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BACTERICIDAL AND FUNGICIDAL ACTIVITY OF POLYETHERGUANIDINIUM CHLORIDE

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There is information in the literature about the salts of polyhexamethylene guanidine (PGMG), which are effective biocidal and sterilizing drugs and disinfectants due to the wide range of their antimicrobial activity against gram-positive and gram-negative bacteria (including Mycobacterium tuberculosis), viruses, and fungi. ***The aim*** *of this work is to study the bactericidal and fungicidal activity of the synthesized polyetherguanidinium chloride against a number of bacteria and microscopic fungi.* ***Methods.*** *Cultivation of microorganisms. Bacteria were grown on meat-peptone agar for 48 hours at a temperature of 28±2 °C. Test cultures of micromycetes were cultured on beer wort agar (6° B), incubated for 14 days in a thermostat at a temperature of 28±2 °C. Antimicrobial activity of newly synthesized polyetherguanidinium chloride was determined by standard disco-diffusion method, and fungicidal activity was determined by agar diffusion method.* ***Results.*** *The synthesis of polyetherguanidinium chloride was carried out in two stages. The first stage was the synthesis of a guanidinium-containing oligoether with terminal guanidine moieties by the reaction between an aromatic oligoepoxide and guanidine. The second stage was the synthesis of polyetherguanidinium chloride by the reaction between a guanidinium-containing oligoether with terminal guanidine moieties and oligooxyethylenediamine. The bactericidal and fungicidal activity of polyetherguanidinium chloride against various heterotrophic bacteria and microscopic fungi has been shown. It was found that polyetherguanidinium chloride at concentrations of 1–3 % inhibited the growth of gram-negative (Escherichia coli 475, Klebsiella pneumonia 479) and gram-positive (Staphylococcus aureus 451) bacteria. The proposed 1 % solution of polyetherguanidinium chloride shows a 1.5 times higher antimicrobial activity than the polymeric disinfectant polyhexamethyleneguanidinium chloride for E. coli 475 and K. pneumoniae 479 bacteria and lower antimicrobial activity for S. aureus 451 bacteria. According to the obtained data, it was noted that polyetherguanidinium chloride at a concentration of 1 % had a high fungicidal activity against almost all investigated isolates: Aspergillus versicolor F-41250, Acremoneum humicola F-41252, Acremoneum roseum F-41251, Cladosporium sphaerospermum F-41255, Paecilomyces lilacinus F-41256 and Scopulariopsis candida F-41257.* ***Conclusions.*** *Received polyetherguanidinium chloride at a concentration of 1 % showed bactericidal activity against S. aureus 451, E. coli 475, K. pneumoniae 479 and fungicidal effect to all fungi studied by us, and so can be used as a disinfectant for building materials.*

Keywords: polyetherguanidinium chloride, bactericidal activity, bacteria, microscopic fungi, fungicides, guanidine.

It is known from the literature that salts of polyhexamethyleneguanidine (PGMG) refer to effective biocidal and sterilizing drugs and disinfectants due to a wide range of their antimicrobial activity against gram-positive and gram-negative bacteria [1–5]. The mechanism of biocidal action of polyguanidines is similar to Quaternary ammonium compounds and has a membrane toxic character: guanidine polycations are adsorbed on the negatively charged surface of bacterial cells; diffuse through the cell wall; bind to acid phospholipids, proteins of the cytoplasmic membrane, which leads to its rupture. The result is a blockade of glycolytic enzymes of the respiratory

system, loss of pathogenic properties and death of microbial cells. Disruption of the contour of the membranes and changes in the structure of microbial cells under the influence of an experiment using electron microscopy in studying the effect of sublethal doses of reagents on the suspension of bacteria and spores of some particularly dangerous infections was studied. The increase in the biocidal activity of PGMG in comparison with low molecular weight biocides is due to the cooperative interaction of neighboring guanidine groups of the polycation with the microbial cell. The increase in the activity of polyguanidines in comparison with quaternary ammonium salts (QAS) is also due to the peculiarities of the structure of the guanidine group: in contrast to the QAS cation, where a large positive charge is localized on one nitrogen atom in the guanidine cation, the positive charge is delocalized and distributed between three nitrogen atoms, as well as additionally delocalized by a system of σ-bonds. Delocalization of the positive charge softens the action of the biocide and reduces its toxicity. The macromolecular nature of the reagent determines the intramolecular interaction of macromolecule fragments removed along the chain, conformational transformations of polymer chains, changes in the complementarity of the polycation and protein macromolecules of the bacterial cell, which further delocalizes the positive charge and reduces the toxicity of the compound.

