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Inactivating and damaging properties of the disinfectant "MultiDez" when exposed to bacteria and spores

Vladimir Nikolaevich Gerasimov [a], Lyudmila Aleksandrovna Kraeva [b], Dmitrij Anatol'evich Svetlov [c,*], Ajgul' Ravilovna Gajtrafimova [a], Elena Vladimirovna Bystrova [a], Sergej Anatol'evich Kotov [a], Daniil Dmitrievich Svetlov [d]

[a] State Scientific Center of Applied Microbiology and Biotechnology of Rospotrebnadzor, 142279, Serpukhov, Obolensk Settlement, Territory "Quarter A", House №24, Moscow Region, Russia
[b] Pasteur Institute of Epidemiology and Microbiology, 14 Mira Street, 197101, Saint Petersburg, Russia
[c] Soft Protector LLC, Khimikov Str., 28, Litera C, Room C1591, 195030, Saint Petersburg, Russia
[d] Peter the Great St. Petersburg Institute, Higher School of Biotechnology and Food Production, 48 Novorossiyskaya Str., 194021, Saint Petersburg, Russia

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ABSTRACT

Disinfectants play a crucial role in controlling the spread of infectious diseases caused by bacteria and spore-forming organisms. Bacteria and spores can persist on surfaces and in the environment for extended periods, posing a significant risk to public health. Disinfectants are designed to inactivate or kill these microorganisms by disrupting their cellular structures and functions. Effective disinfectants are essential for preventing the spread of infectious diseases in hospitals, laboratories, food processing facilities, and other settings where the risk of contamination is high.

This study evaluated the effectiveness of a disinfectant called "MultiDez" on *Y.pestis* bacteria and Bacillus anthracis spores using microbiological and electron microscopic methods. Results showed that after exposure to a 0.5 % solution of the disinfectant, the death of all *Y.pestis* bacteria was achieved after 90 min, while the death of Bacillus anthracis spores was achieved after 240 min. Electron microscopy revealed that the disinfectant caused complete destruction of both bacterial cells and spores by enveloping their outer surfaces with polymer molecules, disrupting the structure and function of their membranes, and destroying their cytoplasm and nucleode. The mechanism of action of the disinfectant on bacteria and spores involved different processes, with the disinfectant causing rapid hydration of dehydrated spores and blocking the functions of spore membranes in the case of bacterial spores.

1. Introduction

Due to the spread of new viral infections in the world (Covid-19, SARS), the preservation of natural anthrax foci, periodic outbreaks of enterocolitis, other bacterial and viral diseases, the epidemiological situation requires strengthening measures for the prevention and control of pathogens. In this situation, non-specific prevention of infections is of particular importance, one of the directions of

* Corresponding author.
E-mail address: teflex@list.ru (D.A. Svetlov).

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which is the development and improvement of disinfectants (DS). Disinfectants are used to destroy or eliminate pathogenic microorganisms in the environment (premises, various objects, tools, etc.).

The development of new drugs and the improvement of known disinfectants is carried out by creating new composite medication from existing active substances, the introduction of synergistic additives into the composition of disinfectants that enhance the effect of active components, the use of new chemical substances as active substances, etc [1–3].

A new disinfectant "MultiDez" has been developed, in which contains modified polyhexamethylene guanidine hydrochloride (PHMG-HC), benzalkonium chloride (H), nonionic surfactants and other commercial classified functional additives. The disinfectant "MultiDez" has antimicrobial activity against gram-negative and gram-positive bacteria, including bacteria and spores of pathogens of particularly dangerous infections, mycobacterium tuberculosis, as well as against viruses, pathogenic and mold fungi.

The product is intended for the current and preventive disinfection of various objects in medical organizations, including medical instruments, including endoscopes, for disinfection of medical waste and biological secretions [4].

In modern conditions, great importance is paid to the study of the mechanism of action of disinfectants, which determines the relevance of research to assess the effects of drugs on the process of damage and destruction of bacterial cells. The mechanism of action of disinfectants is determined by the nature of the active chemical compound and may be associated with damage to surface structures (cell wall, cytoplasmic membrane), inactivation of enzymes, metabolic disorders, and other factors. Thus, when exposed to chlorine-containing compounds, proteins and other components of the cell are oxidized [5]. Surface-acting surfactants (SAS), as shown by experimental data, damage the cytoplasmic membranes of microorganisms, their antimicrobial activity depends on the magnitude of the long-chain alkyl radical [3,6]. Guanidine derivatives, which by their chemical nature belong to high-molecular cationic surfactants, selectively interact with carboxyl groups of amino acids and acidic polysaccharides of the cell membrane, which leads to coagulation of the contents of microbial cells. The effectiveness of disinfectants based on tertiary alkylamines is associated with the destruction of structural components of cells [2]. Oxygen-containing compounds form free radicals that damage proteins and lipids of cytoplasmic membranes, DNA, and other components of the microbial cell [7]. The mechanism of action of aldehyde-containing compounds is based on interaction with amino- and sulfhydryl groups of proteins, resulting in their denaturation.

