

Evaluation of bactericidal properties of PVC-compositions for linoleum production

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Abstract. The present paper deals with evaluating bactericidal properties of polyvinylchloride compositions for linoleum manufacturing. PVC-floor coatings are widely used in health care facilities, hospitals and outpatient departments due to antistatic properties, non-toxicity, advanced resistance to wear, fastness to water, functionality and improved durability. Strict standards of resistance to bacteria and fungi are applied to this type of coatings due to their exposure to detergents and washing agents. Modifying PVC- composition by calcium methylsilicate, also known as wollastonite, increases its resistance to Gram-positive and Gram-negative organisms. Cationic surface-active substances are active to both type of microorganisms and could withstand propagation of bacterial medium on polyvinylchloride linoleum surface. They also exhibit the functions of biostatics inhibiting the growth of microorganisms and of bactericides killing microorganisms. Quaternary ammonium compounds represent efficient group of biocides for water-dispersible coating materials and for this reason their investigation for PVC-linoleum is of utmost interest. PVC floor coatings modified by wollastonite are more resistant to aggressive chemical liquids and microorganisms than linoleum with the base composition. The authors proved that PVC-based linoleum with surface-activated filler, wollastonite, had shown enhanced fastness to water and higher resistance to water solutions of antiseptic agents and bacteria.

1. Introduction

PVC-linoleum could be seen as one of the most advanced floor coatings for health care facilities if evaluated by price/quality ratio. Its popularity for hospitals and outpatient departments use could be reasoned by efficiency, functionality and high durability of a coating [1].

PVC-linoleum is characterized by the high level of shock-absorbing that reduces the load on the musculoskeletal system and muscles of the patients undergoing treatment in health care facilities, in particular those with lower limb injuries. This floor coating has high acoustic isolation creating the comfortable conditions for sick people [1].

Special features of PVC-based medical linoleum which distinguish it from standard floor coatings of this type comprise the following: improved resistance to wear, antistatic

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properties, fire safety, non-toxicity, fastness to water as well as resistance to corrosive medium and various types of microorganisms [2].

Floor coatings in health care facilities, as distinguished from domestic linoleum, for instance, are exposed to impact of various washing agents and detergents. The reason for this is that higher standards of resistance to bacteria and fungi are applied for this type of linoleums.

In order to prevent infection by microorganisms, the various methods for polymer materials protection are used [3]:

- mechanical removal of contamination;
- physical methods (bacterial filters, electromagnetic, radiation and ultraviolet emission, ultrasound, electrochemical protection);
- surface hydrophobization;
- biological shielding (conflict of microorganisms);
- chemical protection (introduction of anti-fungals and bacillicides, the use of biostatics).

As one of the options for providing antibacterial properties to PVC-linoleum could be seen SAS (surface acting substances) surface activation of wollastonite, being effective filler of this floor coating [4]. The choice of these substances as modifying agents could be explained by the fact that many synthetic surface acting substances exhibit antimicrobial characteristics [5].

Cationic SAS are active in relation to both Gram-positive and Gram-negative organisms; these substances could withstand development of bacterial medium on the surface of PVC-linoleum, at the same time, performing the functions of biostatics inhibiting microorganisms' growth, and of bactericides killing microorganisms [6].

The majority of academic specialists suggest that SAS have an impact on microorganisms in specific way: at very low temperatures they could react with discrete cell components disturbing their normal functioning, altering their properties, in particular, permeability of the cell walls, and lead to destructurization of cell membranes [7].

Cationic SAS, being quaternary ammonium salts (QAS), with hydrocarbyls $C_{12}-C_{18}$, obtained on the base of synthetic fatty acids are considered the most advanced in this aspect [8].

Practically all surface-acting quaternary ammonium salts (QAS) are bactericides, while many have anti-fungal, virucidal and sporicidal properties [9]. Thus, quaternary ammonium compounds represent efficient group of biocides for water-dispersible coating materials [10]; for this reason their investigation for PVC-linoleum is of utmost interest.

2. Materials and methods

As the study objects in the present paper there have been used paste-forming emulsion PVC 6250-Zh (All-Union State Standard GOST 14039-78), filler micro marble (Technical Conditions TU 5716-001-99242323-2007), plasticizer EDOS (TU 2493-003-13004749-93). Calcium methylsilicate Wollastonite of grade Miwoll 10-97 (TU 5777-006-40705684-2003) was applied as a modifier. The formulations of researched PVC-compositions are presented in the table 1.

Table 1. Formulations of the researched PVC-compositions.

