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ORIGINAL STUDY

Basil Oil as an Environmentally Friendly Corrosion Inhibitor for AISI 1010 Mild Steel Pipes in the Cooling Towers

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ABSTRACT

One of the most significant industrial problems is the corrosion of construction metals such as mild steel in pipes and storage tanks of cooling towers. Several preventive measures are used to minimize corrosion. One of them uses various corrosion inhibitors, some of which are organic and others inorganic. Most inorganic corrosion inhibitors are environmentally unfriendly materials. These inhibitors, mixed with cooling tower water, are discharged into rivers or seawater. Many of them are toxic and affect biological life through their ingestion by humans and animals or through their entry into the soil. Basil plant oil is suggested as a new corrosion inhibitor; it is environmentally friendly, sustainable, and low-cost. This study examined its effectiveness compared to the well-known green corrosion inhibitor Eugenol. Various concentration rates were tested to determine the optimal efficiency using Eugenol under the actual temperature, velocity, and pH conditions of Al Daura refinery cooling towers: 40°C, 300 RPM, and pH = 7. The exact circumstances applied to Basil plant oil to compare efficiencies. The Weight loss method was used. Tests were carried out in accordance with the American Society for Testing and Materials regulations. The corrosion rate recorded 0.022185947 and 0.004108509 mm per year for the Eugenol and Basil plant oils, respectively. The efficiency reached 89.2% using a concentration of 0.5 milliliter/Liter of Eugenol. The efficiency increased to 98% by using the same amount of Basil plant oil. A new equation was derived to compute the increase in the metal age when using a specific corrosion inhibitor.

Keywords: Basil plant oil, Cooling tower, Eugenol, Green corrosion inhibitor, Sustainable corrosion inhibitor

Introduction

Worldwide, corrosion is a major issue for materials and construction. According to a study, the global loss from corrosion is estimated to be over 3.4% of GDP. However, the cost of metal degradation can be reduced by 15–35% through proper implementation of corrosion-prevention techniques.¹ The presence of water is one of the main reasons for internal corrosion in pipes and storage tanks. One of these sites is cooling towers, commonly used in power plants to cool the flowing water. They consist of tanks and a network of pipes.

Corrosion is an electrochemical process that occurs at anodic and cathodic sites on the material's surface, resulting from the heterogeneous nature of the bulk material and its surface. The corrosion process may occur chemically or electrochemically due to current flow, necessitating at least two reactions inside a specific corrosive environment.²

Anodic reaction

An anode is an electrode through which positive electric charge fluxes occur. Therefore, the anodic corrosion reaction is usually called oxidation, in which the metal is oxidized and loses electrons.³

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Cathodic reaction

The cathode is a negative electrode at which a reduction reaction occurs. The oxidation and reduction reactions are complementary. Furthermore, the cathode and anode must be either different metals or sides of the same metal.⁴

Several preventive measures must be employed to minimize corrosion. One of them uses various corrosion inhibitors, some of which are organic and others inorganic. Most inorganic corrosion inhibitors are environmentally unfriendly materials. These inhibitors, mixed with the cooling towers' water, are discharged from time to time and end up in rivers or seawater. Many of them are toxic and directly or indirectly affect biological life through their ingestion by humans and animals, or through their entry into the soil and thus into the plants that living organisms eat. Therefore, it is necessary to search for environmentally friendly corrosion inhibition materials. The cost and availability of inhibitors play a major role in choosing the optimal one(s). Therefore, there is an increased urge to develop low-cost and environmentally friendly corrosion inhibitors. Recent research on "green" corrosion inhibitors aimed to use inexpensive, effective compounds with a low environmental impact. They are derived from natural and renewable sources such as plant extracts, essential oils, and natural polymers and offer a viable path for long-term sustainable corrosion prevention, such as eucalyptus leaves extract,⁵ which the researchers may obtain green inhibitors from various resources like fruits peel, plant, the dried stems, plants leaves, and plant seeds, etc. . . .⁶ These inhibitors provide numerous advantages: they are non-toxic, biodegradable, and cause minimum environmental harm.⁷

