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STUDY ON THE APPLICATION OF THE ALGAE SPECIES *Sargassum vulgare* TO COMBAT CORROSION OF CARBON STEEL

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Abstract: In industry in general and in the oil industry, corrosion has been a major costly problem, causing financial losses. In this context, this study sought to evaluate *Sargassum vulgare,* collected on the coast of Alagoas, as a corrosion inhibitor for metallic structures on oil platforms, more specifically in carbon steel hydrocarbon production pipes. For that, synthetic produced water was used in the absence and presence of the proposed inhibitor and gravimetric technique for evaluation of the test specimens. The study pointed out that the presence of algae reduced the percentage mass loss, the accumulated load and the corrosion current of the specimens, consequently impacting the reduction of corrosion in steel. Thus, the evaluated seaweed acted as a green corrosion inhibitor.
Keywords: Corrosion. Inhibitor.*Sargassum vulgare*.

INTRODUCTION

From the moment that man started to tame metallurgy techniques and transform ores into forged products by his dexterity and wisdom, there has always been the obstacle of corrosion. Thus, as society developed and became increasingly complex, the need for metallic products increased. Until the industrial revolution in the 18th century gave a new dynamism to this need and today, in the contemporary world, our dependence on these products is undeniable (POHLAK et al., 2004; STEARNS, 2020).

More recently, we started using another naturally occurring product that provided us with more comfort and a better quality of life, not to mention the wide spectrum of possibilities that propelled us towards our current and increasingly advanced lifestyle. Oil provided us with a new era of possibilities (SCHMIDT, 2002).

The need for development in the oil and gas sector in the country and the increase in industrial demand has provided the advancement of several fields in petroleum engineering (SCHÜTZ, 2009). In industry, corrosion has been a major costly problem, causing financial losses due to the maintenance and replacement of corroded materials (HOSSAIN, ASADUZZAMAN CHOWDHURY and KCHAOU, 2021).

Corrosion control is extremely important both in terms of cost reduction and maintenance to preserve the production conditions of the well. Despite having a lot of research in the area, corrosion is still one of the biggest problems that occur in the industry.

In the extraction, transport, processing, distribution and storage of products, which occur in the oil industry, frequent and serious problems caused by the corrosive action of microorganisms on metallic components were observed (CORRÊA, 2003). In reservoirs and pipelines for transporting oil, the presence of these microorganisms is quite common, especially when oil comes from fields where seawater injection is used (VIDELA, 2003).

According to the characteristic and depth of the producing field, the produced water presents varied composition. It presents emulsified oil, pollutants, high salinity, dissolved gases, suspended solids and microorganisms, making it a highly favorable medium for the occurrence of the corrosive process when in contact with the metallic structures of the producing field (MORAES et al, 2004).

Corrosion inhibitors are one of the main methods used in general industries to prevent or minimize corrosion. Such inhibitors can be organic or inorganic substances, which when included in the corrosive environment, inhibit or decrease the evolution of chemical reactions (FRAUCER-SANTOS et al., 2013). Even if very efficient, commercial inhibitors can be quite toxic, causing impacts on both the environment and human health.

After understanding these risks, research was triggered to exchange synthetic inhibitors, through the development of inhibitors extracted from natural products, considering that they are more economical and non-toxic. In this context, we have the seaweed *Sargassum vulgare* (Figure 1), brown in color, one of the species with the highest bioavailability on the Brazilian coast, whose geographic distribution extends from the State of Maranhão to the State of São Paulo (ALMADA et al., 2008). The literature reports some studies on the use of algae of the genus Sargassum with a corrosion inhibitor such as *Sargassum wightii* (KUMAR and CHANDRASEKARAN, 2015), *Sargassum muticum* (NADI et al., 2019), *Sargassum tenerrimuman* (KOKILARAMANI et al., 2021) and *Sargassum polycystum* (THILAGAVATHI et al., 2019).

Figure 1- Seaweed of the species *Sargassum vulgare*.

Source: DORE (2012).

In this perspective, the present work aims to use the alga that has wide bioavailability, *Sargassum vulgare*, and test it as a "green" corrosion inhibitor of carbon steel in the presence of synthetic produced water, in order to evaluate its performance in the anticorrosive protection.

METHODOLOGY

PLACE OF COLLECTION AND PREPARATION OF THE INHIBITOR

The seaweed was collected on the beach of São Miguel dos Milagres, located in the city of São Miguel dos Milagres, in the State of Alagoas. After collection, *Sargassum vulgare* (Figure 2.a) was placed in a thermal bag, transported and washed under running water. Left to dry in the sun for a period of four days until constant weight was obtained (Figure 2.b). Finally, the dried and dehydrated Sargassum was placed in a blender and crushed until obtaining its powder form (Figure 2.c).

