Biological resistance of polymeric pipeline materials

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Abstract. Currently, the problems of biodeterioration are becoming crucial in assessing the durability of buildings and structures for various purposes. Metal, reinforced concrete, polymer, and other products and structures, including the pipelines for water and gas supply, water disposal, etc., are subject to biodeterioration. Biodeterioration processes in construction are considered in many scientists and specialists’ works. From their works it follows that changes in the properties of pipeline materials as a result of microbiological corrosion can lead to a shutdown of facilities, accidents. Materials are exposed to biological and mechanical influences in natural conditions, therefore, the need to study various factors: the chemical composition of the materials used, density, temperature range, and the field of these materials’ use of relevant.

The article presents the studies’ results of soil corrosion of samples from polymer pipes. The descriptions of pipeline materials from different manufacturers are given. The samples were selected for the research from thermoplastic polymers based on polyethylene and polypropylene, including those reinforced with fiberglass. The samples were aged in various layers of soils belonging to the groups of chernozems and loams. Methods for assessing the materials’ accreting degree by microorganisms are given. In the course of the research, the species composition of microorganisms accreting on the samples during the tests was established; the data on changes in the samples’ mass content are revealed. The results can be used to assess the biological resistance of pipeline materials.

Introduction
The problem of biodeterioration in our country has been intensively studied since the 70s of the XX century. The term “biodeterioration” refers to the situations when the living organisms cause changes or disturbances in the structural and functional characteristics of various objects by their presence and activity [1, 2, 3, 4, 5]. The main components of biodeterioration are the living organisms, mainly mycelial fungi and bacteria. The objects of their impact are many building materials, products and structures, brick, concrete, wood, plastics, rubbers, etc., including pipeline materials for water and gas supply, water disposal [6, 7, 8]. At the same time, the nature of the relationship between the microorganism and the object largely depends on the environment in which water, air, or terrestrial biologically damaging process arises and develops [1, 2].

The mechanism of biological damage by microorganisms combines a number of successive stages [1, 2, 3, 4, 5, 6, 7, 8]: transfer of microorganisms to the materials and products’ surface; the formation of microcolonies and their growth to the sizes visible to the naked eye; the accumulation of metabolic
products resulting from the vital activity of microorganisms; stimulation of corrosion destruction processes; synergism of biodeterioration.

The microorganisms’ transfer is possible through the air currents with particles of soil, air moisture and penetrating soil water, migration of insects [1, 2, 5]. The adsorption or adhesion process is very complex and depends on the type of microorganisms, the properties and surface of the materials, and the state of the environment [1, 2]. The formation of microcolonies, accompanied by the appearance of corrosive metabolic products, is a significant hazard [25]. The formation of microcolonies is determined by the property of the material to be a breeding ground for microorganisms and the nature of the pollution. In this case, bacteria produce inorganic, and mycelial fungi produce organic acids. Stimulation of biocorrosion processes can occur at certain values of humidity and temperature [9, 10, 11]. Biodeterioration synergism occurs, on the one hand, as a result of exposure to chemical corrosion, aging, biodeterioration, and on the other hand, when various groups, genera, and types of microorganisms interact [9, 10, 11, 12, 14].

A significant proportion of biodegradation occurs in underground structures, various pipelines that adsorb microorganisms due to the presence of a positive charge on their surface, as well as the various functional groups in the insulating coatings’ composition [5, 6, 12, 13]. The adsorption degree will be determined by the temperature of the soil, aerobic conditions, etc. These conditions contribute to the development of microorganisms to varying degrees. In this regard, the establishment of the microorganisms’ species composition on the surface of pipeline materials in various soil conditions is relevant.

The purpose of the study was to establish the species composition of microorganisms inhabiting the surface of polymer pipeline materials.

Research objectives:
1. The choice of prototypes from polymeric materials.
2. Determination of the microscopic fungi representatives on the samples.
3. Establishment of the biological environment influence on the operational properties of the samples from pipeline materials.

