The main aspects of microbiological protection of underground oil-and-gas pipelines

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Abstract

There are described the main aspects of protection of underground oil-and-gas pipelines against microbial corrosion by soil corrosion-hazardous microorganisms, including the crucial role played by sulfate-reducing (SRB) and thione (TB) bacteria. It is researched the effect of nitrogen-containing organic inhibitors of corrosion on the growth and enzyme activity of the sulfur cycle bacteria and the locking mechanism of TB, it is also determined hydrogenasic reaction of corrosion-active SRB. There is analyzed the influence of the dioxo-decahydroacridine derivatives on the rate of microbial corrosion of steel under the SRB and TB effect. It is theoretically researched the bioresistance of dioxo-decahydroacridine derivatives. The effectiveness of these inhibitors and the industrial "J" inhibitor is compared. The researched inhibitors provide with a high degree of protection against corrosion in the presence of SRB (90%), indicating their antibacterial properties and showing the prospect of their use in industrial conditions of anaerobic corrosion that is caused by SRB.

There are identified the bacteria associates of four physiological groups of the damaged gas pipelines primers that are laid in the regions I, II and III. Their qualitative and quantitative composition is determined. It is found out that the dominant bacteria in association of the isolated bacteria are denitrifying (DN) bacteria; this indicates the intensity of denitrification processes in the underground environment. As a result of this both the protective insulation coating and a primer are destroyed.

There are carried out industrial tests of innovative biological stable protective coating on the basis of the modified by inhibitor "J" mastic at the Regional Pipeline Department "Prykarpattransgas".

Key Words: *corrosion primer, inhibitor, mechanism, microorganisms, oil-and-gas pipelines.*

Introduction

In some regions of Ukraine there is formed an environmental hazard caused by the soil corrosion of pipelines during the long-term operation of underground gas pipelines. Unpredictable pipeline failures lead to significant economic losses and serious environmental consequences. For this reason, prevention of failures, which are caused by the risk of biocorrosion processes by soil micro-organisms, is one of the priority components of the national security of Ukraine.

The intensification of the soil corrosion processes of underground oil-and-gas pipelines under the influence of microorganisms is a clear manifestation of anthropogenic impact on the environment.

The microorganisms have biological impact on corrosion processes of metals and steel that are not of corrosion-mechanical origin. Microorganisms destroy the metal and often influence the chemical, electrochemical and other processes, strengthening or weakening in such a way different types of corrosion. According to modern concepts, the process of microbiological corrosion occurs in the spot of bacteria and metal contact, i.e. at the biofilm (that is the accumulation of bacterial cells and the products of their metabolism) that is formed on the surface [1–2].

The corrosion of metals and metal constructions in the underground environment is often associated with the life cycle of sulfur bacteria: sulphate-reducing bacteria (SRB), genera Desulfovibrio and Desulfotomaculum, and thione bacteria (TB), type Tiobacillus, which are capable of oxygenating the sulfur and its compounds to sulfuric acid, and rapidly lowering the pH. The cases of anaerobic corrosion are more peculiar for underground and metal constructions (oil equipment, pipelines, tank farms, etc.) that are in clay and water-bearing soil layers.

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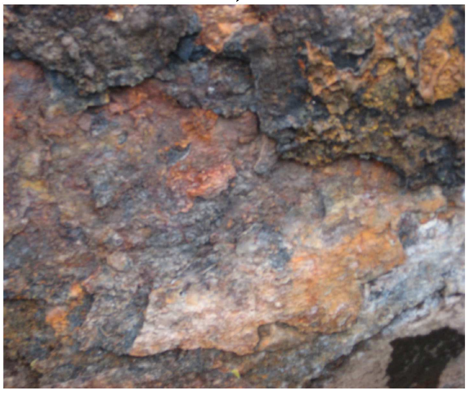
a)



b)

a) coating delamination; b) damage to pipes metal

Figure 1 – Effects of biodeterioration

The biocorrosion, made by the sulfate-reducing bacteria, causes flaws or pittings on steel pipelines, in some cases, a uniform corrosion may occur. On the outer surface area of the pipe, that is laid in moist soils, anaerobic SRB develop more actively if there are more sulfates and organic matters (peat, silt, humus, plant remains, etc.) in the soils [3].

The corrosion process is accelerated in 1–3 times in soil adjacent to the metal (pherosphere). SRB migrate from the pherosphere to the surface of corroding metal (chemotaxis, or the directed movement to iron ions and other compounds), concentrate on it and form a biofilm, which is the place of electrochemical reactions. In such processes SRB directly affect the rate of anodic or cathodic reaction. As a result of microbial degradation of the protective coating, the influence of heterotrophic block of aerobic and anaerobic bacteria – hydrocarbon-degrading (HDB), iron-reducing (IRB), denitrifying (DNB) and SRB bacteria – there occurs the change of physical and mechanical properties of protective materials [4], their strength, elasticity, adhesion properties decrease, resulting in the loss of the main function of the coatings-metal protection against corrosion.