PREPARATION OF SPECIMENS AND PRODUCED WATER

The specimens used in this study were carbon steel, derived from a tube used for the production of hydrocarbons in an oil and gas industry. The tube was taken to a sawmill, where three sections approximately one inch long were sawn and these sections were divided into 4 parts each, making a total of 12 parts.

Then, the specimens were polished with sandpaper of different granulometry of 40, 80 and 220 (numbering provided by the manufacturer to differentiate the abrasiveness of the sandpaper) over its entire surface. They were washed in running water and distilled water, respectively, and dried with absorbent paper.

To simulate produced water, a solution of sodium chloride ($NaCl$) at 3.5% (w/v) with kerosene at 0.2% (v/v) was prepared.

SYSTEM ASSEMBLY AND MASS LOSS

The specimens were previously weighed on an analytical balance, with a precision of 4 decimal places, and placed in individual beakers. In this study, the parameters

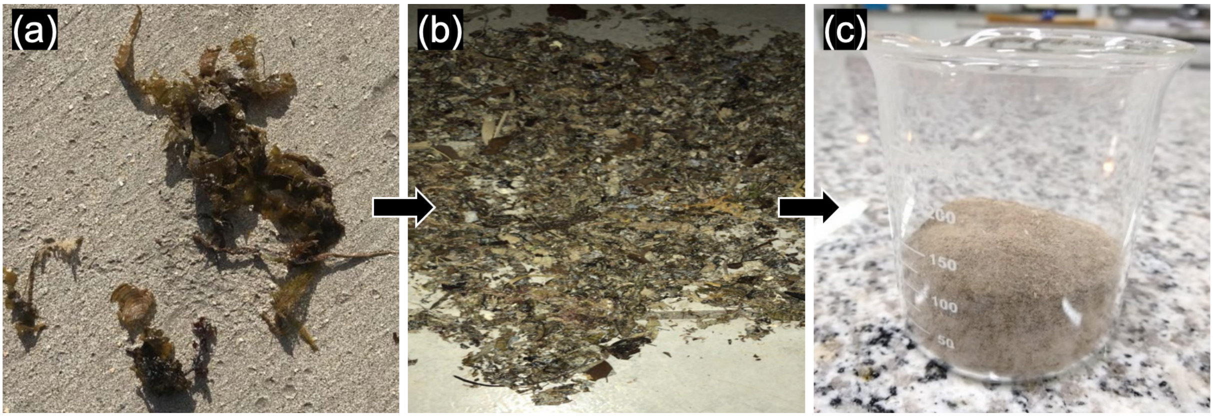

Figure 2- Obtaining the proposed inhibitor, Sargassum vulgare (a) hydrated, (b) dehydrated and (c) in powder form. Source: Authors (2023).

used were: (1) Time: 1-35 days and (2) Concentration: 0 (control), 10, 20, 30, 40 and 50 ppm of the proposed inhibitor. The system was conditioned in a beaker, consisting of the specimen and approximately 100 mL of water produced with different concentrations of *Sargassum vulgare* powder.

From the mass loss of the test specimens used, the percentage mass loss was calculated using Equation 1, where m_x is the mass on the day of weighing and m_i é initial mass of the specimen before being subjected to the aggressive medium, as two specimens were used in each medium, the final percentage value of the loss was calculated by arithmetic mean.

Calculated by arithmetic mean.

$$\% = \frac{m_x}{m_i}.100 \qquad \text{Eq.1}$$

With the data collected in the mass loss, the physical parameters related to corrosion were calculated. The load (Q) involved in the process was calculated, for each day of measurement, Equation 2, in this load calculation only the molar mass was used (*MM*) of the element Iron (Fe) (Fe = 55,85 g.mol^{-1}), because in carbon steel, it enters as a balance in the chemical composition of this material; the Faraday Constant (F) (96.485 s.A.mol^{-1}) and the number of electrons (ne). The value of the corrosion current (i_{corr}) is given by dividing the accumulated load over the corrosion time (ot), as described in Equation 3.

$$Q = \frac{ne^{*}F^{*}\Delta m}{MM} \qquad \text{Eq.2}$$

$$i_{corr} = \frac{Q}{\Delta t} \qquad \text{Eq.3}$$

With the calculated parameters, the data were used to evaluate the performance of Sargassum vulgare as a corrosion inhibitor on carbon steel 1020 in the presence of simulated produced water.

