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Resource Utilization of Waste Drugs: A Case Study of Cephalosporins for Oilfield Water Treatment

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Abstract

In our life, there are a large number of waste drugs, and the traditional treatment of waste drugs will cause great damage to the environment, and even harm human health. Therefore, it is urgent to find a more environmentally friendly and efficient treatment method of waste drugs. In this study, cephalosporins were used as corrosion inhibitors in oilfield water treatment. It was found that when the concentration of cephalosporin was 1000 mg/L and the temperature was 303 K, the cephalosporin as a corrosion inhibitor showed good effect, and the corrosion inhibition rate was as high as 96.21%. This provides a new idea for the reuse of waste drugs. Converting waste drugs into useful resources will not only help reduce environmental pollution, but also save resources. In short, the treatment of waste drugs is an urgent problem to be solved. Traditional methods have environmental and health risks, so it is necessary to find innovative methods. The case study of cephalosporin as a corrosion inhibitor for oilfield water treatment provides us with a simple and effective way to treat waste drugs, which is expected to provide a new direction for future waste drug treatment.

Keywords

Oilfield Water Treatment; Waste Drug Treatment; Cephalosporin.

1. Introduction

In today 's society, the problem of disposal of waste drugs is becoming increasingly serious. The public often has a wrong understanding of the treatment of waste drugs. Traditional waste drug treatment methods often include incineration and landfill, or directly flush the drug into the sewer or simply throw it into the garbage can, but these methods have many drawbacks. Incineration will produce harmful gases and ash, posing a threat to the environment and human health. Landfill may lead to drug leakage into groundwater and pollute water sources. These misconceptions and mishandling practices have led to the widespread distribution of waste drugs in the environment, posing a potential threat to ecosystems and human health[1,2]. Therefore, the high complexity and diversity of waste drugs make it urgent to find a universal and effective treatment method. Traditional treatment methods, such as incineration and landfill, are effective in some cases, but often lead to environmental and health problems. Therefore, there is an urgent need for a novel, environmentally friendly and efficient waste drug treatment method to solve this global problem.

Most of the corrosion inhibitors currently used are organic compounds containing heteroatoms (S, N, O) or multiple bonds (double bonds and triple bonds), such as-C=O, -C=N, -C≡N, -OH, -COOH, -N=O and-CONH2, etc., resulting in the interaction of lone pair electrons or π electrons on the corrosion inhibitor molecule with the empty d-orbital of the metal, thereby inhibiting metal corrosion[3-6]. Studies[7,8] have shown that compared with compounds containing only one

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heteroatom unit, inhibitor molecules containing two or more heteroatom units have more electrons to share with the empty d orbitals on the metal, that is, they can produce stronger adsorption. Cephalosporins have multiple adsorption centers, commonly known as adsorption groups, which lead to stronger adsorption.

In this experiment, the waste drug cephalosporin was used as a corrosion inhibitor in oilfield water treatment. At different temperatures, in 3% HCl solution containing different corrosion inhibitors, Q235 steel was used as the research object, and its corrosion inhibition performance was studied after soaking for 4 h. We hope that this study can provide new ideas for the sustainable treatment of waste drugs and contribute to environmental protection and resource utilization.

2. Experiment Details

2.1 Material Preparation

Cephalosporin (C14H14ClN3O4S), the effective content of about 0.125 g/tablet, chemical structure as shown in Fig. 1. Hydrochloric acid (HCl, concentration of 36-37%), distilled water, petroleum ether (concentration of 99.9%), anhydrous ethanol (C2H5OH, concentration of 99.9%) were purchased from Xi 'an Laka Instrument and Equipment Co., Ltd.

