The economic damage from biodeterioration in building sector

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Abstract. The article deals with the problem of biological impact in building materials and construction. The method of determining the losses from biological damage is given. The structure and method of estimation of direct and indirect costs of biological damage are considered. The definition of environmental damage from biological damage and its components.

Introduction
Currently, the problem of protection against biological impact in construction is becoming acute, which leads to huge material costs and losses [5-8]. It is known that the annual global losses from the biological damage of materials and structures are several percent of the value of the total production produced by mankind for the year. At the same time, biological damage is especially characteristic of processing enterprises – meat and dairy plants and other food enterprises, various warehouses, overpopulated residential and public buildings – hospitals, schools, transport buildings and structures – stations, subways, underground facilities, sewer and collector networks and other facilities. The vital activity of microorganisms invisible to the eye threatens buildings and other engineering structures of cities, as well as the health of citizens. In the course of their life, microbes change and/or destroy the structure of building materials, which leads to a decrease in the strength characteristics of building structures and, ultimately, to premature aging and destruction of the building. The processes of biological damage to engineering structures of cities sharply exacerbate the problems of food preservation: typical are the huge losses of grain and flour at flour mills, meat products and products of other sectors of the food and agricultural industry. The poor condition is exacerbated by the extreme wear and tear of electricity, water, heat and sewage systems. All these systems have a significant service life-about 50 years, which determines the urgent need for reconstruction and replacement of engineering networks.

Biological damage of building structures is one of the main factors determining the rate of wear of buildings and other engineering structures (along with the impact of aggressive gases, acid rain, freezing, weathering, etc.), which has a number of significant features [1]:
- under the combination of certain conditions, microorganisms can accelerate the destruction of materials in hundreds or even thousands of times;
- microorganisms-destructors can be at rest for a long time, not showing themselves;
- microorganisms pass into the active phase of life, as a rule, in non-comfortable conditions for humans: with a relative humidity of more than 60 % and walls (structures) - more than 5 %;
- microorganisms have both chemical and mechanical effects on building materials;
- in the community, some microorganisms can support the life of others (in the case of the last adverse conditions);
- biological damage processes threaten not only buildings and other engineering structures, but also the property and people in them;
- waste products and spores of many microbes living in walls and ceilings, air ducts and other structures of buildings can cause serious diseases in people.

Diseases, the causative agents of which are microbes, are diverse—from various allergies and inflammations to deep mycoses, infectious and systemic diseases. There have been cases of premature deaths of people with weakened immune systems who lived in rooms with obvious signs of injury. The causative agents of diseases can be microorganisms, and their waste products. In fact, the processes of biodegradation in the city are becoming one of the main threats to the urban environment.

When studying the interaction of biodestructors with building materials, with elements of the city’s infrastructure, it is necessary to study such an important aspect of this huge problem as the dependence of sanitary and epidemiological conditions in residential and industrial zones, in the urban environment of human habitation on the nature and intensity of the processes of life of microorganisms settling on the surface and in the thickness of building structures. If we take into account that the processes of biodegradation of the country’s economic infrastructure are progressing every year, any delay in the development and subsequent implementation of the program to combat the biodegradation of the human environment will result in huge human and economic losses in the future.

It is becoming increasingly apparent need for the development and implementation of measures for the prevention and elimination of consequences of biodeterioration of different materials and designs. In industrialized countries, losses from all types of corrosion, including from biocorrosion, have long been recorded, and effective measures to counteract the processes of biodegradation are being developed and implemented. In our country, unfortunately, such accounting is not conducted and, accordingly, there is no assessment of the real economic damage from the life of biodestructors.

Methods and results of research

In our studies, the method of determining losses from biological damage is based on the total expression of the cost of material, labor and energy resources caused by biocorrosion of building structures. Total losses (costs) from biological damage are associated with loss of materials, reduced efficiency of fixed assets, with the cost of protection against biological damage in the production and operation of fixed assets.

Losses from biocorrosion of building structures during the operation of buildings and structures are divided into direct and indirect.

Direct losses ($L_d$) include: the number and cost of structures and their elements that have undergone biodegradation, which are replaced when they are completely worn out and eliminated before the expiration of the depreciation period ($L_{mr}$); the cost of structures and their elements replaced during capital and current repairs ($L_{mr}$); the cost of structures and semi-finished products written off due to biological damage during transportation and storage ($L_{ms}$) [2].

The value of direct losses from biological damage is calculated by the formula:

$$L_d = L_{ml} + L_{mr} + L_{ms}$$

Damage from the structural elements of the object is determined by a combination of two factors: the presence of destruction and the presence of physical wear of the remaining parts of the structural elements. The degree of damage to the structural elements of the object ($P_i$) can be determined by the following formula:

$$P_i = P_{ch} + (100 - P_{ch}) \cdot P_w$$

where $P_{ch}$ – is part of the damaged (or partially destroyed) structural element, as a percentage; $P_w$ – is the percentage of physical wear of the remaining part of the structural element.

