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The Features of Surface Algocenoses in Anthropogenic Conditions of Urban Environment.

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ABSTRACT

The surface of building materials in the man-made urban environment undergo a process of biofouling algae. The degree of damage depends on the environmental factors of the environment that are affected by the level of anthropogenic load areas. The environmental monitoring of urban areas with different functional affiliation and level of contamination is carried out. The composition of algo biocoenosis of urban buildings in areas with varying degrees of anthropogenic load is explored, most stable and sensitive kinds to the level of environmental pollution are revealed. The dependence of species diversity of algocenosis from the level of anthropogenic load territories which changes from one functional area of the city to another is investigated. Biofouling process of modeling concrete of algae under laboratory conditions allowed to determine their impact on the building material, accompanied by changes in the chemical and mineralogical composition of the surface of products. Based on microscopic examination of sample surfaces and evaluate the effectiveness of various ions leach from building materials shows the results of "algal attack" related to the acceleration of biodegradation of materials under the influence of aggressive metabolic products, mechanical action of neogenic crystals, creating optimal conditions for the development of subsequent aerobic microbial decomposers.

Keywords: Algocenosis, biofouling, urban environment, concrete surface.

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INTRODUCTION

Nowadays, the extent and intensity of the destruction of urban buildings and structures steadily increase. External cause, causes a reduction in "efficiency of buildings" are climatic factors, and environmental factors (wind, dust, corrosive atmosphere in the presence of compounds, biological factors) [1].

In real environmental conditions combined fracture occurs from exposure to sunlight, water, low temperature, temperature difference, humidity and changes of complex effects associated with the settlement of construction materials by living organisms. Prolonged exposure of these factors leads to weight loss, reduction in the physical and mechanical properties and freeze resistance as well as operational parameters [2, 3, 4].

In urban areas the ambient air indicated the presence of various contaminants (in the form of dusts, solid and gaseous - formaldehyde, phenols, carbon dioxide, nitrogen dioxide, sulfur in the form of liquids, heavy metal compounds, inorganic acids, drops in the form of aerosols), which are deposited on the outer surfaces of buildings. Pollutants, including contamination of biological origin, in the presence of precipitation, in terms of an additional exposure variable temperature attacking buildings and constructions in the process of construction and operation, compromising the aesthetic appearance of buildings and contributing to premature failure of the material constructions [5, 6].

Algae are autotrophic organisms, the first to appear on the surface of building materials and, sometimes developing in large numbers, give rise to different food chains. Formed biocenosis, the dominant species which are algae that determine the possible existence of other autotrophic and heterotrophic organisms, namely bacteria and lithotrophic micromycetes would accelerate biodamages largely through the provision of aggressive compounds in the process of metabolism [7].

Mass development of microscopic algae is often green or red blooms, soil, snow, rocks, tree bark, house walls, which is accompanied by deterioration in the quality and decrease the durability of building structures [1, 8]. As a result of the increased level of humidity in the dense urban areas in the urban environment, the frequent absence of guttering, hydrophilic materials used, there is considerable amount of moisture condensation on the surfaces of structures [7, 8], which contributes primarily move their algae.

Despite the fact, that the study of colonization buildings by algae there was always taken into account the impact of the quality of environment element for this process to date identifying features algocenosis surfaces of buildings and structures in the open atmosphere of the various functional areas populated localities received little attention. However, due to the increasing level of anthropogenic stress in modern cities, the problems associated with the biodegradation of urban development are becoming more relevant.

The purpose of the study. Reveal the presence of algae on the damaged surface of urban buildings functional areas of a large city (for example, the city of Belgorod) in situations of different levels of anthropogenic loads. Perform identification and study the composition algocenosis biodeterioration of building materials. Establish the influence of anthropogenic environmental factors on species composition and biodegradation process algocenosis surfaces.

Object of study in this paper were the city buildings, samples of materials damaged surfaces of building, as well as model samples of cement-sand concrete. Heat and humidity characteristics of the medium was determined by aspiration wet-and-dry-bulb thermometer, the amount of solid pollutants (dust) in the atmosphere through their rate of deposition, the concentration of heavy metals by atomic absorption analysis of solid plant material, assessment of air quality obtained using the method lichenoides indication.

Samples of building materials with traces source of biofouling were mixed and pure cultures of algae in various mineral nutrient media for algae cultivation and by flushing lyuminostat in [5, 6, 7]. Identified culture microscopic methods using determinants algae. Pure cultures were obtained by dilution followed by culturing on solid nutrient media.

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The main part. A survey of buildings and structures of various areas of the city for the presence of traces of visual colonization surfaces algae showed that these phototrophic organisms colonize both brick and concrete for public or plastered surfaces (Fig. 1).

