SYNTHESIS, ANTIMICROBIAL AND ANTIFUNGAL ACTIVITY OF PLATINUM (II) AND PALLADIUM (II) COMPLEXES

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Abstract. *The aim of the work is the synthesis of mono- and binuclear complexes of platinum (II) and palladium (II) containing terminal and bridging atoms of chlorine and sulfur as ligands and the study of their biological activity in relation to test cultures of Bacillus subtilis B4647, Aspergillus brasiliensis (niger) F679, Pseudomonas aeruginosa B8243, Escherichia coli. The composition and structure of the synthesized platinum (II) and palladium (II) complexes were established by methods of elemental analysis, X-ray photoelectron spectroscopy (XPS), IR spectroscopy, and X-ray diffraction (XRD) technique, which correspond to our results on the X-ray structural analysis of these complexes. Antimicrobial and antifungicidal properties were assessed by the ability of the synthesized complexes to suppress the vital activity of bacteria and fungi using the agar diffusion method and the in vitro dilution method. The results obtained showed high activity of the binuclear complex of palladium (II) (μ-S)$[Pd_2(SCH_2CH_2NH^+_3)_2Cl_4]$ and platinum (II) (μ-Cl)$[Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot 3H_2O$ of non-electrolyte type. Binuclear complexes of palladium and platinum, in contrast to mononuclear trans-$[Pd(SCH_2CH_2NH_2)_2]$ and cis-$[Pt(SCH_2CH_2NH_2)_2]$, exhibit higher antibacterial activity. The effectiveness of the antibacterial action of the non-electrolyte palladium complex against the bacteria Bacillus subtilis, Escherichia coli and fungi Aspergillus niger was more pronounced.*

The results of our study showed that by changing the structure of the complex, the composition and charge of the inner sphere, the number of coordination centers, the nature and dentacy of the ligands, it is possible to achieve a higher toxic effect of the complexes (μ-S $[Pd_2(SCH_2CH_2NH^+_3)_2Cl_4]$, μ-Cl $[Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot 3H_2O$) in relation to bacteria and fungi.

Keywords*: platinum complexes, palladium, sulfur, chlorine-bridged ligands, denticity, antimicrobial properties.*

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Introduction

One of the most important problems of our time remains human resistance to various viruses and bacteria, which pose a great danger not only to the health and life of people, but also to various ecosystems. Due to the high resistance of microorganisms, today we cannot be satisfied with the achieved results in the field of obtaining and use of antibacterial substances [1, 2]. In recent years, the impact of drug therapy has been recognized as an extremely important issue not only medically, but also environmentally; improving the quality of medical care and increasing its effectiveness must be combined with the safety of pharmacotherapy, a real assessment of the influence of drugs as chemical factors affecting the human biocenosis and the ecology of the environment. This especially applies to antibacterial drugs, which can change the sensitivity of microorganisms, contribute to the formation of their resistance, and transform the local "microbial landscape" and the ecological environment [3]. Therefore, constant monitoring of antibacterial drug therapy is necessary, it is necessary to synthesize new antimicrobial agents that can be created in an affordable, fast and environmentally friendly way. The discovery of cisplatin [4] as an antitumor agent

has attracted attention to the targeted design of metal complexes that could potentially be used in chemotherapy. Transition metal chemotherapy plays a key role in the treatment of cancer, and among all the metals studied, platinum and palladium are the most effective [5].

The authors [6–11] synthesized numerous complexes based on platinum (II) and palladium (II) ions and studied their antimicrobial activity. Among them are complexes with nitrogen-containing ligands, recognized as biologically active compounds exhibiting great DNA-binding and antimicrobial activity [12].

The aim of the work is the synthesis of mono- and binuclear complexes of platinum (II) and palladium (II) containing terminal and bridging atoms of chlorine and sulfur as ligands and the study of their biological activity in relation to test cultures of Bacillus subtilis B4647, Aspergillus brasiliensis (niger) F679, Pseudomonas aeruginosa B8243, Escherichia coli.

