



# The use of green *Bistorta Officinalis* extract for effective inhibition of corrosion and scale formation problems in cooling water system



Zakiyeh Mohammadi, Mansour Rahsepar\*

Department of Materials Science and Engineering, School of Engineering, Shiraz University, Zand Boulevard, Shiraz 7134851154, Iran

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## ABSTRACT

*Bistorta Officinalis* extract was thoroughly characterized as an effective green inhibitor for prevention of corrosion and scale formation problems in cooling water system. Electrochemical impedance spectroscopy, DC polarization, weight loss measurement and UV–Vis spectroscopy have been conducted to investigate the mechanism and performance of the proposed inhibitor. The results of this study demonstrated the high corrosion inhibition performance of *Bistorta Officinalis* extract in cooling water. It was revealed that the inhibition action of this extract is due to adsorption of insoluble  $\text{Fe}^{2+}$  complexes over the steel surface which obeys the Langmuir adsorption isotherm and behaves as a mixed-type film forming corrosion inhibitor. In addition, the *Bistorta Officinalis* extract exhibited an excellent scale inhibition performance of 99.5% which make it an ideal material to prevent the scale formation in cooling water. Accordingly, the *Bistorta Officinalis* extract could be proposed for effective treatment of cooling water systems.

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## 1. Introduction

Cooling water systems are widely used in various industries to remove heat from processes and equipment [1]. However, the working conditions of these systems, such as the use of hard water at high temperatures, can cause severe corrosion and scaling problems and results in adverse effects on the system operation [2,3]. Therefore, proper treatment of cooling water to eliminate or reduce the corrosion and scaling problems is an integral part of the cooling system operation. An optimal operating condition can be achieved through proper selection of water treatment chemicals. The use of corrosion inhibitors is one of the most practical methods for corrosion protection of metal components [4]. Currently, a variety of chemical components are used as inhibitor material to prevent or reduce the corrosion and scale formation problems [5–7]. However, most of the available organic and inorganic inhibitors may have toxic effects that damage environment and underground resources. Therefore, the use of environmentally friendly components such as naturally occurring plant extracts and biodegradable chemical compounds have attracted increasing

attention as alternatives materials [8,9]. Because of the ecofriendly nature of plant extracts, these materials are called green inhibitors. Plant extracts contain diverse chemical compounds which can be adsorbed onto the metal surface via functional groups in their molecular structure and act as corrosion inhibitors. In this regard, many plant extracts namely *Cordia Latifolia*, Curcumin [10], *Azadirachta Indica*, *Punica Granatum*, *Momordica Charantia* [11] and aqueous extract of the beet root [12] have been used as green inhibitors to prevent corrosion problems in cooling water systems with various compositions.

Also, diversity of molecular structure and functional groups of organic compounds in a plant extract provides the possibility of the chelate formation between some extract constituents and hardening ions in cooling water that makes it possible to use the herbal extracts for inhibition of scale formation. Accordingly, several investigations have been conducted and reported that some plants extracts such as aqueous extract of *Paronychia Argentea*, *Spergularia Rubra* and *Parietaria Officinalis*, palm leaves, *Punica Granatum* hull and *Punica Granatum* leaf [13–16] can be used to inhibit the scale formation in the presence of water hardening ions.

However, an acceptable water treatment program should simultaneously provide control over corrosion and scale formation in cooling water. Fortunately, diversity of molecular structure and functional groups of herbal extracts provides the possibility to use some plant extracts to inhibit the corrosion and scale formation at

\* Corresponding author.

E-mail addresses: [rahsepar@shirazu.ac.ir](mailto:rahsepar@shirazu.ac.ir), [mansour.rahsepar@gmail.com](mailto:mansour.rahsepar@gmail.com) (M. Rahsepar).

the same time [3,17]. Recently, we have investigated the Mazuj galls of *Quercus Infectoria* tree as green corrosion and scale inhibitor for water treatment of a cooling water systems [18]. The results of our investigation revealed that the Mazuj galls extract can effectively inhibit the corrosion and scaling in cooling water. In the present study, *Bistorta Officinalis* rizhome was extracted to investigate its efficiency to inhibit corrosion and scale formation problems for mild steel corrosion in simulated cooling water. Different methods such as GC, electrochemical studies, weight loss studies, UV–Visible spectroscopy and scale deposition tests have been used to examine this extract.

## 2. Materials and methods

### 2.1. Materials

Simulated cooling water was used for corrosion and scale inhibition studies. The chemical composition of simulated cooling water was prepared based on the studies that were done on several cooling waters in different industries and attempts were made to select the average composition of cooling waters. To prepare simulated cooling water, desired amounts of  $MgCl_2$ ,  $CaCl_2$ ,  $NaCl$  and  $NaHCO_3$  salts were dissolved in distilled water and stirred well with a magnetic stirrer to achieve a homogenous solution. All salts were purchased from Merck Company. All reagents were used as received without further purification. Quality of this water is stated in Table 1. Commercial mild steel specimens that were used in this study have chemical composition based on Table 2.

