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**«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ**

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PERFORMANCE AND APPLICATION OF ORGANIC CORROSION INHIBITORS IN THE PETROCHEMICAL INDUSTRY OF THE CIS COUNTRIES. REVIEW

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Abstract. Metal corrosion is one of the most serious technical and economic problems in the oil and gas industry, as it leads to equipment destruction, hydrocarbon leaks, environmental pollution, emergencies, and significant material losses. This issue is especially relevant in the CIS countries – particularly Kazakhstan, Russia, and Uzbekistan – during field development and refinery operations. In these regions, many factors accelerate the corrosion process: complex natural and climatic conditions (sharp temperature changes, high humidity, salts and sand in soil and groundwater), and the presence of chemically aggressive components common in production environments, such as H_2S, CO_2, O_2. One of the most effective and universal methods to protect metal structures is the use of inhibitors – substances that significantly slow down electrochemical metal degradation. Organic inhibitors, due to their ability to adsorb on the metal surface and form protective films, have proven high efficiency in aggressive environments and are widely used in the oil and gas sector. Their main advantages include low dosage requirements, adaptability to various operating conditions, and better environmental safety compared to inorganic alternatives. Currently, the industry is increasingly shifting to eco-friendly, biodegradable "green" inhibitors, aligning with the principles of sustainable development. This review discusses the main types of organic inhibitors used in the CIS oil and gas sector and analyzes their mechanisms, application areas, and performance in real conditions.

Key words: corrosion in the oil and gas industry, organic inhibitors, nitrogen-containing inhibitors, phosphorus-containing inhibitors, green inhibitors

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ТМД ЕЛДЕРІНІҢ МҰНАЙ-ХИМИЯ ӨНЕРКӘСІБІНДЕ КОРРОЗИЯҒА ҚАРСЫ ОРГАНИКАЛЫҚ ИНГИБИТОРЛАРЫНЫҢ ТИІМДІЛІГІ ЖӘНЕ ҚОЛДАНЫЛУЫ. ШОЛУ

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Аннотация. Металл коррозиясы мұнай-газ өнеркәсібіндегі ең күрделі техникалық-экономикалық мәселелердің бірі болып табылады, өйткені ол жабдықтың бұзылуына, көмірсутектердің ағуына, қоршаған ортаның ластануына, төтенше жағдайларға және айтарлықтай материалдық шығындарға әкеледі. Бұл проблема Тәуелсіз Мемлекеттер Достастығы (ТМД) елдерінде, әсіресе Қазақстанда, Ресейде және Өзбекстанда кен орындарын игеру және мұнай-газ инфрақұрылымының объектілерін пайдалану кезінде өзекті болып табылады. Бұл аймақтарда коррозия процесін тездететін көптеген факторлар бар: табиғи-климаттық жағдайлардың күрделілігі (температураның күрт өзгеруі, жоғары ылғалдылық, топырақ пен жер асты суларында тұздар мен құмдар), сонымен қатар өндірістік ортада жиі кездесетін химиялық агрессивті компоненттердің болуы – H_2S, CO_2 және O_2. Металл конструкцияларын коррозиядан қорғаудың ең тиімді және әмбебап әдістерінің бірі ингибиторларды пайдалану болып табылады – металды бұзудың электрохимиялық процестерін айтарлықтай баяулататын белсенді заттар. Органикалық ингибиторлар металл бетінде адсорбциялану және қорғаныш қабықшалар түзу қабілетіне байланысты агрессивті ортада жоғары тиімділігін көрсетті және мұнай-газ секторында кеңінен қолданылады. Органикалық қосылыстардың артықшылығы – олардың аз мөлшерде қолданылуы, әртүрлі өндіріс жағдайларына бейімделуі және бейорганикалық аналогтармен салыстырғанда экологиялық қауіпсіздігі мен тиімділігі. Қазіргі уақытта мұнай-газ өнеркәсібінде экологиялық таза, биологиялық ыдырайтын «жасыл» ингибиторларға көшу үрдісі кеңінен байқалуда. Бұл тұрақты даму қағидаттарына жауап беретін заманауи шешімдердің бірі болып саналады. Бұл шолуда ТМД мұнай-газ өнеркәсібінде қолданылатын органикалық ингибиторлардың негізгі топтары қарастырылып, олардың әсер ету механизмі, қолдану аймақтары және нақты жұмыс жағдайында тиімділігі жан-жақты талданады.