Although HD bacteria do not take direct part in the corrosion processes they convert hydrocarbons into carbohydrates, which are the source of food for SRB and of hydrogen sulfide generating. DNB that reduce nitrates to nitrites and then to such gases as nitrogen and nitrogen oxides lead to the destruction of the protective coating. The results of biodeterioration of insulating materials, used for corrosion protection of underground pipelines, are eloquently illustrated by economic losses.

Thus, annual losses (that weren't completely taken into account) from biodeterioration in the U.S. are about $ 1.5 billion, in Japan – up to several billion yen, in England – around £ 10 million. [4]

Realia of the production structure and application of anticorrosive materials to isolate different types of trunk pipelines and domestic pipelines in Ukraine won`t allow us to leave cheap and affordable petrobituminous coatings in the next 5–10 years. While in most European countries and the United States the percentage of petrobituminous insulation does not exceed 10%, besides its application is limited with pipes diameter up to 600 mm and with operation in low corrosive media, the production backlog of modern forms of insulation (polyethylene, polypoxy, polyurethane) leads to the fact that most pipe-insulated oil-and-gas companies in Ukraine use petrobituminous and petrobituminous-film coverage, the percentage of which in the gas sector exceeds 90% [5].

The coating degradation takes place with the loss of its dielectric properties during the long-term operation of pipelines with bituminous coating in track conditions, and then cracking of the protective coating is possible. While pipelines are operated in strong-saline soils that contain soluble CO_2 and H_2S, if the salt content is up to 3.4% or more, the corrosion phenomenon occurs in the formed coating cracks; this is a consequence of the accelerated transition of iron into solution caused by hydrogen sulphide and H_2 formation from hydrogen ions. Hydrogen penetration into the steel surface results in a sharp weakening of the metal structure and corrosion processes.

Today we cannot underestimate the role of microbial processes during destroying of underground metal constructions. According to the assessment of foreign researchers-corrosionists, more than 50% damage to metal pipeline constructions can be caused by the activity of microorganisms. The action of the sulfur bacteria (such as thione bacteria and sulphate-reducing bacteria) as corrosion agent in underground medium is clearly limited by environmental conditions and the oxygen content [4].

That is why the corrosion in underground medium should be considered as the bioelectrochemical process, in which the biological factor must be necessarily taken into account in addition to the electrochemical component. Therefore, the protection against corrosion of underground structures should be made based both on the results of a preliminary analysis of biological corrosion of soils activity and also the biological stability of soils [6].

So the problem of improvement of petrobituminous isolation in order to provide it with new properties remains burning both in the scientific and practical aspects.

One of the solutions to this problem is modification of petrobituminous mastic by corrosion inhibitors that can both hamper electrochemical corrosion and show biocidal properties for inhibiting of dangerous corrosion microorganisms in order to produce modified mastics, which possess enhanced physical and mechanical parameters and are biologically stable. An integrated approach to the modification processes of petrobituminous coatings has great prospects and will help to improve their reliability and duration of operation.

Since the main metabolite of sulphate-reducing bacteria is hydrogen sulfide – a stimulant of corrosion and hydrogen embrittlement of steels – the task of inhibiting of SRB activity is particularly topical.

The Main Aspects of the Biocides Use for Microbiological Protection

Among the various methods of corrosion control of underground oil-and-gas pipelines the leading place at present and in the near future will be given to the inhibitor protection because it does not require substantial investment.

Organic corrosion inhibitors provide a high degree of protection against corrosion of metal at low concentrations in corrosive medium. Inhibitors have a rapid effect and their use is cost effective.

The main advantages of inhibitor protection are its simplicity, efficiency and the possibility of replacing the existing inhibitor to a more efficient without violating the scheme of the technological process.

A necessary condition for biocides, which are used in the oil-and-gas sector, is the ability to detect the bactericidal activity and block the enzyme activity of bacteria according to the mechanism of uncompetitive inhibition.

