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Disinfectants based on polyhexamethylene guanidine for use in underground space

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This paper presents the results of a comparative analysis of preparations used for reducing the risk associated with biological agents, which may cause diseases in humans, as well as biological destruction of materials and biofouling of different equipment. In course of selecting disinfectants it is possible and necessary to combine such actual requirements as high level of ecological compatibility and economical feasibility. Preparations on the basis of PHMG completely comply with these requirements. Therein domestic preparations, that do not concede by quality to foreign ones, are proposed for users in convenient forms and concentrations. Their application in underground spaces permits to reduce risk to health of underground workers and to prevent biodeterioration of working zone.

Keywords: biological agents, disinfectants, working area, risk of biofouling.

Development of underground spaces has a long history, presenting a solution to a number of problems of urbanized territories, to development of their industry, transport and supply infrastructure. Beginning from prehistoric caves and catacombs till recent time, human beings proceed their expansion underground, encompassing ever-greater number of people, subjected in varying degree to influence of underground environment factors of physical, chemical and biological nature.

It is necessary to understand the whole complex of biological agents (including macro- and microorganisms), products of their metabolism, as well as the products of biological synthesis, which, impacting on human organism and environment, exert negative influence. For development of diseases, caused by biological agents activity, the following conditions are necessary: pathogenic or potentially pathogenic causative agent or its de-

rivatives (products and forms of vital activities), friendly environment and susceptible organism — a human being with immunodeficiency status [1; 2].

Because of the fact that scope of the people, affected by underground biological factors, continuously widen, it appears important to evaluate risk of possible health deterioration for further planning of measures, directed at it reduction down to its elimination.

Risk evaluation procedure of biological factors impact, regardless of its nature, shall be carried out wholistically, including the following stages:

- determination with account of certain underground objects presence of dangerous biological agents, potentially susceptible persons, favorable conditions for diseases appearance;
- revealing reasons which may contribute to appearance and spread of biological agents;
- inspecting and studying health condition of persons contacting with a biological agent, including modeling with constructing mathematical model on the basis of epidemiological and microbiological data;
- separation and risk levels gradation of biological factor impact.

Planning and implementation of the measures directed on controlling risk associated with pathogenic conditions initiation and progression may become a final stage of biological factor impact risk estimate. Thereby it is necessary to consider, that biological factor of underground environment has a number of distinctive features. First of all, it is high concentration and multiform composition of micromycete species (yeasts and moulds) and cryptogamic forms of bacteria. The following feature is coexistence of biological agents in the form of communities or biofilms, hampering identification and selection of means for their liquidation. Upcoming of biological factors from natural focuses of underground environment also hampers combating them. It is necessary to consider all that in developing and applying tactics of biological factors impact liquidation and prevention, giving preference to methods and means with high efficiency and ecological compatibility. Economic feasibility of the proposed means is rather actual characteristic. In the given work we concentrate our attention on these characteristics of modern the domestic and foreign means.

The most effective and common approach in reduction of risk, associated with biological agents, causing diseases in people, biodestruction of materials and biofouling of equipment, is biocidal means application.

At domestic market till now phenolic preparations were used, as well as disinfecting agents with available chlorine, peroxide compounds, which are rather toxic and exert sensibilizing, irritating skin and mucous coats impact. Besides, these means may exert corrosive and destructive impact on processed materials; they possess sharp odor and provide low activity in respect of a number of biological agents, for example, to mold fungi and cryptogamic bacteria forms. May be the only reason for application these preparations are their low price.

In this case biocidal disinfectants may be called preparations of choice; they were developed on the basis of polyhexamethyleneguanidine (PHMG), derivative of guanidine, mainly used in the form of its salts — polyhexamethyleneguanidine phosphate (PHMG-Ph) or polyhexamethyleneguanidine hydrochloride (PHMG-HCh). Results of performed investigations showed, that PHMG demonstrates antibacterial and antifungal activity, as

well as it is effective against biofilms and possesses detergent, rust-preventing and flocculant properties [3].