The advantages of PGMG salts include their moderate toxicity and the lack of cumulative action against living organisms (hazard class 4 according to GOST 12.1.007-76) [6, 7]. The convenience of using such polymeric biocides lies in their high solubility in water and in the absence of volatility, which makes it possible to carry out disinfecting operations in the presence of humans [7, 8]. The introduction of such compounds into rubber products in percentage concentrations of 0.5–1.5 % leads to a delay in the growth of microscopic fungi on the surface of the rubber by two to three times [9, 10].

Previously, we investigated the fungicidal activity of guanidine-containing oligoether (GO) with finite guanidinium fragments based on aromatic oligoepoxide and guanidinium chloride against isolates of microscopic fungi that caused damage to rubber materials. It was found that guanidine-containing oligoether at a concentration of 3 % inhibited the growth of the majority of studied micromycetes [11]. It was therefore advisable to synthesize a functionalized polymer based on functional oligoetherguanidinium chloride and aliphatic oligooxyethylenediamine and to investigate its bactericidal and fungicidal properties.

The aim of this work is to study the bactericidal and fungicidal activity of the synthesized polyetherguanidinium chloride against a number of bacteria and microscopic fungi.

Materials and methods. ***The objects of the study*** are strains of gram-positive *Staphylococcus aureus* 451 and gram-negative *Escherichia coli* 475 and *Klebsiella pneumonia* 479 bacteria, which were isolated from pathogenic material (urogenital system) of sick people and stored in the Laboratory of bacteriological research of the Institute of Urology of NAMS of Ukraine. Microscopic fungi *Aspergillus versicolor* F-41250, *Acremoneum humicola* F-41252, *Acremoneum roseum* F-41251, *Cladosporium sphaerospermum* F-41255, *Paecilomyces lilacinus* F-41256, *Scopulariopsis candida* F-41257 were previously isolated from the premises that suffered from mycological damage (Kiev) and stored in the Department of Physiology and Systematics of Micromycetes of D.K. Zabolotny Institute of Microbiology and Virology of the NAS of Ukraine [19].

Research materials. Dian epoxy oligomer DER-331 (DOW Chemical Company, Germany), MW 365 g/mol, mass fraction of epoxy groups 23.5 %, hydroxyl groups 0.6 %, were dehydrated in vacuum for 2–6 hours at 80–90 °C and a residual pressure of 2 mbar. Guanidine hydrochloride (GD) (Aldrich Company, 99.9 % purity) was used without further purification. Oligooxyethylenediamine D-400 MW 400 (Aldrich Company, 99.9 % purity) was used without further purification. Medical 96 % ethanol was used without further purification. Dimethylformamide (DMF) was purified by distillation.

For the synthesis of guanidinium-containing oligoether based on the aromatic epoxy oligomer DER-331 MW 365.5 and guanidinium chloride, 10 g of epoxy oligomer dissolved in 30 ml of dimethylformamide was added into the reactor and then a solution of guanidine (3.3 g) previously transformed in the base form using alkali was added. The reaction was carried out for 2–3 hours at temperatures of 50–60 °C.

The completion of the reaction was monitored by IR spectroscopy for the disappearance of absorption bands of epoxy groups at 920 cm^{-1}. 5 ml of hydrochloric acid (37 %) was added to the solution of the product obtained with stirring to convert the oligoether into acidic form, the solvents

were distilled off from the reaction mixture under reduced pressure. The obtained GO was re-precipitated from dimethylformamide in diethyl ether. To remove residual solvents, the product was kept under vacuum at a pressure of 1 mbar at 80 °C for 12 hours. The reaction product yield was 95 %.