Since modified polyhexamethylene guanidine hydrochloride (PHMG-HC) is a new active substance, the purpose of the research was to study the interaction of the disinfectant "MultiDez" with bacterial cells of the vaccine strain of the causative agent of the plague - *Yersinia pestis* str. EV SRIEH and bacterial spores of the vaccine strain *Bacillus anthracis*, str. STI-1.

The study was conducted on the basis of the State Scientific Center for Applied Microbiology and Biotechnology in 2022.

2. Materials and research methods

The antimicrobial activity of the disinfectant "MultiDez", developed by « Soft Protector», Russia, was investigated in the work. The culture of *Yersinia pestis* str. EV SRIEH was chosen as the tested microorganism. The culture of *Bacillus anthracis*, in. STI-1 was chosen as the tested bacterial spores. Bacterial cultures of spores were obtained from the collection of microorganisms of the SBU SSC PMB, Obolensk.

The study was carried out using microbiological and electron microscopic methods (Table 1) [8].

The working suspension of the Y. pestis test culture, str. EV SRIEH was prepared from daily cultures grown on a solid nutrient medium PNM (plague nutrient medium) at a temperature of 28 ± 1 °C for 24–48 h. To prepare the working suspension, the daily culture was washed off with sterile saline solution and diluted to a concentration of 1×10^{10} cfu/cm^3 corresponding to the BAC-10 optical turbidity standard.

The biomass of spores obtained by a well-known technique was used in the work [9]. The biological concentration of test spores in the spore suspension was determined by the method of successive tenfold dilutions of the suspension and subsequent inoculation on the medium of LB-agar in Petri dishes. The cultures in Petri dishes were incubated in a thermostat at a temperature of 37 ± 1 °C. After 24 h, the grown colonies were counted. Only the biomass of spores containing at least 80 % of mature bacterial spores was used in the work.

The exposure time is 30, 60 and 90 min. To determine the bactericidal effectiveness of the disinfectant after 60, 120, 180 and 240

Table 1
Materials and methods used in the study of the antimicrobial effect of the disinfectant "MultiDez" on bacteria and spores.

Disinfectant, exposure mode	Research methods	Sample	Criteria
"MultiDez", the concentration of the solution 0.5 % of the drug, exposure time 15–120 min	Microbiological	Suspension of Y. pestis bacteria str. EV SRIEH	The Titer of a viable bacterial culture
	Electron microscopic	Ultrathin sections of suspension sediment samples	The extent of damage to the structure of bacteria, the number of bacteria in the microbial population with an intact structure, the number of cells with a damaged and lyzed structure
"MultiDez", the concentration of the solution is 100 % according to the drug, the exposure time is 30–240 min	Microbiological	Suspension of B. anthracis spores in. STI-1.	The titer of a viable culture of spores
	Electron microscopic	Ultrathin sections of suspension sediment samples	The degree of damage to the spore structure, the number of spores in the biomass with intact, the number of spores with damaged and lyzed structure.

min and to determine the sporicidal effectiveness of the agent. After each exposure time, the centrifuge tubes were centrifuged at 6000 rpm for 15 min. The filler fluid was drained, and 5.4 ml of neutralizer was added to each centrifuge tube to exclude the bacteriostatic effect of the active substances AS on test cultures. Neutralization of the active substances (AS) was carried out with a solution of a universal neutralizer. The composition of the neutralizer: twin-80 (3 %), histidine (0.1 %), cysteine (0.1 %), saponin (0.3–3.0 %), sodium thiosulfate.

After treatment with a neutralizer, 0.5 ml of a suspension of test microorganisms were selected to perform microbiological studies and determine the effectiveness of disinfection of the disinfectant. The remaining part of the suspension was also centrifuged at 6000 rpm for 15 min. Preparation of samples for electron microscopic studies was carried out after centrifugation and removal of the filler fluid. A 4 % solution of glutaraldehyde was added to the precipitate.

2.1. Determination of the viability of microorganisms by microbiological method

To assess the effectiveness of the disinfectant, 0.5 cm^3 culture suspensions of 1 $\times$ 10 cfu/cm^3 in the working solution of the disinfectant (sample №1) were introduced into 4.5 cm^3 of saline solution and, using the method of tenfold serial dilutions, titrated to a concentration of 10^2 cfu/cm^3. The samples were sown on Petri dishes with a solid nutrient medium of Pseudomonas Nutrient Agar (PNM). The results were considered after 24–48 h [10].