Biocidal PHMG action is stipulated by effective sorption of biocidal polycation by phospholipid cell membranes of microorganisms, possessing negative charge; biocidal polication destruct cellular membrane, inhibit exchange function of ferments, disorders reproduction ability of nucleic acids and proteins Such an impact together with cell walls destruction results to death of respective microorganisms. By its physical properties PHMG agents are convenient in application: they are solid, very soluble in water substances, stable and safe in storing (storage life 15 years), colorless and odorless. They are also safe in respect to ecology: falling at the bottom of water body, they, under the influence of activated sludge, decompose to simple, non-toxic substances without any mutagenic and cancerogenic action [4].

PHMG preparations have a long storage life without loss of biocidal activity; after solution desiccation they form at processing surfaces thin polymeric film, ensuring for a long time surface asepticity. Providing high biocidal effect towards many microorganisms, PHMG salts belong to the IV class (low-hazardous substances) for skin penetration into organism and to the III class (mederatly-hazardous substances) for through the stomach penetration. Low PHMG toxicity for endothermic organisms is stipulated by their enzyme systems, capable to metabolize these polymers[1].

Comparative characteristic of common preparations, presented in Table 1, permits to make mostly optimal choice of means for reduction negative impact of biological factors in underground space.

Russian preparations, presented in Table 1, — biopag and phosphopag — belong to PHMG disinfectants and characterized by high efficiency also in respect to viruses. Low toxicity enables to apply them in the presence of people in processed premises. So, preparation biopag is recommended for disinfecting surfaces in premises (floor, walls, doors, windowsills), rigid furniture, sanitary ware in medical preventive institutions, childcare institutions, at communal facilities, hotels, public catering establishments and for use to disinfect railway transport and underground railway.

It is necessary to underline, that risk control of pathological states, associated with biological factors is possible to provide at initial stages of construction and operating of buildings, at their repair and reconstruction. Especial interest presents construction materials, which contain biocidal preparations. For example, biocidal paints of "Biocrapag" series were developed, which contain such preparations as biopag and phosphopag as anti-microbial components. Table 2 presents results of biocidal paints ("Biocrapag" series) testing. Industrial tests of biocidal paints demonstrated, that their application provide high level of sanitary and hygienic protection during prolonged timeperiod[2].

One of essential restrictions of PHMG application, especially of foreign production, is its high price. But Russian preparations biopag and phosphopag by their characteristics are not inferior to foreign means and considerably cheaper, that make them preparations of choice, recommended for biological factors negative impact reduction in underground space development and use.

[1] Hygienic conclusions on the use of preparations for water purification and disinfection: Biopag — no. 77.99.4.515.П. 10909.5.00 from 03.05.2000, Phosphopag — no. 77.99.4.515.П. 10910.5.00 from 03.05.2000, Ceopag — no. 77.99.4.515.П. 10908.5.00 from 03.05.2000.

[2] Instructions no. 1/07, no. 2/09 on the use of the disinfectant "Biomag-D".

Table 1. **Comparative characteristic of prevailing biocidal means**

Main properties and indices	Chloramine (Russia)	Septabic (Israel)	Biopag (Russia)	Phosphopag (Russia)	Chlorhexidine (England)
Activity towards: cryptogamous forms of bacteria	Moderate	Active	Active	Active	Active
Green algae	Moderate	Active	Active	Active	Active
Fungi	Moderate	High	Moderate	Moderate	Moderate
Toxicity	Toxic	Moderately toxic	Low toxic	Low toxic	Low toxic
Irritant action on skin and mucous membrane	Expressed	Moderate	Absent	Absent	Absent
Odor	Expressed pungent	Absent	Absent	Absent	Absent
Corrosive action	Expressed	Absent	Absent	Absent	Absent
Detergents	Absent	Expressed	Expressed	Expressed	Expressed
Interaction with surfaces and tissues	Decolourize, leave traces, spots	Leave traces, spots	Absent	Absent	Absent
Flow rate of process solution per 1 m^2 (ml)	200–300	150–200	100–200	100–200	200–300
Cost of 1 m^2 surface processing (conventional units)	0.003	0.45	0.023	0.038	1.5