Түйін сөздер: мұнай-газ өнеркәсібіндегі коррозия, органикалық ингибиторлар, азот құрамды ингибиторлар, фосфор құрамды ингибиторлар, жасыл ингибиторлар

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ЭФФЕКТИВНОСТЬ И ПРИМЕНЕНИЕ ОРГАНИЧЕСКИХ ИНГИБИТОРОВ КОРРОЗИИ В НЕФТЕХИМИЧЕСКОЙ ПРОМЫШЛЕННОСТИ СТРАН СНГ. ОБЗОР

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Аннотация. Коррозия металлов является одной из наиболее серьезных технических и экономических проблем в нефтегазовой промышленности, поскольку она приводит к разрушению оборудования, утечкам углеводородного сырья, загрязнению окружающей среды, аварийным ситуациям и значительным материальным потерям. Особую актуальность данная проблема приобретает в странах СНГ – особенно в Казахстане, России и Узбекистане – при разработке месторождений и эксплуатации объектов нефтегазовой инфраструктуры. В этих регионах существует множество факторов, ускоряющих процесс коррозии: сложность природно-климатических условий (резкие перепады температур, высокая влажность, соли и песок в почве и грунтовых водах), а также наличие химически агрессивных компонентов, часто встречающихся в производственной среде – H_2S, CO_2, O_2. Одним из наиболее эффективных и универсальных способов защиты металлических конструкций от коррозии является использование ингибиторов – веществ, способных значительно замедлять электрохимические процессы разрушения металла. Органические ингибиторы, благодаря своей способности к адсорбции на поверхности металла и образованию защитных плёнок, доказали высокую эффективность в агрессивных средах и получили широкое распространение в нефтегазовом секторе. Преимущества органических соединений заключаются в использовании в малых количествах, адаптивность к различным производственным условиям, а также их экологическая безопасность по сравнению с неорганическими аналогами. В настоящее время в нефтегазовой отрасли наблюдается тенденция перехода на экологически чистые, биоразлагаемые «зеленые» ингибиторы. Это считается одним из современных решений, отвечающих принципам устойчивого развития. В данном обзоре рассматриваются основные группы органических ингибиторов, применяемых в нефтегазовой отрасли СНГ, а также анализируются их механизм действия, области применения и эффективность в реальных условиях эксплуатации.

Ключевые слова: коррозия в нефтегазовой отрасли, органические ингибиторы, азотсодержащие ингибиторы, фосфорсодержащие ингибиторы, зеленые ингибиторы

Introduction. Steel is the main structural material used in oilfield equipment, but it is prone to various forms of corrosion, including pitting, crevice, and hydrogen corrosion. High water content in many CIS oil and gas fields intensifies corrosion of drill strings, heat exchangers, pumps, tanks, and pipelines operating under harsh chemical and thermal conditions. The composition of oil, formation water, and associated gas often includes corrosive compounds such as hydrogen sulfide, mercaptans, thiophenes, carbon dioxide, oxygen, organic acids, and other oxygen- and sulfur-containing substances (Groysman, 2014). Dissolved salts like chlorides and sulfates also accelerate corrosion and promote the formation of salt deposits on internal surfaces of equipment. Corrosion and scaling reduce equipment life and pose serious operational and environmental risks, including leaks and soil or groundwater contamination. They also complicate well operation and increase production costs.

To enhance reliability and extend the service life of equipment in aggressive environments, corrosion and scale inhibitors are widely used. In recent years, increasing attention has been paid to highly effective and often eco-friendly organic inhibitors, making them promising for oilfield applications in the CIS countries. The most common are nitrogen-, oxygen-, and sulfur-containing organic compounds with polar functional groups or aromatic rings (e.g., quaternary ammonium salts, imidazole's, fatty acid amides) (Verma, et al., 2016). These compounds form protective films on metal surfaces, preventing electrochemical corrosion and scale formation. This review aims to classify organic corrosion inhibitors, describe their mechanisms of action, and analyze their effectiveness in CIS oilfield operations. It also explores development prospects, considering environmental safety, cost-effectiveness, and technological compatibility.