2.2. Sample preparation for electron microscopic studies

The neutralizer on amount of 5.4 cm^3 was added to the sludge of bacterial biomass (spores) treated with the disinfectant "MultiDez", thoroughly mixed, incubated for 5 min and re-centrifuged for 10 min (rotation speed 6000 rpm).

To study the ultrastructure of bacteria (spores), the biomass of microbial cells was treated with an 8 % solution of glutaraldehyde in a 0.2 M Na-cacodilate buffer, pH 7.2. Fixation was carried out overnight at a temperature of 4°*C*. Additional fixation of bacteria was carried out in a 4 % aqueous solution of osmium tetrachloride on the Reiter-Kelenberger buffer overnight at 4°*C*. After fixation and washing in the buffer, bacterial biomass samples were dehydrated for 10 min in solutions of ethyl alcohol of increasing concentration (30 %, 50 %, 70 %, 95 %) and 20 min in absolute alcohol when it is changed three times. Further, the samples were impregnated with mixtures of absolute ethanol and araldite (ratios 3:1; 1:1; 1:3) at 37 °C during the day, transferred to pure araldite, kept in vacuum (10-2 torr) for 1.5 h at a temperature of 37°*C*. The samples were filled with araldite and polymerized at a temperature of 40 °C overnight, then at a temperature of 60 °*C* for one day, at a temperature of 90 °*C* for two days [1]. Sections of fixed bacterial biomass (spores) were obtained with a glass knife on an Ultracut ultramicrotome (Reichert Jung, Austria). The sections were contrasted with uranyl acetate and lead citrate, viewed in a TecnaiG2 SpiritBioTWIN transmission electron microscope (FEI, Holland, Czech Republic) at an accelerating voltage of 120 kV and magnification from 10,000 to 100,000 times. Electron microscopic images were captured using a high-contrast wide-angle SSD high-resolution camera GatanOriusSC200W 120 kV, as well as a high-resolution CCD camera GatanOriusSC 1000V 200 kV. The photographs were processed using the TecnailmagingandAnalysis&Gatan digital micrograph programs [8].

2.3. Supplement to research methods

Determination of the degree of violation of the original ultrastructure (damage to the structure) microorganisms by electron microscopy. The method of determining the degree of structural disturbance and changes in vital bacterial organoids is based on viewing ultrathin sections of samples and assessing the state of individual biomass microorganisms using a set of cytostructural criteria [1].

For this purpose, each sample was photographed 15–20 times, while choosing random fields with 15–30 cells present. Cytological analysis was performed only on equatorial sections of microbes, which revealed the structure of the cell membrane, cytoplasm, and nucleoid.

Cells were divided into 2 main groups (cell division was based on their morphological integrity).

- intact or undamaged cells.
- damaged cells with reversible and irreversible damage.

Intact cells are characterized by the presence of an intact cell wall with a clear, continuous, three-layer contour of the outer and cytoplasmic membrane, the absence of a pronounced periplasmic space since the cell wall fits snugly to the protoplast. At the same time, the cytoplasm of intact cells has a homogeneous, fine–grained structure of medium electron density, and the nucleoid has a thin fibrillar structure in the form of a compact zone that differs in density from the surrounding cytoplasm.

The group of bacteria with damage to the ultrastructure included.

- cells that have a rupture of the outer membrane but have preserved the integrity of the cytoplasmic membrane and with an undisturbed structure of the cytoplasm and nucleoid.
- cells with rupture of all layers of the cell wall with the expiration of the cytoplasm.
- cells with destructive changes in the cytoplasm, with nucleoid damage.
- cells with lysed cytoplasm and nucleoid.
- "shadows" of cells and/or destroyed cells [1].

Statistical processing of the results was carried out based on a visual assessment of photographs taken with an electron microscope. As a result of viewing the photos, about 300–500 images of bacteria were selected. The number of cells with an intact structure was recorded using the cytological assessment of the quality of microbial cells, that you can overview in figures: 2–5.

Based on the results obtained, Table 2 was made and it clearly demonstrated the level of damage to bacterial cells in the microbial population.

The morpho-functional state of spores and the structure of the spore population after exposure to a disinfectant were evaluated using a similar technique.

2.4. Findings and discussions

Microbial cells of *Y. pestis* str. EV SRIEH were treated with a 0.5 % solution of the disinfectant "MultiDez". The concentration of the working solution of the disinfectant was chosen such that it was possible to observe the dynamics of cell destruction over time during treatment, which was recorded by microbiological and electron microscopic methods. Table 1 presents the criteria for assessing the viability of bacteria, methods, and methodological approaches by which certain parameters were studied.