Materials and research methods
The following materials were used as prototypes:

1) Sewage pipe “RosTurPlast” with a diameter of 110 mm. Nominal wall thickness - 2.7mm. Pipe length - 1000mm. Sewage pipes “RosTurPlast” made of polypropylene and propylene copolymers with a nominal outer diameter of 32 mm to 160 mm are used for household sewage systems in the buildings with a maximum temperature of constant drains 80ºC and short-term (within 1 min.) drains with temperatures up to 95ºC at a maximum flow rate of 301/ min.

2) polyethylene pipe PE-80 SDR 17 - 32x2 GOST 18599-2001, the main areas of their application are the pipelines for water supply, sewage, other technical systems;

3) PPRC pipe reinforced with 32x4.4 PN20 “RosTurPlast” fiberglass SDR-7.4. It is used in hot water supply systems, for drinking water, as well as for heating, irrigation systems, for transporting compressed air, aggressive environments;

4) Non-reinforced propylene pipe PN20 32x4.4 mm “RosTurPlast”, single-layer pipe made of polypropylene by the random copolymer with a maximum design pressure in the system of not higher than 2 MPa. Recommended use - cold and hot water supply and low temperature heating, including the transportation of drinking water. Operating temperature - up to 70ºC. Service life up to 50 years.

These samples were laid in one of the regions of the Republic of Mordovia in various soil types (chernozem and loam) to a depth of 410 mm and 630 mm. During testing, the samples were in variable temperature and humidity conditions for 12 months.

During the tests, the influence of weather conditions as well as soil and climatic factors was controlled. Precipitation fell in total within normal limits. The snow density and water content in it were close to normal. Soil freezing was below normal. The hydrothermal coefficient proposed by G.
Selyaninov was characterized by a low rate. (Source: Federal Forestry Protection Center of the Republic of Mordovia 04/12/2019).

During the research, the species composition of microorganisms settled on the samples’ surface and the change in their mass content were established. To determine the materials’ accreting by microorganisms and assess their species composition, the methods of imprints and sampling were used. To identify fungi, the data of mycological reference books were used [14, 15]. Changes in the mass content of the samples are determined by the difference in weight before and after their exposure. The test samples were sent to the laboratory of microbiological research of Nizhny Novgorod State University, physical and mechanical tests were carried out at Moscow State University named after N.P. Ogarev.

The results of the experimental studies and their discussion
The studies’ results on the samples’ accreting by microorganisms are shown in Table 1.

Table 1. Results of microbiological studies.

| Sample Series | Type of material | The species composition of fungi on the samples’ surface in various soils |
|---------------|-----------------|-------------------------------------------------------------------------|
| 1             | Sewage pipe “RosTurPlast” with a diameter of 110 mm. | fusarium moniliforme, aspergillus ustus, fusarium moniliforme. |
| 2             | Polyethylene pipe PE-80 SDR 17 - 32x2 mm GOST 18599-2001 | fusarium moniliforme, fusarium moniliforme, A.ustus, P.chrys, bacteria. |
| 3             | PPRC pipe reinforced 32x4.4mm PN20 “RosTurPlast” fiberglass SDR-7.4. | fusarium moniliforme, A.ustus, Aspergillus terreus, mucor corticola, Cl.globosum, A.ustus, Paecilomyces varioti. |
| 4             | Non-reinforced propylene pipe PN20 32x4.4 mm “RosTurPlast” | A.ustus, mucor corticola, fusarium moniliforme, A.ustus. |

The research results show that almost all the samples detected microorganisms, there was a change in color and mass content. The growth and activity of soil microorganisms are influenced by such factors as temperature, humidity, pressure, soil acidity, etc. The genus Aspergillus and the genus Fusarium fungi are especially thermophile. Humidity above 75% contributes to the appearance of micro-mycetes on polymer structures and products. Since the pipeline materials were 12 months in the soil, this served to form the numerous fungi colonies. The vital processes of fungi largely depend on the acidity of the soil. Fungi of the Aspergillus genus are found in the upper layers of the soil. It is known that they grow actively on organic materials at low values pH. Fusarium fungi are widespread in nature and are the causative agents of wilting and rotting plants. Fungi of the genus Paecilomyces, P. chrys are ubiquitous and are the cause of many serious human diseases’ development. The study of the qualitative composition of microflora is necessary to create better and more effective by the protection methods. The resulting corrosion processes can be stopped with the help of correctly selected biocides, the formation of a situation for the suppression of one species by another, the decrease in the release of metabolites by fungicidal additives. The next stage of the study is the determination of changes in the mass content of the samples immersed in soil conditions. The research results are shown in Table 2.