RESULTS AND DISCUSSIONS

After collecting mass values, these data were applied in the formulas described in the methodology. By obtaining each parameter (percentage mass loss, accumulated load and corrosion current) it was possible to verify the behavior of the test specimens exposed to synthetic produced water in the absence and presence of *Sargassum vulgare.*

The specimens immersed in the simulated produced water were weighed on different days, at the beginning and after 6,

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14, 21, 28 and 35 days of exposure to the aggressive medium. The first perception by the percentage loss of mass data in the medium studied (Figure 3) shows that not all concentrations studied promoted protection in the steel. The medium with 10 ppm showed a percentage loss greater than the control (0 ppm) from the 6th day of the test, a similar behavior happened in the medium with 20 ppm that showed the same behavior from the 21st day of the test.

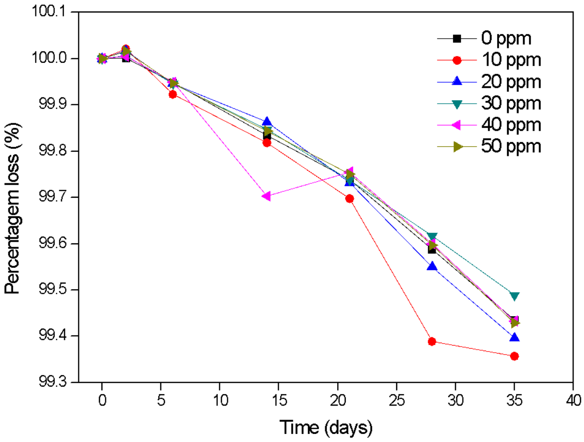

Figure 3 - Relationship between percentage loss of mass and time.

Source: Authors (2023).

Also considering Figure 3, the 30 ppm medium demonstrated a protective behavior for the metal under study, as during the 35 days of testing the specimens showed a percentage loss of mass lower than that of the control. On the other hand, the 40 and 50 ppm media behaved similarly, except for the 40 ppm on the 14th day, which had a lower percentage loss than the control until the 28th day of the test.

The load accumulated in the media studied during the 35 days of testing (Figure 4) showed a reduction in this parameter in all media to which Sargassum vulgare powder was added, except for the 10 ppm medium. Still on Figure 4, it can be seen that the maximum reduction of the accumulated load values was 18%, a reduction promoted by the 30 ppm medium, the 40 and 50 ppm media presented values very close to the accumulated load until the end of the assay, this may be related to the maximum inhibitory activity of the extract which is influenced by its composition.

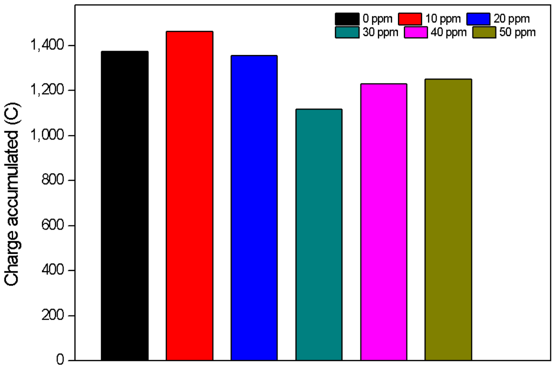

Figure 4- Accumulated load on specimens in simulated produced water solution and in the presence of *Sargassum vulgare* powder.

Source: Authors (2023).

The corrosion current is closely linked to the dissolution of the metal in the aqueous medium, so the lower the density, the less metal is dissolving in the medium (STREHBLOW and WENNER, 1975). Figure 5 demonstrates the variation of the corrosion current for each condition studied as a function of time, it is possible to observe that the current values present a behavior similar to that described in the mass loss, since the 30 ppm medium presented a lower corrosion current than the control throughout the test, indicating that in this condition less metallic material (carbon steel) was dissolved in the saline medium, which was the simulated produced water, an indication of corrosion inhibition promoted by the addition of Sargassum vulgare powder. Another relevant fact is that in the medium of 10 ppm the corrosion current showed higher values than the control throughout the test, this may have occurred due to some salt residue in the seaweed sample used causing greater corrosion than the control.

