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O.V. Savvova [a], V.V. Shevetovsky [b], Ya.O. Pokroeva [a, b], I.V. Zinchenko [c], O.V. Babich [c], H.K. Voronov [a]

DEVELOPMENT OF ANTIBACTERIAL GLAZING FOR CERAMIC TILES

[a] O.M. Beketov National University of Urban Economy in Kharkiv, Kharkiv, Ukraine
[b] PJSC «Kharkiv Tile Plant», Kharkiv, Ukraine
[c] Research Institution «Ukrainian Research Institute of Environmental Problems», Kharkiv, Ukraine

The importance of preventing the spread of pathogenic microorganisms and viruses in the context of an intensifying pandemic and an unsatisfactory state of the environment has been analyzed. The necessity of application of antimicrobial materials with prolonged action to a wide range of pathogenic microorganisms has been established. The prospects of using antibacterial ceramic and glass materials and coatings with high performance characteristics and sanitary-technical properties have been determined. The expediency of the complex application of the method for determining the dehydrogenase activity of microorganisms and the diffusion method in the study of the antibacterial activity of glass coatings has been substantiated. The choice of glaze and bactericidal fillers for obtaining antibacterial glass-crystalline coatings with prolonged action for ceramic tiles has been justified. The antibacterial effect of the developed glazes and the potential need for their use to protect against pathogenic microorganisms in conditions of an increased risk of microbial load have been established.

Keywords: antibacterial glaze, ceramic tile, bactericidal filler, pathogenic microorganism, pandemic.

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Introduction

The implementation of a high level of social security is one of the priority areas for sustainable development of society. Ensuring human health and safety in the context of global stability of the entire society is of great strategic importance. Despite the constant threat of a pandemic caused by the spread of various pathogenic viruses (SARS-CoV-2B, *Influenza virus* A, B and C, *hepatitis B virus*, and *M. Tuberculosis* bacteria), it is important to develop a single strategic plan for anti-epidemic measures around the world. The intensification of the consequences of the pandemic is associated, in particular, with the spread of infections resistant to antibiotics. In general, in recent decades, a catastrophically rapid increase in the resistance of pathogens of infectious diseases to antibiotics has been noted. According to the data from United Nations sources, drug-resistant infections kill 700,000 people every year; in the context of the COVID-19 pandemic, by the beginning of 2021, about 2,400,000 people had died. The destruction of pathogenic microorganisms is becoming on a par with global climate change and other problems of a planetary scale. Therefore, the development of new innovative approaches to solving the problems of antimicrobial protection is an important scientific and practical task. One of the effective methods of an integrated approach to prevent the spread of pathogenic microorganisms is the use of antimicrobial materials with prolonged action to a wide range of pathogenic microorganisms.

Today, urgent antibacterial protection is required by common areas of social buildings and structures: hospitals and clinics (reception rooms, operating and intensive care units, children's and infectious diseases departments, medical and pharmaceutical laboratories), public canteens,

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sanitary facilities, metro, airports, etc. The effectiveness of disinfection of premises is limited by its frequency, the cost of disinfectants and the resistance of many viruses and bacteria to antimicrobial agents. In connection with the need to provide effective protection against the effects of viruses, bacteria and fungi and their metabolic products, more attention is paid to the creation and use of materials with antibacterial properties in various industries and everyday life: metals, plastic, ceramics, glass and composite glass-ceramic and glass enamel coatings for metals and ceramics [1]. The effectiveness of the use of glass coatings is explained by significant advantages when compared with other materials: chemical resistance, mechanical strength, resistance to biological corrosion, environmental friendliness and bacteriostaticity. However, the viability of bacteria and viruses, including SARS-CoV, on the surface of traditional types of ceramics and glasses is up to 4–5 days [2], which is an additional factor of their spread. This problem can be solved by introducing metal cations into their composition in the form of solutions, powders of metal oxides, or by applying films on their surface.

The deposition of photocatalytic films based on the SiO_2–TiO_2 system [3] on the tiles surface makes it possible to ensure their ability to self-cleaning under UV emission and the action of an aggressive environment and abrasives. The deposition of photocatalytic films on the surface of ceramic products significantly increases their cost, and is also a deterrent to the introduction of these products into mass production.