Table 2. **Rate of test-microorganisms inactivation at painted surfaces, %**

Paint	Kind of test-microorganism			
	Bacteria E. coli	Viruses (Colipag MS-2)	Fungi (Penicillium chrysogenum)	Spores (Bacillus cereus)
Biocrapag-1 (oily)	100 % / 10 minutes	100 % / 10 minutes	95 % / 30 minutes	86 % / 3 minutes
Biocrapag-2 (pentaphtol)	100 % / 10 minutes	100 % / 24 minutes	89 % / 30 minutes	86 % / 3 minutes
Biocrapag-3 (nitrocellulose)	100 % / 3 minutes	95 % / 3 minutes	No data	No data
Biocrapag-4 (water emulsion)	100 % / 30 minutes	100 % / 60 minutes	96 % / 24 minutes	No data

Ever more new disinfectants appeared at the market in last decades. One of the reasons to look for new active fractions is stipulated by continuously changing microbal background, having adapted to conventional disinfectants. And finally, rather actual and not the least requirement is environmental safety of disinfectants. It is necessary to underline, thay environmental safety is tightly coupled with the other properties: rust-prevention, maintenance of efficiency during storage, ability to use forms with high concentration, universality of application. Leading positions among such means is occupied by preparations on the basis of PHMG.

Preparations on the basis of PHMG possess a wide spectra of biocidal action in respect to bacteria, yeast and mold fungi, viruses. Dynamics of test-microorganisms inactivation by disinfectant "Biopag-D" presented at Table 3. Investigations, performed at specialized establishments (Institute of Disinfectology of Russian Federation Public Health Ministry, Institute of Microbiology and Epidemiology named after N. F. Gamalei, Institute of Microbiological Problems, Moscow State University of Applied Biotechnology, Institute of Tuberculosis of Midical science Academy, Institute of Balneotherapeutics of Russian Federation Public Health Ministry, Institute of Biophysics of Russian Federation Public Health Ministry), showed that they are not inferior to the best domestic and foreign preparations, particularly to quaternary ammonium compounds and chlorhexidine, and by some indices (for example, action on pseudomonal infection, microbacteria of tuberculosis, viruses, legionellosis) exceed the last[3].

Unique property of these disinfective preparations is their stability and prolonged antimicrobial action, which is stipulated by polymeric nature of preparations and their ability to form thin biocidal film at prtected surface. While action of conventional easily volatile disinfecting agents maintain for several hours (maximum for several days), preparations on the basis of PHMG provide prolonged antimicrobial action, which maintain from several weeks to several months. They also distinguished by environmental safety belonging to the IV class (low-hazardous substances) for skin penetration into organism and to the III class (moderately hazardous substances) for through-the-stomach penetration. Low PHMG toxicity for endothermic organisms, if compared with its direct low-molecular analogue, chlorhexidine bigluconate, is stipulated by its enzyme systems, capable to metabolize these polymers. In doses, recommended for disinfection purposes, the preparations do not cause allergies, do not exert sensibilizing action, do not accumulate in organism, do not give long-term effects[3].

Interaction of biological contaminants with disinfectants depends not only on preparation structure and degree of microorganisms stability, but on biocidal effect expressivity as well. At the same time, important meaning gains amount of the substance coming into interaction with microbial cell and period of its impact. Interaction of chemical agent with microbial cell takes place in a particular environment, which may be gaseous, liquid, viscous and dense. Thereby concentrations of process solutions may vary depending on particular target object.