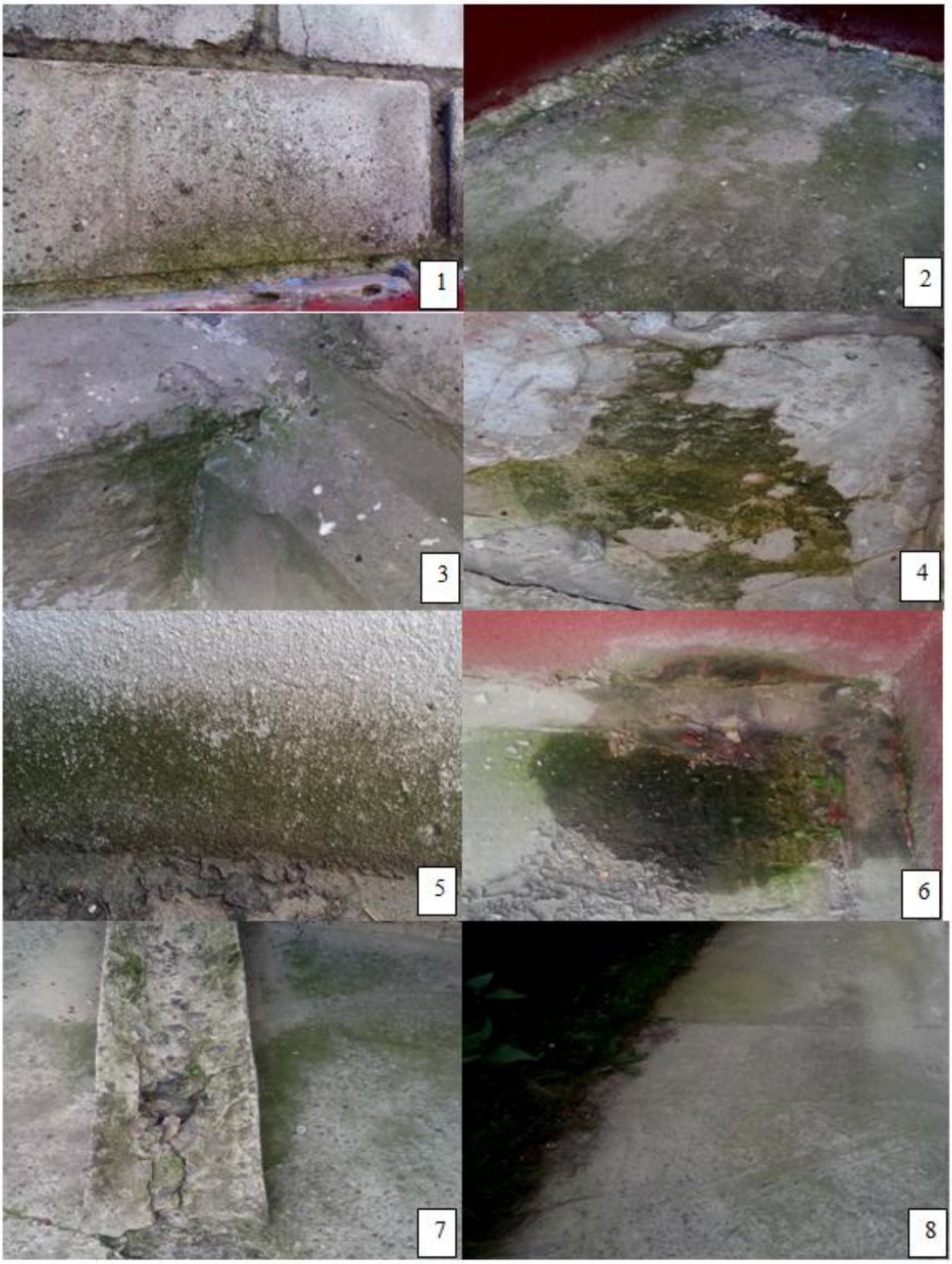

Figure 1: Colonization by algae urban area foundations of buildings:

1 – brick; 2 - concreted tides along the facades of buildings; 3, 4 – concrete; 5, 6 - plastered surface); 7 – drainage; 8 - concreted walkways

Among the abiotic factors influencing the growth of algae on the surfaces of materials there are temperature, light, humidity, porosity, surface roughness of construction materials [9].

Limiting factor in the process of "greening" of building products is humidity, all other listed factors directly or indirectly affect its level. Light intensity not only determines the possibility of photosynthetic organisms, but also affects the temperature of the surface and then to the evaporation rate [10], with the height of the building increases the impact of wind on the process. Probably so, we observed localized areas of development of algae, usually at the height of the lower floors, often on the foundations of buildings, aprons ebbs, sidewalks (Fig. 1). Groundwater at high horizons and rain spray, containing besides nutrients also promote wetting of materials and designs, getting them on a bad or defective insulation of foundations and continue climbing up the walls.

