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***Eryngium bourgatii* Extract Inhibits Iron Corrosion and Bacterial Growth in Fresh and Marine Water Media**

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Abstract

Bi-functional effect of *Eryngium bourgatii* extract on inhibiting iron corrosion and bacterial growth in both fresh and marine water media was studied using weight loss measurements for corrosion inhibition and well diffusion method for bacterial growth inhibition. At 150 mg/100 mL inhibition efficiency of corrosion reached 95% and 91% in fresh and marine medium respectively. The results showed clearly that *E. bourgatii* ethanol-hexane crude extract is strongly active in both media. Three quantitative methods were applied for measuring corrosion rate of iron metal cylinders: relative weight loss, iron released in the medium, and turbidity. Statistical analyses showed that the three methods are comparable and any method of the three could be used to measure corrosion rate. Experimental data obeyed Langmuir isotherm model. Optical and scanning electron microscopy (SEM) images revealed the smoothness and homogeneity of adsorption layer on the iron nail surface. Regarding bacterial growth inhibition at ratio of 150 mg/100 mL medium was found to be effective.

Keywords: *Eryngium bourgatii* - Ethanol-hexane extract- anticorrosion – antibacterial – Marine/Fresh media – Relative weight loss – Iron released in the medium.

Introduction

Eco-friendly natural products have been explored as metal corrosion inhibitors, a considerable number of plant species and phycophyta extracts proved to have high corrosion inhibition efficiencies [1-8]. Wild flora is considered a good resource for large number of active chemical compounds [9-12]. The trend of searching for natural products of plant origin has been so attractive for researchers working on metal corrosion inhibition. The choice of a plant to be tested for containing an inhibitory product(s) should be according to a set of criteria. These criteria are a) previous studies indicating its richness in various phytochemical compounds, either a particular plant species or a species belonging to a genus known to have such characteristic, once the plant is proven to contain compounds with high inhibition efficiency then other criteria are as follows: b) it's abundance in the field if it is a wild plant; c) simple and easy propagation scheme for high yield production; d) easy harvesting and product extraction; e) availability i.e. growing close to the natural inhibitor production utility site; f) economic cost-benefit analysis revealing its economic effectiveness and financial viability.

About 300 species of *Eryngium* genus are widely distributed over most of the temperate zone. As a genus belonging to the *Apiaceae* family, its taxonomy is known to be extensively complex. Several studies have been conducted on the phytochemistry of *Eryngium* species, most of these studies addressed their significance in pharmacological and medical utilization [13-17]. This is due to the richness of these species in containing a huge number of active chemical compounds [18-19]. Only one published paper addressed the essential oil fraction extracted from *Eryngium maritimum* in inhibiting corrosion of mild steel metal [20]. This work was published in 2013, since that time no further work has been done regarding the potential of *Eryngium* species to contain corrosion inhibitors. It is well justified to investigate the occurrence of anticorrosion, and antibacterial chemical compounds in one of Egyptian *Eryngium* species.

The objective of this work is to study the corrosion and bacterial growth inhibition effect of *Eryngium bourgatii* crude extract. The experimental design for this study included comparing the iron corrosion inhibition efficiency of plant extract in fresh and marine water media using relative weight loss measurements. Two quantitative methods other than weight loss for measuring corrosion rate of iron metal cylinders were tested. In addition, morphological changes in the metal surface were investigated using optical and scanning electron microscopy. Different adsorption isotherm models were tested. Antibacterial activity of the extract was figured out in both media.

Materials and Methods

Plant material preparation and extraction

Eryngium bourgatii (Photo 1 A&B) is a herbaceous perennial 30–50 cm tall, also known as Mediterranean Sea-holly, with deeply lobed and silver-veined leaves, and vivid blue, branched stems bearing cone-like flower-heads [21]. The Egyptian ecotype grows in the western desert of Egypt, and its flowering season is spring.

Sampling was done at Borg El-Arab district. Leaves were cut off, washed, rinsed, air dried, and crushed into small pieces by a grinder to fine powder (Photo 2). Plant material (20g) was suspended in 200 mL of pure n-hexane and 200 mL of 70 % ethanol in a 500 mL conical flask. The filtered biomass was washed with solvents and rinsed with water at the end. The total crude extract yield of the obtained two phases; oily and aqueous (Photo 3) was 2.5 g. Physical properties of crude *E. bourgatii* ethanol-hexane extract were: brownish in colour, sticky, oily texture (Photo 4) associated with stiff material, an approximate apparent density of 0.8 g/mL, and a pH of 8.6.



A



B

Photo 1: *Eryngium bourgatii* at flowering season (A & B)



Photo 2: Dry and ground *Eryngium bourgatii* material (20 g)



Photo 3: Two phases of *Eryngium bourgatii* ethanol-hexane extract (oily and aqueous)



Photo 4: Crude *E. bourgatii* ethanol-hexane extract after solvent drying

Iron metal nails preparation

Iron nails were purchased from the local market to conduct corrosion experiments on a commonly used iron metal. Thirty iron metal nails were randomly sampled and weighed as to calculate the most frequent weight (mode) and how much it is close to the mean weight, also the variance and standard deviation were calculated. Iron metal nails were reshaped to be in a cylindrical form by cutting their heads and tips, then abraded to be smooth at each edge with almost equal length of 10 ± 2 mm and a radius of 1 ± 0.1 mm; as for weight, the mean was $0.1740 \text{ g} \pm 0.0048$ and a variance of 0.00002 g . This indicated a more or less homogeneity in the experimental material which minimized experimental error. Cylinder surface area was calculated and found to be $69.08 \pm 1.32 \text{ mm}^2$.

Fresh and marine water

Domestic tap water was used as freshwater medium, and marine water was sampled from El-Shatby beach of Mediterranean sea, Alexandria, as marine water medium.

Relative weight loss measurements

The method involves exposing an iron specimen to an environment for a period of time and then measuring the resultant weight loss after removing the corroded material [22].

The corroded material was carefully removed off from the metal surface and the metal cylinder was dried and weighed, this is according to the American Society of Testing and Materials (ASTM G1, 2003) [23].

The corrosion inhibition rate was then determined by considering the initial total surface area of the sample and the relative mass loss before and after the test period using equation (1) while corrosion inhibition efficiency according to relative weight loss of each cylinder compared with that of the control is calculated using equation (2).

$$CR = \frac{w1-w2}{T.A} \quad (1)$$

Where,

CR = Corrosion rate, g/cm²/h

$w1$ = The weight of cylinder prior to running the experiments, g

$w2$ = The weight of cylinder after running the experiments, g

T = The exposure time, hr.

A = The exposed coupon surface area, cm²

$$\% I.E = \frac{R.L.C - R.L.T}{R.L.C} * 100 \quad (2)$$

Where, I.E is corrosion inhibition efficiency, R.L.C = Relative weight loss of control iron cylinder and R.L.T = Relative weight loss of treated iron cylinder.

Equations (3) and (4) are the relative weight loss of control and treated respectively for each iron metal cylinder.

$$\text{Relative weight loss of control cylinder (R.L.C)} = \frac{I.W - W.W.E}{I.W} * 100 \quad (3)$$

$$\text{Relative weight loss of treated cylinder (R.L.T)} = \frac{I.W - W.A.T}{I.W} * 100 \quad (4)$$

Where, I.W is the initial weight of iron metal cylinder and W.W.E is the weight without the extract and W.A.T is the weight of the treated cylinder. The justification of calculating relative weight loss rather than absolute is based on weight inequality of the iron metal cylinders used in the experiment. Glass vials with caps of 25 mL volume were strictly cleaned. Each vial contained 10 mL liquid medium; each medium was prepared according to the purpose of the experiment. For example, only tap water for the control medium in order to investigate corrosion process in freshwater medium, while marine water was the medium to study the process in the marine environment. Stock media of *E. bourgatii* crude extract at ratios of 1, 10, 50, 100, 150 mg/100 mL fresh or sea water media were prepared. Three vials each containing 10 mL of each ratio and three for control were prepared as replicates. In each vial one iron metal cylinder was immersed, and vials were incubated at 25 °C in an incubator for different time intervals. Measurements were recorded daily over 3 days.

Testing three quantitative methods for measuring corrosion rate of iron metal cylinders

In addition to relative weight loss method, iron released in the medium, and turbidity of corrosion medium were used to measure corrosion rate over 3 days. Turbidity was monitored using a spectrophotometer, Unico 1200, U.S.A. Percent daily increase in turbidity applying equation (5)

$$\text{Percent daily increase in medium turbidity in NTU} = \frac{T_a - T_b}{T_b} * 100 \quad (5)$$

Where T_a is the turbidity reading of the medium the day after, and T_b is the turbidity reading of the medium the day before.