There are used corrosion inhibitors of inorganic and organic nature for microbiological protection of underground oil-and-gas pipelines. Among the inorganic inhibitors the most effective are chlorine, hypochlorites, hydrogen peroxide, potassium permanganate, iodine, iodoform; among the organic inhibitors-derivatives of amines, diamine and imidazolin. During operations in order to inhibit SRB activity, which are the most aggressive among soil microorganisms, there are widely used nitrogen-containing organic compounds: derivatives of tetrazole, triazole, amines and amides, quaternary nitrogen-containing compounds. The protective effect of these inhibitors is influenced by the fact that these compounds form a protective film during sorbing on the metal surface. The adsorbing film inhibits the process of hydrogen adsorption on the metal surface, this leads to the decrease in the catalytic activity of bacteria and the decrease in the catalytic activity of bacteria for the energy producing reaction of sulfate reduction [6]. Taking this into consideration, on the one hand, inhibitors form a protective film on the metal surface, on the other – bacteria tend to form biofilms on the metal, where the most active metabolic and corrosion processes occur.

The main advantage of organic over inorganic biocides is high effectiveness at the low concentration and stability of biocidal activity that is probably related to their cationic structure. Biological effect of quaternary ammonium salts is the disruption of the structure of cell membranes, the cause of denaturation of cellular proteins and reducement of the activity of key enzymes. Other advantages of using such quaternary ammonium salts as biocides are the facts that they provide a high level of steel protection from corrosion with SRB bacteria (90–94%), have good antibacterial properties, they are non-toxic, refer to the IV class of danger and can be successfully used under anaerobic corrosion conditions caused by SRB without harm to the environment [4].

On the other hand, the requirements of environmental legislation have become more stringent for application of xenobiotic substances in open systems in recent years. It is forbidden to use a number of traditional biocides. The main criterion that determines the applicability of biocides-corrosion inhibitors in operational practice – is their low environmental toxicity. These matters must be insensitive to the effects of environmental change, unable to form toxic decomposition products during their destruction, i.e. they must be biologically resistant.

Considering the above mentioned, we can formulate two basic requirements for microbial corrosion inhibitors that are implemented into operational practice: biocidity and biological resistance. The first requirement is already recognized and the studies of biocidal effect of corrosion inhibitors are held. We carry out the research of biological resistance of corrosion inhibitors in relation with the influence of sulfur cycle bacteria for the first time.

Since bacteria, which cause biocorrosion, quickly adapt to existing biocides, which requires an increase in the concentration of biocide during adaptation and increases the environmental impact, the relevant problem is the selection of biocides, which are active to associates of corrosion-hazardous microorganisms at a minimum concentration of their actions.

The aim of this research was to study the effect of organic nitrogen-containing inhibitors of corrosion that are dioxo-decahydroacridine derivatives: "1/0", "3/0", "6/0" and "7/0" and "J" inhibitor in the class of quaternary ammonium salts (QAS) on the biological activity of thione, sulphate-reducing bacteria and corrosion-active microbial associations, which lead to the intensification of biocorrosion processes of underground oil-and-gas pipelines. For business reasons, the names of inhibitors were not disclosed.

The Research Results and Discussion

In previous articles [7] we have demonstrated that the inclusion of corrosion inhibitors, namely different classes of organic compounds, to the basic bituminous-polymeric mastic helps to achieve modified mastics on the bituminous-polymeric base with high physical and mechanical parameters and plasticity. The basic bituminous-polymeric mastic is the one branded as MBPID produced by the Dashava plant of composite materials.

One of the most important qualities of bituminous-polymeric mastics is water saturation, as it defines water repellency and, ultimately, the dielectric properties of the insulating coating. We have previously researched that water saturation of mastic, which is modified by nitrogen-containing corrosion inhibitor, is much lower than water saturation of the basic mastic. This gives the reason to state that the nature of inhibitor that is injected into the base bituminous-polymeric mastic affects the water repellency of modified mastic. Meanwhile, this inhibitor forms a new more water repellent structure during absorbing on the surface of bituminous-polymeric base. These results should be taken into account when using the modified mastic in the swamp, muddy soil. It is also important to note that the sample of the basic mastic after keeping in distilled water becomes brittle; there is formed a brown thin coat on its surface. The brown thin coat on the surface of the basic mastic sample may be caused by desorption of water-soluble components of mastic. At the same time, samples of modified mastic under the same conditions are plastic and there is not any precipitation on the surface.

As it was mentioned above, the vital activity of sulfur cycle bacteria – sulphate-reducing and thione bacteria – results in the most sensitive corrosion deteriorations of the metal of trunk pipelines. Therefore, we considered it appropriate to investigate the effect of organic nitrogen-containing corrosion inhibitors, including dioxo-decahydroacridine derivatives, on these groups of micro-organisms and to compare them with the efficiency of the "J" inhibitor of the quaternary ammonium salts class (QAS). During the model laboratory experiment we investigated the activity of growth inhibition of sulphate-reducing bacteria of the *Desulfotomaculum sp.* genus and *Thiobacillus sp.* thione bacteria, which were provided by the Department of Microbiology of Ivan Franko National University of Lviv. The experiment was performed with the application of two concentrations of inhibitors 0.2 and 0.5 g/cm^3 of the growth medium. Sulphate-reducing bacteria cultures were grown in liquid Postgate medium within 14 days. Cells of acidophobic thione bacteria were grown in an incubator at 28°C for 7 days in a Beierink growth medium. The experimental studies on the effect of nitrogen-containing corrosion inhibitors on growth and enzyme activity of sulfur cycle bacteria were carried out according to the methodologies [8].