Table 2. Mass content of the samples immersed in soil conditions.

| kind of material | soil | Weight before immersion, [gr] | Weight after immersion, [gr] | Mass change, [%] |
|-----------------|------|-------------------------------|-----------------------------|-----------------|
| 1. PPRC pipe    | reinforced | 8.51                          | 9.21                        | 8.22            |
From Table 2 it follows that the samples’ mass all increased during exposure in soil environment. The change in the samples’ mass content indicates the destruction of materials as a result of the soil microorganisms’ vital activity. The greatest changes in mass content underwent polyethylene pipes. Accordingly, the hardness indicators of these materials change.

An analysis of the results shows that the destruction degree of polymer pipelines largely depends on the chemical structure of the polymer itself, its physical structure, molecular weight, molecular weight distribution of fractions, the presence and composition of plasticizers, fillers, stabilizers, and other additives. It is known that PE-80 polyethylene is made of high-density polyethylene of the PE-80 brand - a modification of the LPP polymer (low-pressure polyethylene). Polyethylene of low pressure or high density has a low degree of molecules branching, that is, it has large intermolecular forces and tensile strength. Products from it are less resistant to vapors and water, but resistant to high temperatures, various oils and chemicals. Since high density polyethylene is characterized by weak intermolecular interactions due to the absence of polar groups in the chain, a change in size occurs with constant load over time. The possibility of destruction in a biological way - rotting, fungal formations, etc. is minimal. This was confirmed by testing.

Polypropylene pipes are made of polypropylene “Random copolymer” (PPRC). The propylene random copolymer is obtained by co-copolymerizing ethene and propene. The composition of the molecules of this polymer includes the ethene units, which are distributed randomly along the polymer chain. Features that distinguish this material favorably: corrosion resistance, resistance to aggressive substances, high strength, lack of internal deposits. Pipelines do not lose their original shape as a result of temperature changes, are resistant to the bacteria and algae formation. PPRC PN20 pipes with fiberglass have a multilayer structure. The middle layer of pipes is made of fiberglass reinforced PPRC.
polypropylene, and the inner and outer ones are made of ordinary PPRC polypropylene. The use of fiberglass significantly increases strength. In this case, there is no possibility of the individual pipe elements’ delamination. Tests for biostability showed a decrease in the resistance to the polymer materials’ microorganisms’ action when reinforcing materials based on fiberglass are introduced into their composition.

An important factor in biodeterioration of materials is the effect of the microorganisms’ metabolism products. Mycelial fungi along with organic acids secrete enzymes belong to all classes of the existing international classification. However, oxidoreductases, hydrolases and lyases have a particularly active destructive effect on most polymeric materials. Thus, the creation of polymers by man is reflected in the vital activity of microorganisms on their surface. In this regard, their adaptability to new conditions is increasing. Biological activity is expressed in a variety of enzyme systems and metabolic lability. Therefore, the engineering study of biodegradation consists in establishing the species and quantitative composition of biocorrosion representatives, as well as creating the new materials that are more resistant to biodeterioration.

Summary.

1. It is shown that various products and building designs and structures based on metal, polymer and other materials, including the pipelines for water and gas supply, water disposal, are the subject to biodeterioration.
2. In this article, pipeline materials based on polyethylene and propylene, including those reinforced with fiberglass, are studied, biofouling indicators of the samples under soil corrosion conditions and the changes in mass content are given.
3. It has been shown that various types of microorganisms are populated on the samples’ surface, depending on the type of soil, among them aspergillus, fusarium and mucor are more present.
4. The impact of microorganisms leads to biodegradation of pipeline polymer materials, keeping the samples in both loamy and black soil layers leads to a change in their mass content.
5. The research results can be used to assess the bio-resistance of polymer pipeline materials operating in soil conditions.

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