Materials and methods. Organic corrosion and scale inhibitors. Organic corrosion inhibitors are typically salts of organic bases and inorganic or organic acids, allowing them to inhibit both anodic and cathodic corrosion processes. These inhibitors are considered universal due to their dual-action capability. Their efficiency depends on the presence of hydrophobic and polar fragments, as well as functional groups such as amines, aldehydes, thiourea, phenols, heterocycles, and aromatic carboxylic acid salts. These groups enhance adsorption on metal surfaces, forming protective layers that slow corrosion. The action mechanism of organic inhibitors is based on adsorption onto the metal surface, forming a barrier against aggressive agents. Figure 1 illustrates possible adsorption mechanisms of organic inhibitors on steel.

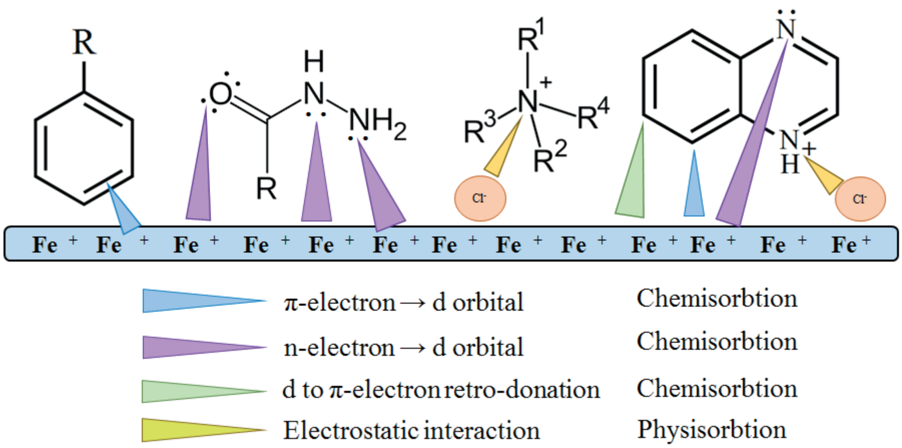

Figure 1 – Adsorption mechanism of organic corrosion inhibitors on the steel surface

Inhibitor molecules orient themselves so that their polar functional groups (e.g. amines, hydroxyls, benzoic rings, carboxylic and sulfonic acids) interact with the metal surface via physical adsorption (van der Waals forces, electrostatic attraction) and chemisorption through coordination bonds between π- or n-electrons and the metal's d-orbitals (figure 1). The hydrophobic parts of the molecules face the solution, forming a barrier against aggressive agents (Lessa, 2023). Aromatic rings further enhance adsorption via π-electron interactions. The adsorption layers formed by organic inhibitors are more stable than those of inorganic ones, which are more fragile and prone to mechanical damage and localized corrosion such as pitting and crevice corrosion.

Classification of organic corrosion inhibitors

Organic corrosion inhibitors are classified depending on the presence of active functional groups that determine their effectiveness and scope of application. Figure 2 shows the main types of functional groups in organic corrosion inhibitors used in the oil field and oil refining industries (Alhaida, et al., 2024).