To obtain polyetherguanidinium chloride (PEG-GC), a mixture of 10 g of GO and 8.2 g of oligooxyethylenediamine with the terminal amino groups of MW 400 was heated to 80 °C and stirred for 4 h, after which the reaction was continued for 4 h at 130–140 °C and 4 h at 180 °C. After cooling the reaction mixture, an amorphous glassy polymer of PEG-GC was obtained. To purify the product from the residues of the original reagents, it was dissolved in 40 ml of water and precipitated by adding 20 ml of a saturated solution of sodium chloride. The purified polymer was separated by decantation, washed with water (20 ml) and dried in vacuum at a pressure of 1 mbar at 80 °C for 24 hours. An amorphous polymer of dark yellow color was obtained. The viscosity characteristic of PEG-GC, determined in 0.1 N aqueous NaCl at 25 °C, was 0.065 dl /g.

Cultivation of microorganisms. Bacteria were grown on meat-peptone agar for 48 hours at a temperature of 28 ± 2 ^{0}C.

Test cultures of micromycetes were cultured on beer wort agar (6° B), incubated for 14 days in a thermostat at a temperature of 28 ± 2 ^{0}C.

Research methods

IR Fourier spectroscopy. The IR spectra of the Fourier transform were taken on a TENSOR 37 spectrophotometer in the spectral region 6000–400 cm^{-1} in KBr tablets.

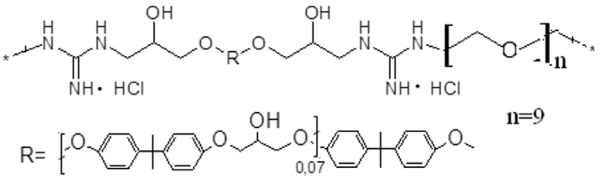
^{1}H NMR spectra were recorded on a "Varian VXR-400 MHz" instrument in $CDCI_3$.

Statistical processing of the results. The experiments were performed in triplicate, the results were expressed using the standard deviation M±n. Data processing was performed using the software package Excel 2016 (MS Office) and Origin 8.5 (MS Office).

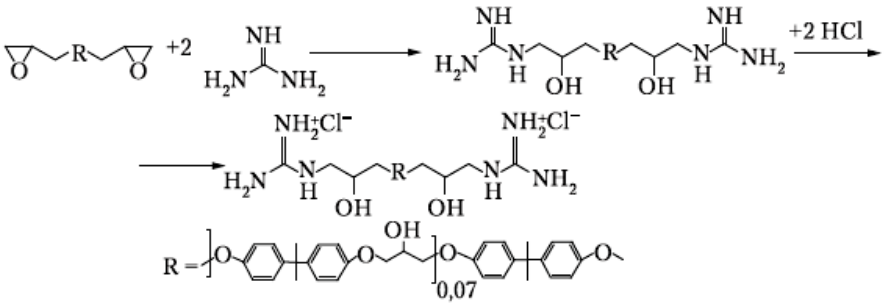
The antimicrobial and fungicidal activity. Antimicrobial activity of newly synthesized polyetherguanidinium chloride was determined by standard disco-diffusion method [6] and fungicidal activity was determined by agar diffusion method. 1 and 3 % oligomer solutions were used: 0.2 ml of each was applied to the standard paper discs (6 mm in diameter), and placed on the surface of meat-and-peptone agar inoculated with the corresponding test culture of bacteria. Incubation was carried out within 18 hours at 28±2 °C. Antimicrobial activity was expressed according to the diameters (mm) of the microorganism growth inhibition zones.

In order to determine the fungicidal activity, a suspension of each fungi species was prepared in sterile distilled water at a concentration of $1 \cdot 10^6$ CFU. The resulting 1 ml suspension was added to a Petri dish, 20 ml of molten Czapek-Dox medium was poured over it, and it was thoroughly mixed. Then in the middle of the dish, wells (8 mm in diameter) were made by a sterile drill, and 0.2 ml of the test substances was added. Incubation was carried out at 28±2 °C; accounting of the results was made on the 7th and 14th day of the experiment. Fungicidal activity was expressed in mm according to the microorganism growth inhibition zone diameters. The study was carried out in triplicate; the obtained results were processed mathematically on a personal computer.