While iron released in the medium was measured using Inductive Coupled Plasma- Optical Emission Spectroscopy (ICP-OES) Agilent Technologies, 5100 VDV, Australia. This method of determining corrosion rate inhibition efficiency is based on measuring the amount of iron released in the test medium (tap or marine water) in the form of ferric hydroxides according to Tan et al., 2018 [24]. The amount released in the medium is supposed to be proportional to the loss in iron metal weight as a result of corrosion. Corroded iron metal is first adhered to the specimen surface, then with corrosion

continues it is released in the medium. If the adhered portion on the surface is mechanically removed and added to the released portion, then by measuring total iron in the medium in the form of ferric hydroxides could be a good method for measuring corrosion rate and the efficiency of any substance that could inhibit it. The accuracy and precision degrees of this method as well as its comparableness with other methods were statistically tested.

Microscopic examination of daily development of metal surface corrosion and its inhibition

Changes in the morphology of the iron metal surface which might occur over the duration of the corrosion process. This was done using optical (light microscope ZEISS MC63A, West Germany) and scanning electron microscopy (JEOL, JSM – IT200 Series, JAPAN) at a ratio of 150 mg/100 mL medium for 3 successive days.

Antibacterial activity

Bacterial cultures

Bacterial microflora of tap and marine water were enriched using nutrient broth liquid medium. Both bacterial cultures were used in testing the antibacterial activity of *E. bourgatii* hexane-ethanol crude extract.

Antibacterial Test

Nutrient broth liquid medium (N.B.L.M) was prepared and sterilized. The medium was used for enrichment of bacterial growth in tap and sea water separately by adding 3 mL of N.B.L.M and 2 mL of tap water, the same for sea water. Test tubes were incubated at 37 °C overnight. These were used as stock culture for both tap and marine water.

Two methods were used for testing antibacterial activity of *E. bourgatii* extract. One with liquid minimal medium, where 0.1 mL of the enriched bacterial suspension of tap water was transferred into two test tubes of 10 mL liquid minimal medium; one was a control and the other one was treated where 150 mg of the extract were added. Tubes were incubated at 37 °C overnight. On the next day, 0.1 mL of control and 0.1 mL of bacterial suspension with extract were spread over nutrient agar plates and incubated at 37 °C overnight. Plates were examined the next day and bacterial colonies were counted. Second method was well diffusion method which applied on solid nutrient agar. Three wells were cut; one was a control supplemented with sterile distilled water and the other two wells were

supplemented with extract at ratios of 100 and 150 mg/100 mL sterile distilled water. The plate was replicated three times and incubated at 37 °C overnight. Plates were examined the next day to observe bacterial growth inhibition zone around wells. The same methods were applied to examine bacterial growth inhibition of sea water.

Results and discussion

Comparison between Corrosion rate inhibition efficiency in fresh tap water and marine water media

Table 1 and Figure 1 illustrate corrosion inhibition efficiency data and behavior of *E. bourgatii* ethanol-hexane crude extract in the two media. Inhibition efficiency increased with increasing ratios of extract. Multifactorial analysis using Graph Pad Prism 7 software was applied on the data for testing three factors, namely: ratio of the inhibitor, time interval (1 and 3 days), and type of medium (fresh tap water and marine water). Table 2 showed that inhibitor ratio and time interval are highly significant in affecting corrosion inhibition efficiency while tap or marine water media as a factor as well as interactions were insignificant. The results showed clearly that *E. bourgatii* ethanol-hexane crude extract is strongly active in both media.

Table 1: Iron metal corrosion inhibition efficiency of *E. bourgatii* ethanol-hexane crude extract in fresh tap water and marine water media, at different ratios and time intervals, 25°C, applying relative weight loss method

Ratio (mg/100 mL water)/ Time intervals (day)	Inhibition efficiency % $\pm$ S. D			
	Medium			
	Fresh water		Marine water	
	1	3	1	3
10	40 $\pm$ 3	62 $\pm$ 1	58 $\pm$ 1	48 $\pm$ 7
50	49 $\pm$ 13	80 $\pm$ 2	53 $\pm$ 21	68 $\pm$ 9
100	71 $\pm$ 16	77 $\pm$ 5	65 $\pm$ 20	75 $\pm$ 6
150	93 $\pm$ 3	95 $\pm$ 4	78 $\pm$ 20	91 $\pm$ 6

S.D: Standard Deviation

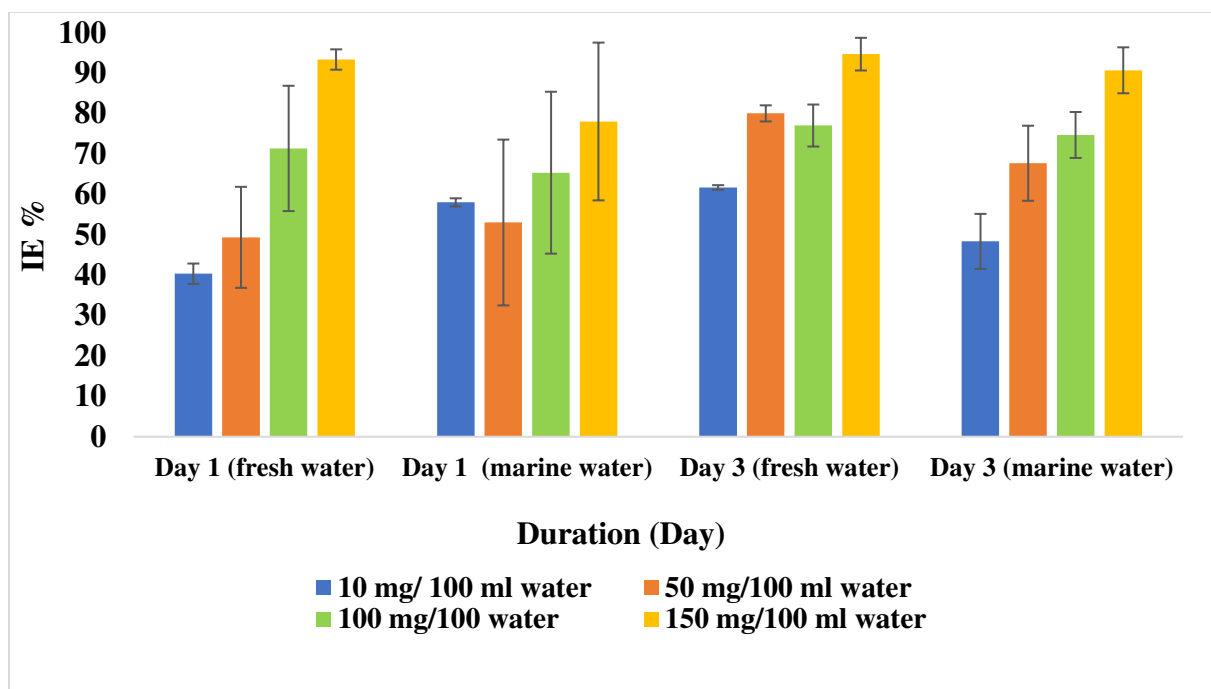


Fig 1. Corrosion inhibition efficiency (IE%) of *E. bourgatii* ethanol-hexane crude extract in fresh tap and marine water media, at different inhibitor ratios and time intervals

Table 2: Multifactorial analysis among three factors: extract ratio, time interval, type of medium (tap-marine water) in corrosion inhibition efficiency of iron metal

Three-way ANOVA				
Alpha	0.05			
Source of Variation	% of total variation	P value	P value summary	Significant?
Ratio	55.68	<0.0001	****	Yes
Fresh vs Marine	1.447	0.1625	ns	No
Time	9.252	0.0010	**	Yes
Ratio x Fresh vs Marine	1.353	0.5968	ns	No
Ratio x Time	3.377	0.2110	ns	No
Fresh vs Marine x Time	1.447	0.1625	ns	No
Ratio x Fresh vs Marine x Time	4.793	0.1008	ns	No

Corrosion rate of iron metal cylinders and its measurement method

Three methods: relative weight loss, iron released in the medium, and turbidity of corrosion medium, were used to measure corrosion rate over 3 days. Table 3 gives corrosion rate measurements according to each method. Correlation and regression statistical analyses were applied on the data. Table 4 gives correlation coefficient R^2 between the pairs of three methods; regression lines and equations are given in Figures 2, 3, and 4. It is clear that the three methods are comparable and any method of the three could be used to measure corrosion rate. There are certain criteria to be considered in choosing which method is to be used. These are: accuracy, precision, simplicity, cost, and time; it will be always depending on the type and objective of the work which method is more suitable and applicable. When accuracy and precision are needed, the iron released in the medium is certainly the right choice, as it gives almost no chance for human experimental error ensuring better accuracy (particularly in handling) and the ICP-OES equipment sensitivity ensuring better precision, where readings are in ppm ($\mu\text{g/mL}$). Yet this method takes more time and expensive. Relative weight loss method is much less expensive, takes short time, and can be used in measuring corrosion rate and its inhibition, but the chance of human experimental error is higher than that of iron released in the medium, so less accurate and precise. Turbidity is of low cost, quick, and simple; its accuracy and precision are comparable with the iron released in the medium (Figure 4). However, it could be used only to measure corrosion rate, but not its inhibition. This is due to possible reactions with the inhibitor, especially when the inhibitor itself is insoluble in water and cause turbidity in the medium, which is the case in most natural corrosion inhibition products of plant origin.