It is known that the antibacterial effect on the surface of materials and coatings is mainly due to the introduction of silver ions into their composition, which block the active catalytic centers of bacterial and viral enzymes. Thus, Dev Kumar et al. [4] found that in relation to HCoV-229E zeolite powders containing silver ions or a silver/copper/zinc mixture provides a decrease in the viral load log10 TCID50 (where TCID50 is the average infectious dose of tissue culture): 1.08 log10 TCID50 (3.5% Ag, 6.5% Cu) or (0.6% Ag, 14% Zn, 80% ZnO) 0.43 log10 TCID50 (20% Ag) and 0.50 log10 TCID50/HCoV-229E after 1 h in physiological suspension. The most effective were silver/copper zeolites, which showed a decrease of 2.06 log10 TCID50 after 4 hours and 5.13 log10 TCID50 after 24 hours.

Antimicrobial ceramics based on hydroxyapatite are used in medical devices such as catheters, vascular grafts and orthopedic implants. Hydroxyapatite doped with zinc oxide [5] or impregnated with chitosan [6] provides new structures of antimicrobial activity against *E. coli*, *S. aureus*, and *C. albicans*. Savvova and Bragina [7] synthesized a bactericidal powder based on hydroxyapatite modified with titanium oxide at the ratio $Ti^{4+}/(Ti^{4+}+Ca^{2+})=0.04-0.07$. It was found that composite glass coatings with a synthesized inorganic powder content of 5 wt.% are characterized by a significant antibacterial and antifungal effect: up to 90% relative to *E. coli* and *C. albicans*. Glass microspheres with silver ions were used for the preparation of composite joints between ceramic tiles [8], which are a medium for the spread of pathogenic microorganisms. However, the use of silver ions as a bactericidal agent not only significantly increases the cost of ceramic and glass products, but also can lead to its accumulation in the human body. This results in argyria and a number of chronic diseases. Therefore, the use of silver as a biocidal and antiviral agent for disinfection of large areas of ceramic surfaces is not advisable.

An effective method of increasing the competitiveness of glass coatings for ceramics is the creation of antibacterial glazes that inhibit the growth of pathogenic organisms using inexpensive and environmentally friendly biocides in their compositions. Savvova [9] developed biocidal glass-enamel coatings for the protection of steel parts, including those based on zinc oxides, state and variable valence metals with prolonged action for operation under conditions of high microbial load.

However, in view of significant differences in the composition and properties of glass coatings for steels and ceramics used for facing rooms, it is advisable to develop fundamentally new approaches to their creation. All this necessitates research in order to create antibacterial glazes for new-generation ceramic tiles.

Experimental

Selection of biotest and method for studying antibacterial ability of glazes

The antibacterial ability of glazes was determined by a diffuse method based on the principle of diffusion of material sample ions into a biotest culture. Antibacterial properties were determined via observations of the formation of zones of inhibition of bacterial growth at the site of contact of the sample with the biotest culture.

The toxicity of the test materials was assessed by the change in the dehydrogenase activity (DHA) of biotest cultures. The choice of a microorganism for the biotest of a pure culture of *Escherichia coli B* (*E. Coli*) is based on their importance in medical practice.

Assessing the toxicity of substances by DHA of bacteria was chosen as a method for studying the antibacterial activity of a composite glass coating. This method has a number of advantages: the possibility of express analysis, high sensitivity and high productivity, allowing for a significant number of replicates of statistical processing of the results and the ability to quantitatively express the effect of the substance [9]. This method is widely used in assessing the quality of drinking and wastewater, bactericidal resistance of stone and cement [10,11].

The DHA method is based on monitoring the activity of the enzymatic system of biotests during their contact with experimental samples. The control of the activity of the enzymatic system of bacteria was carried out via the determination of dehydrogenase (a group of redox enzymes localized in the mitochondria of the cytoplasm of cells and characterized by high sensitivity to the action of toxins, in the presence of which their activity decreases).

Determination of DHA bioassays is based on the ability of dehydrogenase to reduce colorless triphenyltetrazolium chloride (TTC) to triphenylformazan (formazan), which has a dark red color, due to substrate dehydrogenation. The amount of the formed formazan (an indicator of the color intensity) is proportional to the dehydrogen activity: the more the dehydrogenase enzyme, the more intense is the red color of the test sample. The amount of reduced dehydrogenases of microorganisms TTC was determined from the absorbance of the solution using photoelectric colorimetry technique (photocolorimeter KFK-2MP UChL-4.2, the wavelength of 490 nm and the thickness of the light-absorbing layer of 0.5 cm), and the DHA index was calculated by the calibration curve.