Experimental part

Chemical grade salts $K_2[PtCl_4]$, $K_2[PdCl_4]$ and $PdCl_2$ were used as starting platinum and palladium compounds. The ligand cystamine dihydrochloride $(SCH_2CH_2NH_2{\cdot}HCl)_2$ from FERAX was used without additional purification.

Synthesis of *trans*-$[Pd(SCH_2CH_2NH_2)_2]$-$[Pd(L)_2]$. To 10 ml of a suspension of $K_2[Pd(OH)_4]$, obtained according to the method we developed, from 0.83 g (0.0025 mmol) $K_2[PdCl_4]$ with stirring, add 0.57 g (0.0025 mmol) cystamine dihydrochloride, dissolved in 5 ml of water and neutralized with KOH solution. In this case, the color of the reaction mixture turns red. When the pH of the solution is adjusted to 13.5 with KOH, the color of the solution becomes brownish-yellow. Then the reaction solution is evaporated in a water bath at 80°C to a volume of 7 ml. After this, the solution is cooled to 6°C and left at this temperature for 48 hours, as a result of which a yellow precipitate precipitates from the solution. The precipitate is filtered off, washed with water, alcohol and ether. The substance is dried first in air, then in vacuum to constant weight over $CaCl_2$. The yield was 0.34 g (52%).

Single crystals of the same composition $[Pd(SCH2CH_2NH_2)_2]$, which were studied by X-ray diffraction, precipitate from the mother liquor upon slow evaporation under special conditions [1].

Synthesis of *cis*-$[Pt(SCH_2CH_2NH_2)_2]$-$[Pt(L)_2]$. Solutions are prepared from 0.33 g of $H_2[PtCl_4]$ (0.97 mmol), and 0.22 g (0.97 mmol) of cystamine hydrochloride dissolved in 15 ml of water is added to it. In this case, the color of the solution changes from dark cherry to orange. The reaction mixture is heated to 50°C, then neutralized with a concentrated solution of KOH to pH=7.5. In this case, the solution becomes cloudy and its color turns yellow. When the pH of the reaction mixture is brought to 12.5, a yellow precipitate precipitates from the solution. The mixture is kept in the refrigerator for an hour, and then the precipitate is filtered off, washed with water, alcohol and ether. The substance is dried first in air, then in vacuum to constant weight. The yield was 0.16 g (47%).

At room temperature, after a week, crystals precipitate from the mother solution, their structure was determined by X-ray diffraction [1].

Synthesis of (μ-S)$[Pd_2(SCH_2CH_2NH^+_3)_2Cl_4]$- $[Pd_2(HL)_2Cl_4]$. A 1.17 g (0.65 mmol) sample of $PdCl_2$ is dissolved in a mixture of 5 ml of H_2O and 5 ml of HCl (conc.). After filtering, 1.48 g (0.65 mmol) of cystamine dihydrochloride dissolved in 10 ml of water is added to this solution with stirring. In this case, the color of the reaction mixture becomes bright red. By adding HCl to the reaction solution, the pH of the medium is adjusted to 1.7. When this solution is evaporated in a water bath to a small volume at a temperature of 70-75°C, a red precipitate forms. The separated mother liquor is left under special conditions for crystallization. After five days, red crystals precipitate from the solution, which are filtered and dried to constant weight over P_2O_5. Yield: 1.49 g (44%).The structure of the complex was studied by X-ray diffraction [1].

Synthesis of (μ-Cl)[$Pt_2(SCH_2CH_2NH_2)_2Cl_2$]·$3H_2O$-[$Pt_2(L)_2Cl_2$]·$3H_2O$. A sample of 0.47 g (1.14 mmol) of $K_2[PtCl_4]$ is dissolved in 15 ml of warm water and filtered to remove partially reduced metal. First, 0.25 g (1.14 mmol) of cystamine dihydrochloride is dissolved in 10 ml of water and neutralized with a concentrated KOH solution, and then added to the K2[PtCl4] solution with vigorous stirring. The temperature of the reaction solution is brought to 50°C, and a cloudy mixture is formed. By adding KOH, the pH of the reaction mixture is adjusted to 10. At this point, a copious lemon-yellow precipitate forms. The reaction mixture is kept at a temperature of 6°C for 24 hours, then filtered and washed with cold water, alcohol and ether. The precipitate is dried in a vacuum over P_2O_5 to constant weight. The yield was 0.3314g (44%).