The results of microbiological tests are demonstrated in Figure 2. These data show that "J" inhibitor was the most effective for SRB. It inhibited the growth of microorganisms at 93.3% at a concentration of 0.2 g/cm^3, and when the concentration of inhibitor increased to 0.5 g/cm^3 the growth of microorganisms inhibited at 95.9%. The effectiveness of growth inhibition by 1/0 and 3/0 SRB inhibitors was also close. They blocked the growth at a concentration of 0.5 g/cm^3 to 93.8% and 97.7% respectively. The effectiveness of 6/0 and 7/0 inhibitors was significantly lower (not more than 80%) at a concentration of 0.5 g/cm^3.

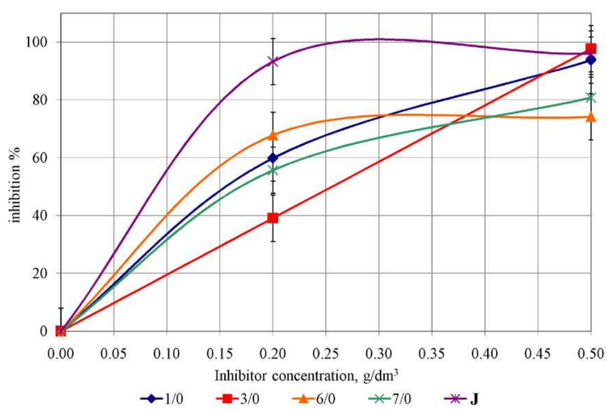


Figure 2 – The intensity of growth inhibition of SRB by nitrogen-containing organic inhibitors

Another indicator that characterizes the activity of corrosion inhibitors is their effect on the rate of corrosion processes. The results of these studies are demonstrated in Figure 3. The figure shows that the rate of corrosion of metal samples under the influence of the inhibitors under investigation decreased according to the previously defined activity of growth blocking of SRB. A high level of blocking of biocorrosion processes performed 1/0, 3/0 and "J" inhibitors. Corrosion rate in their presence decreased from 29.6 mg/dm^2 per day to 3.8 mg/dm^2, 1.7 mg/dm^2 and 2.4 mg/dm^2 per day, respectively. Efficiency of 6/0 and 7/0 inhibitors was 3–4 times less.

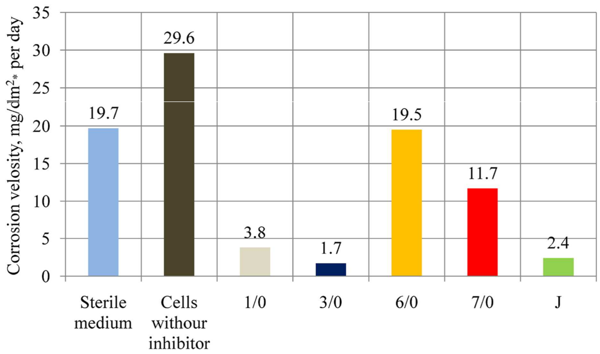


Figure 3 – Inhibition of the corrosion of metallic samples in the presence of inhibitors

Since there are important for blocking reliability of microbial corrosion the inhibition intensity of both bacterial growth and corrosion rate, also the mechanism in accordance with which this blockage occurs we have defined the type and the constant of inhibition for all the inhibitors under research. The results are shown in Figure 4.

Figure 4 demonstrates that inhibitors 1/0, 3/0 and 7/0 blocked the growth activity of SRB in a competitive way (Fig. 4, a), inhibitors 6/0 and "J" – in a non-competitive way (Fig. 4, b). Inhibition constants, which are graphically determined, for competitive 1/0, 3/0 and 7/0 inhibitors were 4.9 ± 0.3 mg/sm^3, 3.3 ± 0.3 mg/sm^3 and 6.5 ± 0.3 mg/sm^3 respectively, while the constants for non-competitive 6/0 and "J" inhibitors were 6.1 ± 0.3 mg/sm^3 and 4.0 ± 0.3 mg/sm^3.