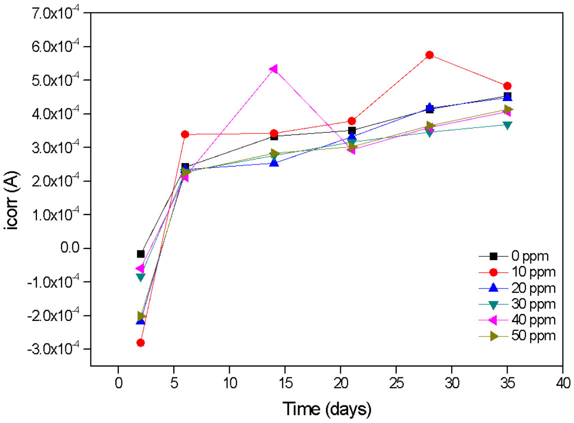

Figure 5- Relationship between corrosion current and time in specimens in simulated produced water solution and in the presence of Sargassum vulgare powder.

Source: Authors (2023).

In addition to the 30 ppm medium, it is noteworthy that the 40 and 50 ppm mediums showed lower corrosion current values than the control from the 21st day of the test, indicating that there was also protection of carbon steel in these media.

CONCLUSION

The use of the seaweed *Sargassum vulgare* was effective for the protection of carbon steel in the presence of produced water, even with the dissolution of the metal alloy, the presence of the seaweed reduced the loss of percentage mass, the accumulated load and the corrosion current of the bodies of proof, consequently impacting on the reduction of corrosion in steel.

The inhibitor used in the study is non-toxic, cheap, available in nature in abundance and easy to extract, characterizing itself as a green corrosion inhibitor.

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REFERENCES

ALMADA, C. H. B. A. et al. Aspectos populacionais de sargassum vulgare agardh (ochrophyta, fucales) na ponta do Arpoador-Rio de Janeiro. **Oecologia Brasiliensis**, v. 12, n. 2, p. 10, 2008.

CORRÊA, Oton Luiz Silva. **Petróleo: noções sobre exploração, perfuração, produção e microbiologia**. Interciência, 2003.

DORE, Celina Maria Pinto Guerra. Aspectos estruturais, farmacológicos e biológicos de fucanas da alga marrom sargassum vulgare. 2012.

FRAUCHES-SANTOS, Cristiane et al. A corrosão e os agentes anticorrosivos. **Revista virtual de química**, v. 6, n. 2, p. 293-309, 2014.

HOSSAIN, Nayem; ASADUZZAMAN CHOWDHURY, Mohammad; KCHAOU, Mohamed. An overview of green corrosion inhibitors for sustainable and environment friendly industrial development. **Journal of Adhesion Science and Technology**, v. 35, n. 7, p. 673-690, 2021.

KOKILARAMANI, S. et al. Characterization of methanolic extract of seaweeds as environmentally benign corrosion inhibitors for mild steel corrosion in sodium chloride environment. **Journal of Molecular Liquids**, p. 117011, 2021.

KUMAR, R. S.; CHANDRASEKARAN, V. Sargassum wightii extract as a green inhibitor for corrosion of brass in 0.1 N phosphoric acid solution. **Orient. J. Chem**, v. 31, n. 2, p. 939, 2015.

MORAES, José Ermírio F. et al. Treatment of saline wastewater contaminated with hydrocarbons by the photo-Fenton process. **Environmental science & technology**, v. 38, n. 4, p. 1183-1187, 2004.

NADI, I. et al. Sargassum muticum extract based on alginate biopolymer as a new efficient biological corrosion inhibitor for carbon steel in hydrochloric acid pickling environment: gravimetric, electrochemical and surface studies. **International journal of biological macromolecules**, v. 141, p. 137-149, 2019.

POHLAK, M. et al. Experimental study of incremental forming of sheet metal products. In: **Proc of the fourth International DAAAM Conference, Tallinn, Estonia**. 2004. p. 139-142.

SCHMIDT, Charles W. Petroleum: possibilities in the pipeline. **Environmental Health Perspectives**, v. 110, n. 1, p. A22-A29, 2002.

SCHUTZ, Priscila. Efeito de ácidos naftênicos na corrosão eletrolítica de aços para dutos de petróleo. 2009.

STEARNS, Peter N. **The industrial revolution in world history**. Routledge, 2020.

STREHBLOW, H. H.; WENNERS, J. Determination of the growth of corrosion pits on iron and nickel in an early stage of development and its relation to the metal dissolution in concentrated chloride media. **Zeitschrift für Physikalische Chemie**, v.98, p. 199-214, 1975.

THILAGAVATHI, R. et al. Performance Evaluation of Sargassum Polycystum C. Agardh Seaweed Extract as Green Inhibitor for Acid Corrosion of Mild Steel. **Oriental Journal of Chemistry**, v. 35, n. 1, p. 241, 2019.

VIDELA, H. A. Biocorrosão, biofouling e biodeterioração de materiais, Edgard Blücher: São Paulo, 2003.