Results. The synthesized polyetherguanidinium chloride can be represented by the following structural formula:



Synthesis of polyetherguanidinium chloride (PEG-GC) is carried out in two stages. The *first stage* is synthesis of a guanidine-containing oligoether with finite guanidine moieties by reaction between an aromatic oligoepoxide and guanidine.



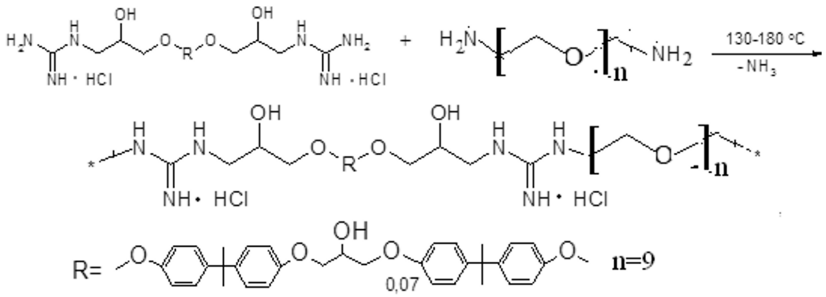
The structure of the obtained oligomer was confirmed by IR and ^{1}H NMR spectrometry.

IR (KBr): (3200–3550) cm^{-1} (νNH, OH), 3156 cm^{-1} (δNH), 2949 (νCH), 2896 cm^{-1} (νsCH2), 2868 cm^{-1} (νCH2), 1648 cm^{-1} (νC = N), (1450–1650) cm^{-1} (νC6H5), (1100–1300)) cm^{-1} (νC-O-C).

The ^{1}H NMR (CDCI3) spectrum of the guanidinium-containing oligomer contains proton signals at 1.72 ppm. (t, 3H, -CH_3), 2.73 ppm. -NH (NH CH_2), 2.58 ppm -CH_2 (CH_2CHOH), 3.58 ppm -OH (CH-OH), 3.96 ppm -CH (CH-OH), 6.8 ppm and 7.2 ppm (-CH) benzene ring, 8.4 ppm and 8.6 ppm -NH (NH_2 groups).

GO is a light-yellow viscous liquid that is soluble in water, ethanol, methanol, methylethyl ketone, dimethylformamide, dimethylsulfoxide, dimethylacetamide and insoluble in diethyl ether, hexane, and acetone.

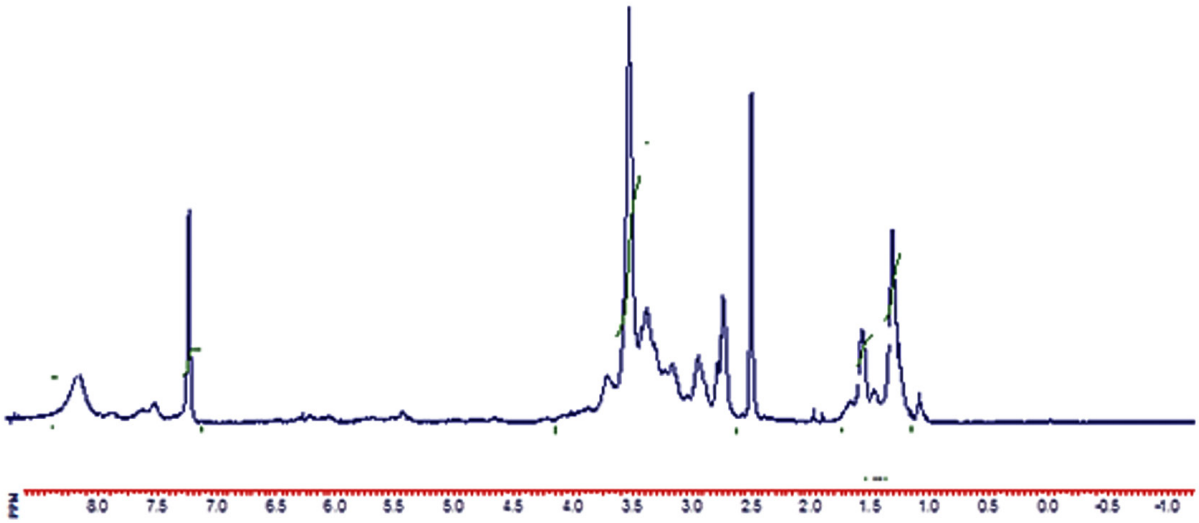
The *second step* is the synthesis of polyetherguanidinium chloride by reaction between a guanidine-containing oligoether with a finite guanidine moiety and oligooxyethylenediamine.