IR spectra of the complexes and the ligand were taken on Thetmoscientifis, Nikoletis 10 and Bruker IFS-113V spectrometers in Vaseline or a suspension of fluorinated oils, as well as in the form of tablets with KBr in the frequency range 200–400 and 400–4000 cm^{-1}, and electronic absorption spectra - on the Shimadzu UV-Vis-240 Evolution-60S device. X-ray photoelectron spectra (XPS) were recorded on a Varian VIEE-15 spectrometer with a Mg anode in vacuum. Elemental analysis of non-metals was performed on a CHNS-O EMA 502 analyzer. The content of platinum and palladium was determined by the X-ray fluorescence method on an EDX-7000P spectrophotometer (SHIMADZU). The thermal behavior of the complexes was studied on a STA 449 F3 Jupiter NETZSCH system at a heating rate of 10 deg/min in the air up to 800^o C.

Studies of the antibacterial and antifungal activity of the synthesized complexes were carried out against Bacillus subtilis B4647, Aspergillus brasiliensis (niger) F679, Pseudomonas aeruginosa B8243, Escherichia coli.

Results and discussion

The resulting mono- and binuclear complexes of platinum and palladium are light yellow to red powders, soluble in water, ethanol and dimethylformamide. The methods of coordination of ligands were confirmed by XRD, XPS and IR-spectroscopy, which are widely used for this purpose.

The study of the interaction of palladium (II) and platinum (II) with cystamine dihydrochloride shows that in an acidic environment (1.7) a binuclear palladium complex (μ-S) [$Pd_2(SCH_2CH_2NH^+_3)_2Cl_4$] is obtained, in alkaline environments (pH-10.5 - 13.5) formation of mono- and dinuclear complexes of the following composition occurs: *trans-[*$Pd(SCH_2CH_2NH_2)_2$], *cis*-[$Pt(SCH_2CH_2NH_2)_2$] and (μ-Cl)[$Pt_2(SCH_2CH_2NH_2)_2Cl_2$]·$3H_2O$.The results of elemental analysis are listed in Table 1.

Table 1. The result of the elemental analysis for the synthesized complex compounds

Coordination compounds	Pd, Pt		N		Cl		C		H (S)	
	Found	Calc.	Found	Calc.	Found	Calc.	Found	Calc.	Found	Calc.
$[Pd(L)_2]$	41.27	41.15	11.79	10.82	24.53	24.79	18.31	18.58	4.44	4.64
$[Pt(L)_2]$	56.09	56.18	8.15	8.06	18.53	18.46	13.61	13.83	3.72	3.45
$[Pd_2(HL)_2Cl_4]$	42.09	41.83	5.55	5.50	27.95	27.87			(12.47)	(12.60)
$[Pt_2(L)_2Cl_2]·3H_2O$	58.29	58.46	4.37	4.19	10.42	10.63	7.41	7.19	(9.73) 2.80	(9.60) 2.69

The IR spectra of these complexes show that during complex formation a five-membered metallocycle with bidentate coordination of the ligand by sulfur and nitrogen atoms is formed.

This is evidenced by absorption bands at 383 and 468 cm^{-1}, respectively, related to bonds and. The coordinated amino group $(\nu^{coor}_{NH_2})$ is characterized by absorption bands at 3196 and 3122 cm^{-1}. The observed values and number of absorption bands of the Pd-S and Pd-N bonds indicate their trans arrangement. In the IR spectrum of the $[Pt(SCH_2CH_2NH_2)_2]$ complex, absorption bands are observed at 470 and 449 (V_{Pt-N}), as well as at 394 and 346 (V_{Pt-S}), which are absent in the spectrum of the ligand. These absorption bands are in good agreement with the literature [13]. The observed two absorption bands for the Pt-N and Pt-S bonds indicate that these atoms in the $Pt(SCH_2CH_2NH_2)_2]$ complex are in the cis arrangement [13] (Fig.1).