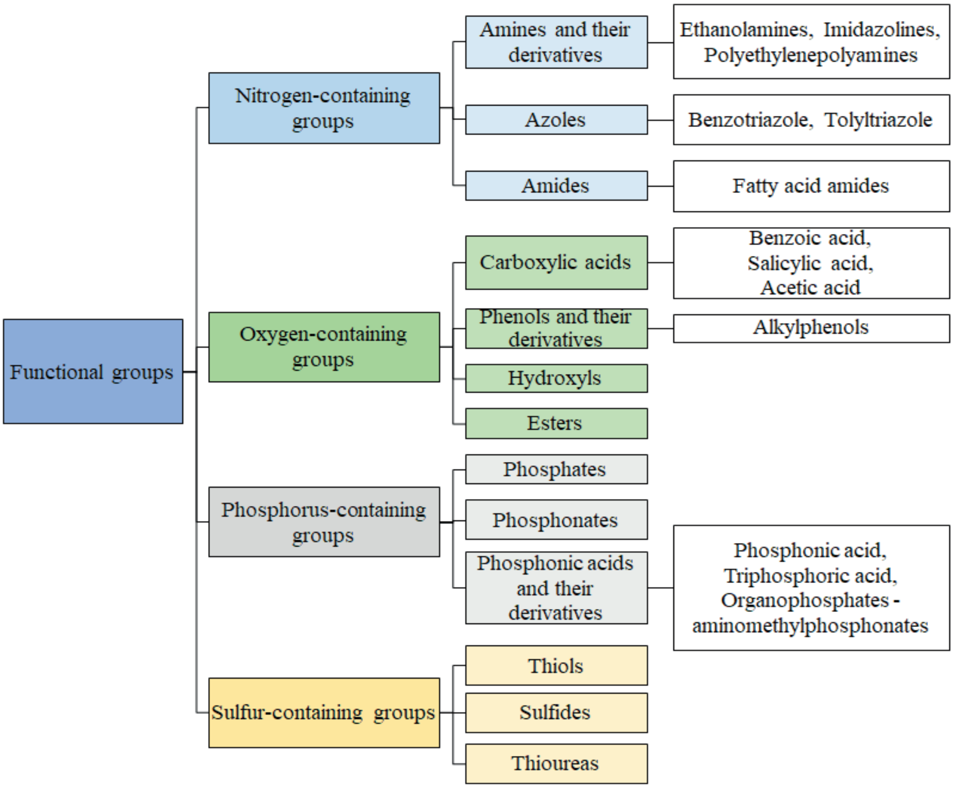

Figure 2 – Functional groups of organic corrosion inhibitors used in the oil and gas industry

The most effective organic corrosion inhibitors are compounds with electron-donating functional groups (e.g. $–OCH_3$, $–OH$, $–NH_2$) and flat molecular geometry, which promotes adsorption on steel surfaces. In contrast, inhibitors with electron-accepting groups (e.g. $–NO_2$, $–CN$, $–COOR$) show lower efficiency due to reduced electron density and hindered adsorption from bulky structures (Goyal, et al., 2018). The choice of inhibitor depends on operating conditions and the nature of the corrosive environment. A distinct group consists of "green" inhibitors – eco-friendly compounds derived from natural sources such as plant extracts. They often contain terpenoids, polyphenols, and organic acids (e.g. tannin, caffeine, succinic and ascorbic acids) and show good performance in aggressive media (Galleguillos Madrid, et al., 2024).

Nitrogen-containing organic corrosion inhibitors

Among the variety of functional groups of organic inhibitors, nitrogen-containing compounds, especially amines, imidazolines, triazoles and other heterocyclic derivatives, demonstrate the greatest efficiency in the oil and gas industry. The high inhibitory activity of nitrogen-containing inhibitors is due to the ability of nitrogen atoms to donor-acceptor interaction with a metal surface, which contributes to the formation of a protective adsorption film. The type of corrosive environment and process operating conditions determines the specific choice of compound.

1. Amines and their derivatives

Fatty amines and their ethoxylated derivatives are among the most widely used inhibitors. They are effective against corrosion caused by the presence of CO_2 and H_2S, both at the production stage and during transportation of oil and gas.

Quaternary ammonium salts are also common, which demonstrate high efficiency in the presence of H_2S due to their ability to adsorb on the metal surface and inhibit anodic and cathodic reactions (Hassan, et al., 2022).

2. Pyridine and its derivatives

Pyridine and its derivatives are also widely used in the oil and gas industry as inhibitors of corrosion caused by the action of acid gases typical of oil refining. Pyridine contains a heteroaromatic ring with a nitrogen atom, with an unshared electron pair, which ensures high adsorption activity of pyridine and its derivatives (Hegazy, et al., 2023).

3. Imidazolines and their derivatives

Imidazole's are used to protect against CO_2 corrosion in the oil and gas industry of the CIS countries - especially in Russia, Kazakhstan and Uzbekistan. These compounds form strong, hydrophobic protective films on the surface of steel, providing resistance to aggressive environments. The ability to modify the structure of imidazoline allows its properties to be adapted to specific operational requirements (Abbasov, et al., 2014).