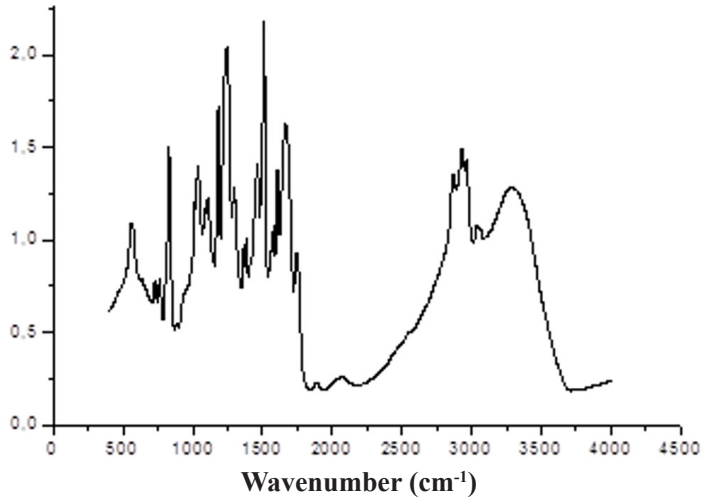
The structure of the obtained polyetherguanidinium chloride is confirmed by ^{1}H NMR (Fig. 1) and IR spectra (Fig. 2).

The resulting polymer is a resinous product of a dark yellow color, which is soluble in water, ethanol, methanol, methylethyl ketone, dimethylformamide, dimethyl sulfoxide, dimethylacetamide and insoluble in diethyl ether, hexane, acetone. The synthesized polyetherguanidinium chloride is a reactive polyfunctional polymer with a hydrophobic aromatic and hydrophilic oligoethylene oxide component containing hydroxyl groups and guanidinium moieties along the chain. Data on the study of bactericidal activity of the obtained polyetherguanidinium chloride in relation to a number of gram-positive and gram-negative bacteria are shown in Table 1, Fig. 3.

According to the results of microbiological studies, polyetherguanidinium chloride exhibits antimicrobial activity against the test cultures in the concentration range of 1–3%, which is recommended for commercial disinfectants based on polyhexamethylene guanidinium chloride salts.



F i g. 1. ^{1}H NMR spectrum of aromatic polyetherguanidinium chloride ^{1}H NMR (400 MHz, DMSO-D_6): δ = 1.32 ppm (m, 4H, CH_2), 1.57 ppm (m, 4H, NCH_2CH_2), 2.74–3.72 (м, 24H, NCH_2, OCH_2, CH, OH), 7.2 ppm. -CH benzene ring 8.1 ppm (m, 4H, NH)

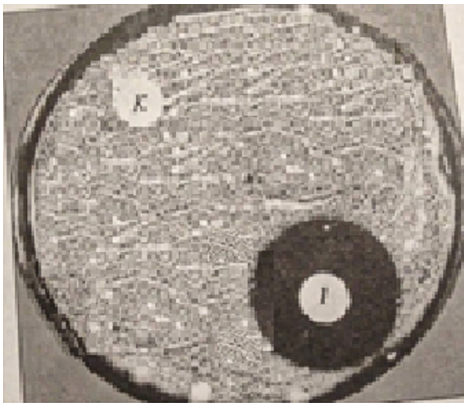


F i g. 2. IR spectrum of aromatic polyetherguanidinium chloride IR (KBr): 3314 cm^{-1} (ν NH, OH), 3156 cm^{-1} (δ NH), 2949 (ν CH), 2896 cm^{-1} (2s CH_2), 2868 cm^{-1} (ν CH_2). 1648 cm^{-1} (ν C = N), 1076 cm^{-1} (ν C-O-C)