Many researchers have used green corrosion inhibitors:

Sahib studied the efficiency of pomegranate peel powder as a green corrosion inhibitor; at 40 g/Liter, the inhibitor efficiency was 88.2%.⁸

Prabakaran, Kim, et al. extracted and analyzed the total phenolic and flavonoid components in the leaves of *Cryptostegia grandiflora*. The findings validated that the extract included Myricetin at 3582.22 ($\mu\text{g/g}$) = 0.00187 mL/L and Rutin at 45.62 ($\mu\text{g/g}$) = 0.000033 mL/L as principal constituents. The extract of *C. grandiflora* was assessed for its anti-corrosive capabilities on mild steel. A peak inhibition efficiency of 87.54% was attained with 500 ppm of the inhibitor.⁹

Rosli, Yusuf, et al. used 500 mg/Liter = 37 mL/L of *Musa sapientum* as an eco-friendly corrosion inhibitor to achieve 89% as the optimum efficiency.¹⁰

Jaouadi, Cherrad, et al. used 0.6 g/Liter *Cedrus atlantica* wood tar as an environmentally friendly

corrosion inhibitor, and the inhibitor efficiency was recorded 84%.¹¹

Ghalib, Al Jaaf, et al. harvested the leaves of *Eucalyptus Camaldulensis* from their natural habitat, then cleansed, rinsed with double-distilled water, and dried them for 3 days in the absence of sunlight. The leaves of *Eucalyptus Camaldulensis* were meticulously pulverized into a fine powder (150 mesh) and weighed with precision using a digital microbalance. Leaves of *Eucalyptus Camaldulensis* were employed as inhibitors at concentrations of 0.02, 0.04, 0.06, and 0.08 g/mL. The documented efficacy was 91.56%.¹²

Manssouri, Chraka et al. used a 2 g/L solution of *Ruta graveolens* as an environmentally friendly corrosion inhibitor, and achieved an efficiency of 94.8%.¹³

CHaieb, Bouyanzer, et al. studied the effect of Eugenol and acetyl Eugenol on steel alloy; They found that the inhibition efficiency attained 91% by adding 0.173 g/l from acetyl Eugenol, and the inhibition efficiency reached 80% by adding 0.173g/l from Eugenol.¹⁴

Azzouyaha, Abu-Obaid, et al. studied Eugenol oil as a corrosion inhibitor for aluminum alloy. 4 g/l of Eugenol oil achieved an optimum efficiency of 72%.¹⁵

Merchan, Sanabria, et al. studied the efficiency of adding 200 ppm of both Eugenol and o-Eugenol to carbon steel (AISI 1020) alloy; the efficiency of Eugenol and o-Eugenol reached 76.88% and 71.09%, respectively.¹⁶

Furtado, Nascimento, et al. investigated the efficiency of Eugenol oligomer in carbon steel, which reached (84%), by adding (5%v/v) from the inhibitor to the solution.¹⁷

The research aims to study the efficiency of Basil plant oil material as a corrosion inhibitor for cooling tower pipes that would be an alternative to the currently used chemical inhibitors that harm water quality and the biological environment.¹⁸

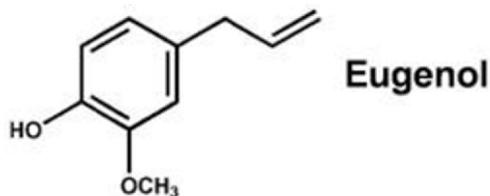
Experimental work

The pilot project simulates the conditions and materials of pipes (Mild steel) used in cooling towers (Daura refinery) in Baghdad. Different concentrations of Eugenol were tested to find the optimal concentration rate.

Instruments and materials

Eugenol

Eugenol, which has the chemical formula $\text{C}_{10}\text{H}_{12}\text{O}_2$, is an extracted plant compound. Its chemical structure is shown in Fig. 1.¹⁹ In this study,



Eugenol

Fig. 1. Chemical structure of Eugenol.



