The Austrian Journal of Technical and Natural Sciences, No 3–4
ISSN 2310-5607

PREMIER Publishing
ppublishing.org

DOI:10.29013/AJT-25-3.4-69-74

STUDY AND ANALYSIS OF THE IR SPECTRUM AND PHYSICO-CHEMICAL PROPERTIES OF CORROSION INHIBITORS THAT PREVENT THE DEPOSITION OF SALTS CONTAINING NITROGEN AND PHOSPHORUS USED IN INDUSTRIAL WATERS

Shamuradov Ulugbek Meilievich [1], ***Beknazarov Hasan Soibnazarovich*** [2], ***Jalilov Abdulakhat Turapovich*** [3], ***Togaev Eldar Makhmanazarovich*** [4]

[1] Tashkent Research Institute of Chemistry and Technology.

[2] Department of "General Medicine" of the Faculty of Medicine, Angren University

[3] Academician, "Tashkent Scientific Research Institute of Chemical Technology LLC"

[4] Department of Chemical Engineering and Biotechnology, Karshi State Technical University

Cite: *Shamuradov U.M., Beknazarov H.S., Jalilov A.T., Togaev E.M. (2025). Study and Analysis of the ir Spectrum and Physico-Chemical Properties of Corrosion Inhibitors That Prevent the Deposition of Salts Containing Nitrogen and Phosphorus Used in Industrial Waters. Austrian Journal of Technical and Natural Sciences 2025, No 3–4.* https://doi.org/10.29013/AJT-25-3.4-69-74

Abstract

The article discusses in detail the physico-chemical properties of the EDF-1 corrosion inhibitor containing nitrogen and phosphorus, which prevent the deposition of salt in the pipelines of heating boilers, as well as the occurrence of corrosion in water systems used in industry for heating and cooling. Which functional groups are present and formed in this inhibitor using an IR-Fourier device, Shimazu, were studied and, accordingly, the absorption peaks of the new substances obtained were determined. As a result of the synthesis, metal corrosion inhibitors were obtained and the degree of their corrosion protection was checked in accordance with the requirements of GOST 9.506–87 and conclusions were drawn.

Keywords: *Corrosion inhibitors, Nitrogen, organic compounds, inorganic compounds, industrial waters, furnace, GOST 9.506–87*

The formation of mineral deposits and corrosion of structural steels in technological processes related to industrial use as a heat carrier, heat carrier and hydraulic transport has been a serious problem for more than a hundred years and remains relevant today.

One of the most optimal ways to protect metals from corrosion is to use corrosion inhibitors. The use of inhibitors can only slow down corrosion, but not stop it completely (Shamuradov, Ulugbek Meylievich, Hasan Soyibnazarovich Beknazarov, and Abdulakhat Turapovich Dzhalilov. 2025;

Andreatta F., Fedrizzi L., 2016). Corrosion leads to huge economic losses for many industries. According to an international Nice study conducted in 2016, global corrosion costs amount to 2.5 trillion US dollars per year, which is equivalent to a significant portion of the global gross domestic product (GDP) (Amin H. M. A., Galal A., 2021). Various countries have conducted studies on the corrosion of national costs. According to this survey, the U.S. economy has shrunk by $70 billion due to corrosion, accounting for 4.2 percent of the gross national product. The government of India spends about 3.5% of the country's GDP per year on corrosion losses (Kamath, R., Venumuddala, V.R., 2023). Oil and gas storage tanks are made of aluminum and steel, which must be protected due to their tendency to corrosion, which directly or indirectly affects the economy. Steel and aluminum are important metals that are used in almost all parts of the Vegas oil industry prior to the distribution of final products (Kamath, R.; Venumuddala, V.R., 2023). Synthetic inhibitors are widely used in various industrial applications due to their effectiveness, but their potential environmental impact must be considered, and their choice and dosage must be carefully monitored (Fayomi O. S.I., Akande I. G., Odigie S., 2019).