Table 1

Antimicrobial activity of polyetherguanidinium chloride

Compound	Concentration, %	Growth inhibition zone diameters (mm)		
		E. coli 475	*K. pneumoniae* 479	S. aureus *451*
PEG-GC	1	25±0.35	25±0.36	0
	3	29±0.37	28±0.37	12±0.07
PGMG	1	17±0.15	15±0.26	20±0.35
	0.1	12±0.10	10±0.07	15±0.07



F i g. 3. Growth inhibition zones of *K. pneumoniae* 479 affected by polyetherguanidinium chloride (К – control (distilled water), 1 – 3 % solution of polyetherguanidinium chloride)

The proposed 1 % solution of polyetherguanidinium chloride exhibits 1.5 times higher antimicrobial activity than the polymer disinfectant polyhexamethylene guanidinium chloride against *E. coli* and *K. pneumoniae* and lower antimicrobial activity against *S. aureus*. Compared to PGMG hydrochloride, the PEG-GC polymer exhibits antimicrobial activity at higher concentrations, which indicates its lower toxicity to microorganisms.

Table 2 shows the data on the fungicidal activity of polyetherguanidinium chloride against different types of microscopic fungi.

The data determined the fungicidal activity of polyetherguanidinium chloride at a concentration of 1 % against isolates of micromycetes that were dominant or frequently found on technical and building materials and could pose a significant threat to human health. For comparison, a study of the fungicidal activity of the original GO against

Table 2

Fungicidal activity of polyetherguanidinium chloride

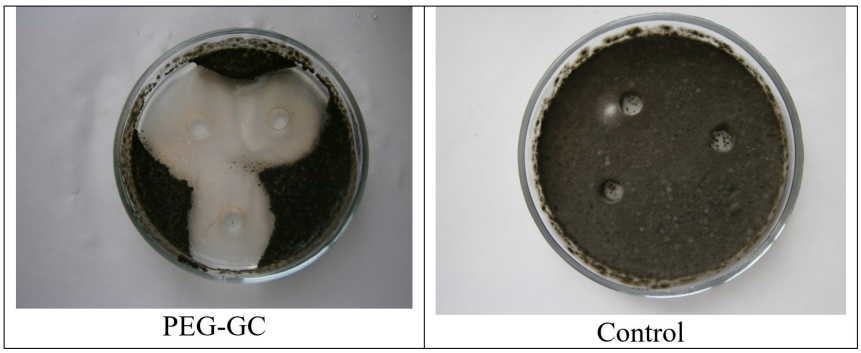
No	Species of micromycetes	The composition and concentration of the solution	
		PEG–GC, 1 %	GO, 1 %
Growth retardation zone diameters of micromycetes, mm			
7 days			
1	*Aspergillus versicolor* F-41250	9.55±1.16	14.42±1.24
2	*Acremoneum humicola* F-41252	9.67±0.50	10.94±1.13
3	*Acremoneum roseum* F-41251	7.00±0.87	**12.78±0.87**
4	*Cladosporium sphaerospermum* F-41255	8.00±0.00	10.94±1.13
5	*Paecilomyces lilacinus* F-41256	8.00±0.00	14.56±1.24
6	*Scopulariopsis candida* F-41257	**7.56±2.00**	**15.42±1.96**
14 days			
7	*Aspergillus versicolor* F-41250	8.89±1.05	13.33±1.37
8	*Acremoneum humicola* F-41252	5.50±0.55	9.44±0.73
9	*Acremoneum roseum* F-41251	12.72±0.67	**9.67±0.50**
10	*Cladosporium sphaerospermum* F-41255	3.00±0.00	13.50±0.95
11	*Paecilomyces lilacinus* F-41256	2.11±0.33	13.61±1.02
12	*Scopulariopsis candida* F-41257	8.89±1.05	**13.33±2.18**

the same isolates of micromycetes was conducted.