3. Triazoles, benzotriazoles and their derivatives

Triazoles are a promising class of inhibitors that demonstrate high efficiency in acidic environments and at elevated temperatures, which is especially important in the acid treatment of oil wells. Due to their resistance to extreme conditions and the ability to form stable complexes with a metal surface, triazoles are finding increasing use in the oil and gas industry (Ibrahimi & Guo, 2020).

4. Other heterocyclic compounds

Benzimidazole derivatives are among the effective nitrogen-containing inhibitors, demonstrating strong anticorrosive performance in acidic media. They are currently under active investigation as promising corrosion inhibitors for applications in the oil and gas industry (Keshavarz et al., 2016).

Oxygen-containing organic corrosion inhibitors

Oxygen-containing organic corrosion inhibitors include functional groups with oxygen and are known for high adsorption capacity and the ability to form stable protective films on metal surfaces. They are often used in combination with nitrogen- or phosphorus-containing groups as part of complex formulations. Common types include phenols, polyphenols, alcohols, esters, organic acids, and flavonoids. These compounds are biodegradable and environmentally safe, making them suitable for use in the oil and gas industry. They also serve as bases, solvents, or auxiliary components in inhibitor solutions.

1. Phenols and Polyphenols

Phenolic and polyphenolic compounds - such as catechin, gallic acid, tannins, and rosemary oil, often derived from plant extracts – are currently being actively explored as potential "green" corrosion inhibitors. Sulfonated alkyl phenols have demonstrated high efficacy against corrosion caused by naphthenic acids, a serious problem in refineries processing certain types of crude oil. Thus, phenolic compounds are considered as a promising direction in the development of environmentally friendly and sustainable corrosion inhibitors for the oil and gas industry (Ansari et al., 2020).

2. Alcohols, polyols, ethers

Alcohols, polyols, and ethers are commonly used as auxiliary substances in corrosion inhibitor formulations to adjust physicochemical properties for specific applications. Methanol, isopropanol, glycerol, ethylene glycol, and sorbitol are frequently employed as solvents to enhance inhibitor solubility and stability. Additionally, ethoxylated alcohols form the basis of some phosphate ester-based inhibitors used in oil and gas production, transportation, and processing.

3. Carboxylic acids and their salts

Carboxylic acids in crude oil can cause severe corrosion of metal equipment. Their modified derivatives can act as effective corrosion inhibitors by adsorbing onto metal surfaces and forming hydrophobic protective films. In Azerbaijan, these compounds are actively studied to enhance corrosion resistance in the oil and petrochemical sectors. Research focuses on their composition, solubility, stability in acidic and saline media, and the influence of temperature and pressure (Alimadatli, 2025). Fatty acid salts, due to their biodegradability and low toxicity, are considered promising components of "green" inhibitors.

Phosphorus-containing organic corrosion inhibitors

Phosphorus-containing organic corrosion inhibitors are highly effective under elevated temperature, pressure, and mineralization due to their multifunctionality and thermal stability. They are commonly used in cooling water systems and in combination with other inhibitors (L. Liu et al., 2018). These compounds – such as phosphate esters, phosphonates, and organophosphorus derivatives – are also effective in protecting drilling equipment in aerated environments, providing defense against both electrochemical and microbial corrosion.

1. Phosphate Esters

Phosphate esters are widely used at various stages of oil and gas operations – from drilling to formation water treatment, demonstrating inhibitory activity in oxygen-containing systems such as drilling muds and brines. Phosphate esters can be used both independently and in combination with other inhibitors, for example, with fatty amines or quaternary ammonium salts, enhancing the properties of the complex composition of the inhibitor. An example is the phosphate-based inhibitor CONQOR 404 EH, which is used in drilling systems with high oxygen and salt ion content (Юсупова et al., 2023).

2. Phosphonates

Phosphonates are multifunctional compounds that effectively prevent both corrosion and scale formation, and are actively used in circulation and water circulation systems of oil refineries and production wells (Kafarski, 2019).