Material and method

Synthesis of composite corrosion inhibitor EDF-1. Ethylenediamine was dissolved in 12 ml of distilled water, taking 2 grams and dissolving 0.59 grams of phosphoric acid in 3 grams of distilled water, and both prepared solutions were placed in a round-bottomed flask with a double bottom, the flask was lowered into an oil bath, into which a reversible inert gas cooler (nitrogen gas) was installed from one neck of the flask with two necks An ashtray was installed in the second neck of the chloride hose for adding acid and formalin and the technological part was prepared. Then the oil was placed in an oven with a bath, nitrogen gas was introduced to create an inert medium and added dropwise with a slow increase in temperature to 60–65 °C for 1.5–2 hours with a concentration of 37% hydrochloric acid of 1.92 g, after which formalin was removed from a 37% solution of 0.7 g until the temperature of the reaction mixture increased to 115–120 °C. taken off 24 hours drops are added during. The resulting reaction mixture is first cooled to room temperature, then neutralized with a 30% NaOH solution, while the precipitate is lowered to the bottom of the flask, and the resulting reaction mixture is dried in an oven until a dry mass is formed. The substance of the bright yellow shape of the tablets was used as a basis.

Infrared Spectroscopy (IR) – IR spectroscopy (Japanese-made Fury spectrometer. IR spectroscopic studies were performed using the powder method on a Shimazu infrared Fourier spectrometer (range 400–4000 cm^{-1}, resolution 4 cm^{-1}).

SEM analysis. The precorrosive, postcorrosive, and inhibited states of the steel surface were studied using a JEOL JSM-it200la multi-faceted tungsten filament scanning electron microscope with intuitive controls, including a touchscreen and a scanning electron microscope with SEM imaging and EDS analysis directly from the optical image.

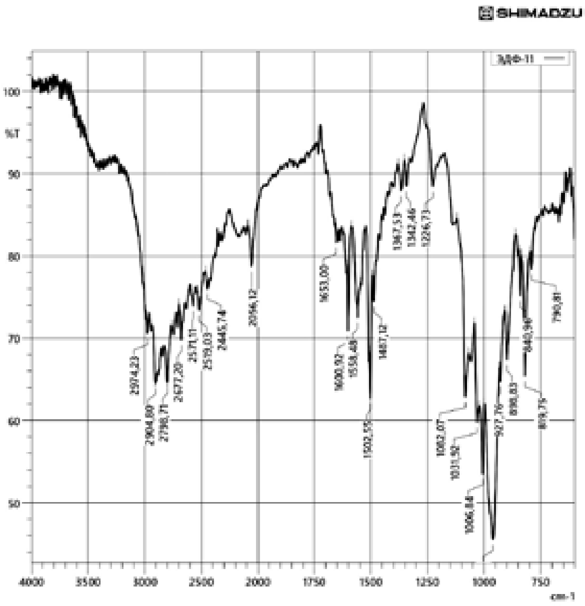
The results obtained and their discussion

The EDF-1 corrosion inhibitor was tested by gravimetric method. This method is one of the widely used and effective methods for determining the rate of metal corrosion and the protective ability of corrosion inhibitors in the laboratory. The gravimetric method is based on calculation by measuring the mass difference before and after exposure to corrosion by placing controlled metal samples in inhibitory and inhibitory media. The disadvantage of using this method is that it describes the average rate of corrosion without taking into account irregularities on the metal surface.

Our test experience has been verified in accordance with GOST 9.506–87 "methods for determining the protective ability of metal corrosion inhibitors in a water-oil environment".

The analysis of the IR spectrum and the corrosion inhibitor EDF-1. EDF-1 was presented to study the composition and structure of the corrosion protection inhibitor (Fig. 1).

Figure 1. *IR spectrum of EDF-1 corrosion inhibitor*



The composition and structure of the EDF-1 corrosion inhibitor were investigated using IR spectrometer technology (IQ-Fury, SHIMADZU, Japan) in the Dead range up to an area of 4000 cm^{-1}. The absorption line of IR spectroscopy is shown. 2677.20–2571.11 cm^{-1} intensity of weak –(PO)oh groups with valence vibrations in absorption regions, 2445.74 cm^{-1} –P–H groups with valence vibrations in absorption regions, 1653–1600.92 cm^{-1} type of vibrations in absorption regions valence, intense –C=N– group, 1487.12–1558.48 cm^{-1} absorption during asymmetric valence vibrations in fields of the C–N=O group, the type of vibrations in absorption fields is 1367.53 cm^{-1} Simm.The valence, intense –N–N=O group has lines corresponding to –P–O–C groups with a valence oscillation in the absorption region of 1226.73 cm^{-1}.