The following reagents were used to perform measurements: (1) tetrazolium salt solution (TTC) 0.05 wt.%; (2) peptone solution 0.5 wt.%; and (3) formazan solution (concentration was calculated by the calibration curve).

The calibration curve of the dependence of the absorbance on the concentration of formazan was built on the basis of measuring the absorbance of solutions using a photocolorimeter

Concentration of formazan was calculated using the following formula:

$$C_x=(41.224\cdot D+0.0362)\cdot 25/V_{pr}, \qquad (1)$$

where C_x is the concentration of formazan (mg/L); D is the absorbance; V_{pr} is the sample volume (ml).

Total DHA (mg/L) was calculated using the formula:

$$DHA=C\cdot R, \qquad (2)$$

where C_x is the formazan concentration (mg/L); P is the dilution (taken P=1).

The prepared biotests were placed in a nutrient medium, peptone broth (PB), in which experimental samples were also placed. Prepared tubes were placed in a thermostat for incubation at 37 ± 1^{0}C. For comparison, tubes with clean (without contact with samples) biotests were incubated under the same conditions in PB (control samples (cultures)). For the purity of the experiment, tubes with PB and samples (without adding bioassays) were incubated, which were used as reference samples. After 24 hours of exposure, the viability of bioassays was determined by their DHA both in control and in experimental samples. A suspension of biotests was prepared for the experiment with an initial concentration of colony-forming organisms (CFU) $C_{yield}=10^8-10^9$ cells/mL, which is typical of conditions of an epidemiological threat. Measurement of DHA *E. Coli* was carried out for 6 hours and 24 hours of its growth (cultivation). The change in DHA of the *E. Coli* biotest on the surface of the test glaze samples was determined threefold.

Microbiological studies were carried out in a certified microbiological laboratory of the Research Institute «Ukrainian Research Institute of Environmental Problems» (certificate of compliance of the measurement system with the requirements of DSTU ISO 10012:2005 dated 07.19.2021).

The properties of the developed antibacterial glazes were determined in accordance with EN ISO 10545 in a certified incoming inspection laboratory of PJSC «KhTP» (certificate No. 2011516 to 17025:2017). The bending strength of the tile was determined using a Crometro CR4/5-E3 device; water absorption in vacuum was determined by means of an EKM-1U electric contact vacuum.

The choice of glaze as the basis for obtaining an antibacterial glass coating for ceramic tiles

The zinc-containing glaze G-50 produced by PJSC «KhTP» (Kharkiv, Ukraine) was chosen as a basis for obtaining an antibacterial glass coating for ceramic tiles. It also served as a reference sample, which is used for interior wall cladding of sanitary and hygienic premises in public places. Frit glaze was synthesized based on the $SiO_2-CaO-ZnO$ system with the following content of the main components (wt.%): SiO_2 30–35; Al_2O_3 3–6; Na_2O 3–4; K_2O 2–3; CaO 11–12; ZnO 10–12; ZrO_2 8–9; and TiO_2 <0.1.

The content of the components was chosen taking into account the fundamental possibility of synthesizing the crystalline phase, which simultaneously provides high performance characteristics and the ability to inhibit the growth of pathogenic microorganisms.

When assembling the charge, the following raw components were used: quartz sand of PK 050-P grade, ground chalk, grade MM-3, feldspar charge PShS-16, ground, zinc whitewash, atmospheric zinc grade G-00. The maximum melting temperature was 1515^{0}C.

For the manufacture of the glaze coating, the following composition of the irrigated slip was chosen, wt.%: frit G-50 90; AK Prime kaolin 9–11; CMC CARBOCEL, ST/25-PT 0.2–0.3; NaCl 0.8–1.0; and stabilizer READYONE KS 0.15–0.20. Slip irrigation properties were as follows: residue on sieve No. 0045 5.0–5.5 wt.%; density 1.86–1.87 g/cm^3; and fluidity 60–80 s. The CTE of glaze coating was $5.5 \cdot 10^{-6}$ deg^{-1}.