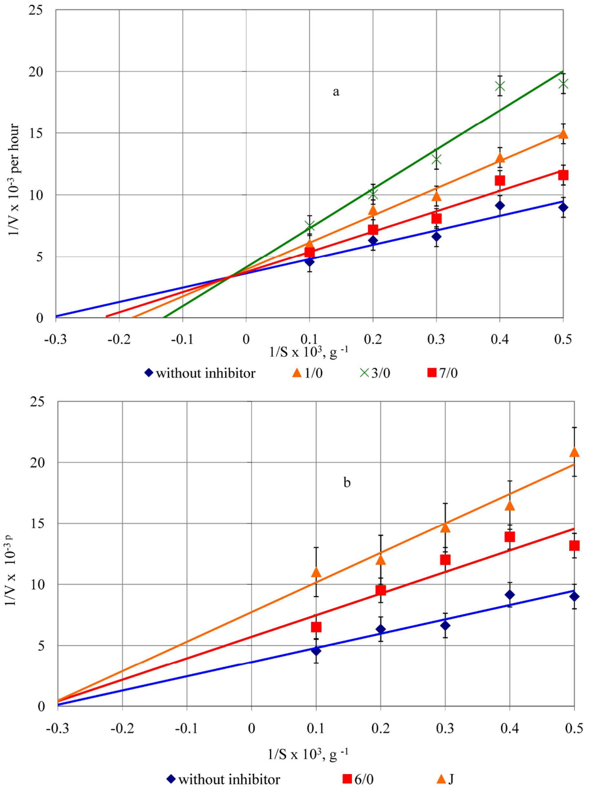


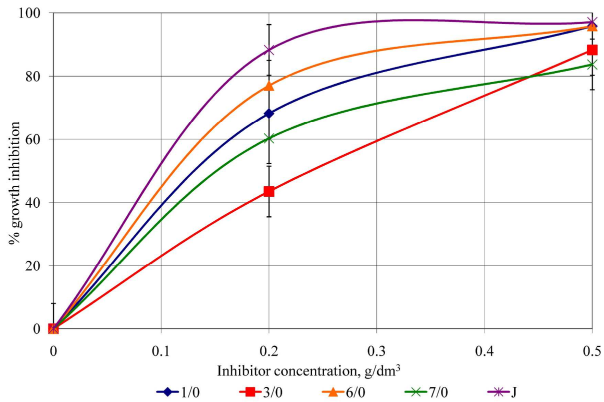
Figure 4 – SRB inhibition according to competitive (a) and noncompetitive (b) mechanism

Based on these results it can be concluded that the most effective mean of corrosion protection of the researched nitrogen-containing compounds is "J" inhibitor, which influences SRB in a noncompetitive way and shows the minimal inhibition constant; i.e. it meets the requirements that are applicable to the corrosion inhibitors (biocides).

The dioxo-decahydroacridine derivatives can be theoretically evaluated based on the energy values of the chemical bonds between the carbon atoms of the phenolic nuclei and atoms of the modifying elements. 3/0 and 7/0 inhibitors differ from 1/0 inhibitor, which is the base for all the researched series, by the additional chloride and nitro groups in the 4' position, respectively. Carbon-carbon bonds of the benzene ring are very stable and the energy of their breaking is 90 kcal/bond, and the energy of breaking of carbon-hydrogen bonds in methyl radicals is 100–104 kcal/bond [9]. Based on these considerations, we can assume that 1/0 inhibitor will resist the devastating attacks of corrosion active microflora, i.e. it has bioresistant properties. The prospects for long-term use of 3/0 and 7/0 inhibitors are not obvious, since carbon-chloride (85 kcal/bond) and carbon-nitrate (79 kcal/bond) bonds can be actively broken down by microorganisms. As a result of these changes, chloride and nitrate ions, which can significantly enhance the progress of corrosion process, accumulate in the environment [10].

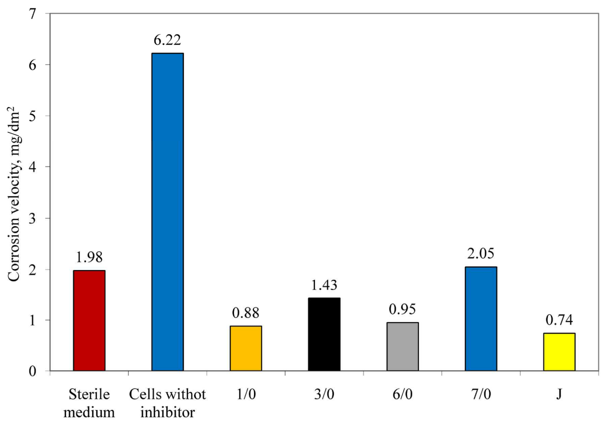
Noncompetitive 6/0 inhibitor is not bioresistant because any carbon-oxygen bond is very stable (90–100 kcal/bond) but very active in biochemical reactions, and the energy of carbon-carbon bonds in aliphatic chains is less than 32 kcal/bond and it decreases when the number of carbon atoms in the chain increases.