According to these analyzed results, our investigated corrosion inhibitor contains nitrogen and phosphorus, which indicates that it has anti-corrosion properties.

The results obtained using a scanning electron microscope, as well as their analysis.

A scanning electron microscope (SEM) is a device that uses directed beams of high-energy electrons on the surface of solid samples to generate various signals. SEM makes it possible to extract data such as surface structure (external morphology), chemical composition, orientation of components, as well as the crystal structure of the sample from the electronic interaction signals of the sample. The purpose of the SEM analysis is to determine the presence of an inhibitor on the steel surface.

Figure 2.1. *Initial photo of the steel sample*

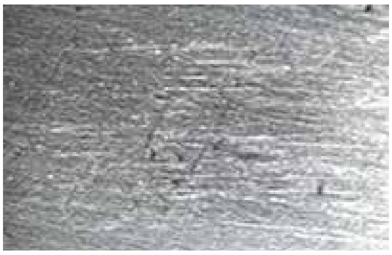


Figure 2.2.*Photo of a steel sample in SEM*

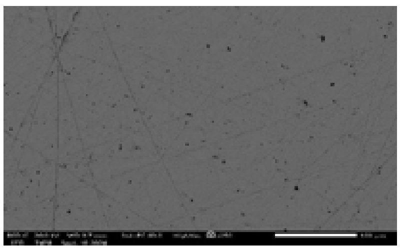
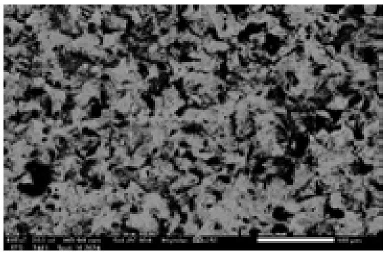


Figure 2.3. *Photo of a hardened steel sample in SEM*

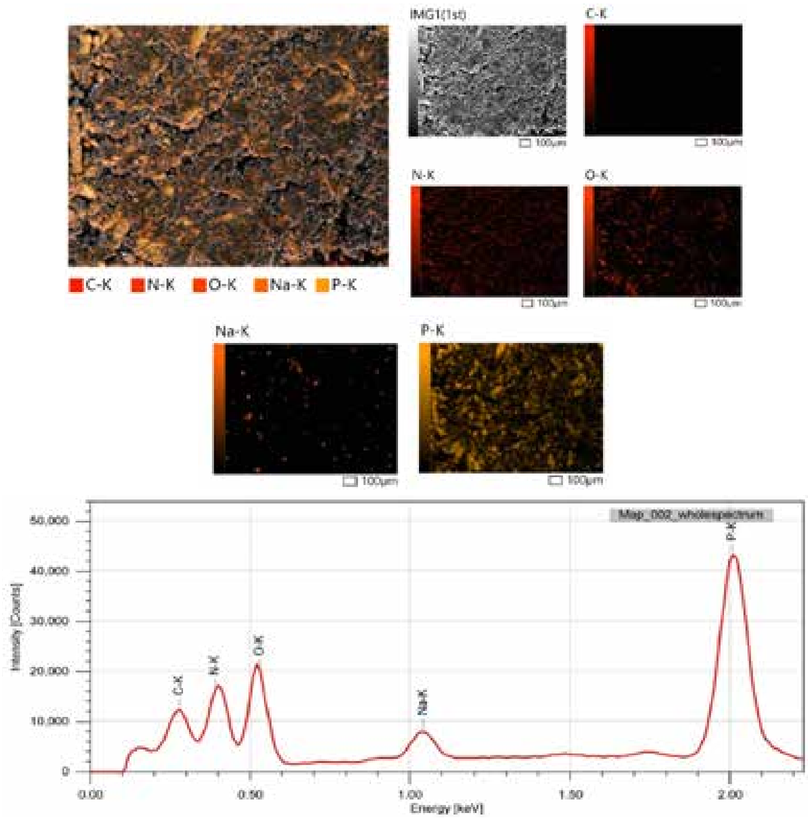


Typically, data is taken from the sample surface using a selected area (from 1 cm to 5 microns), represented as a 2D image. Magnification can range from 20× to 30000× with a spatial resolution of 50 to 100 Nm. In addition, SEM analysis does not lead to a change in the composition of the sample. The reason is that the sample does not lead to a loss of sample volume during electronic interaction.