### 2.2. *Bistorta Officinalis* extracting

*Bistorta Officinalis* plant was collected from a forest in Iran. Its rizhome was cleaned and rinsed with water, dried and ground to powder form. Then, *Bistorta Officinalis* powder and methanol were mixed in the weight ratio of 1:10. The mixture was placed on a shaker in a dark room for three days to be well mixed. In the next step, the mixture was filtered with Whatman filter paper to remove its solid contents. After filtration, a dark red solution remained, and its methanol was removed by IKA Rotary Evaporator. When almost all methanol had evaporated, the resulted gel was placed in an oven at 80 °C for 24 h to evaporate the remained methanol in the gel. Remained red solid was ground to powder form to be used as *Bistorta Officinalis* extract for corrosion and scale inhibitor studies.

### 2.3. Gas chromatography mass spectrometry

Gas chromatography–mass spectrometry (GC–MS) analysis was carried out to analyze the chemical composition of extract using an Agilent GC 857890B 5977B MSD gas chromatograph equipped with nonpolar fused silica capillary DB-3ms column (30 m × 0.25 mm i.d.; film thickness 0.25 μm). The program of oven temperature was first, 50 °C for 4 min and then an increase in the rate of 7 °C min<sup>-1</sup> to 220 °C for 42 min. The injector temperature was kept at 220 °C. The carrier gas was Helium at a flow rate of

**Table 2**

Chemical composition of commercial mild steel samples.

Element	Fe	Mn	Cu	C	P	S	N
Analysis (%)	Balanced	1.4	0.55	0.17	0.045	0.045	0.012

1 mL min<sup>-1</sup>; splitting ratio was 20:1. The mass spectral ionization temperature was set at 230 °C. The mass spectrometer was operated in the electron impact ionization mode at a voltage of 70 eV. Mass spectra were taken over the  $m/z$  range 40–550 amu. Extract solution for GC–MS analysis was prepared by dissolving the desired amount of *Bistorta Officinalis* extract powder in a solvent like acetone. Then the mixture was filtered to achieve a transparent solution for GC–MS analysis. To identify chemical compounds of *Bistorta Officinalis* extract, NIST05 software was used for database matching.

### 2.4. Potentiodynamic polarization test

Potentiodynamic polarization test was applied to obtain corrosion inhibition efficiency of *Bistorta Officinalis* extract, corrosion rate and corrosion current density of commercial mild steel samples in simulated cooling water in the presence and absence of *Bistorta Officinalis* extract. To conduct this test, a conventional three-electrode cell was used with an Ag/AgCl electrode (3 M KCl) as the reference electrode and a platinum wire as the auxiliary electrode. The working electrode was a mild steel rod that was attached to a copper wire to have electrical connection and mounted by using an epoxy resin to expose required surface area to corrosive media. Test specimens were ground by using SiC abrasive paper, polished to obtain a mirror-like surface, cleaned with ethanol and rinsed with distilled water and finally dried in hot air. To reach a stable potential for mild steel samples without significant change in potential, specimens were immersed in simulated cooling water for 1 h and then open circuit potential (OCP) was measured for 30 min to ensure complete stability of specimen's potential. Potentiodynamic polarization measurements were carried out with respect to OCP (step potential 0.5 mV) at a scan rate of 1 mV s<sup>-1</sup>. Polarization data were analyzed by Tafel extrapolation technique.

### 2.5. Electrochemical impedance spectroscopy

Corrosion inhibition efficiency of *Bistorta Officinalis* extract could also be studied through characterization of the metal/solution interface which was conducted by EIS method. For this purpose, after the initial immersion time, specimens were placed in the three-electrode cell system and EIS tests were conducted at open circuit potential within the frequency range of 0.01–100000 Hz by using a sinusoidal signal with the amplitude of 10 mV. The specimens that were used in EIS measurements were prepared like those in polarization technique.

Potentiodynamic polarization tests and electrochemical impedance spectroscopy were performed by an Autolab potentiostat/galvanostat (Model: type 3) equipped with frequency response analyzer. All electrochemical tests were carried out at least three times at room temperature, and EIS analysis and curve fitting were done using NOVA software.

### 2.6. UV–Visible spectroscopy

UV–Visible spectroscopy could help to better understand inhibitor adsorption, as this test can show the formation of adsorbed Fe<sup>2+</sup> complexes. To perform UV–Visible spectroscopy, test

**Table 1**

Quality of the simulated cooling water.

Parameters	Value of parameter
Ca <sup>2+</sup> (ppm)	360
Mg <sup>2+</sup> (ppm)	250
Cl <sup>-</sup> (ppm)	1980
Conductivity (mS cm <sup>-1</sup> )	4.5
TDS (ppm)	2700
pH	7.5

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