The viability of microbial cell biomass was evaluated primarily by microbiological method. The titer of the suspension treated with a working solution of a disinfectant is shown in Fig. 1. The results obtained indicate that after 30 min of treatment with a 0.5 % solution, there is a noticeable change in the state of *Y. pestis* bacteria. EV SRIEH. The titer of the culture decreases by about 30 % and is 1.7×10^7 cfu/cm^3 (the titer of the initial culture is 1.0×10^9 cfu/cm^3). Complete inactivation of microorganisms is observed after 60 min of incubation with a disinfectant.

A visual representation of the changes occurring inside the cells of *Y. pestis* str. EV SRIEH was obtained by analyzing electron microscopic images that allow us to observe the transformation of cells during exposure to a disinfectant (Figs. 2–5). According to electron microscopy data, bacterial cells of the initial (control) culture of *Y. pestis*, str. EV SRIEH had a thin structure typical of gram-negative bacteria: a cell membrane consisting of a thin, slightly sinuous outer membrane, a thin peptidoglycan layer and a relatively smooth cytoplasmic membrane, homogeneous cytoplasm packed with various globular and fibrillar components. The intracellular membrane apparatus of the cell is poorly developed (Fig. 2).

As evidenced by electron microscopic studies, the mechanism of cell death of *Y. pestis* str. EV SRIEH was triggered in the first minutes after exposure to the disinfectant. In the first 30 min of exposure to the agent, the number of intact cells was 46 % of the initial number of bacteria in the population (Table 2). Bacteria with damaged ultrastructure were characterized by the following features. The bacterial cell wall after contact with the disinfectant was noticeably deformed and had ruptures, in another part of the damaged cells, a violation of the layered structure of the outer and cytoplasmic membranes or complete destruction of the bacterial cell wall was observed (Fig. 2).

It is assumed that polymer molecules of modified polyhexamethylene guanidine hydrochloride (PHMG-HC) partially or completely envelop the outer surface of the bacterial cell wall through selective interaction with carboxyl groups of amino acids and acidic polysaccharides of the cell membrane, which lead to disruption or loss of its main functional activity (respiration, nutrition, transport of metabolites and nutrients, etc.). The primary blockade of the functional activity of the bacterial cell membrane with a disinfectant led to irreversible structural damage to the outer membrane of the cell, to ruptures in the cytoplasmic membrane or to its complete disintegration, to destruction of the cytoplasm and destruction of the nucleode, which are visualized on electron microscopic images as coagulation of intracellular contents. With an increase in the exposure time to 60, 90 min after the start of culture treatment with a disinfectant, the number of intact cells continued to decrease sharply and amounted to 26 % and 0 %, respectively (Figs. 4–5). In the control, the number of viable cells was 90 % (Table 2).

Thus, the disinfectant "MultiDez" in the sublethal concentration of the working solution (0.5 % of the preparation) shows a high bactericidal effectiveness from the first minutes of exposure to bacteria. For 60–90 min of contact of bacterial biomass with disinfectant, viable bacteria completely disappear in it. The disinfectant "MultiDez" initially causes lethal functional and structural disorders at the level of the external and cytoplasmic membranes of bacteria, which lead to the destruction of the cytoplasm and nucleoid of the cell, and then to its lysis and decay.

Results of the findings about the analysis of ultrathin sections of suspension sediment samples are presented in Table 2.

Microbiological studies of the antimicrobial activity of the disinfectant "MultiDez" showed that when treated with a whole preparation of the biomass of *B. anthracis* culture spores, str. STI-1, it led to a decrease in the titer of the suspension of spores from 1.5×10^9 (before exposure to DS) to 0 after 240 min of exposure to the agent, results presented in Fig. 6 (it was made by the authors with usage of special software). The decrease in the titer of viable spores under the influence of the agent occurs roughly equally for 4 h.

Visualization of changes occurring in the biomass of spores and inside the spore cells of *B. anthracis*, str. STI-1 at different stages of exposure to disinfectant was carried out in an electron microscope on ultrathin sections of samples of spore biomass (Figs. 7–11).

Table 2
Results of the of ultrathin sections of suspension sediment analysis.