Porosity and heterogeneity (roughness of the material or mechanical damage) surface (Fig. 1-3, 1-5), the presence of horizontal space structures (Fig. 1, 2, 1-7, 1-8), contribute to a longer retention of moisture and how consequence of the intensive development of algae.

Use of air conditioning in modern residential area made its negative contribution to the maintenance of humidity areas located directly under the projecting part of the installation, and which collects the condensate when the unit is that even when dry weather helps to preserve moisture and intensive growth of algae (Fig.1 - 6).

As for the " visual " surface contamination of building products, then, as a rule, it was associated with staining latest in green and greenish algae photosynthetic pigments (Fig. 1, 1 - 2, 1 - 7, 1 -8) or (and) to yellow brownish shades of degradation products of chlorophyll and phycobiliproteins (Fig.1 -4) [11].

Ecosystem surface buildings and structures of the urban environment represents an autonomous complex, which acts biotope construction material presented biocenosis, primarily microorganisms, the environment is characterized by microclimatic changes, primarily due to occur during industrialization and urbanization, pollution [12].

In order to identify the level of anthropogenic stress in the various functional areas of a particular city there were conducted heat and humidity researches of environment, to determine the concentration of major pollutants urban atmosphere.

Heat and humidity characteristics of the study sites showed a tendency of increase in temperature is not only compared to the suburban area (on 1,0-1,5 ^{0} C), but also when moving from a recreational residential zone through to industrial and roadside areas when the temperature increased at each stage to 0,15-0,20 ^{0} C, which is associated with "hot" stationary industrial sources of emissions and exhaust emissions of vehicles. Humidity within the city limits ranged from 79-84 %.

Taking into account that the most common industries in the construction industry is an enterprise with powerful emissions of inorganic dust, assessed the level of particulate air pollution in different parts of the city on the rate of deposition of dust.

According to the study of industrial dust deposition rate on the territory of enterprises was the highest and reached 1.358 g/ (m^2·day) (Table 1). Dust levels near roads was at least an order of magnitude smaller and amounted to 0.123 g/ (m^2 · day), which is probably associated with quality pavement urban highways and regular sanitary cleaning at mainline territories, reducing the probability of accumulation of road dust. The intensity of dust accumulation in residential urban areas was 7-10 times higher than in suburban single-story building and recreational area, respectively.

In a dense housing wind speed and as a result, dispersion of emissions reduced, the frequency of fog in the air due to the presence of condensation nuclei in the form of dust particles (in our case, cement, lime, chalk) increases by more than 30%. Last promotes long-term preservation of surface moisture buildings, adding to wet processes, settling algae, and later heterotrophic organisms, joint activity which often leads to mechanical failure of finishing, facade layers and even the supporting structures.

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High concentration of cement dust in the air led to alkalizing rainwater and meltwater from the industrial site of the city (pH = 9.89 and pH = 6.24 in the control area). Use anti-icing agents on pavements caused salinity meltwater roadside sites (chloride content - 298.20 mg / L and 6.96 mg / L in the control). When spraying a water moving vehicles observed crystallization of salts on the outer surface of the foundations.

Table 1: Some indicators of anthropogenic stress in the city

#	Urban areas	Speed deposition of dust, g/ (m^2 day)	pH	Heavy metals				Degree of pollution air
				Cu	Zn	Pb	Cd	
1.	At mainline territory	0,123	7,31	27,52	132,75	46,41	0,56	Strong pollution
2.	Industrial enterprise	1,358	9,89	16,01	139,4	35,54	0,61	Strong pollution
3.	Suburban one-storey residential buildings	0,004	6,45	13,62	28,31	11,42	0,13	Moderate pollution
4.	Multistory construction residential areas	0,029	6,82	15,32	32,28	13,75	0,23	Relative pollution
5.	Country recreation area	0,002	6,24	5,08	26,12	4,11	0,08	Fresh air

The most dangerous pollutants of urban ecosystems are considered heavy metals, which are a source of both industrial emissions and urban vehicles. The outer part of the bark (crust) is a barrier-free accumulative phytometer which allows year-round to study the degree of air pollution, as the greatest amount of pollutants, particularly metals from the atmosphere is concentrated in this part of the trees.

Derived from the analysis of this material indicative data exist that halos pollution lead, zinc, copper and cadmium accompany highways, as well as the industrial area of the city. The content of heavy metals near roadways 5-12 times higher than the concentration of metals in the control point (suburban recreation area). This is due to wear IU metallic parts and tire treads, the exhaust gases of vehicles, as well as with technological gas emissions of industrial enterprises.