The researches of the influence of dioxo-decahydroacridine and quaternary nitrogen-containing derivatives on acidophobic thione bacteria *Thiobacillus sp*. showed (Fig. 5) that the most effective against this group of microorganisms were 1/0 inhibitors among dioxo-decahydroacridine derivatives and "J" inhibitor among QAS, which showed the blocking of these organisms growth 95.8 and 97.1%, respectively, and reduced the rate of corrosion at almost 90% under the influence of thione bacteria (Fig. 6).



Dioxo-decahydroacridine derivatives – 1/0, 3/0, 6/0, 7/0; QAS – "J" inhibitor

Figure 5 – Inhibition of thione bacteria growth by nitrogen-containing corrosion inhibitors



Dioxo-decahydroacridine derivatives – 1/0, 3/0, 6/0, 7/0; QAS – "J" inhibitor

Figure 6 – Effect of nitrogen-containing inhibitors on the corrosion rate of metal samples caused by thione bacteria

We can summarize the results by recommending the simultaneous application of two effective 1/0 and "J" inhibitors in bituminous-polymeric coatings, each of the inhibitors executes its strategic protective function. 1/0 inhibitor quickly and efficiently kills most of the dangerous bacteria, "J" inhibitor makes microbial colonization of oil-and-gas pipelines surface impossible over a long period of underground facilities operation.

Table 1 – The variants of microbiological researches

Variant I	
Experiment	Control
Towson medium + «3/0» sample + HDB bacteria association	Towson medium + «3/0» sample
Towson medium + «6/0» sample + HDB bacteria association	Towson medium + «6/0» sample
Towson medium + «7/0» sample + HDB bacteria association	Towson medium + «7/0» sample
Variant II	
Experiment	Control
Hilti medium + «3/0» sample + HDB bacteria association	Hilti medium + «3/0» sample
Hilti medium + «6/0» sample + HDB bacteria association	Hilti medium + «6/0» sample
Hilti medium + «7/0» sample + HDB bacteria association	Hilti medium + «7/0» sample

Based on the results of microbiological tests of dioxo-decahydroacridine derivatives, we can regard these inhibitors with antibacterial properties as components for modeling of multifunctional inhibitory system, which will protect oil-and-gas pipelines from corrosion in an underground medium.

We obtained the samples of modified mastic on the basis of industrial mastic with these biocides and made a research of their microbial resistance according to the State Standards of Ukraine (SSU) 3999–2000. The heart of the method was to quantify the intensity of bacterial growth in the presence of coating as the only carbon source. We identified the associations of HDB and DNB at the damaged bituminous coating of marsh trunk pipeline "Pasichna–Dolyna" (Fig. 7).

Figure 7 – Photo of the damaged bituminous coating

The experiments were in two versions: Towson medium (excluding hydrocarbons) and Hilti medium (Table 1).

We immersed the samples of modified mastic by 3/0, 6/0 and 7/0 inhibitors, which had been sterilized with ethyl alcohol and UV rays, and inoculated these samples by 10^6 cells/cm^3 of HDB and DNB in a glass flask (volume 200 cm^3) with appropriate nutrient medium. The samples of modified mastics were kept in an incubator at a temperature of 28 ± 2^0C for 90 days. The experimental and control flasks with mastic samples were visually inspected after the tests end. According to the criteria of microbial resistance of SSU 3999–2000 in comparison with the control, the results of visual inspection showed that the Towson and Hilti media, where the resistance of mastic samples to HDB and DNB was tested, were transparent and there was not any bacteria film on their surfaces.

After analyzing the results it can be stated that the bituminous-polymeric insulating mastics modified by the corrosion inhibitors 3/0, 6/0 and 7/0 are biostable towards the action of HDB and DNB.

The results of experiments are important from a practical point of view, since the introduction of the researched biocides into the basic mastic helps to receive modified mastics and protective insulating coatings, which will be resistant to the damaging effects of HDB and DNB.

Another important aspect of improving the microbiological protection of underground pipelines is the removing of the damaged insulation layer and the surface preparation during reconstruction and repair of pipelines.