Name of microorganism	Intact cells	Cells with reversible damage	Cells with irreversible damage
1. *Y.pestis* bacteria, str. EV SRIEH (control)	91 %	4 %	5 %
2. *Y.pestis* bacteria (30 min)	46 %	3 %	51 %
3. *Y.pestis* bacteria (60 min)	26 %	2 %	72 %
4. *Y.pestis* bacteria (90 min)	0 %	0 %	100 %

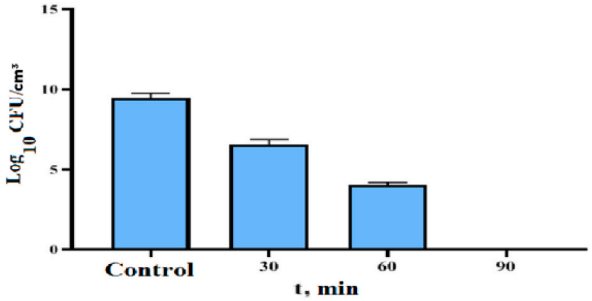

Fig. 1. Change in the titer of *Y. pestis* culture pcs. EV SRIEH during treatment with a 0.5 % solution of the disinfectant "MultiDez".

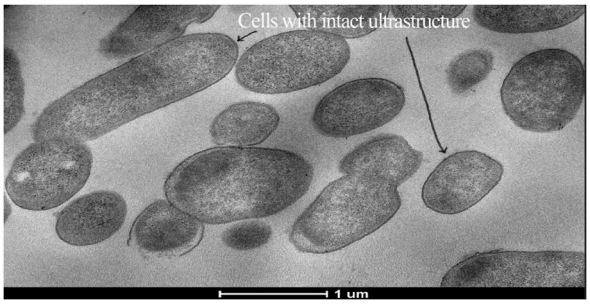

Fig. 2. Electron microscopic images of ultrathin sections of *Y.pestis* bacteria, str. EV SRIEH before exposure to disinfectant. Cells with intact ultrastructure are indicated by an arrow. The magnification on the micrograph is 20,000 times.

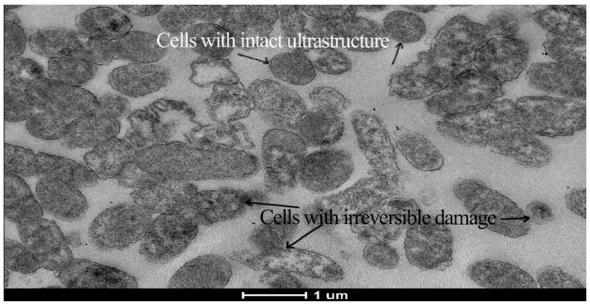

Fig. 3. Electron microscopic images of ultrathin sections of *Y.pestis* bacteria, str. EV SRIEH after 30 min of exposure with a disinfectant. Cells with intact ultrastructure and irreversible damage are indicated by an arrow. The magnification on the micrograph is 20,000 times.

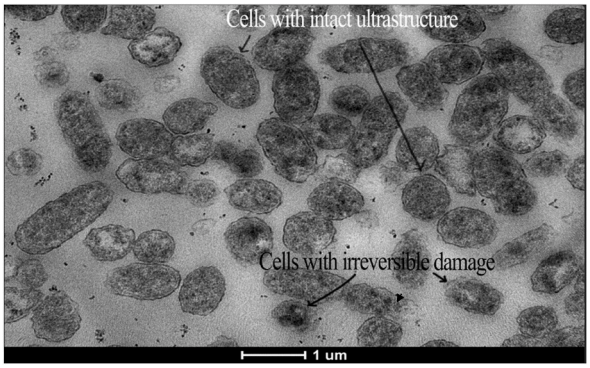

Fig. 4. Electron microscopic images of ultrathin sections of *Y.pestis* bacteria, str. EV SRIEH after 60 min of exposure with a disinfectant. Cells with intact ultrastructure and with irreversible damage are indicated by an arrow. The magnification on the micrograph is 20,000 times.

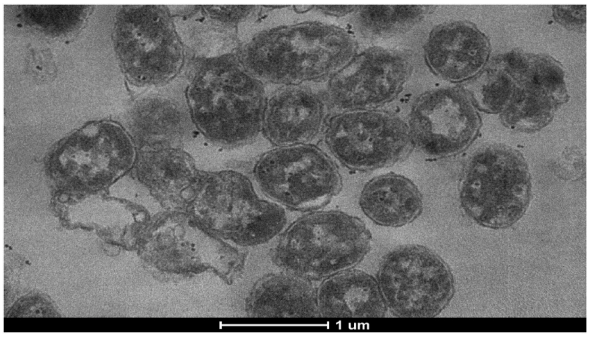

Fig. 5. Electron microscopic images of ultrathin sections of *Y.pestis* bacteria, str. EV SRIEH after 90 min of exposure with a disinfectant. All cells in the population have irreversible structural damage or are completely lysed. Magnification of 20,000 times.