Fig. 2. Pure Eugenol.



Fig. 3. Basil plant.

Eugenol is suggested to be used as an environmentally friendly corrosion inhibitor.

Eugenol is found in natural resources such as cinnamon; *Cinnamomum Tamala* extract contains Eugenol.²⁰

Fig. 2 shows pure Eugenol from Switzerland. It was used to determine the optimal concentration rate, which will be used to evaluate the newly suggested corrosion inhibitor for mild steel (Basil plant oil).

Basil plant

The Basil plant, shown in Fig. 3, is widely available in Iraq and other countries worldwide. It doesn't need special conditions to cultivate, is low-cost, and is environmentally friendly.

Its scientific name is *Ocimum Basilicum*. It is well-known for its therapeutic properties and fragrant oils, which have significant economic value. Essential oils are the main reason for its growth. Moreover, it



Fig. 4. Basil plant oil.



Fig. 5. Distillation process.

contains many phenylpropanoid derivatives, including Eugenol, monoterpenes, sesquiterpenes, chavicol, methyl chavicol, and methyl Eugenol.²¹ Iraqi Basil plant oil is shown in Fig. 4.

The essential oil extracted from *Ocimum Basilicum* exhibited notable variability in chemical composition, influenced by geographical location, seasonal changes, and developmental stage.²² In this study, Basil plant oil, shown in Fig. 4, is suggested to be a corrosion inhibitor for mild steel.

Distillation instrument

In the distillation process, shown in Fig. 5, Basil leaves and stems are crushed, placed in the distillation device, covered with water, and then heated over a direct flame until the water boils. The resulting steam carries the essential oil. The steam and oil are condensed in a condenser, where the oil floats on top of the water in the distillation device. The oil is separated through the graduated tube and collected through the valve. Care should be taken not to exceed 100 degrees Celsius and to keep the pressure inside

Table 1. Composition of AISI 1010 mild steel.

Fe	Mn	S	P	C
99.18 – 99.62 %	0.3 – 0.6 %	< 0.05 %	< 0.04 %	0.08 – 0.13 %

**Fig. 6.** The experiment magnetic hotplate stirrer device.**Fig. 7.** Coupons.

the distillation device below atmospheric pressure, to avoid altering the chemical and physical properties of the extracted oil.

Magnetic hot plate stirrer

Its base diameter is 5 inches, and it has two LED digital screens for monitoring temperature and velocity, which can be controlled via two knobs. Accessories: a temperature probe, a stand with a clamp, a wood catcher, and a graded beaker of one litre volume. Inside the beaker, there is a magnetic stirrer to circulate the water. The country of origin is China, as shown in Fig. 6.

Coupons

Standard specimens of AISI 1010 Mild Steel that simulate the metal composition of targeted cooling tower pipes, as shown in Fig. 7.

The chemical composition of the studied alloy is shown in Table 1.

Weight loss method

One common method for calculating corrosion rates is determining the coupon's weight loss in a corrosion experiment. This method can be utilized

in any laboratory methodology to monitor corrosion rates in the field by utilizing coupons.²³ This international standard was developed according to the internationally recognized principles of standardization established in the Decision on Principles for the Development of International Standards, Guides, and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.²⁴

The weight-loss method evaluates the efficiency of the suggested inhibitor. This test method outlines the procedure for determining the corrosion rate in a water system without accounting for heat transfer. This is achieved by measuring weight loss in metal specimens, commonly called coupons, especially from pitting (considered a form of localized corrosion). Weight loss facilitates the determination of the average corrosion rate.

The corrosion rate of a metal submerged in water depends on the properties of the water and the water-included materials present, which can either facilitate or prevent corrosion.

The rate at which a substance corrodes in water is measured in relative rather than absolute terms because the two tendencies for metal to erode and for water and the materials it contains to encourage or prevent corrosion are interdependent. By comparing a substance's corrosion rate in water with and without a corrosion inhibitor, one can assess the material's relative propensity to erode. These tests help determine the impact of corrosion inhibitors applied to water. The weight-loss test method was used on AISI 1010 Mild Steel coupons that had been carefully prepared and weighed. The AISI 1010 Mild Steel coupons were fully immersed in flowing water for a limited time; 72 hours were chosen for all tests in this study.