Table 3: Control corrosion rate results for 3 days using three methods

Day	Relative weight loss (g)			Iron released in the medium (μg)			Turbidity (NTU)		
	1	2	3	1	2	3	1	2	3
Amount of corrosion products	0.012	0.013	0.037	229	390	540	0.067	0.175	0.316

Table 4: Correlation coefficient R^2 matrix among three methods of measuring corrosion rate: relative weight loss, iron released in the medium and turbidity of the medium

	Turbidity	Relative weight loss	Iron released in the medium
Turbidity	1	0.91	0.99
Relative weight loss	0.91	1	0.87
Iron released in the medium	0.99	0.87	1

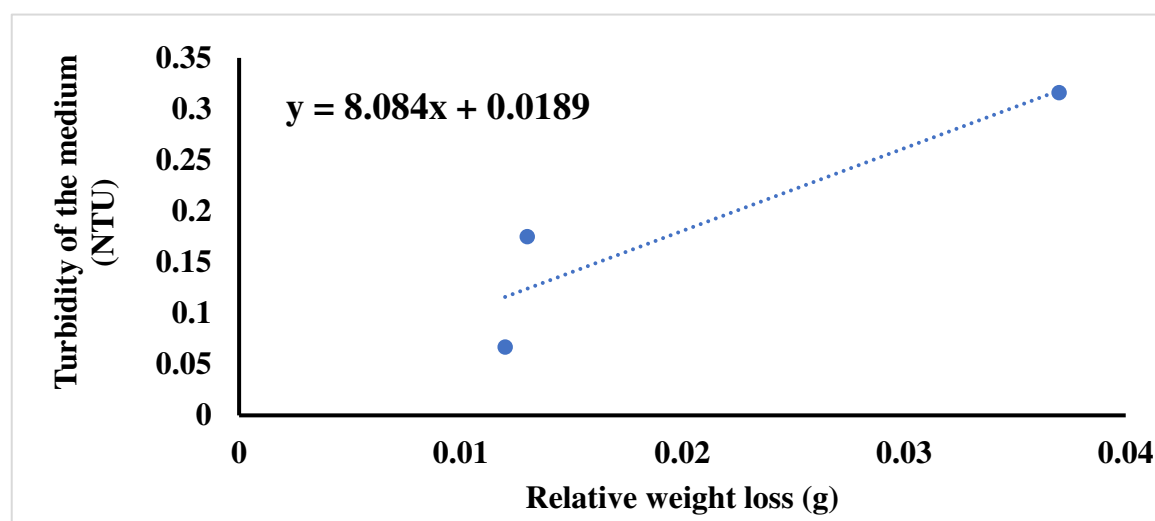


Fig 2. Regression analysis of two methods of measuring corrosion rate: relative weight loss and turbidity of the medium

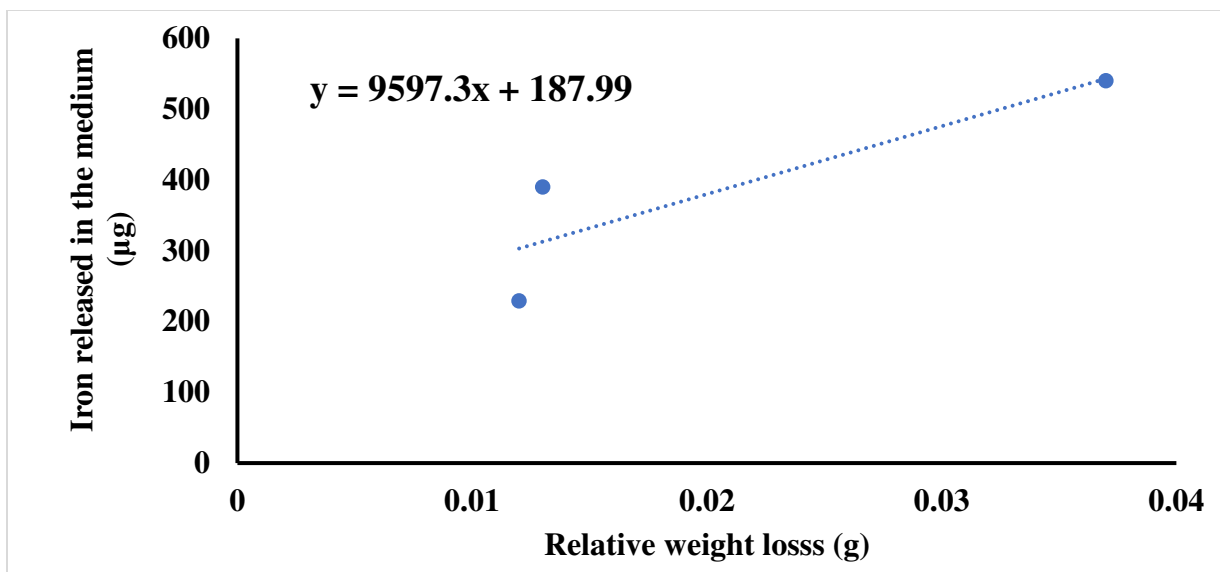


Fig 3. Regression analysis of two methods of measuring corrosion rate: relative weight loss and iron released in the medium

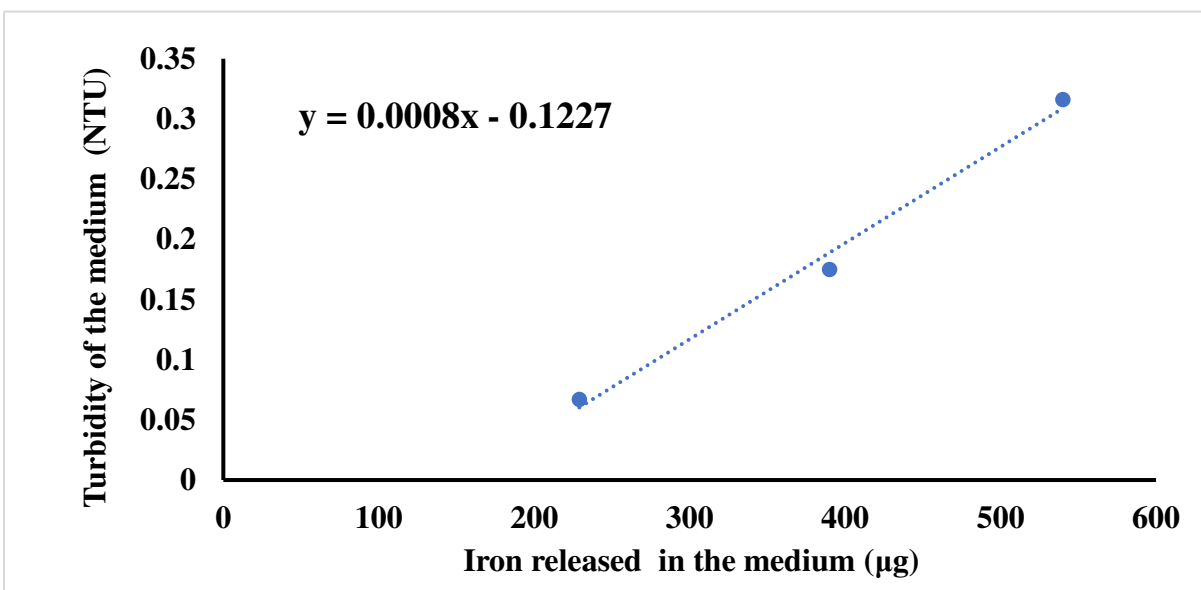


Fig 4. Regression analysis of two methods of measuring corrosion rate: iron released in the medium and turbidity of the medium

Adsorption Isotherm

Different isotherm models [25] were applied for describing different adsorption Processes, mechanisms and studying how the adsorbed inhibitor molecules interact with the metal surface. Results indicate that Langmuir isotherm model (Fig 5) gives the best fit with $R^2 > 0.95$ which indicates the adsorbed molecules occupy only one site and there are no interactions with other adsorbed species. The adsorption equilibrium constant (K_{ads}) value was calculated according to equation (6):

$$\frac{C}{\theta} = \frac{1}{K_{ads}} + C \quad (6)$$

where C is the concentration of the inhibitor, K_{ads} is the adsorption equilibrium constant and θ is the surface coverage of inhibitor.