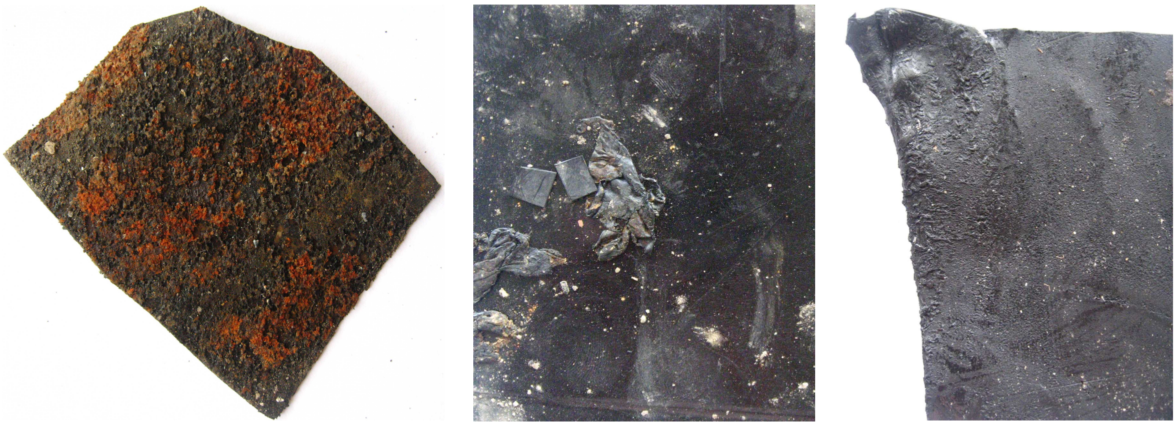
In the places where a technology primer, which is an adhesive layer between the pipe metal and insulation, remains intact, there are significant difficulties with the removing of insulation in these areas, particularly bitumen, film and paint area; this fact results in significant loss of abrasive material during preparation of surface for further application of new insulation construction, which reduces the speed of repair of pipelines in several times depending on conditions.

In addition, pipelines are laid in the soil with different corrosion activity and mineralization, insulating coatings of which are damaged by bacteria-destructors. Therefore the problem of removing of localized intact insulation and of the damaged primer with bacteria-destructors is an urgent technological challenge, the successful solution of which will save considerable material and energy resources.

There were sampled the damaged primers based on bituminous mastics of oil and gas trunk pipelines (TP), laid in the I, II and III regions.

Fig. 8 (a–c) demonstrates the photos of damaged primers.

The damaged primers differed in strength and color of corrosive layer on the surface. Thus, the TP primer of the region I was brittle; its surface was covered by corrosion products colored from black to reddish-brown. A black TP primer of the region II was sticky and plastic, while a black and gray TP primer of the region III was brittle. Using the appropriate culture media [2] we took cultures of IRB, DNB, HDB and SRB of damaged primers.



a) b) c)

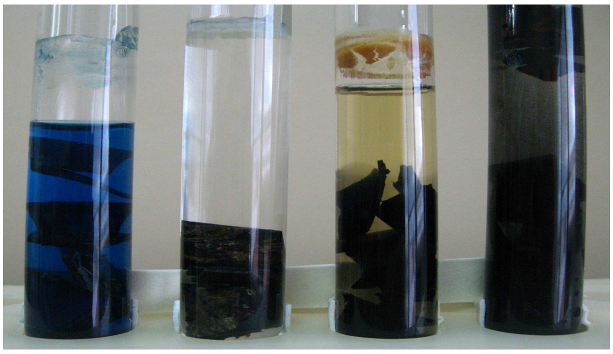
Figure 8 – A damaged primer of TP in region 1 (a), region II (b), region III (c)

Table 2 demonstrates a qualitative and quantitative composition of bacteria, which were taken out of the damaged primers.

Table 2 – Qualitative and quantative composition of bacteria, which were taken out of the damaged primers

Region Name	IRB	DNB	HDB	SRB
Region I	10^4	10^8	10^4	10^2–10^3
Region II	$10^{2\text{-}3}$	10^3	10^6	10^2
Region III	10^3	10^6	10^5	10^1

Fig. 9 demonstrates the photos of bacteria of different physiological groups. The analysis of the presented data showed that there were identified four groups of bacteria taken of all the researched primers regardless of the region of trunk pipelines laying.



a b c d

a – DNB; b – HDB; c – IRB; d –SRB

Figure 9 – Photo of bacteria, which were taken out of the damaged primers

These experimental data are of great practical importance, because they indicate the devastating influence of bacteria-destructors upon insulation material and a primer. It is important to pay attention to the fact of higher concentrations of denitrifying bacteria in regions I and III. This indicates that denitrification processes are intensive in the underground medium of trunk pipelines of these regions; as a result bacteria reduce nitrates to gaseous products N_2, N_2O, NO, which lead to the destruction of integrity of both a protective coating and a primer.

We carried out industrial tests of insulation coating based on the modified mastic by “J” inhibitor, which is biostable to influence of SRB and HDB bacteria [11], in a gas pipeline "Pasichna–Dolyna" with a diameter of 529 mm and a length of 30 m (00 447 PCs+00).

The test results are demonstrated in Table 3.