The degree of damage to the object ($P$) can be calculated using the formula:
\[ P = \sum P_i \cdot W_i / \sum W_i \]  

(3)

where \( P_i \) – is the degree of damage to the \( i \)-structural element, \( W_i \) – is the weight of the \( i \)-th structural element (according to the collections of enlarged indicators of replacement cost (EIRC)).

To determine the direct economic damage from the biological damage of building structures, buildings and structures, you can use the formula for partially damaged objects. The cost of restoration of object \( (C_r) \) taking into account its volume and extent of damage is defined on the following expression:

\[ C_r = C_f \cdot V \cdot I_{ch} \cdot F_c \]  

(4)

where \( C_f \) – the full replacement cost of the meter on collections of EIRC; \( V \) – construction volume of object from the inspection act; \( I_{ch} \) – the index of change of the prices of construction and installation works for date of determination of cost in relation to the prices used in EIRC; \( F_c \) – conversion factor of cost expression of damage of object in the cost of its restoration corresponding to a certain percentage of damage of object.

Thus, the calculation of the cost of restoration can be commensurate with the size of the damage from the biological damage.

Indirect losses \( (L_{in}) \) include losses and losses associated with the downtime of the main technological equipment and machines located in the production building during repairs of building structures and a decrease in the volume or deterioration in the quality of products \( (L_{pp}) \), as well as losses of materials \( (L_m) \) and products, compensation for damage to related industries and the environment that occurs due to biological damage to structural elements of buildings and structures \( (L_{reim}) \) [3]. The value of indirect losses from biodegradation is calculated by the formula:

\[ L_{in} = L_{pp} + L_m + L_{reim} \]  

(5)

At carrying out capital repairs or renewal of protection against bioremediation of building designs in the operating productions indirect losses are expressed in the form of decrease in volume of products because of idle time of the main processing equipment. For production shops losses from idle time of the technological equipment placed in the building are calculated by the formula:

\[ L_{pp} = (C_p \cdot C_f) \cdot V_{an} \cdot T_d \]  

(6)

where \( C_p \) – is the unit cost of manufactured products (at current wholesale prices); \( C_f \) – factory unit cost of production; \( V_{an} \) – the annual volume (capacity) of production; \( T_d \) – downtime are posted in the building technological equipment and machinery during construction and repair works (expressed in fractions of years) are accepted for the acts or records of repair and construction works.

According to the Equation 3 can be calculated losses from downtime in case of accidents caused by the corrosion of building structures and during periods of suspension of production during the survey of the technical condition of corrosion-damaged structures.

The cost of losses from leakage or damage of materials, semi-finished and finished products, from biocorrosion of structural elements of tanks, pipelines, warehouses and storage facilities is determined by acts drawn up to account for unproductive costs and losses of the enterprise’s products. The costs of elimination of damage from biocorrosion caused to related industries and agriculture, the environment (fines, penalties, etc.), reimbursed by the enterprise, are taken into account.

Economic losses from final marriage are determined by the amount of costs incurred in the production of defective products, i.e. their cost. They include: the cost of materials; transport and procurement costs; costs of maintenance and operation of machinery and equipment; general production costs; wages; social insurance contributions.

From the received amount of losses it is necessary to exclude the cost of returnable waste, the cost of marriage at the price of scrap and that its part which is collected from perpetrators of marriage. So should be determined by the loss of marriage for the company, the company as a whole. When choosing the most cost-effective solutions from the standpoint of minimizing social costs, it is
necessary to determine the amount of losses from marriage without taking into account whether or not the damage is recovered from the perpetrators. On the corrected marriage losses are determined by the costs of its elimination. They include the cost of materials, raw materials and semi-finished products, the amount of wages with charges, the share of General production costs and costs for the maintenance and operation of machinery and equipment.

When calculating the economic losses of the manufacturer as a result of an unbiased reduction in the volume of production (work), it is necessary to take into account the presence of constant and variable costs in the total, gross costs of the company:

$$C_t = C_f + C_v$$  \hspace{1cm} (7)$$

where $C_t$ – is the total cost of the manufacturer of the product; $C_f$ and $C_v$ – are fixed and variable costs as part of the total cost.

Fixed costs include: rent, repayment of bank loan, depreciation on full restoration of fixed assets, payment for commercial services, etc. Variable costs include, for example, staff salaries, costs of raw materials, components, etc.