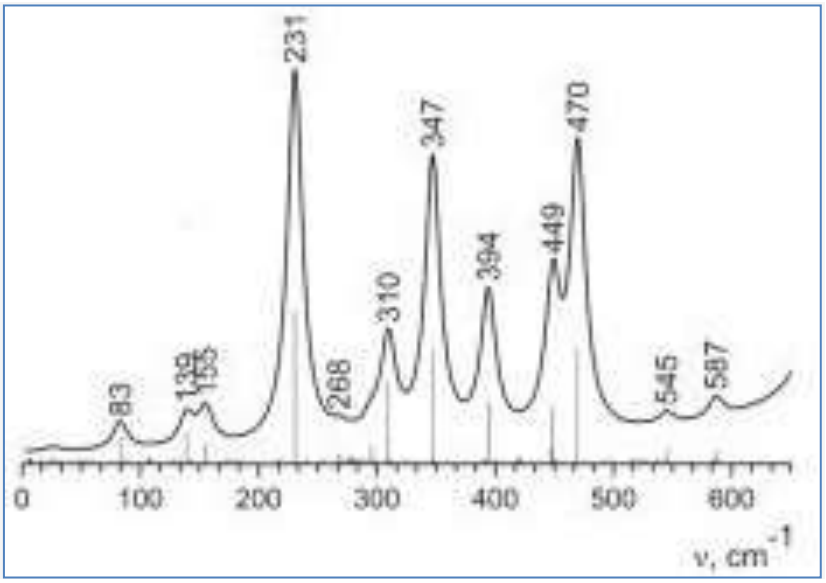
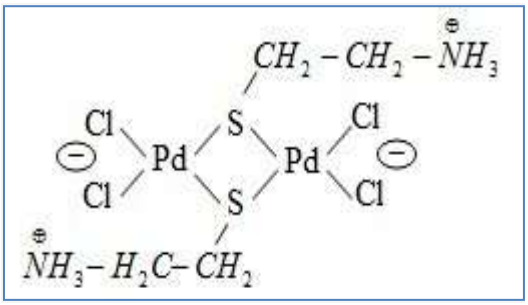


Fig. 1. IR absorption spectrum of the *cis*-$[Pt(SCH_2CH_2NH_2)_2]$ complex in the region 0-500 cm^{-1}

XPS data also indicate the presence of nitrogen (E_{N1S} = 400.3 eV) and sulfur (E_{S2P} = 163.0 eV) atoms coordinated with platinum in the $Pt(SCH_2CH_2NH_2)_2$ complex. Conclusions about the structure of the *trans*-$[Pd(SCH_2CH_2NH_2)_2]$ and cis-$[Pt(SCH_2CH_2NH_2)_2]$ complexes made on the basis of IR and XPS studies are also confirmed by X-ray diffraction results [14]. At pH = 1.7 and a temperature of 70-75°C, with a metal:ligand ratio of 1:1, a complex of composition (μ-S) $[Pd_2(SCH_2CH_2NH^+_3)_2Cl_4]$ is obtained. Using the X-ray diffraction method, it was shown that the molecule of the complex is binuclear in which the palladium atoms, each having two terminal chlorine atoms, are united by a pair of bridging thiolate ligands - $SCH_2CH_2NH^+_3$[1]. Schematically, the structure of the (μ-S)$[Pd_2(SCH_2CH_2NH^+_3)_2Cl_4]$ complex can be represented as follows:



Scheme 1. The structure of the (μ-S)$[Pd_2(SCH_2CH_2NH^+_3)_2Cl_4]$ complex

The results of an IR spectroscopic study of the (μ-S)$[Pd_2(SCH_2CH_2NH^+_3)_2Cl_4]$ complex are in good agreement with X-ray diffraction data, according to which the central Pd_2S_2 metallocycle in the complex is nonplanar and has local C_{2v} symmetry [14]. The most

characteristic in the spectra of palladium chloride complexes are the frequencies of stretching vibrations, which give intense bands in the region of 300-380 cm^{-1}. For C_{2V} symmetry, the selection rules require the presence in the IR spectra of three bands of stretching vibrations of Pd-Cl bonds (types A1+B1+B2). Indeed, in the IR spectrum of the (μ-S)$[Pd_2(SCH_2CH_2NH^+_3)_2Cl_4]$ complex three bands are observed with frequencies of 378, 366 and 322 cm^{-1}, which is consistent with the non-planar structure of the metallocycle in this complex. Stretching vibrations correspond to absorption bands at 287 and 273 cm^{-1}. The protonated amino group in the complex (μ-S)$[Pd_2(SCH_2CH_2NH^+_3)_2Cl_4]$ is characterized by broad absorption bands in the region of 2000-3200 cm^{-1} and absorption bands of bending vibrations $\delta_{\overset{\oplus}{NH_3}}$ around 1632 and 1491 cm^{-1}. Fig. 2.

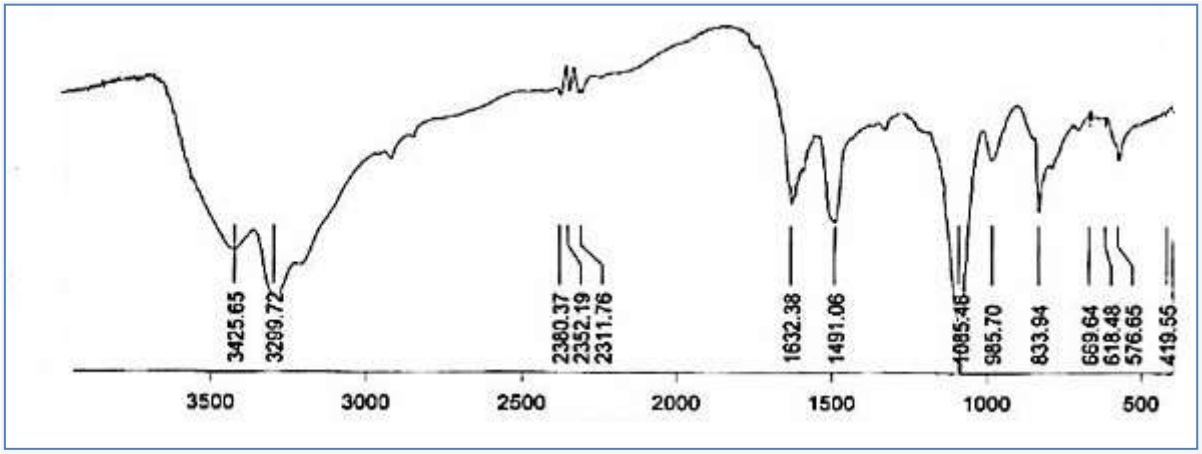


Fig. 2. IR absorption spectrum of the (μ-S)$[Pd_2(SCH_2CH_2NH^+_3)_2Cl_4]$ complex in the region of 400-4000 cm^{-1}

XPS data are also consistent with the presence in the complex (μ-S) $[Pd_2(SCH_2CH_2NH^+_3)_2Cl_4]$ of a protonated $\overset{\oplus}{N}H_3$-group (Econ. (N_{1s}) = 401.4 eV), the same as in the original cystamine hydrochloride (Econ. (N_{1s})=401.4 eV), and a sulfur atom coordinated by palladium (Econ.(S_{2p})=163.4 eV). The results of various physical research methods allow us to conclude that in the complex (μ-S)$[Pd_2(SCH_2CH_2NH^+_3)_2Cl_4]$, sulfur atoms occupy the bridging position, and chlorine atoms occupy the terminal position [15].