The standard free energy of adsorption, ΔG_{ads} , is related to the equilibrium constant of adsorption K_{ads} and can be calculated by the equation (6) where 55.5 mol/L was the molar concentration of water, R is the gas constant and T is the absolute temperature in Kelvin (26).

$$\Delta G_{ads} = -RT \ln (55.5 K_{ads}) \quad (7)$$

ΔG_{ads} was calculated (Table 5) for both fresh and marine medium and the negative values obtained indicated the spontaneity of the adsorption process and stability of the adsorbed layer on the metal surface. Generally, values of ΔG_{ads} up to -20 kJ mol^{-1} are compatible with the electrostatic interactions between the charged metal (physisorption) while those around -40 kJ mol^{-1} or higher are associated with chemisorption as a result of sharing or transfer of unshared electron pair or π -electrons of organic molecules to the metal surface to form a coordinate type of bond (chemisorption). Hence, it is clear that the crude extract is physically adsorbed onto the metal surface [25-27].

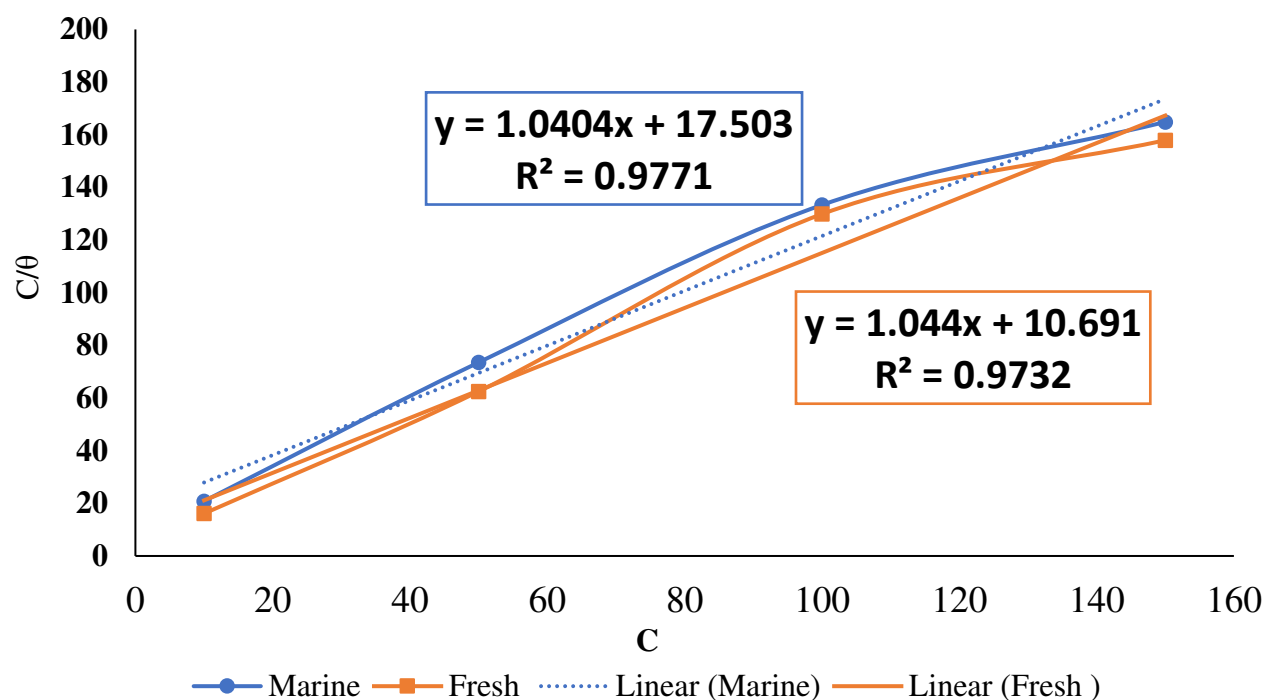


Fig 5. Langmuir adsorption isotherm plot for the adsorption of *E. bourgatii* ethanol-hexane crude extract

Table 5: The values of K_{ads} and ΔG_{ads} of *E. bourgatii* ethanol-hexane crude extract at 25 °C

Medium	Adsorption equilibrium constant K_{ads}	Free energy of adsorption (ΔG_{ads}) KJ/mol
Fresh	0.093	-4.066
Marine	0.057	-2.853

Qualitative measurements of corrosion rate and its inhibition

Optical microscopy

Optical microscopy revealed clear daily successive changes of control and treated iron metal surface (Photos 5 A, B, C for control and A`, B`, C` for treated). Adsorption of inhibitor on the metal surface was all around the cylinder (Photo 6). More details of the adsorbed layer on the metal surface are shown in Photo 7 A, B, C, and D at higher magnifications. Plant extract was found to contain oil and other substances some of which are in crystalized form (Photo 8 A, B), this oil fraction probably played a role in the adsorption process. Microscopic examination of the corrosion inhibition medium showed a wide and dense dispersion of oil droplets of various size (Photos 9 A, B, C, and D). It is clear from examining photos of adsorption and plant extract constituents, that a certain fraction of the extract is adsorbed on the metal surface, which form a homogenous layer on the metal surface.

Scanning electron microscopy

Clear differences were observed between control and treated iron metal surface. Adsorption of plant extract on the metal surface gradually developed day after day until it was completely covering the whole surface (Photo 10) in tap water medium and (Photo 11) in marine water medium. At the same time, progressive corrosion of the iron metal surface was observed in the control. There was no difference between tap water and marine water media with respect to such changes, which confirm the effectiveness of the extract to inhibit corrosion in both media.

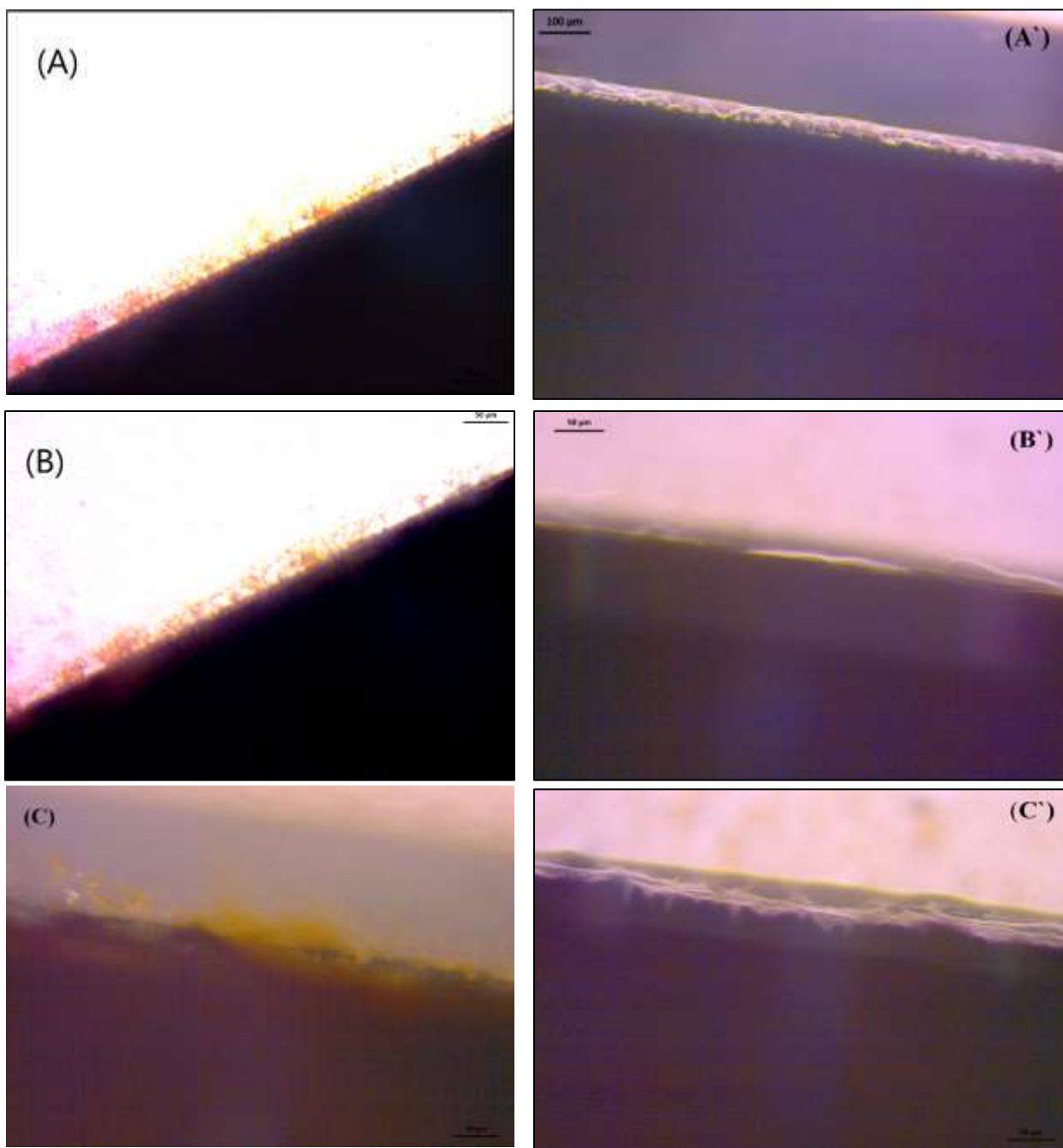


Photo 5: Optical microscopic images of successive 3 days of iron metal surface immersed in Control (tap water, A, B, C) and treated (*E. bourgatii* ethanol-hexane crude extract in fresh tap water medium A', B', C')