Given the presence of sudden (emergency) situations caused by biodiversity-the abuses, the company has to have reserve production capacity sufficient to compensate for losses and perform the tasks of production volume.

The annual value of losses from under-production is determined by the size of the rise in the cost of production [4]:

$$\Delta C_{an} = V_{an} (C_{fu} - C_f)$$  \hspace{1cm} (8)$$

where $V_{an}$ – the annual volume of production in the absence of negative effects of biodegradation, $C_f$ – fixed costs per unit of production in the absence of negative consequences of biodegradation.

Thus, the following expression can be used to calculate the economic losses of the manufacturer from the underworking of the unit of production in case of emergency failures:

$$L_{ec} = C_f + E \cdot K_s$$  \hspace{1cm} (9)$$

where $K_s$ – specific capital investments in basic and current assets per unit of output.

When working in hostile environments, there may be damage to objects of labor and a decrease in the quality of products.

Spoilage of objects of work can be final if it is not subject to correction or inconclusive when it can be eliminated. There may be occasions when the final damaged items of work, the company may use them improperly, or may implement on the side.

Losses from the reduction in the quality of products intended for final consumption can be defined as a change in the form of a decrease in part of the profit due to the sale of goods of reduced quality, since the price of these products is reduced due to a decrease in consumer properties:

$$L_{eq} = \Delta P Q_{rd} = (P_n - P_r) Q_{rd}$$  \hspace{1cm} (10)$$

where $\Delta P$ – decrease in profit from the sale of goods of reduced quality per unit of production; $P_n$ and $P_r$ – the price of a unit of production according to the nominal and reduced level of quality; $Q_{rd}$ – the number of units of goods of reduced quality.

The development of material production is accompanied by a progressive impact on environmental pollution, so it is no coincidence that recently began to pay much attention to this problem. Damage can be manifested in the deterioration of the environment by the concentration of harmful substances in the atmosphere, water, air, soil, radiation pollution, violation of the thermal balance. These pollutants include industrial enterprises whose fixed assets are subject to biodegradation. Damage
from environmental pollution in the form of money can be estimated as a loss of society in the form of costs or reduce the level of material production, additional costs to cover the negative consequences in the non-productive sectors at the expense of the budget or personal funds of the population. The peculiarity of economic damage associated with biological damage is that it is, as it were, an additional value in relation to environmental damage. Costs associated with environmental factors are presented as the sum of environmental costs and damage from environmental disturbance. The damage from biodeterioration, accompanied by environmental pollution, should be divided into the sum of certain additional losses and costs due to emergency situations, including the additional costs of conservation and additional environmental damage from pollution to the environment [2]:

\[ D_{\text{env}} = U_1 + U_2 + U_3 + U_4 \]  

where \( U_1 \) – additional environmental measures aimed at protecting the environment from biodegradation of building structures and structures; \( U_2 \) – additional costs for the restoration of the natural environment; \( U_3 \) – additional costs for the protection of users of natural resources from environmental pollution due to biodegradation; \( U_4 \) – additional costs for users of natural resources to compensate for the negative consequences caused by pollution.

Thus, it can be concluded that the environmental damage from biodegradation is estimated by some value of additional environmental costs due to environmental pollution.

The first three groups of damage consist mainly of one-time costs, taking into account the economic efficiency factor and the current costs associated with biodegradation. The most difficult assessment of environmental damage from biodegradation is the fourth group of losses and costs. Nevertheless, this group should be considered the most important, since it is supposed to take into account the anthropological consequences of environmental pollution. Losses for the fourth component in the sphere of material production are expressed in a decrease in net production or profit, and in certain industries and enterprises – in an increase in the cost of production of works or services, in the sphere of personal consumption-in an increase in the cost of personal funds of the population. Each of the structural values of damage included in the fourth group has its own characteristics in the calculation of quantitative expression.

With the increase in the morbidity of the population, the damage due to the increase in the level of environmental pollution consists of: additional payments to the population from social security funds; costs in the health care industry; losses of clean products during the illness of workers.

Economic studies of operating costs and losses from bio-damage are most appropriate to perform during the periods of specialized organizations surveys of the technical condition of building structures exposed to aggressive environments.

**Summary**

In the design and construction of industrial buildings and structures exposed to biodestructors, it is necessary to strive to ensure that, through appropriate measures to protect building structures from biological damage, ensure the smooth operation of fixed assets of enterprises during the regulatory life of their service. This can be achieved by using the following measures to protect against biodegradation of structures; the creation and implementation of building materials and structures with increased resistance to biological damage; the use of protective coatings or special additives; development of constructive measures of protection against biological damage; design and implementation of measures for protection against biological damage carried out in the manufacture of construction products and parts designed to work in an aggressive environment; design and implementation of objects constructed from materials resistant to biodestructors.

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