The results of the study with platinum (II) showed that the ligand, a product of the cleavage of cystamine dihydrochloride, can coordinate bidentately to form a binuclear halo-bridge complex with the composition: (μ-Cl)$[Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot 3H_2O$. In the IR spectrum of the (μ-Cl) $[Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot 3H_2O$ complex, we attributed the two observed absorption bands at 302 and 285 cm^{-1} to the bridging $\nu_{Pt\text{-}Cl}$ connection. And the terminal $\nu_{Pt\text{-}Cl}$ bond is characterized by an absorption and at 329 cm^{-1}. With a comparative study of the IR spectra of the bromine-bridge complex (μ-Br) $[Pt_2(SCH_2CH_2NH_2)_2B_{r2}]$, the assignment made to the characteristic absorption band becomes more reliable [15].

Metal-bromine bridge bonds in the IR spectrum of the (μ-Br)$[Pt_2(SCH_2CH_2NH_2)_2Br_2]$ complex are characterized by absorption bands at $\nu_{Pt\text{-}Br}$ =200 and 210 cm^{-1}. The observed absorption bands at 368 and 360 cm^{-1} in the IR spectrum of the (μ-Cl) $[Pt_2(SCH2CH_2NH_2)_2Cl2]\cdot 3H2O$ and (μ-Br)$[Pt_2(SCH_2CH_2NH2)_2Br_2]$ complexes are assigned to the terminal bond, respectively. In the (μ-Cl)$[Pt_2(SCH_2CH_2NH_2)2Cl_2]\cdot 3H_2O$ complex, the Pt-N bond has an absorption band at 466 cm^{-1}. The amino group coordinated with the metal is characterized by a bending vibration δ_{N-H} band at 1570 cm^{-1}. Based on the results obtained, we can say that in these binuclear chloro- and bromine-bridge complexes (μ-Cl) $[Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot 3H_2O$ and (μ-Br)$[Pt_2(SCH_2CH_2NH_2)_2Br_2]$ mercamine is coordinated bidentately at the sulfur atom and

nitrogen amino group to form two terminal five-membered metallocycles [16].

Thermogravimetric study of the (μ-Cl)$[Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot 3H_2O$ complex showed that three water molecules in the composition of this complex correspond to endo-peaks at 130, 160 and 210°C. The complex decomposes at 295°C without melting. The final product of thermolysis is platinum metal:

$$[Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot 3H_2O \xrightarrow{130^oC} [Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot 2H_2O \xrightarrow{160^oC}$$

$$[Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot H_2O \xrightarrow{210^oC} [Pt_2(SCH_2CH_2NH_2)_2Cl_2] \xrightarrow{295–900^oC} Pt$$

X-ray phase analysis showed that for the ligand and the binuclear complex, the crystalline phases of the initial reagents do not appear. This indicates the formation of new products. Figure 3 shows the diffraction patterns of a nonelectrolyte-type platinum dimer complex (μ-Cl) $[Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot 3H_2O$ and the ligand taken as the starting reagent in the synthesis.