Recently, majority of new disinfecting agents are registered and produced in the form of concentrated liquids. Concentration of active fraction in case of disinfectants of PHMG group should not exceed 20 %. However, liquid concentrated agents require special storage and transportation conditions. Development of non-conventional solid forms of preparations (in granules and tablets, containing safe solid concentrates of disinfectants) may consider a solution of this problem. High biocidal activity, ecological

[3] Hygienic conclusions on the use of preparations for water purification and disinfection: Biopag — no. 77.99.4.515.P.10909.5.00 dated 03.05.2000, Phosphopag — no. 77.99.4.515.P.10910.5.00 dated 03.05.2000, Ceopag — no. 77.99.4.515.P.10908.5.00 dated 03.05.2000. Instructions no. 1/07, no. 2/09 on the use of the disinfectant "Biomag-D". See: *Kopytenkova O. I., Shilova E. A., Sazonova A. M.* Certificate of state registration of the program for EVM no. 2015617486 Russia Federation. Determination of the microbial number of air in the working area of underground facilities: no. 2015614450: application 28.05.2015; published 13.07.2015; applicant — Federal State-Funded Educational Institution of higher professional education "Emperor Alexander I Saint Petersburg State Transport University".

compatibility, safe transportation and storage, high accuracy of dosing, excluding mistakes in process solution preparation are unquestionable advantages of these forms [5].

Among tableted preparations on the basis of PHMG the best known at domestic market is "Neotabs" with maximal concentration by active fraction 52 % (manufacturer — Research and Production Company "Genics"). Just like liquid agents of PHMG group, "Neotabs" is active in respect of aerobic and anaerobic bacteria, yeast and mold fungi, viruses, possesses sporicidal, detergent and deodorizing properties, does not cause metal corrosion, does not decolour fabrics, does not fix organic contaminations, is not aggressive to processed objects[4] [6]. Consumption of this disinfectant is similar to consumption of the other preparations: from 100 to 300 ml at square meter of processed surface depending on application method.

At selecting disinfectant, it is necessary to consider, besides quality and quantity characteristics, economical feasibility. Comparison of PHMG group preparations value indices in liquid and tableted forms are presented in Table 3.

Table 3. **Price comparison of 1 liter process solution of disinfecting agent on the basis of PHMG**

Name of preparation	Form of issue	Concentration of active ingredient (AI), %	Price of 1 liter process solution for surfaces processing, rubles
Anavidin	Liquid concentrate	20	0.5
Biopag D	Liquid concentrate	20	0.7
Fogucide Neo	Liquid concentrate	20	0.7
BIOR N		19.2	0.1
Neotabs	Dry concentrate in tablets	52	0.3

It was found out that in course of selecting disinfectants it is possible and necessary to combine such actual requirements as high level of ecological compatibility and affordability. Preparations on the basis of PHMG completely correspond to these requirements. Thereby, domestic preparations, which do not concede by quality to foreign ones, are proposed for users in convenient forms and concentrations.

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Дезинфицирующие средства на основе полигексаметиленгуанидина для использования в подземных помещениях

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Освоение подземного пространства становится все более актуальным, что позволяет интенсифицировать строительную отрасль, однако такие особенности подземных пространств, как повышенная относительная влажность, замкнутость и недостаточная вентиляция создают благоприятную среду для их постоянной контаминации биологическими агентами, которые в свою очередь являются причиной биоповреждения конструкций и строительных материалов, представляют опасность для здоровья людей, вызывая как спорадические, так и массовые заболевания. Химические методы защиты занимают ведущее место. Предпочтение отдается современным дезинфицирующим составам на водной основе, например четвертичным и третичным аммониевым соединениям. В статье представлены результаты о выборе дезинфицирующих средств на основе высокого уровня экологической безопасности и экономической целесообразности. Предлагаются отечественные препараты, не уступающие по качеству зарубежным, в удобных формах и концентрациях. Их применение под землей позволяет решить все поставленные задачи снижения контаминации подземных пространств и снижения негативного воздействия на здоровье населения.

Ключевые слова: биологические агенты, средства дезинфекции, рабочая зона, риск биообрастания.

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