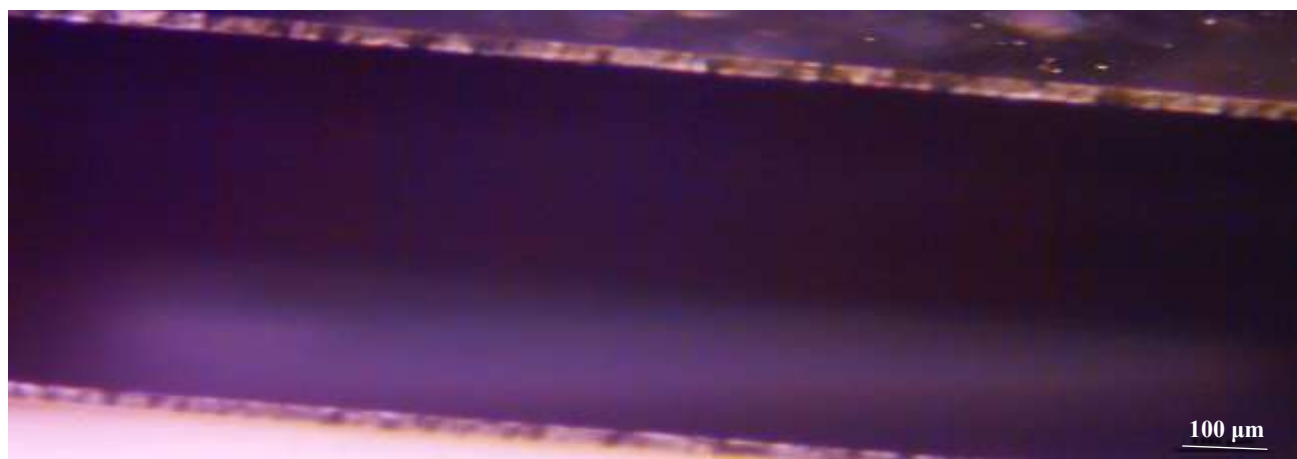


Photo 6: Optical microscopic image of all-around inhibitor adsorption on the metal surface

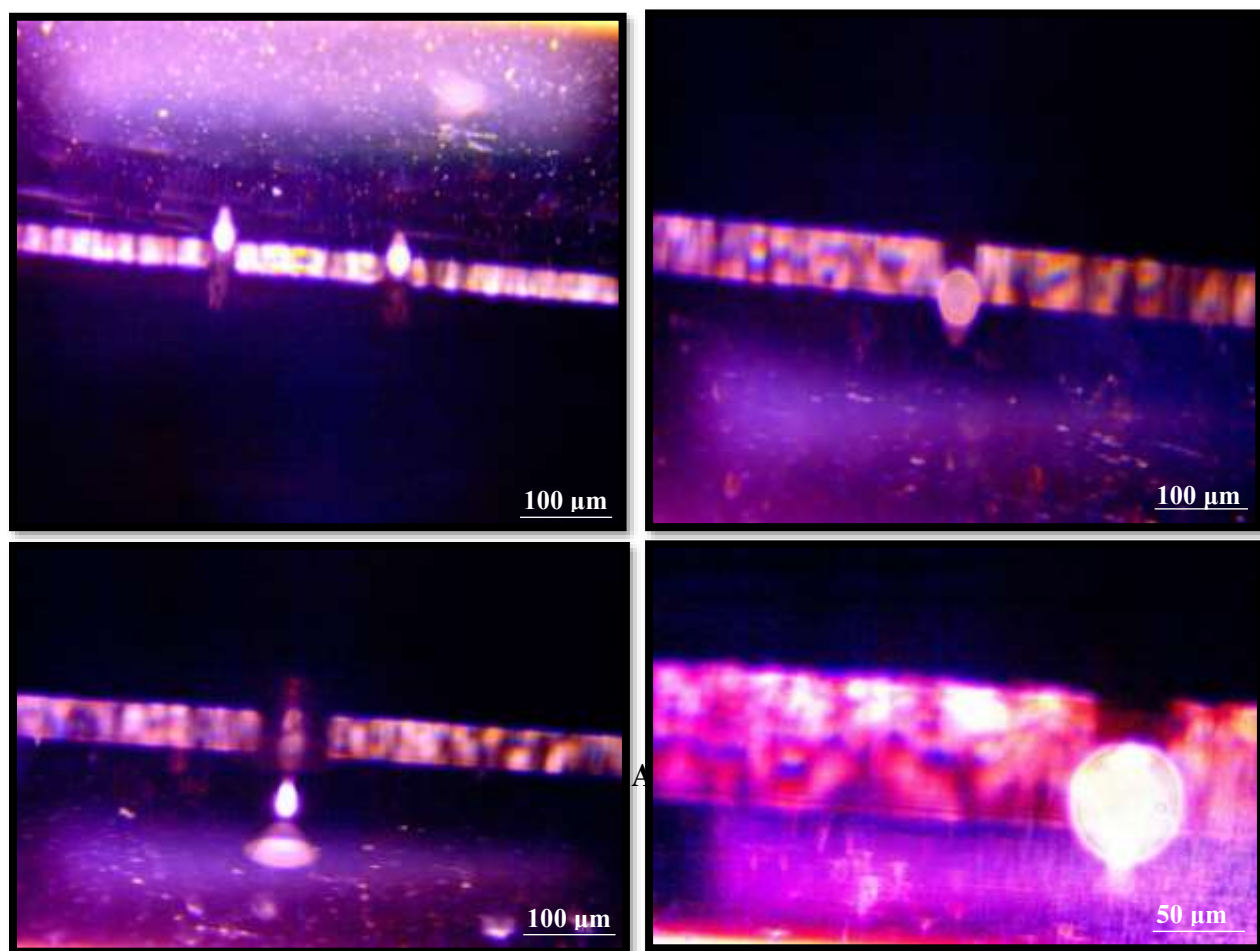
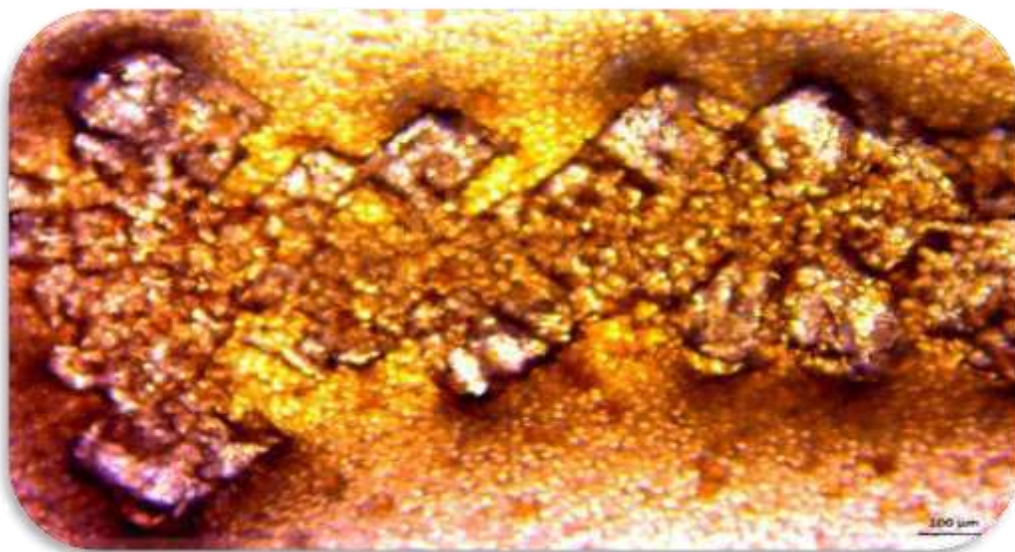
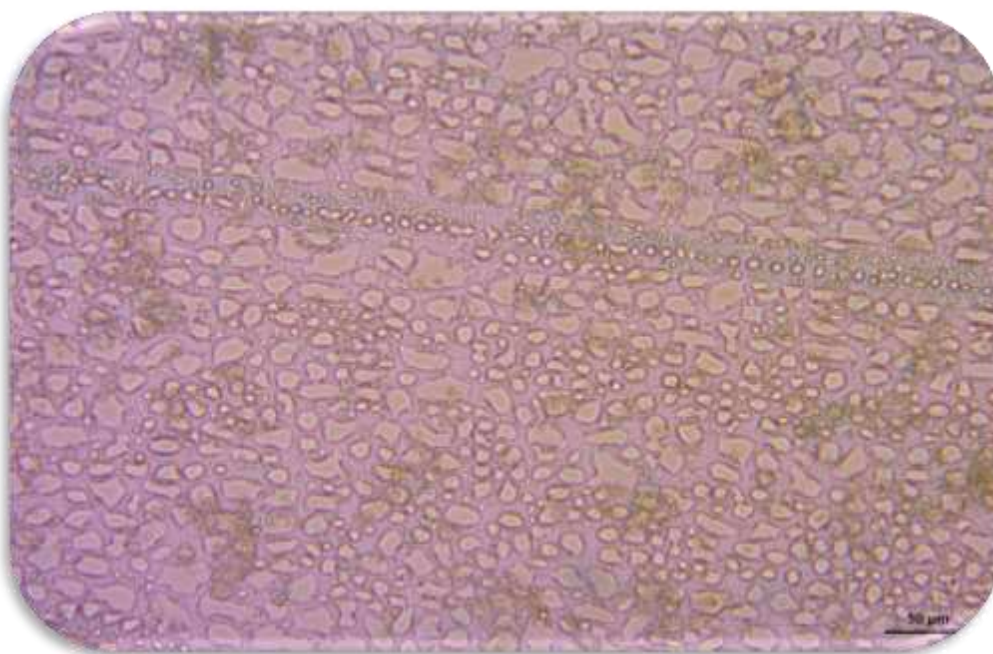