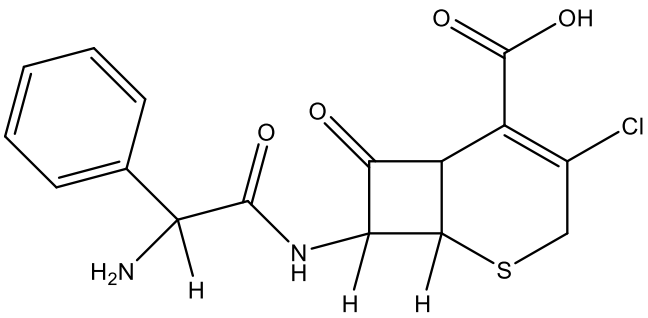

Fig.1 Chemical structure of C14H14ClN3O4S

The steel sheet used in the experiment is Q235 steel. The steel sheet specification is 40×13×2mm3. The element content and physical properties of the steel sheet are shown in Table 1 and Table 2, respectively. The test pieces are purchased from Shanghai Mechanical and Electrical Equipment Co., Ltd. Before the experiment, the rust and scratches on the surface of the steel sheet need to be removed with metallographic sandpaper of different meshes (400-600-800-1000), and then cleaned with petroleum ether to remove the oil stain on the surface of the steel sheet. Finally, it is cleaned with anhydrous ethanol and dried with cold air.

Table 1. Q235 mild steel sheet composition content

Coupons	C	Si	Mn	P	S	Al	Cr	Ni	Cu
Content(%)	0.16	0.26	0.15	≤0.015	≤0.09	/	0.02	0.025	0.024

Table 2. Q235 mild steel sheet tensile and process properties

Tensile strength(b/MPa)	Yield strength(0.2/MPa)	Elongation(5%)	Density(g · cm-3)
425	310	35	7.85

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2.2 Preparation of Hydrochloric Acid Solution

According to the actual needs of the experiment, distilled water and 36% concentrated hydrochloric acid solution were prepared into 3% hydrochloric acid solution in a certain proportion. In order to reduce the experimental error as much as possible, it is necessary to accurately measure the amount of concentrated hydrochloric acid and distilled water in the preparation process. Because concentrated hydrochloric acid has strong volatility, strong pungent odor, and produces a large amount of smoke, it is necessary to slowly pour a certain amount of concentrated hydrochloric acid into a large beaker filled with distilled water during preparation. Add and stir until the stirring is uniform; then, the glass rod is drained into a 1000 mL volumetric flask, and the measuring cylinder, the rubber head dropper, the beaker and the glass rod are washed with distilled water. Finally, constant volume with distilled water, cover the stopper for use.

The amount of concentrated hydrochloric acid required is calculated according to Eqs. (1):

$$V_0=\frac{1000\cdot W}{36} \tag{1}$$

Where, W denotes the mass fraction of hydrochloric acid prepared, %. V_0 denotes the volume of concentrated hydrochloric acid required, mL.

2.3 Weight Test

In 3% HCl, the Q235 steel sheet was used to carry out the hanging test in different concentrations of cephalosporin (0,10,50,100,200,400,1000 mg/L) solution. In each group of experiments, two steel sheets were hung in parallel as a parallel test, and the experimental results could be obtained by repetition. The experimental data were obtained by soaking in a water bath at different temperatures (303 K, 313 K, 323 K, 333 K, 343 K, 353 K) for 4 h. After the soaking, the steel sheet was taken out, first washed with distilled water, then washed with anhydrous ethanol, dried, and then weighed accurately. At different temperatures, the corrosion inhibition efficiency of different concentrations of cephalosporin on low carbon steel in 3% HCl was studied by weight loss experiment. The corrosion rate CR(mg·cm-2·h-1) and the corrosion inhibition rate η (%) were calculated by Eqs. (2) and (3):

$$C_R=\frac{M_0-M_1}{St} \tag{2}$$

$$\eta(\%)=\frac{M_0-M_1}{M_0}\times 100 \tag{3}$$

Among them, M_0 *and* M_1 are the mass loss values of low carbon steel with and without corrosion inhibitors, respectively. S(cm2) is the surface area of low carbon steel, and t(h) is the soaking time.

3. Results and Discussion

3.1 Effect of Inhibitor Concentration

At 303 K, the corrosion of low carbon steel in 3% HCl solution with different inhibitor concentrations was studied, as shown in Fig.2. It can be seen from Fig.2 that as the concentration of the corrosion inhibitor increases, the corrosion rate decreases and the corrosion inhibition rate increases. This is because as the concentration of the corrosion inhibitor increases, the steric hindrance occupied by the corrosion inhibitor molecules on the metal surface increases, and the adsorption film formed on the metal surface is more stable. Therefore, the barrier effect of the adsorption film on the corrosive ions is also strengthened, which means that the increase in the concentration of the corrosion inhibitor is beneficial to its effect.