In order to prepare antibacterial glaze glass-crystalline coatings, the Zn^{2+} cation was chosen as a bactericidal component, which exhibits a toxic effect in relation to pathogenic microorganisms. The concentration of Zn^{2+} cations migrating from the coating does not exceed the permissible amount of migration for humans [12]. In comparison, a silver compound was used as a known bactericidal agent. Zinc oxide was chosen for the introduction of Zn^{2+} cations; silver was introduced using an $AgNO_3$ solution. Bactericidal compounds were introduced in the following amount: ZnO 5 wt.% and $AgNO_3$ 0.1 wt.% per 100 wt.% of glaze slip, taking into account recommendations given in preliminary studies and requirements for fillers in the composition of glass coatings [8].

Only samples of glaze G-50 with fillers ZnO and $AgNO_3$, designated as G-50Z and G-50A, respectively, were used when establishing the antibacterial effect. This is because it is the glaze that is the contact surface during the interaction of pathogenic microorganisms and humans. The porous ceramic body will promote the adsorption of pathogenic organisms, which can lead to distortion of research results.

Experimental samples were prepared in the form of tablets with a diameter and height of 10 mm; they were sintered at the temperature of 1130–1150^{0}C for 15 minutes.

Results and discussion

Analysis of the phase composition of the glass-ceramic coating after firing allowes establishing the presence of a crystalline phase, hardystonite $Ca_2Zn[Si_2O_7]$, in an amount of 30 vol.%. This indicates the potential for providing a synergistic effect with the simultaneous action of the zinc-containing crystalline phase and zinc oxide as a filler. A significant advantage of antibacterial watering is their significant chemical resistance and the ability to contain cations of heavy metals in the glass structure. This allows them to be used in an environmentally sound manner as prolonged antibacterial protection of human objects. This is confirmed by the analysis of the antibacterial properties of the developed coatings on solid nutrient media with a high CFU of *E. Coli* (10^9 cells/ml) in order to simulate an epidemiological infection.

Thus, when examining Petri dishes for glaze coating G-50 without fillers, there is a slight change in the number of CFU *E. Coli* during their contact. This indicates the bacteriostatic properties of irrigation, which is a natural process.

With the introduction of fillers into the composition of the coatings, a change in the density of the biotest medium is observed when they come into contact with *E. Coli*. Thus, a zone of inhibition of bacterial growth was noted around sample


a b

Fig. 1. Zone of growth inhibition of *E. Coli* biotest after contact with samples G-50Z (a) and G-50A (b)

G-50Z. The diameter of the zone of inhibition was about 15 mm (Fig. 1,a), which was defined as a moderate antibacterial effect and indicating the selective ability of zinc cations to resist pathogenic microorganisms. For sample G-50A containing Ag^+ cations, a weak antibacterial effect with an inhibition zone of up to 10 mm was visually observed (Fig. 1,b). This indicator, reflecting the degree of influence of the tested samples of glass materials on the biotesting environment, must be strictly controlled, since silver cations are capable of accumulating in the human body and the environment.

The antibacterial activity of glass-ceramic coatings is explained by the toxicity of zinc(II) cations in relation to *E. Coli* bacteria. When studying the change in DHA in *E. coli* upon contact with the test coatings, the following relationship was established. After 6 hours of contact of the test coatings and the bioassay of *E. Coli*, which was in the exponential growth phase, the maximum reproduction rate of the *E. Coli* population and an increase in the number of cells exponentially and, accordingly, an increase in DHA for control culture ($C_{culture}$) were observed. Inhibition of bacterial growth was observed for the experimental glazes G-50A, G-50Z, and G-50 upon contact of *E. Coli* with the samples, which was expressed in a decrease in their DHA relative to the DHA of bacteria when the $C_{culture}$ was controlled (Table 1). This can be explained by the intrinsic bacteriostaticity of the G-50 glaze, which is characterized by high chemical resistance. The G-50Z sample showed the highest antibacterial effect with a change in the DHA value relative to the control of 45.3% (Fig. 2). However, sample G-50A cannot be recommended for the development of antibacterial glazes due to the high cost of silver compounds, although it exhibits an insignificant