Photo 7: Optical microscopic images of higher magnification showing adsorbed inhibitor layer on the metal surface

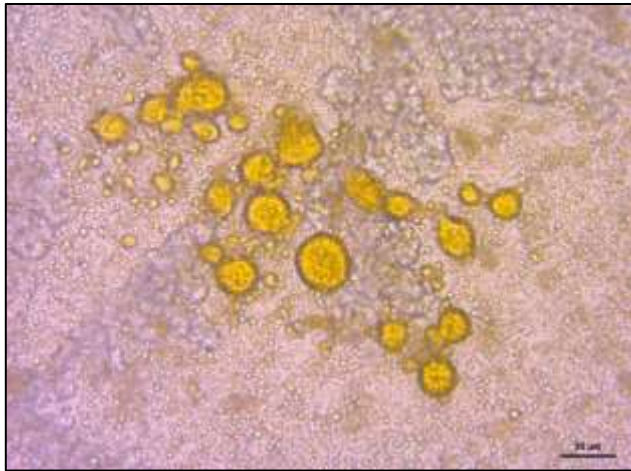


A

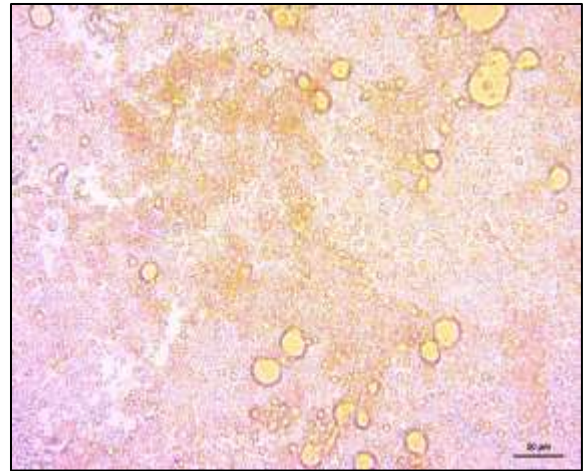


B

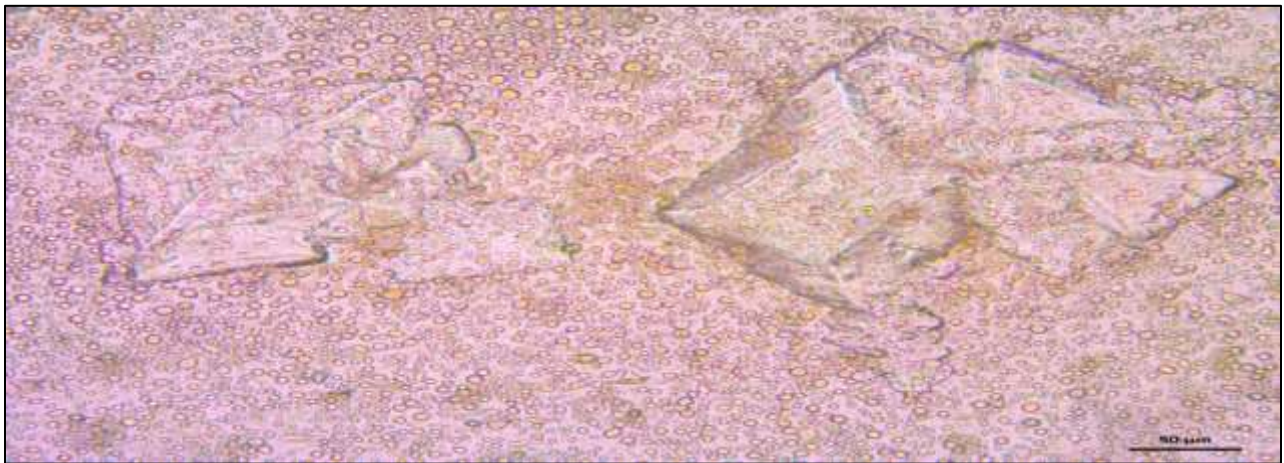
Photo 8: Optical microscopic images of the crystallized forms of substances and oil in *E. bourgatii* ethanol-hexane crude extract A 100 μm and B 50 μm



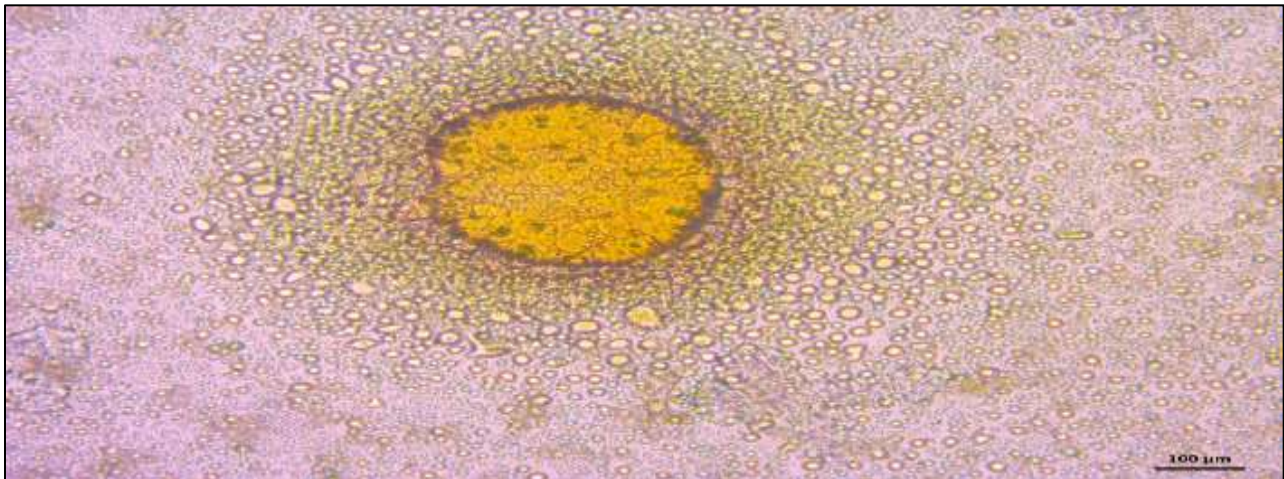
A



B



C



D

Photo 9: Optical microscopic images of oil droplets of various size and crystallized forms in corrosion inhibition medium, A, B, C 50 μm and D 100 μm