In the conditions of the CIS countries, new generation phosphonates, for example, Sintanol phosphonates, developed by Russian manufacturers, are becoming especially relevant. These inhibitors are highly resistant to calcium, thermally stable and effective at high pH and mineralization values. They are used to protect pipelines, heat exchangers and other equipment operated at temperatures above 100°C and in solutions saturated with salts (Шуматбаев et al., 2019).

Phosphorus-containing polymeric corrosion inhibitors are increasingly used in oil production due to their combined properties: polymers provide strong adsorption and film formation, while phosphonate groups ensure chemisorption, resistance to Ca^{2+} ions, and effectiveness across a wide pH range. Their high thermal stability makes them suitable for high-temperature refining processes. Unlike low-molecular analogs, they resist deposit formation in the presence of calcium ions.

3. Other organophosphorus compounds

New phosphorus-containing inhibitors, such as melamine phosphate and hexamethylenediamine phosphate, are being actively studied for their ability to interact with metal ions and form protective films. The combination of phosphorus- and nitrogen-containing groups enhances protection: phosphorus promotes metal passivation, while nitrogen stabilizes the protective layer and prevents its degradation.

Sulfur-containing organic corrosion inhibitors

Sulfur-containing organic corrosion inhibitors are widely used in the CIS oil and gas industry due to their high efficiency during production, transportation, and processing. Sulfur atoms (in thiol, thioamide, thiocarbamide, or disulfide groups) enhance adsorption on metal surfaces, forming dense protective films that block aggressive agents. In Russia and Kazakhstan, such inhibitors are commonly applied in in-field pipeline systems, oil gathering networks, acid well treatments, and secondary recovery processes like water injection.

1. Thiourea and its derivatives

Thioureas and their derivatives are among the most widely used sulfur-containing compounds in the CIS oil and gas industry. Thioureide-imidazolinium quaternary ammonium salts show high inhibitory activity in aqueous and water-oil systems, especially under high H_2S concentrations. Their effectiveness is due to the formation of strong Fe–S bonds and a dense protective adsorption layer (Sun et al., 2024). The presence of both sulfur and nitrogen atoms enhances donor–acceptor interactions, providing combined physical and chemical protection by inhibiting both anodic and cathodic processes.

2. Sulfonates and sulfides

Sulfonates (including petroleum-based) are important components of inhibitors and additives used in oil processing and transport. They act both as corrosion inhibitors and emulsifiers. Widely applied in metalworking fluids at refineries, sulfonates ensure corrosion protection and emulsion stability. In pipelines, their ability to form stable protective films under varying temperatures and pressures makes them particularly effective (Arellanes-Lozada et al., 2023).

3. Mercaptan-based inhibitors

Mercaptans (thiols) in their original form can enhance environmental corrosivity due to the formation of volatile sulfur compounds, especially in fuels. However, modified derivatives like mercaptopyrimidines demonstrate promising inhibitory properties.

Russian studies highlight that proper substitution in the heterocyclic core significantly reduces aggressiveness and enhances corrosion inhibition (Мамедов, 2024). To improve stability and efficiency under dynamic and high-temperature conditions, complex formulations based on organosulfur compounds and surfactants are being actively developed.

Results and discussion. In oil-producing regions of Russia, Kazakhstan, and Uzbekistan, multifunctional industrial inhibitors are widely used. These formulations combine anti-corrosion and anti-scale components, providing effective protection of metal equipment in environments with H_2S, CO_2, high salinity, and temperature fluctuations. Table 1 summarizes key industrial inhibitors used in the CIS, with their chemical composition, application area, efficiency, and usage geography.

Table 1. Composition, purpose and efficiency of industrial corrosion inhibitors used in the oil and gas industry of the CIS countries