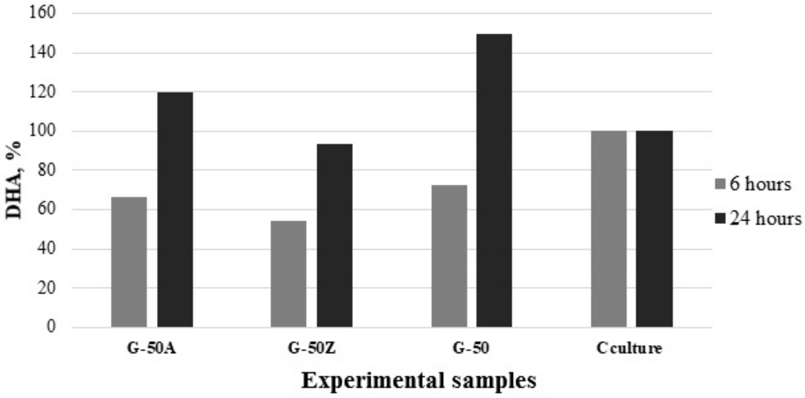

Fig. 2. Changes in the dehydrogenase activity of *Escherichia coli* bacteria under the action of the developed glass-ceramic glaze coatings

Table 1

Change in absorbance and DHA of *Escherichia coli* bacteria when interacting with experimental samples for different exposure times

Experimental sample	Absorbance		DHA, mg/L	
	for 6 hours of exposure	for 24 hours of exposure	for 6 hours of exposure	for 24 hours of exposure
G-50A	0.11	0.105	2.285	2.182
G-50Z	0.090	0.070	1.873	1.461
G-50	0.120	0.150	2.491	3.109
Control culture *E. Coli*	0.165	0.075	3.419	1.564

Table 2

Properties of the prototype and developed glazes

Marked sample	Properties according to EN ISO 10545				
	Flexural strength, N/mm^2	Thermal resistant, thermal cycle	Cracking resistance, cycle	Chemical resistance, class	Resistant to stains, class
G-50	52.8	10	2	GLA, GHA, GA	4
G-50Z	52.8	10	2	GLA, GHA, GA	4

bacteriostatic effect against $C_{culture}$.

The growth of bacteria was observed to stop (the phase of death) after 24 hours of cultivation of *E. Coli* in a volume of unchanging medium where nutrients were consumed. During this period, the DHA of *E. Coli* ($C_{culture}$) decreased by 2.2 times (Table 1, Fig. 2) in relation to the DHA value, which was noted in the exponential growth phase (for 6 hours). However, the DHA of *E. Coli* cells in contact with the test samples for samples G-50A and G-50 was greater than in the control. This may be due to the consumption of ions from experimental materials as nutrients for bacteria metabolism. Even for the G-50A sample containing silver ions, an intensive growth of the biotest was observed. Only after contact of *E. Coli* with the G-50Z sample, a 6.2% decrease in DHA relative to DHA in $C_{culture}$ was observed, which may be due to a pronounced bactericidal effect under conditions of significant microbial load.

The service properties of the developed antibacterial glaze G-50Z (Table 2) are similar to those typical of the glaze G-50 (production prototype) used at PJSC «KhTP» for the production of ceramic tiles for facing the interior of public places.

The results of studying the antibacterial properties of glass-crystalline glaze containing zinc oxide made it possible to establish its inhibitory ability against *E. coli* bacteria under a significant microbial load. The prolonged antibacterial effect of the developed glass-crystalline glaze within 24 hours is explained by the nature of the glass matrix and the synergistic action of the crystalline phase and filler on inhibiting the development of *E. Coli* bacteria.

Conclusions

The prospects of using ceramic tiles with antibacterial glazes to protect human life objects and the environment from the negative influence of pathogenic microorganisms and the spread of a pandemic have been determined. The expediency of the complex application of the diffuse and express method for assessing the dehydrogenase activity of biotests in determining the antibacterial activity of glazes has been established. It was determined that the provision of a prolonged antibacterial effect of the developed glass-crystalline coating is realized due to the synergistic action of the crystalline zinc-containing phase and the filler. Ensuring high performance properties of the developed antibacterial glaze makes it possible to recommend ceramic tiles for facing the interior of public places operated in the zone of risk of epidemiological threat.

The use of the developed antibacterial zinc-containing glaze with a prolonged action based on domestic raw materials in the production of ceramic tiles with high performance properties will significantly increase the competitiveness of products for this purpose and will help in solving the important task of stopping the spread of the pandemic.

REFERENCES

1. *Search* for biologically active substances with antimicrobial and antifungal action in the series of 2.5-disubstituted 1, 3, 4-tiadiazoles / Sych I.V., Drapak I.V., Suleiman M.M., Rakhimova M.V., Kobzar N.P., Sych I.A., et al. // Res. J. Pharm. Technol. – 2019. – Vol.12. – No. 6. – P.2871-2876.