After removal from the system, these specimens are cleaned and weighed using a sensitive balance.

The weight loss (ΔW)

$$= \text{Initial weight} - \text{Final weight}^{25} \quad (1)$$

Preparing coupon^{24,26}

The surface finish was achieved through sanding using abrasive paper. Sanding effectively removes mill scale and oxides, along with other imperfections in the material, such as scratches and pits, which could lead to inaccurate results during data



a) Before preparation



b) After preparation

Fig. 8. AISI 1010 Mild Steel Coupons before and after preparation.**Fig. 9.** Rust removing solution.**Fig. 10.** Rust removing process.

analysis. Wet sanding prevented specimens from heating up and avoided metallurgical change. Sanding was done with coarse abrasives and progressively moved to finer abrasives (400, 500, 600) grades.

The AISI 1010 Mild Steel coupons were not handled with bare fingers. This can affect the results by transferring oils from the fingers to portions of the AISI 1010 Mild Steel coupon, preventing consistent contact between water and the entire surface of the AISI 1010 Mild Steel coupon. Fig. 8 shows the AISI 1010 Mild Steel coupons before and after preparation.

Cleaning AISI 1010 mild steel coupon

An optimal procedure must eliminate only corrosion products without causing the removal of any base metal. According to the American Society for Testing and Materials,²⁶ the coupon was immersed in a specific solution consisting of 500 mL hydrochloric acid (HCL, sp gr 1.19), 10 g Antimony trioxide (Sb_2O_3) and 25 g Stannous chloride ($SnCl_2$), as shown in Fig. 9. The solution was vigorously stirred at 25 Celsius Centigrade for 15 minutes, as shown in Fig. 10. The specimen was brushed to prepare it for measuring its final weight, which will be used in weight loss method equations.

Compute corrosion rate, efficiency, and increase in metal age

Corrosion rates are normally calculated as an average annual penetration in millimeters. The corrosion rate in the water system is determined from the difference in AISI 1010 Mild Steel coupon weight, using Eq. (2):²⁷

$$X = \left(\frac{K * \Delta W}{D * A * T} \right) \quad (2)$$

Where:

X = corrosion rate in mm/year

K = constant $8.76 * 10^4$.

T = time of exposure in hours. Here equals 72 hours

A = area of AISI 1010 Mild Steel coupon in cm^2 . Here equals $18.862 cm^2$

D = density of AISI 1010 Mild Steel coupon in g/cm^3 . Here equals $7.85 g/cm^3$

ΔW = mass loss in grams (Initial weight – Final weight).

The primary criterion for evaluating any corrosion inhibitor is its efficiency, computed according to

Eq. (3).²⁷

$$IE\% = \left(\frac{X_o - X}{X_o} \right) * 100 \quad (3)$$

Where:

IE% = is the inhibitor efficiency

X_o = is the corrosion rate in the absence of an inhibitor.

X = is the corrosion rate in the same environment with the added inhibitor.

A new equation was derived to estimate the increase in the age of metals while using a specific concentration of corrosion inhibitor as follows:

From Eq. (2)

$$X_o = \left(\frac{K * \Delta W_{Blank}}{D * A * T_1} \right) \quad (4)$$

$$X = \left(\frac{K * \Delta W_{Inh}}{D * A * T_1} \right) \quad (5)$$

Where:

ΔW_{Blank} = is the weight loss in the absence of an inhibitor.

ΔW_{Inh} = is the weight loss in the same environment with the inhibitor added.

What is the value of T in Eq. (4) if we use the Corrosion Rate value from Eq. (5)?

$$T_2 = \left(\frac{K * \Delta W_{Blank}}{D * A * X} \right) \quad (6)$$

Here $T_1 = 72$ hours

$$Ig = \left(\frac{T_2}{T_1} - 1 \right) * 100 \quad (7)$$

Where:

Ig = is the increase in metal age %

Results and discussion

The weight loss method was used to evaluate the efficiency of the tested and suggested corrosion inhibitors.