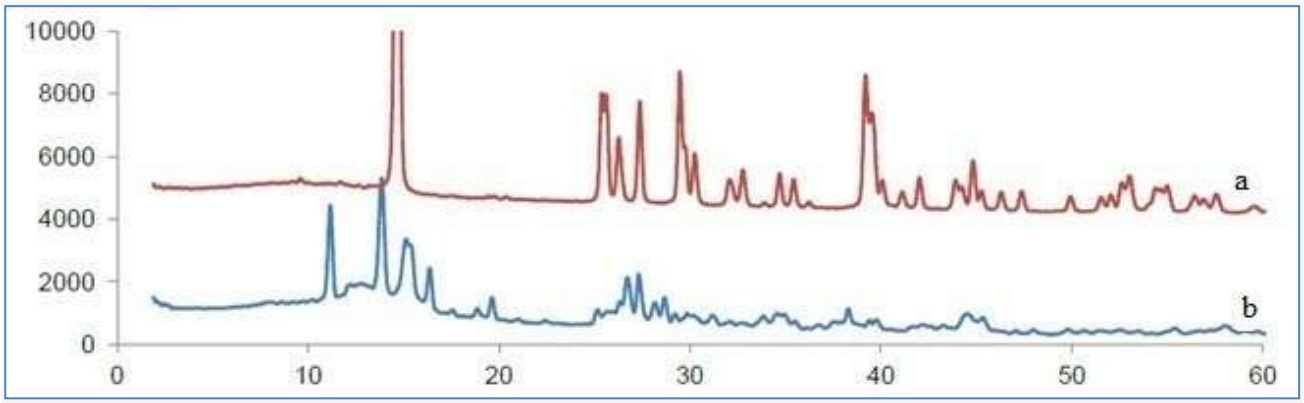


Fig. 3. Diffraction patterns of the ligand $(SCH_2CH_2NH_2)_2$ ***(a)*** and the dimeric complex (μ-Cl) $[Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot 3H_2O$ ***(b)***.

Antibacterial properties were assessed by the ability of the synthesized complexes to suppress the activity of bacteria using the method diffusion in agar and dilution in vitro. Testing was carried out in test tubes by doubling the liquid nutrient medium in a row of 8–12 test tubes containing the test complex at an initial complex concentration of $1\cdot 10^{-3}$ mol/dm^3 (1000 μM). Suspensions of daily agar cultures were densitometrically adjusted (densitometer Densimat Bio Merieux) to a density of 0.5 according to the McFarland standard containing 1.5 x 10^8 CFU/ml. A series of serial dilutions of 1:10 was prepared from the resulting microbial suspension to a concentration of 10^6 CFU/ml. To obtain the required final inoculum ($5\cdot 10^5$ CFU/ml), 50 μl of the test bacterial suspension containing 10^6 CFU/ml was added to each tube. The control tube contained 1 ml of broth without the drug and 50 μl of culture for each test strain. The growth of microorganisms after incubation at 37 ºC after 24 hours was monitored visually, determining the presence or absence of growth in a medium containing various concentrations of the test compound, and measuring light scattering with using a UV 1800 spectrophotometer (Shimadzu) at λ = 980 nm. The minimum inhibitory concentration was determined as the concentration of the highest dilution of the complex that inhibits the growth of the test culture.

All transparent tubes were inoculated onto a solid nutrient medium (Muller-Hinton agar) to determine cell viability. After incubation of the crops in a thermostat, the lowest concentration of the drug was noted in the test tube, the seed from which did not produce growth. This concentration was taken as the minimum bactericidal concentration.

Antibacterial screening of the complexes was carried out by measuring the diameter of the zone of inhibition of bacterial and fungal

growth after 24 hours. For bioassays, a suspension of approximately 1.5 x 10^8 cells per cubic cm was prepared in sterile normal saline. Bacterial isolates were pre-grown in nutrient broth for 24 hours, followed by inoculation on an agar medium, on the surface of which disks treated with an aqueous solution of the complexes (c = 1000 μmol/dm^3) were placed. The dishes were then incubated at 37°C for 24 hours, after which zones of inhibition were observed. Experiments were repeated at least three to five times for each organism, and data are presented as mean ± confidence interval [17].

Based on the results of antibacterial screening of the complexes (Fig. 4), it was noted that the complexes exhibit varying degrees of inhibitory effects on the growth of the tested species of bacteria and fungi: their antimicrobial activity in relation to the tested test cultures depends on the composition and structure of the internal sphere of the coordination center, the nature of the central atom, number of coordination centers, their charge. Compared to binuclear complexes, mononuclear complexes of platinum (II) and palladium (II) exhibit low antibacterial activity. The platinum and palladium complexes are characterized by a sharp difference. Thus, a neutral binuclear platinum complex containing only bridging chlorine atoms exhibits a greater effect of inhibiting the growth of microorganisms Bacillus subtilis B4647, Pseudomonas aeruginosa B8243, Escherichia coli and fungi Aspergillus brasiliensis F679 compared to the mononuclear complex of non-electrolyte platinum (see Fig. 4, item 5), containing both terminal sulfur atoms and amino groups of the ligand.