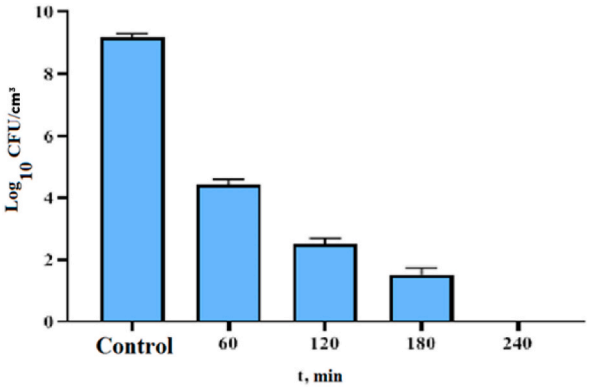

Fig. 6. Change in the titer of the suspension of *B.anthracis* culture spores strain STI -1 in the process of exposure to a whole disinfectant "MultiDez".

According to electron microscopy data, spores with intact ultrastructure in the initial biomass (suspension) of *B. anthracis*, str. STI-1 had a thin structure typical of bacterial spores: exosporium, intact spore shells, cortex, spore core or germ cytoplasm surrounded by a thin cytoplasmic membrane (Fig. 7). At least 80 % of the spores in the population were found to have intact ultrastructure based on electron microscopic assessment of the morphological and population state of the biomass of spores prior to exposure to the disinfectant. The remaining spores in the biomass are damaged or destroyed (Fig. 7). When disinfectants were exposed to the biomass of spores for 60 min, profound changes were observed in the structure of the spore population and in the fine structure of bacterial spores. It was found that during 60 min of contact of biomass with the disinfectant, the number of spores with intact ultrastructure in it decreases by more than 2 times and is approximately 42 % in the population, the remaining spores had irreversible structural damage or were at different stages of destruction and decay (Fig. 8).

With a longer exposure to the disinfectant on the biomass of spores during 60–240 min a gradual decrease in the number of spores with intact structure (viable spores) to zero in the population was observed after 180 min of contact with the disinfectant (Figs. 8–11). Spores in the process of exposure to disinfectant receive such damage as rupture and disruption of the structure of the spore membranes, rupture and damage to the cortex, destruction of the germ cytoplasmic membrane and germ cytoplasm. At the later stages of exposure (180–240 min), only deep structural damage to the spores was detected: destruction of all structural elements of the spores, lysis, and then decay of spore cells (Figs. 10–11).

Thus, it has been established that the disinfectant "MultiDez" has a sporocidal effect. It has been shown that the biomass of anthrax bacteria spores *Bacillus anthracis*, str. STI-1, when treated with a disinfectant, is completely inactivated within 180–240 min. The results obtained by microbiological methods of studying the dynamics of inactivation of the biomass of spores with a disinfectant are confirmed and correlate well with the results of visualization in an electron microscope of the structure of the biomass of spores and the ultrastructure of spore cells at different stages of exposure to a disinfectant. Ultrastructural changes detected using a transmission electron microscope indicated the complete absence of intact bacterial spores of *Bacillus anthracis,* str. STI-1 after 240 min of exposure to the disinfectant in the biomass of spores. Results of this experiment are presented in Table 3.

As a result of the research, it was also found that the mechanism of action of the disinfectant "MultiDez" on bacterial spores is most likely associated with partial hydration of dehydrated (dry) spores in the aqueous medium of the disinfectant, minor activation of spore metabolism, as well as the manifestation of the activity of polymer molecules of modified polyhexamethylene guanidine hydrochloride (PHMG-HC) by partially or completely enveloping the outer surface of the spore shells of the spores and selectively interacting with carboxyl groups of amino acids and acid polysaccharides of the spore shells, leading to blocking of the main functions of the spore

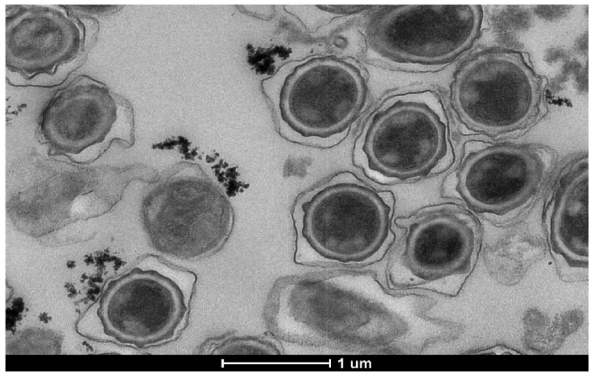

Fig. 7. Electron microscopic images of ultrathin sections of *Bacillus anthracis* bacteria spores, *str. STI-1* before exposure to disinfectant. Spores with intact ultrastructure are indicated by an arrow. Magnification of 30,000 times.