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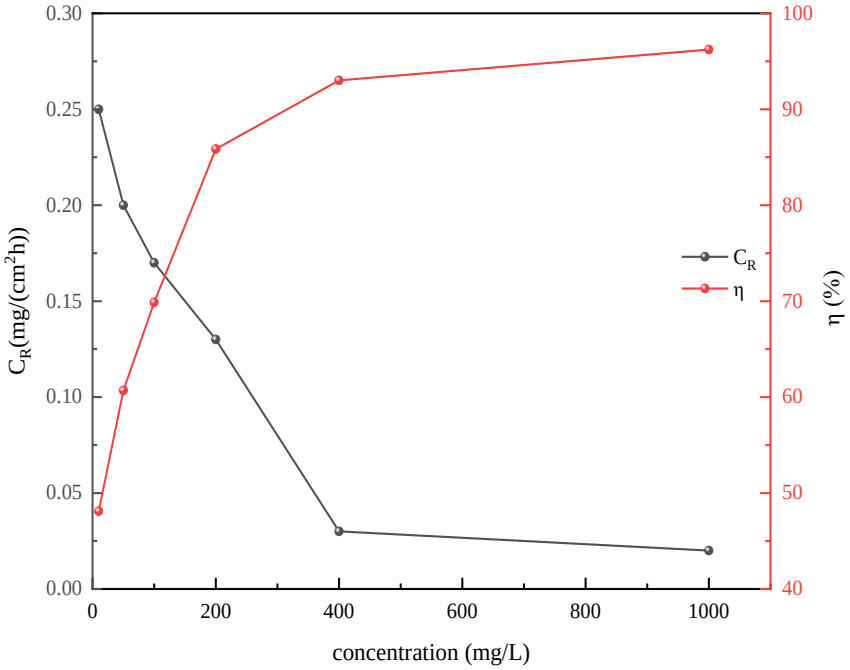

Fig.2 Corrosion of Q235 steel in 3% HCl at 303 K

Fig. 3 is the comparison of low carbon steel before and after soaking in HCl solution. It can be seen from the comparison diagram that the surface of the steel sheet before soaking is smooth, with obvious grinding marks, no rust and burr (Fig. 3 (a)); at 303 K, the surface of the steel sheet immersed in 3% HCl solution for 4 h has obvious large area of rust, and there is no grinding mark (Fig.3 (b)).

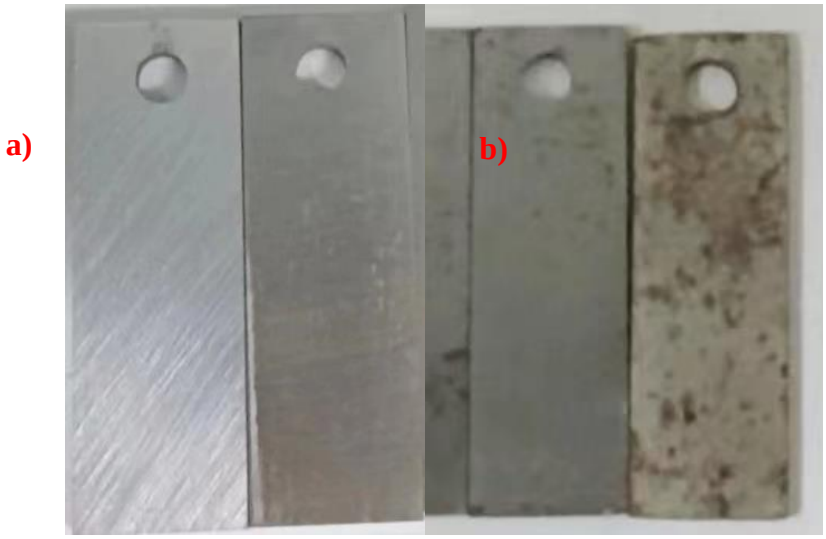

Fig. 3 Different forms of Q235 steel sheet before and after the hanging piece experiment

3.2 Effect of Temperature on Corrosion Inhibition

In order to study the effect of temperature on the corrosion inhibition efficiency of cephalosporin, we carried out weight loss experiments at 303 K, 313 K, 323 K, 333 K, 343 K and 353 K, respectively. The steel sheet was immersed in a mixed solution of cephalosporin and HCl at different concentrations and temperatures for 4 h. According to the results of weight loss experiments, the relationship curves of corrosion inhibition rate and corrosion rate with corrosion inhibitor concentration at different temperatures were calculated by Eqs. (2) and (3). The results are shown in Fig. 4. Fig.4 shows that at all temperatures in the experiment, as the concentration of the corrosion inhibitor increases, the corrosion rate increases, and the corrosion inhibition rate generally shows a

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decreasing trend. This is because at any temperature, the increase of the concentration of the corrosion inhibitor always leads to the increase of the volume occupied by the cephalosporin molecules on the metal surface, which will block the contact between the corrosive ions and the metal. Moreover, the higher the concentration of the corrosion inhibitor, the greater the blocking effect, the more stable the adsorption film formed by the corrosion inhibitor molecules on the metal surface, and the better the corrosion inhibition effect.