Morphologically, the surface surface of steel samples conducted with samples of the St30 grade in various concentrations was studied using the Sem method.

It is known from the above figures that Figure 2.1 shows a preliminary photograph of a steel sample cleaned with sandpaper of different grades and washed in acetone. Micrographs of the initial steel sample made on an inhibitor-free surface were also obtained using a scanning electron microscope (Fig. 2.2) and inhibitory (Fig. 2.3) media.

Figure 3. *Microscopic image of the arrangement of elements on the surface of a trapped metal and a diagram of their presence using a scanning electron microscope*



The analyses obtained using a scanning electron microscope show that our EDF-1 grade corrosion inhibitor provides excellent protection for metal surfaces, and we can see that it contains anti-corrosion elements, as well as how it settles on the metal surface. The properties of corrosion inhibitors that are highly soluble in water and retain nitrogen and phosphorus in their composition were tested according to GOST 9.506–87. The molecules of these corrosion inhibitors consist of one or more functional groups, which are organic substances containing a hydrocarbon radical.

3 different concentrations for 360 hours in the tester at atmospheric pressure. The test time is calculated from the moment the samples are placed in the environment. The duration of the tests was determined according to GOST 9.506–87. The tests were carried out on waters used in the oil and gas industry.

The concentration of EDF-1 grade corrosion inhibitor containing nitrogen and phosphorus is 1%, 3%, 5%; this was done in an acidic environment. The tests showed protection levels of 84.34, 96.3, and 99.98 percent, respectively. The graph below shows the degree of protection of our corrosion inhibitor at various temperatures.

Table 1 shows the corrosion rate and degree of protection for 360 hours in an environment without inhibitors and inhibitors.

Table 1. *Corrosion rate and degree of protection 360 hours in an environment without inhibitors and inhibitors*

	Sample Surface; S, m²	Sample weight before testing; M, g	Mass of the sample after the test; M, g	Sample mass loss; M1 – M2, g	Degree of corrosion in an environment without inhibitors, g/m² * s	Degree of corrosion in an inhibitory environment; g/m² * s	Protection level; (Z)%
Without inhibitors	0,11053	14,20894	13,26007	0,94887	0,02384		
1	0,11053	14,10306	14,09591	0.00715		0,000179	84,34
2	0,11053	14,63365	14,63027	0.00338		0,000085	96,3
3	0,11053	14,85650	14,85374	0.00276		0,00073	99,98

Table 2. *The values of corrosion rate, protection levels and surface treatment coefficient are EDF-1 corrosion inhibitors in various molar mass ratios*

Ethylenediamine: phosphic acid	Corrosion rate	Protection level	θ	Temperature, °C
1:3	0,074	73,3	0,733	20
1:2	0,068	81,7	0,817	50
1:1	0,053	92,6	0,926	70
2:1	0,061	85,5	0,855	80
3:1	0,079	69,7	0,697	90

Table 2 shows the values of the corrosion rate, protection levels, and surface treatment coefficient of the EDF-1 corrosion inhibitor in various molar mass ratios. The results showed that the rate of metal inhibition was also higher when the starting products obtained in different proportions during the reaction, namely ethylenediamine and phosphitic acid, were obtained in a 1:1 ratio.

Figure 3. *Dependence of EDF-1 corrosion inhibitor on molar ratios and degree of protection, scheme*