The assumptions used in this study. Our pilot project is the Daura refinery, so some data was taken from the site of the Daura refinery cooling tower as it existed in actuality, such as:

Temperature of water = 32 – 42 Centigrade

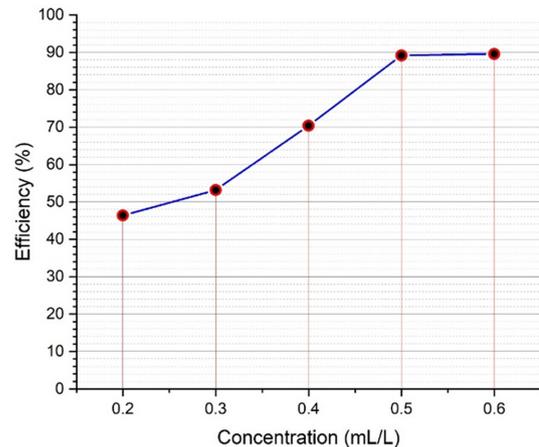


Fig. 11. Efficiency against concentration.

Velocity of Water = 1 – 2 m/s, which equals 204 – 410 RPM

Potential of Hydrogen (pH) = 7.5 – 8.3

Corrosion test alloy is AISI 1010 Mild Steel

In this study, the following parameter values are used in all tests:

Water from the cooling tower water supply

Temperature of water = 40 Centigrade

Velocity of Water = 300 RPM

Potential of Hydrogen (pH) = 7

The corrosion test alloy is AISI 1010 Mild Steel

Eugenol as a corrosion inhibitor

Various concentrations of pure Eugenol (0.2, 0.3, 0.4, 0.5, and 0.6) mL/L were used as corrosion inhibitors for mild steel in the aquatic environment to find the minimum weight loss that occurs for the same AISI 1010 Mild Steel coupon alloy. Table 2 shows the detailed calculations, while the efficiency against concentration rate is shown in Fig. 11.

Two notes have to be seen:

1. While testing 0.4 mL/L as the concentration rate, an unreasonable result appeared (assigned in red) in Table 1. The test was repeated, and a reasonable value was obtained.
2. Although the efficiency of 0.6% is greater than 0.5%, the latter depended on economics; the difference in efficiency is invaluable.

Suggested corrosion inhibitor

Basil plant oil is suggested as a new green corrosion inhibitor for mild steel. The computed optimal concentration rate of pure Eugenol, 0.5mL/L, was used under the same conditions of temperature, velocity, pH, and type of water to compute the efficiency of

Table 2. The efficiency of Eugenol with various concentrations (See Figs. S1–S6).

Coupon	Conc. (mL/L)	Velocity RPM	Temp. °C		Win (gm)	Wfin (gm)	Win-Wfin (gm)	Corrosion Rate (mm per year)	Efficiency %	Increase in Age %
			pH							
3832	0	300	40	7	10.0135	9.9885	0.0250	0.205425438	0	0
3830	0.2	300	40	7	9.9762	9.9628	0.0134	0.110108035	46.40	86.57
3835	0.3	300	40	7	10.0010	9.9893	0.0117	0.096139105	53.20	113.68
3834Reg.	0.4	300	40	7	9.9046	9.8857	0.0189	0.155301631	24.40	32.28
3832	0.4	300	40	7	9.9505	9.9431	0.0074	0.06080593	70.40	237.84
3835	0.5	300	40	7	9.9119	9.9092	0.0027	0.022185947	89.20	825.93
3833	0.6	300	40	7	9.7168	9.7142	0.0026	0.021364246	89.60	861.54

Table 3. Basil oil and Eugenol efficiencies (See Fig. S7).