Generalized environmental assessment of air quality in the urban environment has been given the results of bioassay method lichenoides indication territories. Accounting coverage of tree trunks and lichen species diversity has allowed them to evaluate the qualitative state of the environment as "very dirty" along city roads and in the industrial zone, "moderately polluted" in the residential multi-storey building, "relatively polluted" in the one-storey residential development, while outside city limits occurred "clean air".

Thus, the level of anthropogenic load on the city varies depending on the functional planning zones, and most tense situation persists in the areas of industrial zones and along city roads. The presence of "spots" of algae in different sizes, color, frequency of occurrence on buildings and structures found in all of the observed field. Features detected algocenosis determined under laboratory studies using swabs from the surface of reclaimed building materials and algae chips damaged areas.

As part of washouts during cultivation on nutrient media were identified by four departments: green (Chlorophyta), yellow-green (Xanthophyta), blue-green (Cyanophyta) and diatoms (Bacillariophyta) [1, 8], but the species diversity of surface algocenoses in the studied areas varied depending on their functional purpose or, as mentioned above, the level of anthropogenic load.

The presence of representatives of all four divisions of algae on morphological structure sufficiently diverse (filamentous, colonial, single cells), with the greatest species diversity (total number of species more than 10) was observed only in the samples of material from the suburban areas of private buildings and suburban recreational area.

Only in these cases revealed the presence of some representatives of the yellow-green algae, which are indicator species and the first "fall" of algal groups for any of the types of anthropogenic impacts.

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As for the dominant species, in this case we can speak about equally presence organisms listed with a slight predominance of blue-green and diatoms (Fig. 2).

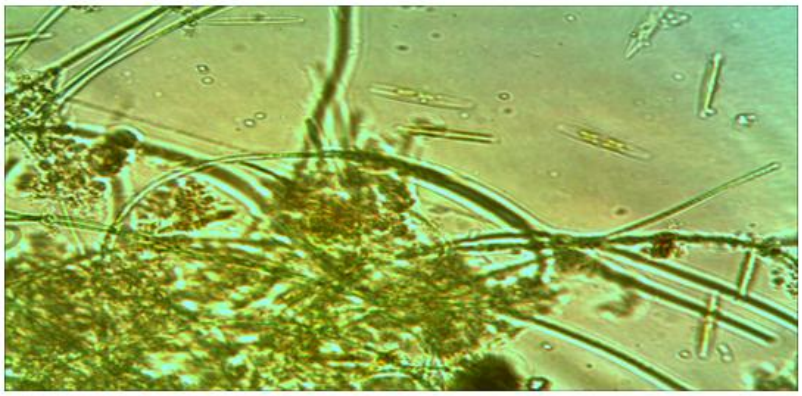

Figure 2: Algocenosis surface structures suburban private housing and suburban recreational area

The most important devices of blue-green algae is the mucus around the cell, which is the exopolysaccharides. Mucus vaginal mucous colonies and filamentous forms are a good protective shell that protects the cells from drying out and at the same time acting as a filter that removes harmful outside influences [12, 13]. In consideration of problems within the mucus cells provides an effective fastening on the surfaces of building materials. That is why the blue-green algae in one form or another is met in all variants.

Blue-green algae were mostly presented such Chloroococcales and Oscillatoriales. First of all, there were noted the presence of mucous cells colonies randomly arranged spherical genus Microcystis, as well as spherical, at least - some kind of ellipsoidal forms Gloeocapsa. As it is known, the latter are characterized by high resistance to temperature change of the environment, breeding in large quantities at low temperatures even "disappearing" in the crevices of building materials [8, 14]. Also unicellular blue-green algae in places "greening" surfaces of building structures are detected and filamentous blue-green algae. More over, the representatives of two kinds of Oscillatoriales were: Oscillatoria and Phormidium.

In washings with landscaped surfaces, the presence of diatoms belonging to the order Naviculales, leave Pinnularia, Nitzschia and Navicula was revealed.

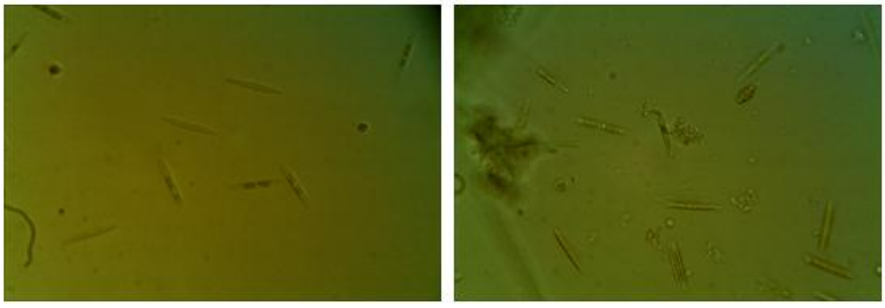

Figure 3: Diatoms: Pinnularia sp., Navicula sp., Nitzschia sp.