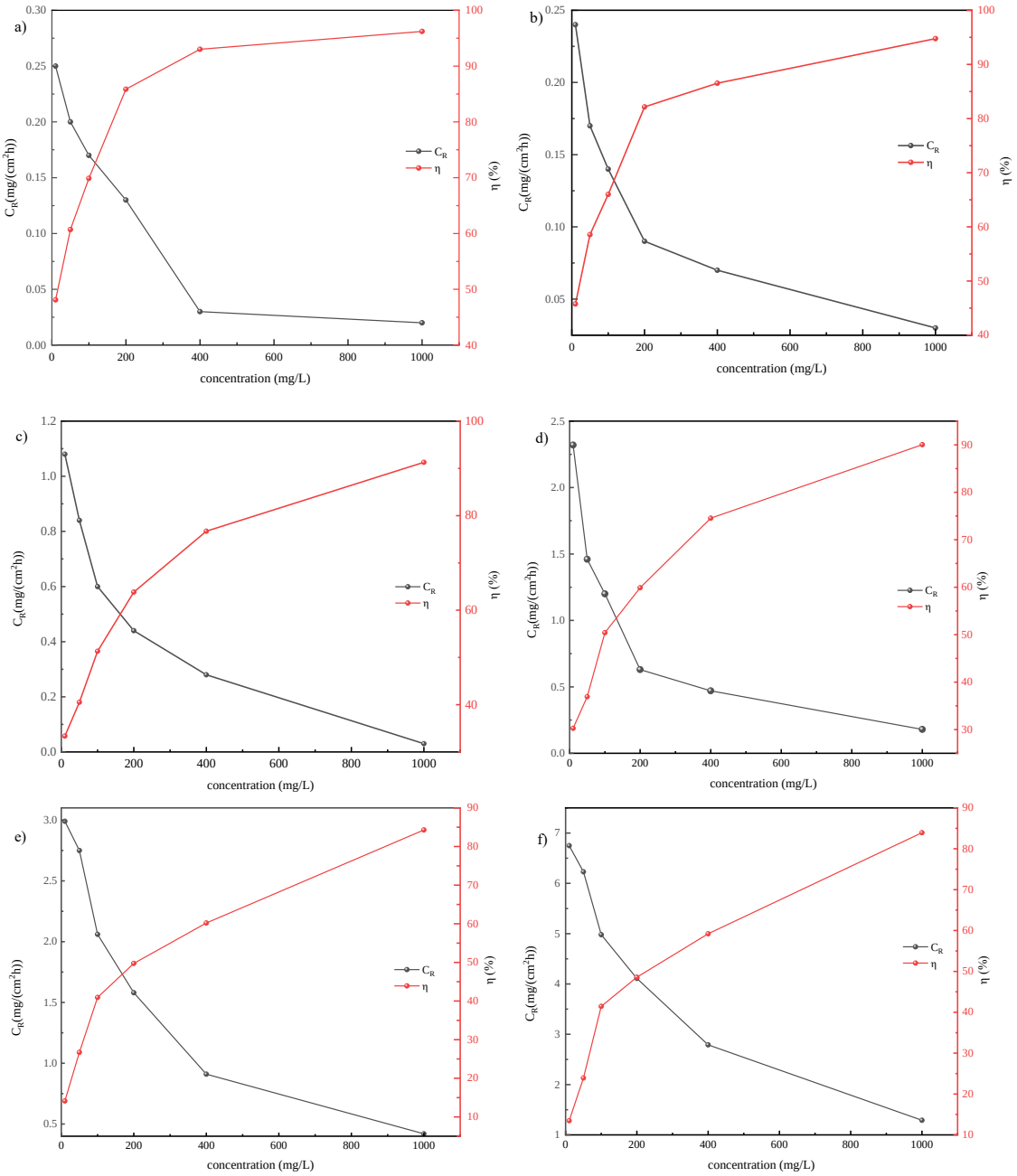

Fig. 4 Double Y axis diagram of corrosion inhibition effect of cephalosporin molecules on low carbon steel at different temperatures (a-f: 303 K-353 K)