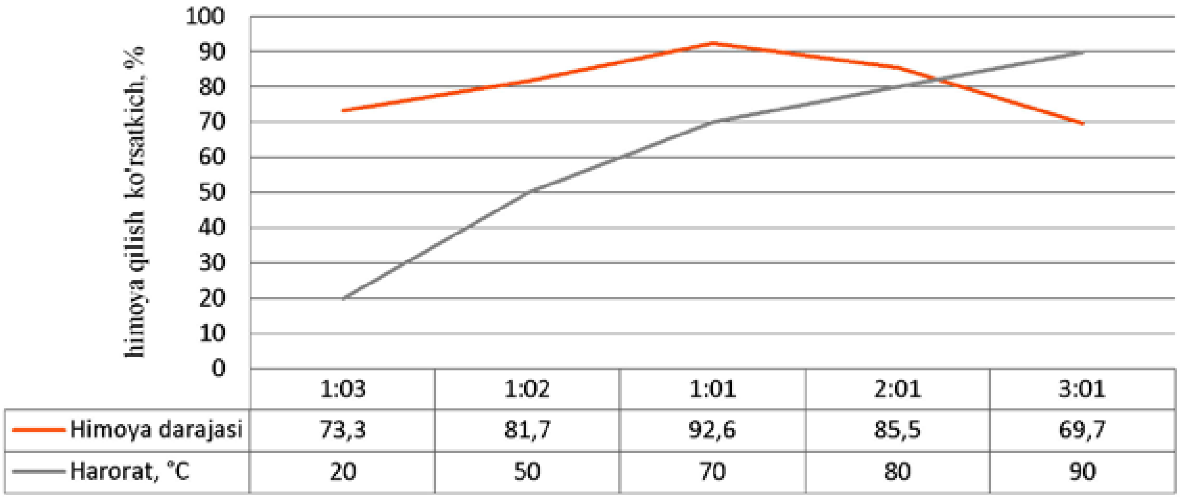


Figure 3 shows a graph of the dependence of the molar ratios of the synthesized corrosion inhibitor on the degree of protection. The results show that the optimal conditions for the synthesis of an EDF-1 inhibitor are 70°C, and the concentration of the starting substance is 1:1, and the reaction yield is 92.6%, as can be seen from the data presented.

As a result of trial studies, we can see using Table 1 and Table 2 that the best mass ratio of amino compounds and phosphitic acid is 1:1, and its protection level is 92.6%.

Conclusion

The physicochemical properties of the EDF-1 corrosion inhibitor synthesized by us and the analysis of the IR spectrum of the synthesized product, SEM (scanning electron microscope), were obtained. From the analysis results, it can be concluded that the corrosion inhibitor contains nitrogen and phosphorus, these elements have maximum inhibitory properties at a temperature of 70 °C. Exposure to metals in testing processes has shown that inhibitors slow down the corrosion process and also protect the metal surface from corrosion. These compounds have proven to be the most effective against corrosion.

References

Shamuradov, Ulugbek Meylievich, Hasan Soyibnazarovich Beknazarov, and Abdulakhat Turapovich Dzhalilov. "Differential thermal analysis of corrosion inhibitor edf-1 used to prevent salt deposition in heating and cooling systems. Study and characteristics". Universum: technical sciences. 2025. – 7.2 (131). – P. 23–27.

Andreatta F., Fedrizzi L. Corrosion ingibitors // Springer Ser. Mater. Sci. Springer Verlag, 2016. – Vol. 233. – P. 59–84.

Amin H. M. A., Galal A. (ed.). Corrosion protection of metals and alloys using graphene and biopolymer based nanocomposites. – CRC Press is, 2021.

Kamath, R., Venumuddala, V. R. Emerging Technologies and the Indian IT Sector; CRC Press: Boca Raton, FL, USA, 2023. ISBN 9781000853759. [Google Scholar]

Fayomi O. S.I., Akande I. G., Odigie S. Economic Impact and Prevention of Corrosion in Oilfields: An Overview // Journal of Physics: Conference Series. – IOP Publishing, 2019. – T. 1378. – No. 2. – P. 022037.

Olajire A. A. Recent Advances in Oil and Gas Production Water Treatment Technology for Sustainable Energy Industry – Mechanistic Aspects and Process Chemistry Perspectives // Journal of Chemical Engineering Advances. 2020. – T. 4. – 100049 p.

Shomuradov, Ulugbek, Hasan Beknazarov, and Abdulahat Djalilov. "Investigation of the Physico-Chemical Properties of Inhibitors Based on Ethylene Diamine and Hydrochloric Acid". Science and innovation 2024. – 3.A2. – P. 128–131.

submitted 03.04.2025;
accepted for publication 17.04.2025;
published 29.05.2025

Contact: ulugbekshomurodov94@gmail.com