For "wall" algocenosis buildings along the city roads was characterized by the lowest species diversity (no more than five species of blue-green and green algae). Here, not only revealed the presence of representatives of the yellow - green and diatoms (Fig. 4 - 1), but even green algae were represented only by single-celled individuals Pleurococcus sp. (Fig. 4-2). Most sensitive to drying of diatomaceous algae exhibit. Maybe that's why as part of algocenosis this territory, where, as mentioned above, recorded the highest temperature of the urban environment, which leads to intense evaporation of moisture, no representatives of Bacillariophyta.

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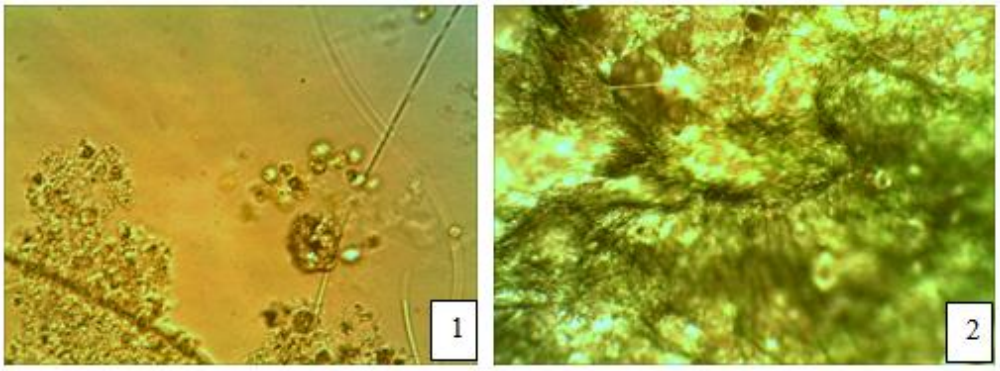

Figure 4: Algocenosis surface structures located along urban roads:
1 - general view, 2 - cluster of cells Pleurococcus sp.

In the industrial area, where the total number of species equal to the average of seven, noted the appearance of diatoms, especially the most adapted to living in conditions of anthropogenic stress Navicula sp. Among detected here filamentous green algae dominated by representatives of some kind Ulotrichales Chlorhormidium (Fig. 5-1). These algae under adverse conditions, in this case, industrial sites, can form spores (Fig. 5-2), or reduce the amount of cytoplasm, which leads to fragmentation of the filaments to small pieces (Fig. 5-3). The observed decrease in the volume of cytoplasm and, as a result, increase in the concentration of dissolved substances can be regarded as a potential mechanism of adaptation to environmental conditions changing - providing algae survival in urban ecosystems.

In addition, on surfaces of building structures found unicellular green algae including Chlorella sp., Scenedesmus sp., Pleurococcus sp., Stichococcus sp. etc.

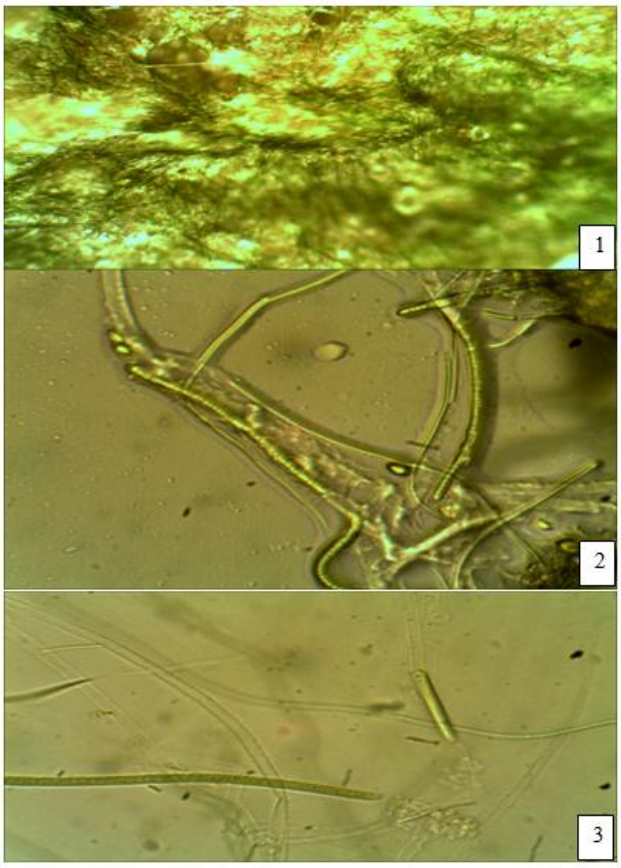

Figure 5: Filamentous algae Chlorhormidium sp. in algocenosis industrial areas of the city.
1 - algae on the surface of the basement, 2 - education aplanospor when drying, 3 - fragmentation of filaments

It is important to note that among the blue-green algae, mastered almost the entire city, met amazing views, combining photosynthesis ability to fix atmospheric nitrogen, which increases their relative nutritional independence and enables the first to colonize the lifeless surface of building materials and construction, to create conditions for further development other organisms (bacteria, fungi, mosses, lichens, etc.) in need of inorganic and organic sources of nitrogen.