2. *Persistence* of coronaviruses on inanimate surfaces and their inactivation with biocidal agents / Kampf G., Todt D., Pfaender S., Steinmann E. // J. Hosp. Infect. – 2020. – Vol.104. – No. 3. – P.246-251.

3. *Sciancalepore C., Bondioli F.* Durability of SiO_2–TiO_2 photocatalytic coatings on ceramic tiles // Int. J. Appl. Ceram. Technol. – 2015. – Vol.12. – No. 3. – P.679-684.

4. *Biocides* and novel antimicrobial agents for the mitigation of coronaviruses / Dev Kumar G., Mishra A., Dunn L., Townsend A., Oguadinma I.C., Bright K.R., et al. // Front. Microbiol. – 2020. – Vol.11. – P.1351-1367.

5. *Antimicrobial* materials with medical applications / Sun D., Babar Shahzad M., Li M., Wang G., Xu D. // Mater. Technol. – 2015. – Vol.30. – No. 6. – P.B90-B95.

6. *Savvova O.V.* Biocide apatite glass-ceramic materials for bone endoprosthetics // Chem. Chem. Technol. – 2013. – Vol.7. – No. 1. – P.109-112.

7. *Savvova O.V., Bragina L.* Use of titanium dioxide for the development of antibacterial glass enamel coatings // Glass Ceram. – 2010. – Vol.67. – No. 5-6. – P.184-186.

8. *Yilmaz Atay H.* Improving mechanical properties and antibacterial behaviors of ceramic tile junctions with glass spheres and nano-Ag particles // Inorg. Nano-Met. Chem. – 2017. – Vol.47. – No. 9. – P.1304-131.

9. *Savvova O.V.* Effect of zinc and tin oxides on the bactericidal properties of glass enamel coatings // Glass Ceram. – 2014. – Vol.71. – No. 7-8. – P.254-257.

10. *Malachowska-Jutsz A., Matyja K.* Discussion on methods of soil dehydrogenase determination // Int. J. Environ. Sci. Technol. – 2019. – Vol.16. – P.7777-7790.

11. *Sobsey M.D.* Methods to identify and detect microbial contaminants in drinking water // Identifying future drinking water contaminants. – Washington: National Academy Press, 1999. – P.173-260.

12. *Developing* a method for measurement of dehydrogenase activity in biological wastewater treatment processes applied for toxic compounds degradation / Pourakbar M., Behnami A., Mahdavianpour M., Dariy F.S., Aghayani E. // MethodsX. – 2020. – Vol.7. – Art. No. 100970.

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РОЗРОБКА АНТИБАКТЕРІАЛЬНИХ ПОЛИВ ДЛЯ КЕРАМІЧНОЇ ПЛИТКИ

О.В. Саввова, В.В. Шеветовський, Я.О. Покроєва,
І.В. Зінченко, О.В. Бабіч, Г.К. Воронов

Проаналізовано важливість попередження розповсюдження патогенних мікроорганізмів та вірусів в умовах поширення пандемії та незадовільного стану навколишнього середовища. Встановлено необхідність застосування антимікробних матеріалів з пролонгованою дією до широкого спектра патогенних мікроорганізмів. Визначено перспективність використання антибактеріальних керамічних і скляних матеріалів й покриттів з високими експлуатаційними та санітарно-технічними властивостями. Обгрунтовано застосування методу дегідрогеназної активності мікроорганізмів та дифузійного методу при дослідження антибактеріальної активності склопокриттів. Обгрунтовано вибір глазурі та бактерицидних наповнювачів для одержання антибактеріальних полив для керамічної плитки та визначено оптимальне вміст токсикантів. Встановлено антибактеріальну дію розроблених антибактеріальних полив та їх потенційну необхідність застосування для захисту від патогенних мікроорганізмів в умовах підвищеного ризику мікробного навантаження.

Ключові слова: антибактеріальні поливи, керамічна плитка, бактерицидні наповнювачі, патогенні мікроорганізми, пандемія.