According to the obtained data, it was noted that the initial GO at a concentration of 1 % had high fungicidal activity in almost all the studied isolates, fungicidal activity of the PEG-GC polymer at the same 1% concentration was 1.5 times less. The diameter of the growth inhibition zone of *A. versicolor* F-41250, *A. humicola* F-41252, *A. roseum* F-41251, *C. sphaerospermum* F-41255, *P. lilacinus* F-41256, *S. candida* F-41257 strains under the influence of GO after 7 days was from 10 to 15 mm (Table 2), and under the influence of PEG-GC – 7.0–9.5 mm depending on the type of fungi. The highest diameter of the growth inhibition zone for 1 % solution of GO after 7 days of the experiment was observed for the fungus *S. candida* F-41257, and for 1 % solution of PEG-GC – for the fungus *A. humicola* F-41252.

After 14 days of the experiment, there was a slight decrease in the diameter of the growth inhibition zone by 1 % solution of GO for all isolates, and by 1 % PEG-GC solution – for *A. roseum* F-41251 and *S. candida* F-41257 isolates; in contrast, the growth inhibition zone diameter increased by 1.2–1.5 times, for *C. sphaerospermum* F-41255 (Fig. 4), and the growth inhibition zone diameter of *P. lilacinus* F-41256 fungi decreased by 2–2.5 times.

Discussion. The synthesized olieterguanidinium chloride showed quite high growth inhibition zones of gram-negative bacteria *E. coli* 475 and *K. pneumoniae* 479 and less for gram-positive bacteria *S. aureus* 451. It can be assumed that the negative effect of the obtained polymer on microorganisms is based on one of the following



F i g. 4. Growth inhibition zone diameters (mm) of fungus *Cladosporium sphaerospermum* F-41255 on the 14th day of the experiment under the influence of PEG-GC (three repetitions of the experiment)

mechanisms: a) the biocide enters the cell, binds to some of its components (proteins, lipids, carbohydrates), resulting in decreased metabolic rate, leading to death; b) the biocide does not penetrate the cell, but on the cell surface blocks the activity of lipid and protein substances (in particular, enzymes or their active centers), which causes negative lethal changes in the functions of membranes. The strong fungicidal effect of the original GO is probably related to the presence of a diphenylolpropane group in its composition. Molecules of organic substances are known to be redistributed by the electron density of chemical bonds (positive or negative inductive effect) under the influence of different atoms or atomic groups present in them. The presence of a diphenylolpropane group in a GO molecule causes a negative induction effect – the substituent reduces the electron density on the carbon atom to which it is attached. In this case, the substituent acquires a partial negative charge (δ-), and a carbon atom – a partial positive charge (δ +) [10]. According to the literature, the value (δ +) may be one of the factors that enhance the fungicidal substances interaction with the cell wall of fungi [12].

Macromolecules of guanidine polymers are known to be adsorbed on the negatively charged surface of the cell, thereby blocking the processes of respiration and nutrition (transport of metabolites through the cell wall and cytoplasmic membrane). They diffuse through the cell wall, causing irreversible damage inside the cell and inactivating a number of enzymes [1, 4]. The low toxicity of such compounds to humans and warm-blooded animals should be noted [12].

As can be seen from the presented data, the fungicidal activity of GO and polyetherguanidine is practically the same only for *A. humicola* fungus, for other types of fungi fungicidal activity of polyetherguanidine is 1.5 times less than of GO. This may be due to the fact that in the polymer PEG-GC, the concentration of diphenylolpropane groups on the elementary link of the polymer is twice less than in the original guanidine-containing oligoether. And the content of guanidine fragments per elemental section of the polymer was 1.5 times less than in GO.

The obtained data indicate the selectivity of the fungicidal action of solutions for different types of microscopic fungi, which may be related to differences in their metabolic processes and mechanisms of adaptation.

Conclusions. The obtained GO and polyetherguanidinium chloride based on it at a concentration of 1 % showed bactericidal activity against *Staphylococcus aureus* 451, *Escherichia coli* 475, *Klebsiella pneumoniae* 479, fungicidal activity against all fungi studied by us and so can be used as a disinfectant for building materials.