Received selective culture of green and blue-green algae used for laboratory study of the process of biofouling surface of concrete samples in liquid media the optimal composition.

It is known that algae can influence the concrete matrix products of metabolism, leaching out of it some of the necessary elements for life [14, 15]. Therefore, to determine the orientation of the chemical processes in the system "Algocenosis - concrete" recorded changes in the chemical and phase (mineralogical) composition of the surface layer of products.

The results of the determination of the main chemical elements in terms of the ions to the surface layer of concrete samples after two months aging in algal culture medium and in parallel in tap water (control) are shown in Table 2.

Table 2: The chemical composition of the surface layer of the concrete samples, wt. %
(data given to 100%)

Ion	Environment	
	water without algae (control)	nutrient medium with algae
Ca^{2+}	51,03	45,51
Si^{4+}	33,43	37,48
SO_4^{2-}	5,231	3,729
Al^{3+}	4,159	4,994
Fe^{3+}+Fe^{2+}	3,139	3,887
Mg^{2+}	1,166	1,232
K^{+}	1,146	1,889
Na^{+}	0,2517	0,3859
Mn^{2+}	0,0939	0,1050
Zn^{2+}	0,0377	0,0338
PO_4^{3-}	0,3156	0,7563

The table shows that during the development of green and blue-green algae from the surface of concrete samples in most leached ions Ca^{2+} and SO_4^{2-}. Increased calcium loss associated with algae release acidic metabolites: CO_2 (due to the "dark" breathing algae) and organic acids. Highlighting these metabolites, algae normalize blood pH, which contributes to their further penetration deep into the concrete.

However, also other ions are washed out, but the efficiency is hidden due to the use of relative units (% by weight). Therefore, the efficiency of the leaching of ions of each species under cultivation in-algae with respect to water was estimated by the parameter F:

$$F = 1 - \frac{m_1}{m_0},$$

where m_0 - mass of the ions i-th species remaining in the concrete after leaching with water, m_1 - mass of the ions i-th species remaining in the concrete after the cultivation of algae. It should be noted that the numerical values of F are conventional and are used only to compare the effectiveness of the leaching of ions with respect to each other. F parameter dependence on the type of ion is shown in Fig. 6.

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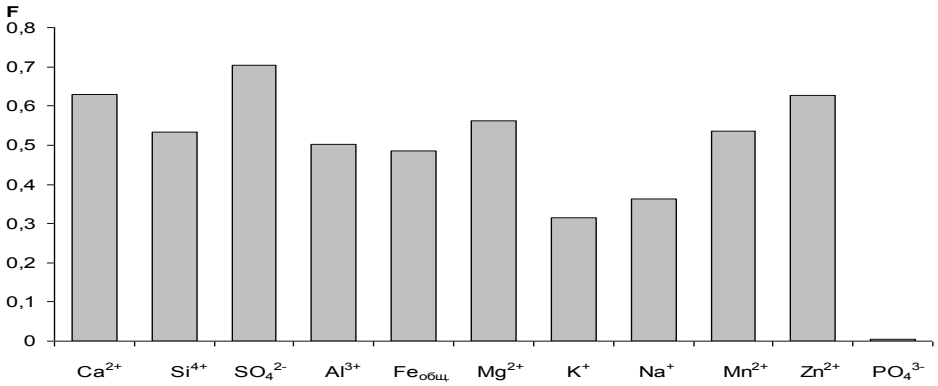

Figure 6: Evaluating the effectiveness of ion leaching during cultivation of algae

According to Fig. 6 algocenosis facilitates leaching of ions from the concrete except for most phosphate ions, which are strongly retained material. Loss of concrete rather significant amount of sulfate ions rather explained decreasing Ca^{2+} concentration due to the binding of CO_2 and elution of Na^{+} and K^{+}, to facilitate translation sulfates soluble state. Celebrated rather strong leaching of silicate ions, which should contribute to the development of diatoms. Thus, algocenosis green and blue-green algae in addition, significantly changes the composition of the surface layer of concrete, mineral also forms a favorable environment for the other microorganisms.

Fig. 7 shows the diffraction patterns of the surface of the three test samples: aged in tap water and two nutrient media - among Drew (Drew) and Chu-10 medium (Chu-10).