DEVELOPMENT OF ANTIBACTERIAL GLAZING FOR CERAMIC TILES

O.V. Savvova [a, *], ***V.V. Shevetovsky*** [b], ***Ya.O. Pokroeva*** [a, b],
I.V. Zinchenko [c], ***O.V. Babich*** [c], ***H.K. Voronov*** [a]

[a] O.M. Beketov National University of Urban Economy in Kharkiv, Kharkiv, Ukraine

[b] PJSC «Kharkiv Tile Plant», Kharkiv, Ukraine

[c] Research Institution «Ukrainian Research Institute of Environmental Problems», Kharkiv, Ukraine

[*] e-mail: savvova_oksana@ukr.net

The importance of preventing the spread of pathogenic microorganisms and viruses in the context of an intensifying pandemic and an unsatisfactory state of the environment has been analyzed. The necessity of application of antimicrobial materials with prolonged action to a wide range of pathogenic microorganisms has been established. The prospects of using antibacterial ceramic and glass materials and coatings with high performance characteristics and sanitary-technical properties have been determined. The expediency of the complex application of the method for determining the dehydrogenase activity of microorganisms and the diffusion method in the study of the antibacterial activity of glass coatings has been substantiated. The choice of glaze and bactericidal fillers for obtaining antibacterial glass-crystalline coatings with prolonged action for ceramic tiles has been justified. The antibacterial effect of the developed glazes and the potential need for their use to protect against pathogenic microorganisms in conditions of an increased risk of microbial load have been established.

Keywords: antibacterial glaze; ceramic tile; bactericidal filler; pathogenic microorganism; pandemic.

REFERENCES

1. Sych IV, Drapak IV, Suleiman MM, Rakhimova MV, Kobzar NP, Sych IA, et al. Search for biologically active substances with antimicrobial and antifungal action in the series of 2.5-disubstituted 1, 3, 4-tiadiazoles. *Res J Pharm Technol.* 2019; 12(6): 2871-2876. doi: 10.5958/0974-360X.2019.00483.9.

2. Kampf G, Todt D, Pfaender S, Steinmann E. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. *J Hosp Infect.* 2020; 104(3): 246-251. doi: 10.1016/j.jhin.2020.01.022.

3. Sciancalepore C, Bondioli F. Durability of SiO_2–TiO_2 photocatalytic coatings on ceramic tiles. *Int J Appl Ceram Technol.* 2015; 12: 679-684. doi: 10.1111/ijac.12240.

4. Dev Kumar G, Mishra A, Dunn L, Townsend A, Oguadinma IC, Bright KR, et al. Biocides and novel antimicrobial agents for the mitigation of coronaviruses. *Front Microbiol.* 2020; 11: 1351-1367. doi: 10.3389/fmicb.2020.01351.

5. Sun D, Babar Shahzad M, Li M, Wang G, Xu D. Antimicrobial materials with medical applications. *Mater Technol.* 2015; 30(6): B90-B95. doi: 10.1179/1753555714Y.0000000239.

6. Savvova O. Biocide apatite glass-ceramic materials for bone endoprosthetics. *Chem Chem Technol.* 2013; 7(1): 109-112. doi: 10.23939/chcht07.01.109.

7. Savvova OV, Bragina LL. Use of titanium dioxide for the development of antibacterial glass enamel coatings. *Glass Ceram.* 2010; 67: 184-186. doi: 10.1007/s10717-010-9258-8.

8. Atay HY. Improving mechanical properties and antibacterial behaviors of ceramic tile junctions with glass spheres and nano-Ag particles. *Inorg Nano-Met Chem.* 2017; 47(9): 1304-1311. doi: 10.1080/24701556.2017.1284082.

9. Savvova OV. Effect of zinc and tin oxides on the bactericidal properties of glass enamel coatings. *Glass Ceram.* 2014; 71: 254-257. doi: 10.1007/s10717-014-9663-5.

10. Malachowska-Jutsz A, Matyja K. Discussion on methods of soil dehydrogenase determination. *Int J Environ Sci Technol.* 2019; 16: 7777-7790. doi: 10.1007/s13762-019-02375-7.

11. Sobsey MD. Methods to identify and detect microbial contaminants in drinking water. In: *Identifying future drinking water contaminants.* Washington: National Academy Press; 1999. p. 173-260. doi: 10.17226/9595.

12. Pourakbar M, Behnami A, Mahdavianpour M, Dariyan FS, Aghayani E. Developing a method for measurement of dehydrogenase activity in biological wastewater treatment processes applied for toxic compounds degradation. *MethodsX.* 2020; 7: 100970. doi: 10.1016/j.mex.2020.100970.