БАКТЕРИЦИДНА ТА ФУНГІЦИДНА АКТИВНІСТЬ ПОЛІЕТЕРГУАНІДИНІЙХЛОРИДУ

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Резюме

Відомо, що солі полігексаметиленгуанідину (ПГМГ) є ефективними біоцидами, стерилізуючими препаратами та дезінфектантами завдяки широкому спектру їх антимікробної активності відносно грампозитивних і грамнегативних бактерій. Механізм біоцидної дії полігуанідинів подібний четвертинним амонієвим сполукам і носить мембрано токсичний характер. В порівнянні з четвертинними амонієвими солями (ЧАС) полігуанідини мають вищу антибактеріальну активність, що обумовлено особливостями будови гуанідинового угруповання. До переваг солей ПГМГ слід віднести їх помірну токсичність (4 клас небезпеки). Зручність застосування таких полімерних біоцидів полягає у їх високій розчинності у воді та у відсутності леткості. Тому було доцільним синтезувати функціоналізований полімер на основі вказаного олігоетергуанідинійхлориду та аліфатичного олігооксиетилендіаміну і дослідити його бактерицидні та фунгіцидні властивості. **Метою** даної роботи є дослідження бактерицидної та фунгіцидної активності синтезованого поліетергуанідинійхлориду по відношенню до ряду бактерій та мікроскопічних грибів. **Методи**. Культивування мікроорганізмів**.** Бактерії вирощували

на м›ясо-пептонному агарі протягом 48 години за температури 28±2° С. Тест-культури мікроміцетів культивували на агаризованому пивному суслі (6° Б), інкубували 14 діб у термостаті за температури 28±2° С. Антимікробну активність синтезованого полімеру визначали методом дифузії в агар. **Результати**. Синтез поліетергуанідинійхлориду нами проведено у дві стадії: перша стадія полягає у синтезі гуанідинійвмісного олігоетеру з кінцевими гуанідиновими фрагментами по реакції між ароматичним олігоепоксидом та гуанідином; друга стадія – синтез поліетергуанідинійхлориду по реакції між гуанідинійвмісним олігоетером з кінцевими гуанідиновими фрагментами та олігооксиетилендіаміном. Показано, що синтезований поліетергуанідинійхлорид проявляє бактерицидну та фунгіцидну активності по відношенню до різних гетеротрофних бактерій та мікроскопічних грибів. Встановлено, що поліетергуанідинійхлорид за концентраціями 1–3 % інгібує ріст грамнегативних (*Escherichia coli* 475, *Klebsiella pneumonia* 479) і грампозитивних бактерій (*Staphylococcus aureus* 451). *Отриманий нами поліетергуанідинійхлорид (1 % розчин) проявляє в 1,5 рази вищу антимікробну активність в порівнянні з існуючим на ринку дезінфектантом полігексаметиленгуанідинійхлоридом щодо тест-культур E. coli 475 та K. pneumoniae 479, однак він виявився менш активним щодо S. aureus 451.* Встановлено, що синтезований полімер в концентрації 1% мав високу фунгіцидну активність щодо майже всіх досліджуваних мікроміцетів: *Aspergillus versicolor* F-41250, *Acremoneum humicola* F-41252, *Acremoneum roseum* F-41251, *Cladosporium sphaerospermum* F-41255, *Paecilomyces lilacinus* F-41256, *Scopulariopsis candida* F-41257. **Висновки**. Отриманий гуанідинвмісний олігоетер та поліетергуанідинійхлорид на його основі у концентрації 1 % проявляли бактерицидну активність проти *Staphylococcus aureus* 451, *Escherichia coli* 475, *K. pneumoniae* 479 та фунгіцидну активність до всіх досліджених нами мікроскопічних грибів та можуть бути використані як дезінфікант для будівельних матеріалів.

Ключові слова**:** поліетергуанідинійхлорид, бактерицидна активність, бактерії, мікроскопічні гриби, фунгіциди, гуанідин.

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