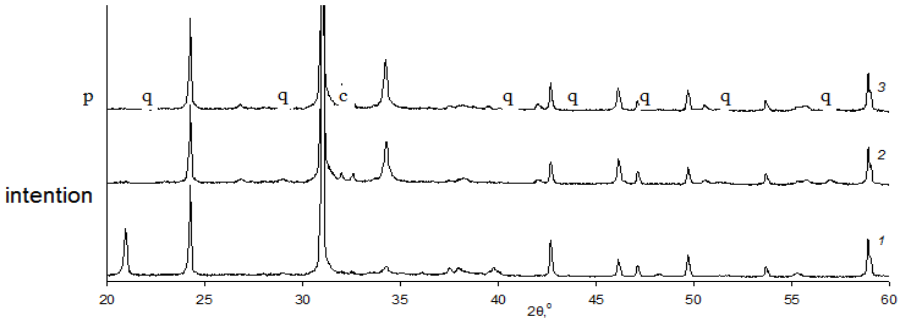

Figure 7: Diffractograms of the surface layer of concrete samples

1 - in water, 2 - after cultivation of green algae in the medium Chu-10, 3 - after cultivation of blue-green algae in the medium Drew, p - the peak of portlandite with - the peak of calcite,
q - quartz peaks

The experimental results are shown in Fig. 7, confirm a transition Ca (OH) 2 in the presence of CaCO3 on the surface of the concrete algae. Also this process, metabolites residual algae accelerate hydration of the clinker minerals (Ca3SiO5, Ca2SiO4) hydrosilicates into crystalline, as evidenced by the calculation of concentrations of crystalline phases (Table 3) formed by modeling powder diffractograms.

Table 3: Evaluation of the phase composition of samples, %

Mineral	Condition of the experiment		
	water	nutrient medium Chu-10	Nutrient medium Drew
Quartz (SiO_2)	57,5	65,6	65,2
Portlandite ($Ca(OH)_2$)	32,9	-	-
Calcite ($CaCO_3$)	4,9	26,7	30,5
Hatrurite (Ca_3SiO_5)	1,6	-	-
Larnite (Ca_2SiO_4)	1,6	0,7	-
Scawtite ($Ca_7(Si_6O_{18})CO_3 \cdot 2H_2O$)	-	5,8	-
Gismondine ($CaAl_2Si_2O_8 \cdot 4H_2O$)	1,5	1,2	4,3

Accumulation of calcite on the concrete surface in the environment of algae observed on microscopic examination of changes in the samples (Fig. 8), confirming the previously noted fact of carbonates on concrete surfaces populated algal organisms [14, 16], to create optimal conditions for the development of other representatives algocenosis, in particular bacteria and protozoa.

Figure 8: Calcite crystals on the surface of the concrete samples after culturing in a nutrient medium Chu-10

Found that after 60 days the strength of the samples is maintained in the medium of green and blue-green algae hardly decreased, weight increased, in some cases, sometimes by 10%, mainly due to calcium leaching process of concrete to form on the surface calcite. In an environment with a predominance of diatoms, which are characterized by the presence of rigid silicate shell mass samples also increased somewhat, and increased strength (pores and microcracks " hammered " calcite and hydration products of residual clinker minerals).

However, the visual monitoring of the concrete surfaces, populated by algae in the real environment indicative about progressing violation of their integrity (Fig. 1).

Undoubtedly, in the urban environment of building products surface attacks the whole complex organisms and destruction, in particular concrete is sufficiently rapidly with favorable conditions for emerging agents with predominant aggressive type of exposure (chemolithotrophic bacteria and fungi are). These agents are able to leach mineral matrix with consequent weakening of the binding of the building complex.

CONCLUSION

The study confirmed the fact that the development of biocenosis on the surface of buildings and structures determined by a combination of environmental factors and climatic conditions, taking into account the mechanical and physico-chemical characteristics of construction products [17, 18].

Surface irregularities of building materials, the horizontal position of structures, vertical surface at the base of the foundations of the building, where a significant contribution of capillary soil water splashing and surface transport wastewater availability moist areas in places vanishing on the facade of rainwater drainage systems, air conditioners determine places the greatest development of algae.

One of the factors governing the settlement process and the further destruction of the surface material is algae pH alkaline values which are characteristic of cementitious products, film-coated carbonates, which explains the emergence of a favorable situation for the development of algae on concrete surfaces. Level of urban pollution, defined by the presence of gaseous and particulate components of vehicle emissions and industrial enterprises, using anti-icing agents, the presence of unauthorized landfills creates various anthropogenic pressures in the functional areas of the city. In the process of studying the influence of environmental factors on the characteristics of the urban environment algocenoses a correlation between the level of anthropogenic pressures and the degree of species diversity of algae inhabiting the surface buildings.