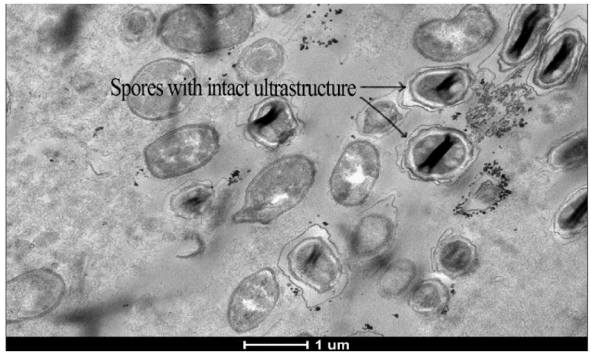

Fig. 8. Electron microscopic images of ultrathin sections of *Bacillus anthracis* bacterial spores, *str. STI-1* after 60 min of exposure to disinfectant. Spores with intact ultrastructure are indicated by an arrow, the remaining spores are damaged or destroyed. Magnification of 20,000 times.

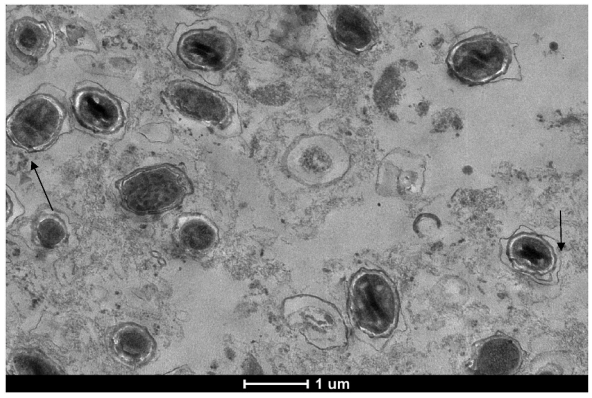

Fig. 9. Electron microscopic images of ultrathin sections of *Bacillus anthracis* bacterial spores, *str. STI-1* after 120 min of exposure to disinfectant. The spores are damaged (arrow), destroyed and completely lysed. Magnification of 20,000 times.

shells, and then to the destruction of the germinal cytoplasmic membrane and germinal cytoplasm of the spores.

3. Conclusions

1. The evaluation of the effect of the disinfectant “MultiDez”, containing modified polyhexamethylene guanidine hydrochloride (PHMG-HC), benzalkonium chloride (QAC) as an active substance, on *Y.pestis* bacteria, str. EV SRIEH and on bacterial spores of *Bacillus anthracis*, in. STI-1 b y microbiological and electron microscopic methods.

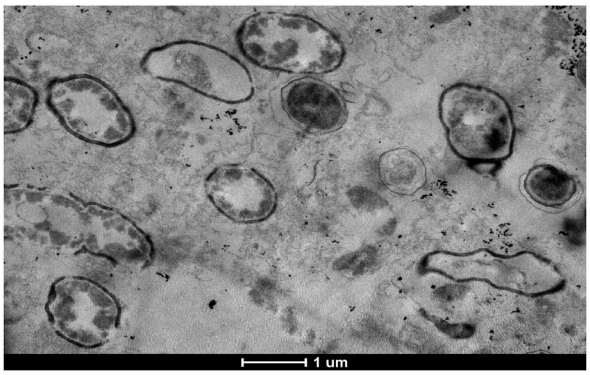

Fig. 10. Electron microscopic images of ultrathin sections of *Bacillus anthracis* bacteria spores, *str. STI-1* after 180 min of exposure to disinfectant. Magnification of 20,000 times.

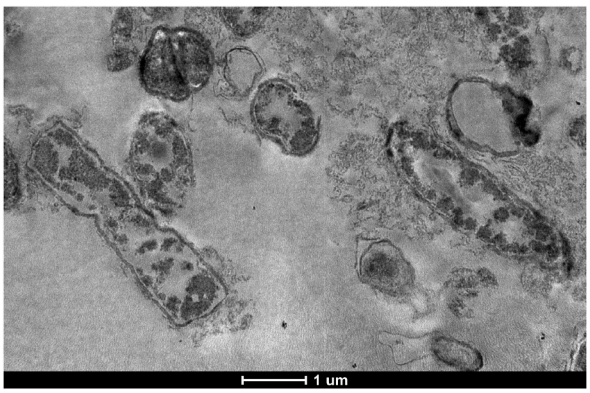

Fig. 11. Electron microscopic images of ultrathin sections of *Bacillus anthracis* bacterial spores, *str. STI-1* after 240 min of exposure to disinfectant. Magnification of 20,000 times.