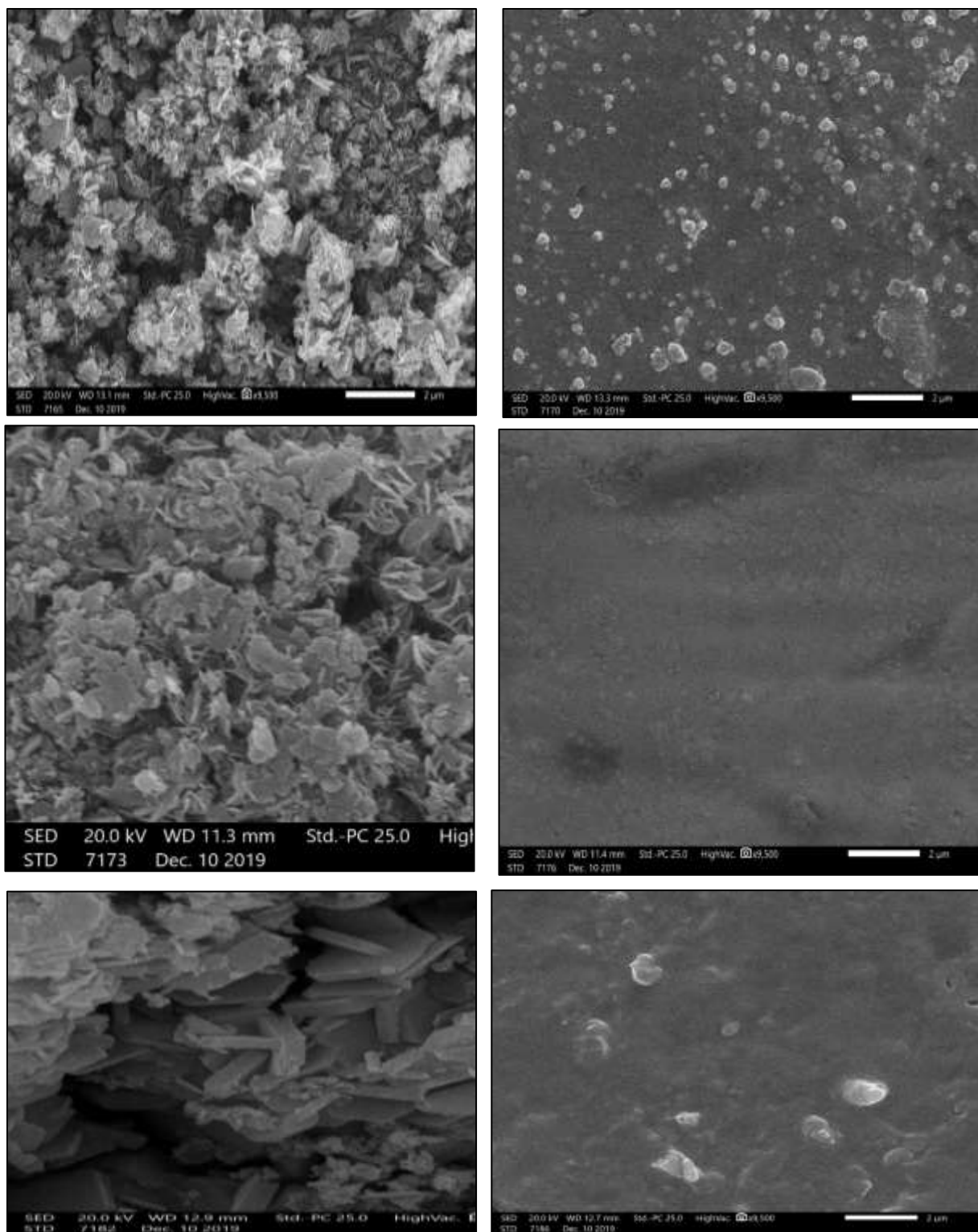


Photo 10: SEM images x9500 of successive 3 days of iron metal surface immersed in control (tap water) and treated (*E. bourgatii* ethanol-hexane crude extract in tap water medium), 25 °C

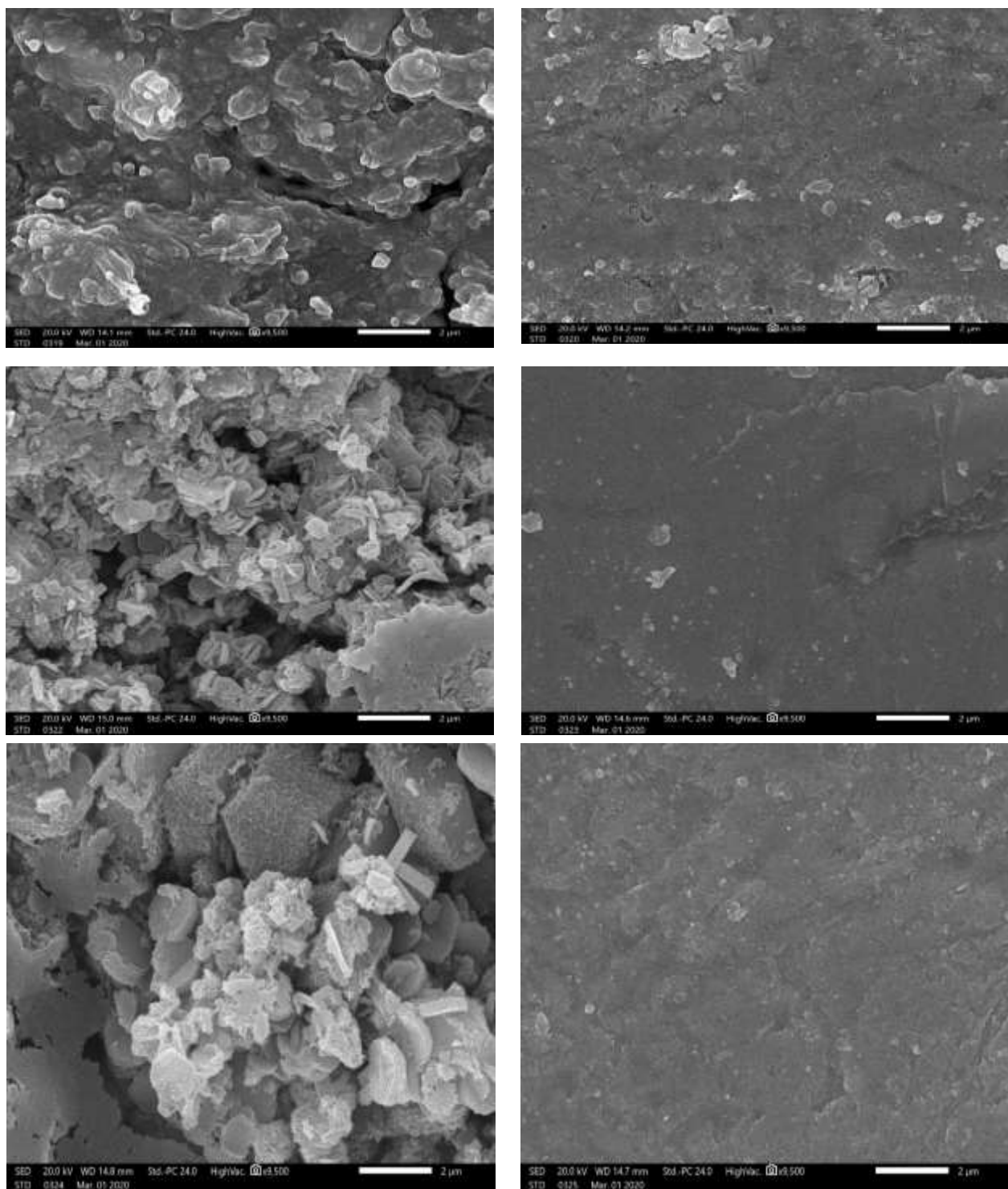


Photo 11: SEM images x9500 of successive 3 days of iron metal surface immersed in control (sea water) and treated (*E. bourgatii* hexane crude extract in sea water medium), at 25 °C

Antimicrobial activity of *E. bourgatii* ethanol-hexane crude extract

The inhibitory effect of *E. bourgatii* ethanol-hexane extract on the growth of microflora in fresh and marine water is shown in photos 12 & 13. It was clear that the extract inhibited the growth of both microflora, except two resistant species present in fresh water, and one resistant species in marine water. Optical microscopic examination of stained bacterial films revealed vegetative bacterial cells in control culture (photo 14), while in treated culture bacterial endospores were observed and an absence of vegetative forms (Photo15). Photos 16 & 17 respectively show bacterial growth inhibition zone around wells. Antifouling activity of a corrosion inhibitor is its ability to kill microflora associated with salts deposition in these processes. Microflora inhabiting fresh and marine water used as corrosion media in the present work was found to be unable to grow in the presence of *E. bourgatii* ethanol-hexane crude extract at ratio 150 mg/100 mL water. The antimicrobial activity of plants belonging to the genus *Eryngium* was reported in Erdem *et al.*, 2015 [19]. In their work, they could phytochemically identify three major compounds in the stem and leaves of *E. bourgatii*, these were Phyllocladene (37.6 %), Y-Muurolene (11.8 %), and (E)-Caryophyllene (10.1 %). They also reported that Eryngial, which is one of the most important and major compounds in the essential oil of genus *Eryngium* plants, it possesses a significant antibacterial effect. Wang *et al.*, 2012 [18] reported antibacterial and antifungal activity of a number of *Eryngium* spp; this activity was related to Eryngial and saponin mixture extracts. These findings agree with the results of the present work.