Biofouling process modeling concrete algae in the laboratory allowed to show the impact of the latter on the building material, accompanied by changes in the chemical and mineralogical composition of the surface samples.

Effect algae processes biodamages building constructions due to the fact that these organisms belonging to phototrophs and standing at the beginning of the food chain, initiate new microbial growth (in which the yeast composition, bacteria, microscopic fungi), providing a habitat organic and inorganic nutrients (lysis of algal cells and atmospheric pollutants), firmly held on the surface in the thickness of the film exopolysaccharides allocated to these organisms, as well as reducing the alkalinity of the medium. Consequence there is an intense close-microbocenosis tampering and destruction of building materials.

Algocenosis of biodegradation surfaces of urban buildings of different functional areas are characterized by considerable diversity of species- variety (with a predominance of resistant species - Phormidium sp., Chlorhormidium sp., Navicula sp.). Most of them (in all four divisions of algae) are observed in conditions of minimal anthropogenic impact suburban neighborhoods and recreational areas.

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REFERENCES

[1] Cuzman, O. A., Tiano P., Ventura S. and Frediani P., 2011. Biodiversity on Stone Artifacts: The Importance of Biological Interactions in the Study of Biodiversity, Ed., Dr. Jordi LÃpez-Pujol. Date Views 24.06.2014 http://cdn.intechopen.com/pdfs-wm/20152.pdf, pp.367-390.

[2] Ecological improvement of inhabited territories of the large cities of Russia. Eds., Kapustin A.A., Hvatova V.F. In the Proceedings of a scientific and practical seminar of the 2007 VII International ecological forum, St. Petersburg, MANEB publishing house, pp: 152.

[3] Savin, A.V., V.S. Lesovik , N.I. Alfimova, 2013. To a problem of corrosion resistance of reinforced concrete. Bulletin of BSTU named after V.G. Shukhov, 2: 7-12.

[4] Baydin, O. V., 2012. To a question of formation of cracks in reinforced concrete damaged by corrosion. Bulletin of BSTU named after V.G. Shukhov, 4: 20-24.

[5] Vasilenko, M.I., E.N. Goncharova, 2013. Microbiological features of process of damage of concrete surfaces. Basic researches, 4 (4): 886-891.

[6] Goncharova, E.N., V.A. Yurchenko, E.V. Brigada and Yu.V. Chaplina, 2003. Activators of microbiological corrosion of concrete. Ecology and industry of Russia, 3: 22-24.

[7] Künzel, H., H.M. Künzel, K. Sedlbauer, 2006. Long-term performance of external thermalinsulation systems. Architectura 5 (1): 11-24.

[8] Goncharova, E.N., M.I. Vasilenko, 2013. Algotsenoza of the damaged city buildings and constructions. Basic researches, 8 (1): 85-89.

[9] Cutler, N.A., H.A.Viles, S.Ahmad, St. McCabe and B.J. Smith, 2013. Algal 'greening' and the conservation of stone heritage structures. Science of the Total Environment, 442: 152–164.

[10] Smith, B.J., S. McCabe, D. McAllister, C. Adamson, H.A. Viles and J.M. Curran, 2010. A commentary on climate change, stone decay dynamics and the 'greening' of natural stone buildings: new perspectives on 'deep wetting'. Environ. Earth Sci., 63: 691–700.

[11] Warscheid, Th., J. Braams, 2000. Biodeterioration of stone: a review. International Biodeterioration and Biodegradation, 46 (4): 343-368.

[12] Levequê, C., 2003. Ecology – from ecosystem to biosphere. Science Publishers, Enfield, NH, USA: pp.85-200.

[13] De Belie, N., 2010. Microorganisms versus stony materials: a love–hate Relationship. Materials and Structures, 43: 1191–1202.

[14] Sand W., 2001. Microbial corrosion and its inhibition. Biotechnology, 10, Wiley-VCH Verlag GmbH, Weinheim, Germany: pp. 183–190.

[15] Jayakumar, S., R. Saravanane, 2010. Biodeterioration of Coastal Concrete Structures by Marine Green Algae. International Journal of Civil Engineerng, 8 (4): 352-361.

[16] Bertron, A., G. Escadeillas and J. Duchesne, 2004. Cement paste alteration by liquid manure organic acids: Chemical and mineralogical characterization. Cement and Concrete Research, 34 (10): 1823-1835.
[17] Caneva, G., 2010. Cultural landscapes and climate change, In Climate change and cultural heritage: Edipuglia, pp: 181-192.
[18] Roeselers, G., M.C.M. van Loosdrecht, and G. Muyzer, 2007. Heterotrophic pioneers facilitate phototrophic biofilm development. Microbial Ecology, 54 (4): 578-585.