Material	Conc. (mL/L)	Velocity RPM	Temp. °C		Win (gm)	Wfin (gm)	Win-Wfin (gm)	Corrosion Rate (mm per year)	Efficiency %	Increase in Age %
			pH							
Eugenol	0.5	300	40	7	9.9119	9.9092	0.0027	0.022185947	89.20	825.93
Iraqi Basil	0.5	300	40	7	9.6618	9.6613	0.0005	0.004108509	98.00	4900.00

Basil oil as a corrosion inhibitor material for mild steel. The computed efficiency is 98%, as shown in Table 3.

Discussion

Many researchers have used Eugenol and its compounds as corrosion inhibitors for various materials, such as stainless steel, aluminum, tin, etc., under various environmental conditions. Some were experimented on an acidic medium, and others on a basic or saline medium in different environments, see Table 4. This research was conducted on cooling towers, particularly those at the Daura refinery in Baghdad. The inputs were similar to the reality of the cooling towers under study. To evaluate the efficiency of the proposed material as a green corrosion inhibitor, pure Eugenol and Basil plant oil were studied under the same environmental conditions, using the same metal used in the cooling towers at the Daura refinery. Results in the last two rows of Table 4 were taken into consideration. They are considered sources and results for comparison and evaluation to determine the efficiency of the proposed material as a corrosion inhibitor.

Two studies,^{26,27} have evaluated two imported materials as corrosion inhibitors used in the Daura refinery for the same materials under the same circumstances as in this study; Table 5 presents a comparison of the efficiency of previous inhibitors and the proposed inhibitors.

Conclusion

Basil plant oil is suggested to be used as a corrosion inhibitor for AISI 1010 Mild Steel pipes used

in Daura refinery cooling towers in Baghdad. Experimental tests were carried out according to the American Society for Testing and Materials regulations using the weight-loss method under average ordinary environmental conditions at the Daura refinery. Results showed that the corrosion rate decreased from 0.022185947 to 0.004108509 mm per year for the Eugenol and Basil plant oils, respectively. At the same time, the corrosion inhibition efficiency rate of the Basil plant increased to 98%, compared to 89.2% for Eugenol. Basil plant oil has additional features, such as being environmentally friendly, locally cultivated, and low-cost compared to expensive imported corrosion inhibitors. The cost of one liter of extracted basil plant oil available in local markets is less than 50 USD. A new functional equation was derived to compute the increase in the metal age when using a specific corrosion inhibitor. This equation shows that the increase in metal age was approximately 826% and 4900% when Eugenol or Basil plant oil was used as a corrosion inhibitor for AISI 1010 Mild Steel pipes in the aquatic media of the cooling tower, respectively.

Authors' declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images that are not ours have been included with the necessary permission for republication, which is attached to the manuscript.
- No animal studies are present in the manuscript.
- No human studies are present in the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee at Mustansiriyah University.

Table 4. Comparison between this study and previous research.

Studies	Used Inhibitor	Concent. mL/L	Metal type	Additives	Efficiency
Chai. 2005 ¹⁴	Eugenol	0.163	Steel	1M HCL	80%
Chai. 2005 ¹⁴	Acetyl Eugenol	0.163	Steel	1 M HCL	91%
Azzo. 2016 ¹⁵	Eugenol oil	3.77	Aluminum	Na ₂ CO ₃	72%
Merc. 2018 ¹⁶	o-Eugenol	188.68	Carbon Steel	1M HCL	71.09%
Merc 2018 ¹⁶	Eugenol	188.68	Carbon Steel	1M HCL	76.88
Furt. 2022 ¹⁷	Eugenol oligomer	5	Carbon Steel	1M HCL	84%
This Study	Eugenol	0.5	Mild Steel	Non	89.4%
This Study	Basil plant oil	0.5	Mild Steel	Non	98%

Table 5. Efficiency comparison among materials.