Inhibitor	Country	Description / composition	Application area	Efficiency
Nitrogen-containing organic corrosion inhibitors				
IKB-2-2	Russia	Amidoimidazoline	Protection against CO_2 corrosion of pipelines	Effective at temperatures up to 90°C, pH 3-7, up to 98 % protection
VFIKS-82	Russia, Kazakhstan	Complex inhibitor based on imidazolines	Oilfield protection against H_2S/CO_2 corrosion	Up to 94 % protection from corrosion and up to 80 % protection from scale formation
DON-52	Russia, Kazakhstan	Mixtures of quaternary ammonium salts	From oxygen corrosion	Up to 90 % protection
PF-1	Uzbekistan	Amines + fatty acids	General protection at oil refineries	Effective, local production
IFHAN-1	Russia	Mixtures of quaternary ammonium salts	From H_2S corrosion	Up to 85 – 95 % protection
INK-1	Uzbekistan, Kazakhstan	Mixtures of quaternary ammonium salts	Under mechanical loads	Up to 85 % protection
Catasol 28-5-1	Russia	Salt of higher aliphatic amines	At high temperatures	Up to 85 % protection
Napor-1007	Kazakhstan	Salt of higher aliphatic amines	In water-oil mixtures	Up to 88 – 93 % protection
HOPS-10	Russia Uzbekistan	Salt of higher aliphatic amines	In the presence of complex salt compositions	Up to 90 % protection
Olazol-T2P	Russia	Imidazolines	Protection against CO_2 corrosion of pipelines	Up to 95 % protection
Vokor-1	Kazakhstan	Imidazolines	Protection of pipelines in contact with formation waters	Up to 88 - 92 % protection

Sepakor 5478AM	Russia, Kazakhstan, Uzbekistan	Imidazolines	At high temperatures up to 120 °C	Over 90 % protection
MAD-20	Uzbekistan	Diazooctanedinitrile with functional groups	Protection against acid corrosion of columns	High level of protection, up to 99 % protection
Oxygen-containing organic corrosion inhibitors				
Polyethyleneglycol based inhibitors	Russia	Polyesters	Inhibitors in water circulation cooling systems	Effective in combination with phosphonates, non-toxic
Salicylieneaniline	Russia	Aldimin (azomethine compound with phenolic group)	Protection of tanks and pipelines	Good adsorption on steel, thermal stability
Oxyl inhibitors	Kazakhstan	Derivatives of ethoxylated fatty alcohols (oxyl)	Anti-corrosion emulsions for drilling fluids	Improved solubility in oil and water, stability of surfactants
GPMSh	Uzbekistan	Surfactant composition based on hydrolyzed polyacrylonitrile and urotropine	Heat exchange equipment of the oil refinery (Fergana)	up to 97.5 % protection from corrosion and up to 91.76 % protection from scale formation
Phosphorus-containing organic corrosion inhibitors				
Sintanol phosphonates	Russia	Phosphonates	Oil pipeline protection	High level of protection
IKF-1, IKF-2	Uzbekistan	Oligomers based on crotonaldehyde and phosphates	Protection of oil refinery heat exchangers	Up to 99 % protection
HEDP/OEDFK	Russia, Kazakhstan	Oxyethylidene diphosphonic acid (1-hydroxyethylidene-1,1-diphosphonic acid)	Inhibition of scale and corrosion at T up to 250 °C.	Up to 94,11 % protection from scale formation
Zn-OEDF	Russia	Zinc Complex Disodium Salt HEDP	Inhibition of corrosion and salt deposits in the presence of Zn ions of heat exchange equipment, pipelines	Up to 94 % protection
AFON 200–60A	Russia, Kazakhstan	60% solution of 1-hydroxyethylidenediphosphonic acid	Oil production, circulation cooling systems, additive to drilling fluids and detergents	High efficiency against scale and salt deposits in the pH range of 2–12; resistant to H_2S, up to 80 % protection
PHOSPHONE+	Kazakhstan, Uzbekistan	A mixture of polyamines and phosphonates	Protection of oil gathering and transportation systems, inhibition H_2S corrosion	Up to 97% corrosion protection at 60 °C and pH = 6–8