Table 3
Structural changes of ultrathin section of *BacilJlus anthracis* bacterial spores.

Name of the bacterial spore population	Spores with intact structure	Spores with reversible damage	Spores with irreversible damage and/or fully lysed structure
1. *Bacillus anthracis*, str. STI-1, before exposure	87 %	5 %	8 %
2. *Bacillus anthracis*, str. STI-1, after 60 min	42 %	3 %	55 %
3. *Bacillus anthracis*, str. STI-1, after 120 min	23 %	4 %	73 %
4. *Bacillus anthracis*, str. STI-1, after 180 min	16 %	2 %	82 %
5. *Bacillus anthracis*, str. STI-1, after 240 min	0 %	2 %	98 %

2. Determination of the survival rate of test microorganisms by microbiological method with usage the 0.5 % of "MultiDez" solution, showed that, after 30 min there was 46 % intact cells, then after 60 min, the percentage of intact cells decreased to 26 % and the death of all cells of *Y.pestis* bacteria, *str. EV SRIEH* was achieved by the end of the 90-min incubation of bacterial biomass with a disinfectant.
3. Ultrastructural changes detected using electron microscopic studies indicated the complete absence of intact *Y.pestis* cells, str. EV SRIEH units in the microbial population after 90 min of exposure to the disinfectant.
4. As a result of the research, it was found that the mechanism of action of the disinfectant "MultiDez" on bacteria is associated with the enveloping of the outer surface of cells with polymer molecules "MultiDez" and a violation of the structure and basic functions of the outer and cytoplasmic membranes, leading to the destruction of the cytoplasm and nucleode of bacteria.
5. Determination of the survival rate of test microorganisms by microbiological method with usage the 0.5 % of "MultiDez" solution, showed that after 60 min from the beginning of the experiment percentage of the spores with intact structure was 42 %, after 120

min the percentage was 23 %, after 180 min percentage equals 16 % and the death of bacterial spores of *Bacillus anthracis*, *str. STI-1* was achieved by the end of 240-min incubation with a disinfectant.
6. Ultrastructural changes detected in a transmission electron microscope testified to the complete absence of intact bacterial spores of *Bacillus anthracis*, str. STI-1 after 180–240 min of exposure to the disinfectant.
7. As a result of the research, it was found that the potential mechanism of action of the disinfectant "MultiDez" on bacterial spores is associated with rapid hydration of dehydrated spores in the aqueous medium of the disinfectant, insignificant activation of spore metabolism, blocking of the main functions of the spore membranes, destruction of the germinal cytoplasmic membrane and germinal cytoplasm of spores.

Data availability

- Has data associated with your study been deposited into a publicly available repository?
- No
- Please select why. Please note that this statement will be available alongside your article upon publication.
- Data included in article/supp. Material/referenced in article

CRediT authorship contribution statement

V.N. Gerasimov: Data curation, Investigation. **L.A. Kraeva:** Formal analysis, Methodology, Visualization. **D.A. Svetlov:** Data curation, Funding acquisition, Investigation, Project administration, Supervision, Writing – original draft. **A.R. Gajtrafimova:** Formal analysis, Investigation, Resources, Software, Validation. **E.V. Bystrova:** Formal analysis, Investigation, Resources, Software, Validation. **S.A. Kotov:** Formal analysis, Investigation, Methodology, Resources, Software. **D.D. Svetlov:** Investigation, Resources, Software, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Gerasimov Vladimir Nikolaevich – Phd of Biological Sciences, Head of the Department of Disinfection of the State Scientific Center for Applied Microbiology and Biotechnology

Gajtrafimova Ajgul' Ravilovna – Junior Researcher of the Disinfection Department of the State Scientific Center for Applied Microbiology and Biotechnology

Bystrova Elena Vladimirovna – Researcher of the Disinfection Department of the State Scientific Center for Applied Microbiology and Biotechnology

Kotov Sergej Anatol'evich – Junior Researcher of the Disinfection Department of the State Scientific Center for Applied Microbiology and Biotechnology

Kraeva Lyudmila Aleksandrovna – Phd of Medical Sciences, Head of the Laboratory of Medical Bacteriology in Saint-Petersburg Pasteur Institute of Epidemiology and Microbiology, corresponding member of the Petrovsky Academy of Sciences and Arts

Dmitrij Anatol'evich Svetlov – Phd of Technical Science, CEO of Soft Protector LLC

Daniil Dmitrievich Svetlov – 1st year master's student of the Higher School of Biotechnology and Food Industry of the Peter the Great's Polytechnic University