The tests results showed that the insulation coating, based on bituminous-polymeric mastic modified by “J” inhibitor, had higher physical, mechanical and adhesive properties compared to standard rates in accordance with SSU 4219–2003.

Taking into account biological stability and increased hydrophobicity of the bituminous-polymeric mastic modified by “J” inhibitor, it is recommended to use the mentioned innovative insulation coating at the problem pipeline tracks where soils are corrosionally active and there is the risk of biocorrosion.

Therefore, obtaining of biostable modified mastics by nitrogen-containing corrosion inhibitors with high hydrophobicity, development and practical implementation of biostable modified insulating coatings at the bituminous-polymeric base is one way to solve important scientific and applied problem of microbiological protection of underground oil-and-gas pipelines.

The assessment of biological stability of corrosion inhibitors under microorganisms influence during the operation of insulating coatings can help to predict environmental response to anthropogenic interference into the environment.

Conclusion

1. An important ecological and technological challenge is the protection of underground oil-and-gas pipelines against microbiological corrosion under the influence of microbiological corrosion-hazardous soil microorganisms, including the crucial role of sulphate-reducing (SR) and thione (TB) bacteria.

2. A research is made of the effect of organic nitrogen-containing corrosion inhibitors on biological activity of sulfur cycle bacteria and blocking biocorrosion processes.

Table 3 – Results of testing an insulation coating that is based on bituminous-polymeric mastic modified by "J" inhibitor and PVCH film manufactured by "Ozom" enterprise

Indicator	Requirements under SSU 4219-2003	Experiments results	Method of experiment
The form of protective coating	Continuous layer	Homogeneous continuous	SSU 4219
The total thickness of protective coating, mm	Not less than 4.2	4.5	SSU 4219
Mastic adhesion to primed steel surface, H/mm^2	Not less than 0.25	0.6	Appendix E SSU 4219
Film adhesion to mastic, H/mm	Not less than 1.5	1.7	Appendix E SSU 4219
Continuity of protective coatings for voltage 5 kV per 1mm of coating thickness	No breakdown	Resists	SSU 4219
Strength hit at $t = 20^oC$, J	Not less than 15	18	Appendix A SSU 4219

3. There is defined the blocking mechanism of hydrogenase reaction under the influence of the researched inhibitors and inhibition constants.

4. There are theoretically estimated dioxo-decahydroacridine derivatives as the components of multifunctional inhibiting systems.

5. There are made microbiological researches of biological stability of modified bituminous-polymeric mastics under the influence of HDB and DNB.

6. The researched inhibitors are recommended in order to obtain biostable coatings for corrosion protection of underground oil-and-gas pipelines against corrosion damage by soil microorganisms.

7. There were made the industrial tests of modified bituminous-polymeric mastic by "J" inhibitor in Regional Pipeline Department "Prykarpattransgas."

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Основні аспекти мікробіологічного захисту підземних нафтогазопроводів

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Висвітлено основні аспекти захисту підземних нафтогазопроводів від мікробіологічної корозії під дією грунтових корозійно-небезпечних мікроорганізмів, вирішальну роль серед яких відіграють сульфатвідновлювальні (СВБ) і тіонові (ТБ) бактерії. Досліджено вплив нітрогеновмісних інгібіторів корозії на ріст і ферментну активність бактерій циклу сірки та встановлено механізм блокування ТБ і гідрогеназної реакції корозійноактивних СВБ. Вивчено ефективність похідних діоксодекагідроакридину на швидкість мікробної корозії сталі під дією СВБ і ТБ. Зроблено теоретичну оцінку біорезистентності похідних діоксодекагідроакридину. Проведено порівняння ефективності даних інгібіторів з промисловим інгібітором «Ж». Досліджені інгібітори забезпечують високий ступінь захисту металу від корозії в присутності СВБ (більше 90%), що вказує на їх бактерицидні властивості та відкриває перспективу їх використання в промислових умовах розвитку анаеробної корозії, зумовленої СВБ.

Виділено асоціати бактерій чотирьох фізіологічних груп з пошкоджених праймерів магістральних газопроводів, прокладених у регіонах І, ІІ і ІІІ. Визначено їх якісний та кількісний склад. Встановлено, що домінантом в асоціації виділених бактерій виступають ДНБ бактерії, що вказує на інтенсивність протікання процесів денітрифікації в умовах підземного середовища, в результаті яких руйнується не тільки захисне ізоляційне покриття, але й праймер.

Проведено промислові випробування інноваційного біостійкого захисного покриття на основі мастики, модифікованої інгібітором «Ж» в умовах управління магістральних газопроводів «Прикарпаттрансгаз».

Ключові слова: *інгібітор, корозія, механізм, мікроорганізми, нафтогазопроводи, праймер.*