mehdipour, M.; Ramezanzadeh, B.; Arman, S., 2015. Electrochemical noise investigation of Aloe plant extract as green inhibitor on the corrosion of stainless steel in 1 M H 2 SO 4. *Journal Of Industrial And Engineering Chemistry*, v. 21, p. 318-327.

Mennucci, M.M., 2011. *Study of copper corrosion in sulfate and chloride media with the aid of a microelectrode with a cavity and a microcell*. Ph.D. thesis – Graduate Program in Engineering, Polytechnic School of the University of São Paulo, São Paulo.

Mohamed, M.A., Jaafar, J., Ismail, A.F., Othman, M.H.D. and Rahman, M.A., 2017. Fourier Transform Infrared (FTIR). In: HILAL, Nidal *et al* (ed.). *Membrane Characterization*. Elsevier, 2017. p. 3-29.

Ortega-Ramírez, A. T., Barrantes-Sandoval, L.V., Casallas-Martin, B.D. and Cortés-Salazar, N., 2021. Application of green inhibitors for corrosion control in metals: review. *Dyna*, Bogotá, v. 88, n. 217, p. 160-168.

Özyilmaz, A.T., Tüken, T., Yazici, B. and Erbil, M., 2005. The electrochemical synthesis and corrosion performance of polyaniline on copper. *Progress In Organic Coatings*, v. 52, n. 2, p. 92-97.

Porcayo-Calderon, J., Rivera-Muñoz, E.M., Peza-Ledesma, C., Casales-Diaz, M., Escalera L.M.M., Canto, J. and Martinez-Gomez, L., 2017. Sustainable Development of Palm Oil: synthesis and electrochemical performance of corrosion inhibitors. *Journal Of Electrochemical Science And Technology*, v. 8, n. 2, p. 133-145.

Santos, M.C., Lima, E.R.L., Pereira, A.M., Pereira, L., Castro, D.A.R. and Machado, N.T., 2016. "Biofuel produced in a semi-pilot reactor with residue from the neutralization of palm oil (in Portuguese)". In: Brazilian Congress of Chemical Engineering, 21., 2016, Fortaleza.

Šćepanović, J., Herenda, S., Radonjić, D. and Vuksanović, D., 2019. Investigation of Inhibitory Effect of the Aloe Vera Extract on Corrosion of Aluminium Alloys. *Bulletin Of The Chemists And Technologists Of Bosnia And Herzegovina*, n. 52, p. 23-32, 2019.

Sribharathy, V., Rajendran, S., Rengan, P. and Nagalakshmi, R., 2013. Corrosion Inhibition by an aqueous extract of Aleo vera (L.) Burm F. (Liliaceae). *European Chemical Bulletin*, v. 2, n. 7, p. 471-476.

Umoren, S.A., Solomon, M.M., Obot, I.B. and Suleiman, R.K., 2019. A critical review on the recent studies on plant biomaterials as corrosion inhibitors for industrial metals. *Journal Of Industrial And Engineering Chemistry*, v. 76, p. 91-115.

Putlitz, G.S., Vásquez, A.E., Gómez, F.J.R. and Hernández, H.H., 2019. Application of Electrochemical Techniques in Stainless Steel 316L for a Prosthesis with Aloe-Vera Extract Inhibitor. *Ecs Transactions*, v. 94, n. 1, p. 151-161.

Zhang, W., Ma, Y., Chen, L., Wang, L.J., Wu, Y.C. and Li, H.J., 2020. Aloe polysaccharide as an eco-friendly corrosion inhibitor for mild steel in simulated acidic oilfield water: experimental and theoretical approaches. *Journal Of Molecular Liquids*, v. 307, p. 112950.

7. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.