Component	Content, weight parts	
	Base	With wollastonite
PVC E-6250Zh	100	100
EDOS	92	92
Micro marble	196	186
Wollastonite Miwoll 10-97	0	10

With the purpose of wollastonite surface activation, SAS of the quaternary ammonium salts type were used, such as alkyl trimethyl ammonium chloride 50% solutions in isopropanol – ALKASAS 1214S.50 (alkyl 12-14) and ALKASAS 1618S.50 (alkyl 16-18) as well as cetyl trimethyl ammonium chloride 50% solution in isopropanol – ALKASAS 16S.50.

The surface treatment of Miwoll 10-97 by QAS was carried out in compliance with the standard laboratory procedures for layer silicates activated by organic cations. The method was elaborated by the Department of Colloid Chemistry of Lomonosov Moscow State University of Fine Chemical Technologies [11].

Chemical fastness of PVC-films specimen was evaluated by gravimetric method (by the mass change in dependence to exposure time) in deionized water, in 0.015% aqua solution ‘Aster’ (TU 9392-001-93056039-2009), as an active substance containing sodium salt of dichloroisocyanuric acids, and 0.5% aqua solution ‘Nika Ekstra-M’ (TU 9392-005-12910434-2003), with the active substance alkyl dimethylbenzyl ammonium chloride. These aqua solutions of disinfecting agents are commonly used for indoor floor cleaning in health care facilities.

In order to evaluate bactericide and bacteriostatic properties of PVC-linoleum, the authors applied the modified disc diffusion method for assessment of microorganism’s sensitivity to antimicrobial agents according to the level of their growth retardation [12]. For research implementation, the bacterial suspension of particular density was spread on the surface of agar-meat infusion in Petri dish, then there were placed the disks of analyzed materials with the diameter of 1 cm. The agent’s diffusion into agar leads to formation of the zone of microorganisms’ growth retardation under the disk and in the area surrounding disks. Having incubated the Petri-dishes in the constant-temperature cabinet at 37⁰C within 3 days, the measurements of the diameter of growth retardation zone surrounding the disk have been taken to a precision of 1mm.

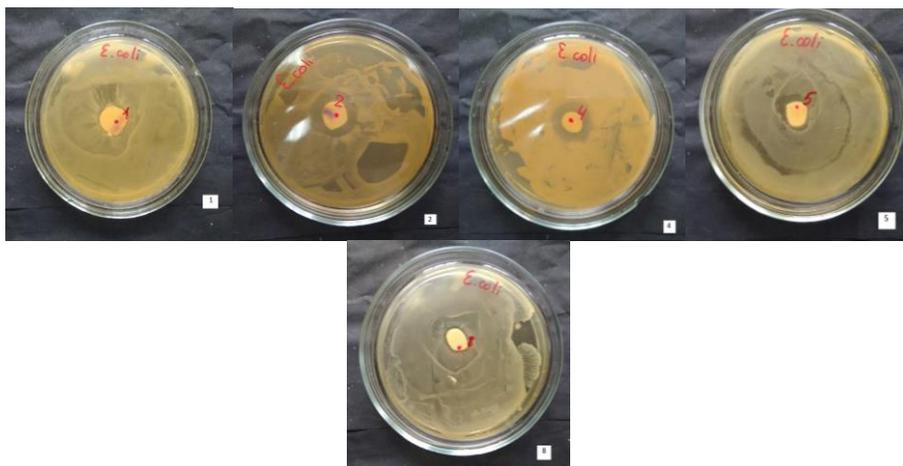
As typical representatives of Gram-positive and Gram-negative bacteria, *Escherichia coli* and *Bacillus subtilis* have been taken as the study objects.

3. Results

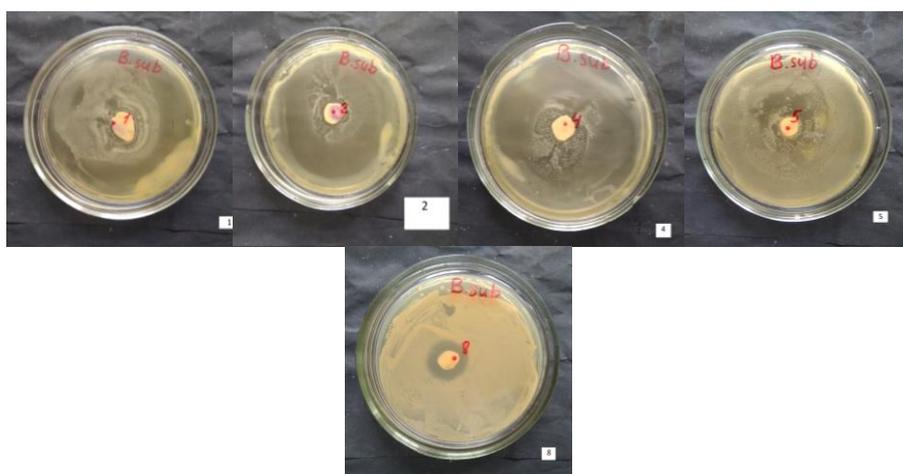
The results of assessment of sensitivity of PVC-materials to microorganisms’ impact are presented in the table 2 and figure 1. Bactericidal activity of materials was estimated in relation to the typical representatives of Gram-positive and Gram-negative bacteria such as *Escherichia coli* and *Bacillus subtilis*. The given results should be regarded as the average values of three tests.