Photo 12: The effect of *E. bourgatii* ethanol-hexane crude extract on sea water microflora control (A) and treated (B)



Photo 13: The effect of *E. bourgatii* ethanol-hexane crude extract on tap water microflora control (A) and treated (B)

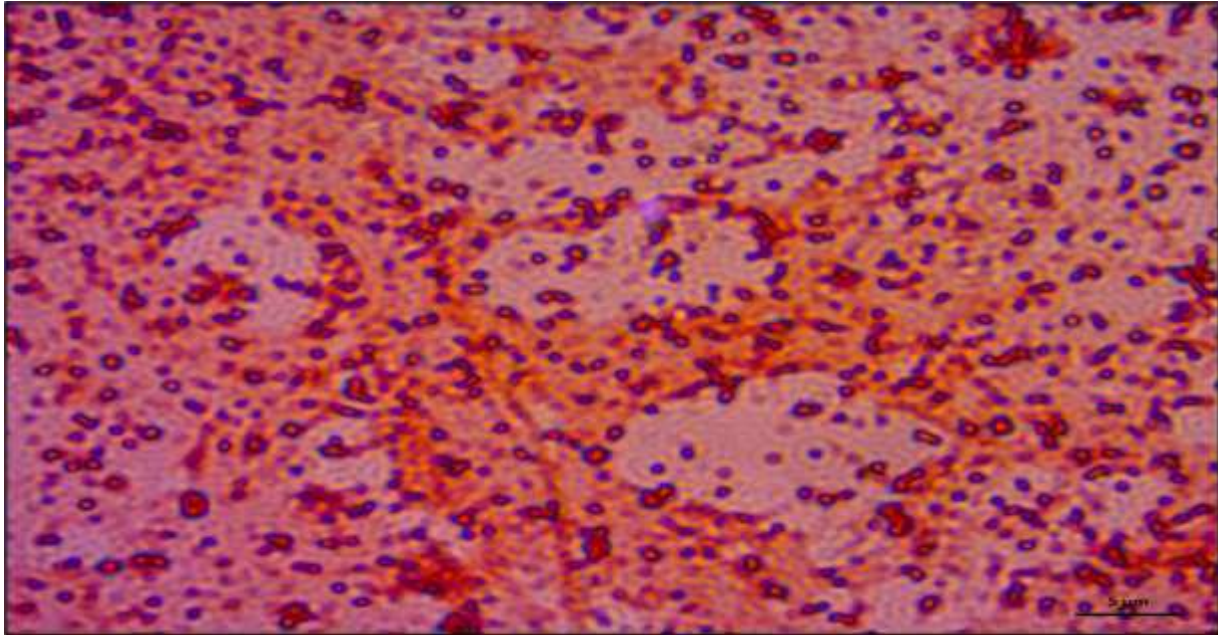


Photo 14: Vegetative bacterial cells of control culture

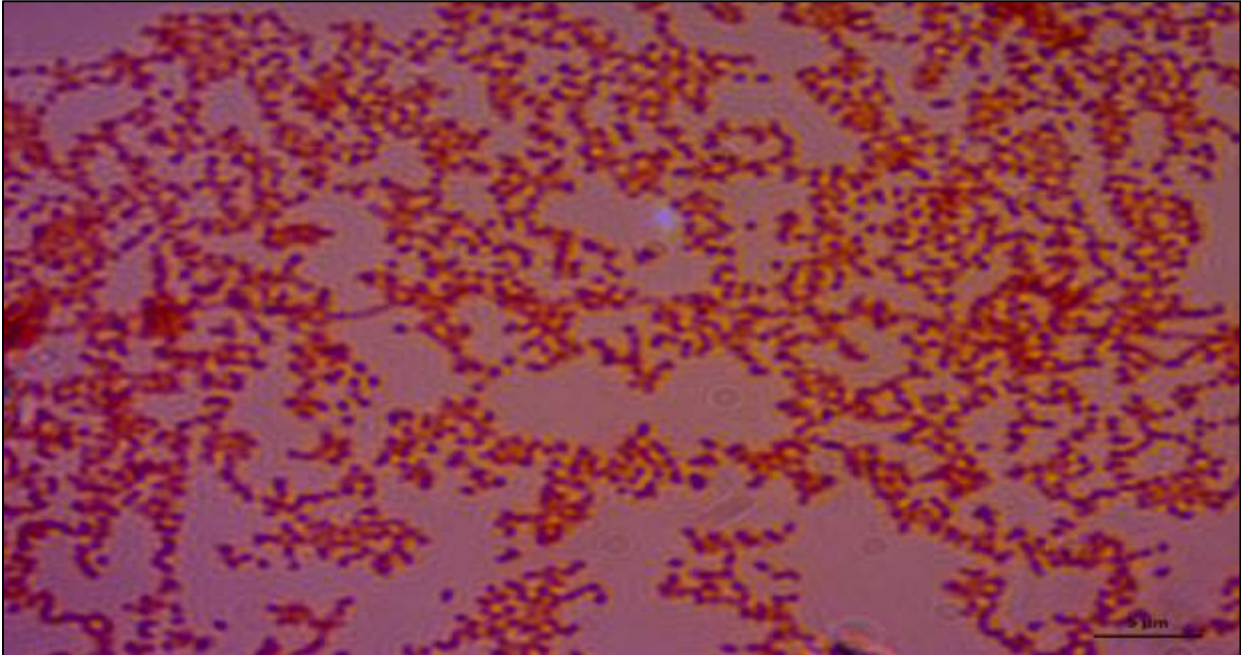


Photo 15: Endospores of treated bacterial culture



Photo 16: Crude extract inhibited the growth of microflora: one well was a control (distilled sterile tap water: two wells inoculated with the extract at ratios 100 and 150 mg/100 ml distilled sterile water, only the ratio 150 mg/mL inhibited the growth



Photo 17: Crude extract inhibited the growth of microflora: one well was a control (sterile marine water: two wells inoculated with the extract at ratios 100 and 150 mg/100 ml sterile marine water, only the ratio 150 mg/mL inhibited the growth

Natural chemical compounds of *Eryngium* inhibiting metal corrosion and its mode of action

There are two aspects that should be discussed regarding mode of action and its relation with extracted chemical fractions. It was so clear that the essential oil fraction extracted using hexane as an organic solvent acts mainly through adsorption. The inhibitory effect of other fractions is most probably due to their reaction with electrolytes present in the fresh or marine water media. Pal'a-Pa'ul *et al.*, 2005 [28] analyzed *E. bourgatii* essential oil in different parts of the plant, a total of 100 compounds were listed. Consequently, it is possible to postulate that the inhibitory activity of the present plant species is not only related to the essential oil fraction, but other fractions have metal inhibitory effect as well. Darriet *et al.*, 2013 [20] related mild steel corrosion inhibition in hydrochloric acid medium only to the essential oil fraction of *E. maritimum*, where a total of 54 compounds were identified in the oil, in addition to hydrocarbon compounds, oxygenated compounds, hydrocarbon monoterpenes, oxygenated monoterpenes, hydrocarbon sesquiterpenes, oxygenated sesquiterpenes, and other hydrocarbon compounds. In the essential oil fraction of the two *Eryngium* spp (*E. bourgatii* and *campestre*), there were 28 compounds common among the two species. Assuming the work on *E. maritimum* is taken as a reference for corrosion inhibition and in comparison, as species difference with *E. bourgatii* proven in the present work having metal corrosion inhibition activity as well; one can postulate that these 28 chemical compounds could be all or some of them behind the inhibitory effect of these two species. Possibly corrosion inhibition needs more than one compound, either for protective adsorption or electrochemical cell disruption of the electrolytes in the medium. *Eryngium* spp were found to contain a number of eryngiosides compounds and saniculasaponins characterized by chemically reactive radicals mainly H^+ , OH^- , acetyl, and carboxylic groups [19]. These active groups probably play a role in the chemical reactions with medium electrolytes resulting in corrosion inhibition, also in the adsorption process.

Conclusions

Eryngium bourgatii hexane-ethanol extract showed high efficiency in inhibiting corrosion of iron metal in both fresh and marine media with efficiency reached 95% and 91% in both fresh and marine media respectively at the third day. *E.bourgatii* extract acts as antibacterial inhibiting fresh and marine bacterial growth at ratio of 150 mg/100 mL; indicating a dual function effect. Statistical analysis revealed that insignificant difference between fresh and marine media. Scanning electron microscopy revealed inhibition of corrosion via adsorption on the metal surface, particularly the oil fraction of the extract. The adsorption of *E.bourgatii* extract on the surface of iron metal obeyed the Langmuir adsorption isotherm and the mechanism of inhibition is the physical adsorption.

Declaration

Ethical Approval

No animals were used in this work

Competing interests

I declare that the authors have no competing interests as defined by Springer, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

Contributions

The authors of the following paper declare that their contribution is equal.

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Availability of data and materials

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