Fig.5 is the effect of different concentrations of corrosion inhibitors on the corrosion inhibition rate of Q235 steel at different temperatures. It can be seen from the figure that the corrosion inhibition rate of cephalosporin molecules on low carbon steel will decrease with the increase of temperature. One of the reasons for this result may be that the reaction rate increases with the increase of temperature. At lower temperatures, the chemical reaction rate between cephalosporin molecules and

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the metal surface is slow, and a protective film is slowly formed. However, when the temperature increases, the reaction rate will be accelerated, and the reaction between the cephalosporin molecule and the metal surface will be faster, so that the formed corrosion inhibition film will become thinner or rupture, resulting in a decrease in the corrosion inhibition rate. Another reason may be that the increase of temperature will increase the corrosion rate of acid to low carbon steel. When the temperature rises, the energy of the active ions or molecules in the acid solution also increases, making them more likely to react with the surface of low carbon steel. In this way, the corrosion reaction will proceed more quickly and may form bubbles on the surface of the steel sheet. These bubbles will hinder the contact and adsorption of cephalosporin molecules on the surface of the steel sheet, making it difficult for cephalosporin molecules to adsorb on the surface of the steel sheet. Therefore, the effect of cephalosporin as corrosion inhibitor will decrease with the increase of temperature.

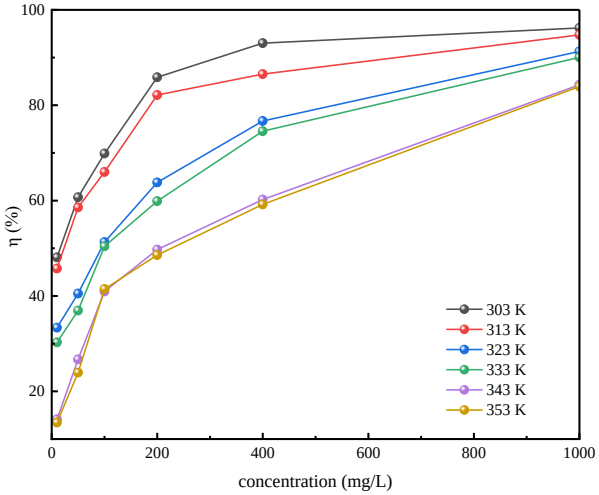

Fig. 5 Corrosion inhibition effect at different temperatures

3.3 Corrosion Inhibition Mechanism

As a corrosion inhibitor, the main role of cephalosporin is to slow down or prevent metal corrosion. The protective means of cephalosporin to metal is to form a dense protective film on the metal surface. The principle of forming a protective film is that the organic corrosion inhibitor molecules will undergo dissolution and adsorb to the metal surface in the solution by van der Waals force or chemical bond force to form a film. There are functional groups such as N, O, and S on the cephalosporin. They all contain lone pairs of electrons and have large electronegativity. They can be coordinated with the empty d orbital of the metal through these lone pairs of electrons, so as to firmly adsorb on the metal surface and produce a layer of strong adsorption film. This layer of film blocks the contact between the metal and oxygen, water or other corrosive particles in the environment, thereby slowing down the corrosion of the metal surface.

4. Conclusion

In this paper, the corrosion inhibition effect of cephalosporin as a corrosion inhibitor on Q235 steel in 3% HCl solution was studied by static weight loss experiment. The results showed that the corrosion inhibition effect of cephalosporin decreased with the increase of temperature. At 303 K, when the concentration of corrosion inhibitor was 1000 mg / L, the corrosion inhibition efficiency was the best. At this time, the corrosion rate was 0.02 mg/(cm2·h), and the corrosion inhibition rate was as high as 96.21%. When the temperature increased to 353 K, the corrosion inhibition rate was also higher than 80%, and the corrosion rate was lower than 1.29 mg/(cm2·h). It can be seen that the corrosion inhibition effect of cephalosporin in high temperature environment is also excellent, which provides a new idea for the resource treatment of waste drugs.

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