Reference	Year	Corr. Inhibitor	Conc.	Corr. Rate	Efficiency
[26]	2012	3 SN/ 2 SM =800 ppm + 20 ppm SHMP*	820 ppm	0.0083	97.6%
[27]	2021	Kurita S-2050	60 ppm	0.3863	98.1%
This Study	2025	Eugenol	530 ppm	0.0222	89.2%
This Study	2025	Basil oil	478 ppm	0.0041	98%

*SN = Sodium Nitrite, SM = Sodium Molybdate, SHMP = Sodium hexametaphosphate.

Authors' contributions statement

M.A.K (Master Student) gained the cooling tower conditions information, conducted all the experiments, processed the data to reach the efficiencies, prepared the primary methodology, provided more than three-quarters of all used resources, and wrote the manuscript, suggested the use of Eugenol as a reference for the experiment, Basil plant oil as a novel corrosion inhibitor for mild steel, detected the coupons cleaning procedure, planned and plotted the flow-diagrams. **N.O.K** (Professor Doctor) gave most of the experimental methodology, suggested using the weight-loss method, supervised and revised the manuscript scientifically, supervised the experiment, revised the calculations, and oriented to make the flow diagrams. Provided the information for preparing the coupons. **R.A.A** (Assistant Professor Doctor) revised the manuscript's grammar, supervised and revised the manuscript, and analyzed the ideas to form opinions.

Data availability statement

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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The authors have no relevant financial or non-financial interests to disclose.

Supplementary materials

Supplementary materials is available at https://bsj.uobaghdad.edu.iq/cgi/viewcontent.cgi?filename=0&article=5182&context=home&type=additional&preview_mode=1.

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زيت الريحان كمتبّط تآكل صديق للبيئة لأنابيب الفولاذ منخفض الكربون AISI 1010 في أبراج التبريد

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الملخص

يُعدّ تآكل المعادن الإنشائية، مثل الفولاذ منخفض الكربون المستخدم في الأنابيب وخزانات أبراج التبريد، من أبرز المشكلات الصناعية. وتُستخدم عدة إجراءات وقائية للحد من التآكل، من بينها استعمال مثبّطات التآكل، التي يكون بعضها عضويًا والآخر غير عضوي. ومعظم مثبّطات التآكل غير العضوية مواد غير صديقة للبيئة؛ إذ تُخلط مع مياه أبراج التبريد ثم تُصرّف إلى الأنهار أو مياه البحر، وكثيرٌ منها سامّ ويؤثر في الحياة البيولوجية عند ابتلاعه من قبل الإنسان والحيوان أو عند تسربه إلى التربة. يُقترح زيت نبات الريحان كمتبّط جديد للتآكل يتميّز بكونه صديقًا للبيئة ومستدامًا ومنخفض الكلفة. درست هذه الدراسة فاعليته مقارنةً بالمتبّط الأخضر المعروف، الأوجينول. وقد جرى اختبار تراكيز مختلفة لتحديد الكفاءة المثلى باستخدام الأوجينول تحت ظروف التشغيل الفعلية لأبراج التبريد في مصفى الدورة، وهي: درجة حرارة 40 °م، وسرعة دوران 300 دورة/دقيقة، ودرجة حموضة $pH = 7$. ثم طبّقت الظروف نفسها على زيت نبات الريحان للمقارنة بين الكفاءات. استُخدمت طريقة فقدان الوزن، وأُجريت الاختبارات وفق لوائح الجمعية الأمريكية للاختبارات والمواد (ASTM). سجّل معدل التآكل بقيمتي 0.022185947 و0.004108509 مل/سنة لكلّ من الأوجينول وزيت نبات الريحان، على التوالي. وبلغت كفاءة التثبيط 89.2% عند استخدام تركيز 0.5 مل/لتر من الأوجينول، في حين ارتفعت الكفاءة إلى 98% عند استخدام الكمية نفسها من زيت نبات الريحان. كما جرى اشتقاق معادلة جديدة لحساب الزيادة في العمر التشغيلي للمعدن عند استخدام متبّط تآكل معيّن.

الكلمات المفتاحية: زيت نبات الريحان، برج التبريد، الأوجينول، متبّط تآكل أخضر، متبّط تآكل مستدام.