Sulfur-containing organic corrosion inhibitors				
Thiourea and derivatives	Russia, Kazakhstan	Contain nitrogen and sulfur atoms (N,S-containing)	Water-oil emulsions, H_2S environments	High efficiency in acidic environments (pH < 4), up to 90–95 % inhibition
Mercap-topyrimidines	Russia	Heterocyclic compounds with a sulfur atom	Acid corrosion, aggressive environments with CO_2 and H_2S	Up to 85–90 % inhibition, especially in HCl and H_2S environments
Thiourea inhibitors	Kazakhstan, Uzbekistan	Thiourea derivatives, often with donor groups	Gas lift wells, oil transportation, refineries	Up to 92 % corrosion inhibition of steel and alloys
Thioetanol-based inhibitors	Russia, Kazakhstan	Mono- and di-thiols, derivatives of thioalkanols	Oil dehydration, H_2S corrosion inhibition	85–90 % protection in environments with high H_2S concentrations
Sulfide-containing amino acids	Russia, Uzbekistan	Taurine and analogues. Biodegradable compounds of natural origin	Eco-technological inhibitors in production systems	Up to 80 % in neutral and slightly acidic environments, high biodegradability

According to Table 1, organic corrosion inhibitors with various functional groups are widely used in the oil industry of CIS countries. The choice of inhibitor depends on operating conditions, chemical composition of oil and gas, presence of aggressive components (O_2, CO_2, H_2S), formation water composition, pH, and temperature. Russia leads in both the development and industrial use of organic inhibitors. The most common are nitrogen-containing compounds – imidazoline derivatives (IKB-2-2, VFIKS-82, Olazol-T2P) and quaternary ammonium salts (DON-52, IFHAN-1, INK-1). Phosphorus-containing inhibitors like HEDP, Zn-OEDFK, and AFON 200-60A are used in systems with thermal and acidic stress. Due to environmental concerns, biodegradable oxygen-containing inhibitors based on polyethylene glycol and salicylidene aniline are gaining attention.

In Kazakhstan, both local and mainly Russian inhibitors are applied. Imidazolines (VFIKS-82, Vikor-1, Sepakor 5478AM), thiourea, and thioethanol-based compounds are effective in H_2S-containing environments. Phosphorus-based complexes (PHOSPHON+, HEDP) are used for corrosion and scale control during oil production and transportation. Uzbekistan is developing inhibitors from local raw materials. Nitrogen-based inhibitors (INK-1), diazo compounds (MAD-20), and phosphorus- and oxygen-containing formulations (GPMSh) are used to protect heat exchange and circulation systems. Overall, the most widely used functional groups are nitrogen-containing (imidazolines, ammonium salts) and phosphorus-containing (phosphonates), due to their multifunctionality and resistance in aggressive environments.

Current trends in the development of organic corrosion inhibitors in the CIS countries

In connection with global environmental changes and tightening environmental protection requirements, the oil and gas industry of the CIS countries is moving towards the use of environmentally friendly and biodegradable corrosion inhibitors. As an alternative to traditional nitrogen- and phosphorus-containing organic corrosion inhibitors, a range of plant-based materials is being investigated. These include vegetable oils and their derivatives – such as sunflower, soybean, linseed, corn, and rapeseed oils – which serve as bases for inhibitors due to their surface-active properties and ability to adsorb onto metal surfaces. Additionally, plant extracts, fruit residues, and agricultural waste rich in biologically active compounds are being explored. Amino acids, particularly sulfur-containing ones such as taurine and cysteine, are also of interest due to their functional groups (–NH_2, –SH), which enable strong interactions with metal surfaces and confer effective anti-corrosion performance. Combined inhibitors that combine the functions of anti-corrosion and anti-salt protection are also being actively developed; they are relevant for areas with a high content of mineralized formation waters.

Conclusion. Organic corrosion inhibitors are widely used in the CIS oil and gas industry to protect drilling, refining, and pipeline equipment. Nitrogen-containing compounds like amines and imidazolines are most common due to their effectiveness in CO_2- and H_2S-rich environments. Phosphorus-containing inhibitors (phosphonates, phosphate esters) are applied where both corrosion and scale must be controlled, especially under high temperature and salinity. Many modern formulations combine functional groups for a synergistic effect. Growing interest is seen in eco-friendly "green" inhibitors based on vegetable oils, phenolics, and plant waste, which meet tightening environmental standards. CIS countries are expanding local production of tailored organic inhibitors. Russia leads in research and industrial base and manufacturing, while Kazakhstan and Uzbekistan adopt both established and green formulations using local resources. Future developments focus on nanotechnology and formulations that withstand extreme conditions – high temperature, pressure, and H_2S – enhancing long-term corrosion protection.

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