Table 2. Assessment of bactericidal activity of materials in relation to *Escherichia coli* and *Bacillus subtilis*.

Type of QAS	Diameter of the growth retardation zone for microorganisms, mm	
	<i>Escherichia coli</i>	<i>Bacillus subtilis</i>
ALKASAS 1214S.50	12 mm	14 mm
ALKASAS 16S.50	24 mm	16 mm
ALKASAS 1618S.50	22 mm	18 mm
with wollastonite	16 mm	16 mm
base composition	12 mm	14 mm



a) Study object - *Escherichia coli*



b) Study object - *Bacillus subtilis*

Fig. 1. Assessment of bactericidal activity of materials in relation to
a) *Escherichia coli* and b) *Bacillus subtilis*.

The results obtained by the authors (table 2) prove that the base composition of linoleum is marginally more resistant to Gram-positive bacteria than Gram-negative ones. Introduction of wollastonite in the formulation of PVC-composition increases resistance to both groups of microorganisms. Treatment of Miwoll 10-97 surface with QAS improves bactericidal properties of the material. The obtained results could be proven by the literature data [13-15] describing activity of cationic surface-active substances in relation to Gram-positive and Gram-negative microorganisms. Along with that, an identified bactericidal effect is higher in the case of Gram-negative bacteria impact (table 2).

Treatment of wollastonite surface by alkyltrimethyl ammonium chlorides ensures the greatest resistance to microorganisms. What is more, in relation to *Escherichia coli* bacterial growth-inhibiting action is more pronounced when applying ALKASAS 16S.50, correspondingly in relation to *Bacillus subtilis* - ALKASAS 1618S.50.

Water fastness of PVC-films modified by both naturally-occurring and QAS-activated wollastonite is rather high and insignificantly depends on the nature of quaternary ammonium salts, widely used for surface activation of this calcium methylsilicate [16].

It was stated that the lowest mass variation of specimen had been observed for PVC-materials containing wollastonite activated by alkylmethyl ammonium chloride (ALKASAS 1618S.50).

The results of comparative analysis for resistance of polyvinylchloride compositions to aggressive substances are presented in the table 3.

Table 3. Resistance of PVC-compositions modified by activated wollastonite to aggressive substances.

Type of QAS	Water, %	0.015% 'Aster' aqua solution	0.5% 'Nika Ekstra-M' aqua solution
ALKASAS 1214S.50	10.7	10.6%	9.2%
ALKASAS 16S.50	11.0	12.1%	9.6%
ALKASAS 1618S.50	9.1	9.7%	9.4%
with wollastonite	10.9	12.2%	9.8%
base composition	11.4	12.8%	10.3%

Note: the table presents the values for specimen mass loss within 7 days of exposure to aggressive substances.

Evaluating the obtained results it can be said that PVC floor coatings modified by wollastonite are more resistant to aggressive chemical liquids and microorganisms than linoleum with the base composition. Along with that, when the alkyl length of quaternary ammonium salts is increased, one could observe enhancement of chemical, bactericidal resistance and water fastness of PVC-films modified by activated wollastonite. This could be related to increase in weight percent of the main substance in the molecule of these surface-active substances [17, 18] which exert an influence on efficiency of interaction on the interface boundary polymer matrix-filler [19].

4. Conclusion

Linoleum on the base of PVC-compositions filled with wollastonite, in particular surface-activated by alkyl methyl ammonium chlorides, are characterized by high fastness to water as well as resistance to water solutions of antiseptic agents and bacteria. When increasing the alkyl length of quaternary ammonium salts, modified polyvinylchloride films could exhibit the improvement of chemical and bactericidal resistance and water fastness. Along with that, it is evident that bactericidal properties of PVC-materials correlate with their resistance to corrosive mediums; such a correlation has been previously described by other researchers [19, 20].

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