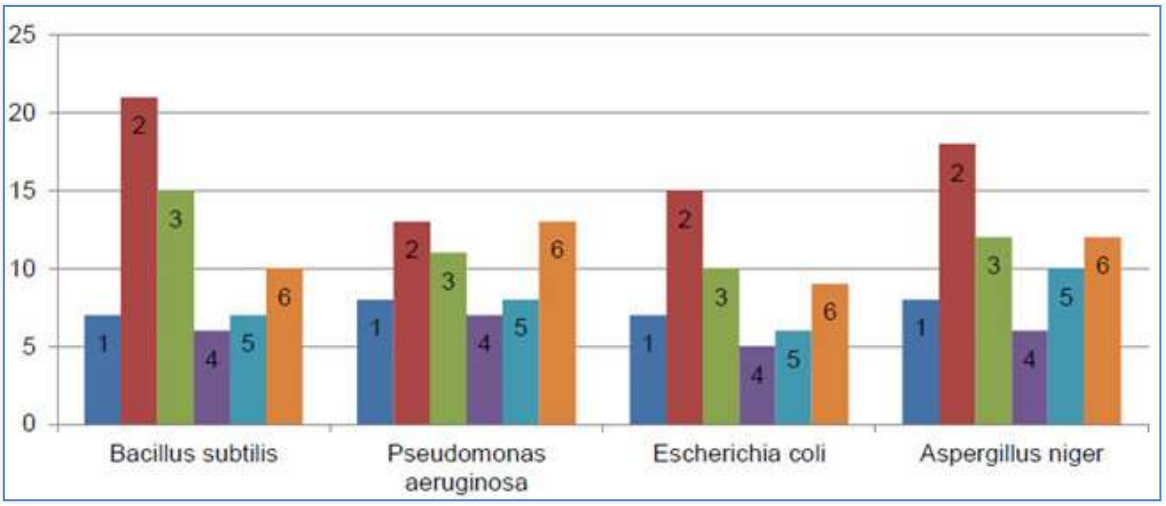


Fig. 4. Diameter, mm, of zones of inhibition of the growth of bacteria and fungi under the influence of complexes: *trans* -$[Pd(SCH_2CH_2NH_2)_2]$, *cis* -$[Pt(SCH_2CH_2NH_2)_2]$, $(\mu\text{-Cl})[Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot 3H_2O$ and $(\mu\text{-S})$ $[Pd_2(SCH_2CH_2NH^+{}_3)_2Cl_4]$

In relation to gram-negative bacteria Pseudomonas putida and Escherichia coli, the greatest antimicrobial activity was shown by the palladium dimer complex (Fig. 4, position 2) and the non-electrolyte-type platinum dimer complex (Fig. 4, position 3).

The results of the study of antibacterial activity reliably showed that the activity of the binuclear gray-bridge complex-palladium is more pronounced against the bacteria Bacillus subtilis, Escherichia coli and the fungi Aspergillus niger (Fig. 4, position 2). The exception was Pseudomonas aeruginosa, in relation to which the activity of the mononuclear palladium nonelectrolyte complex is comparable to the activity of the binuclear palladium complex (Fig. 4, position 6). Thus, the greater lability of the complex favors the manifestation of antibacterial properties.

The data obtained confirm the results of a number of works on the study of palladium complexes [18]. The authors of these and other works have experimentally proven: the easier it is for a complex to decompose into its component parts in an aqueous solution, the more capable it is of damaging DNA. Data from

studies of binuclear complexes with chlorine and sulfur bridging ligands confirmed the higher activity of multinuclear complexes compared to mononuclear analogues; the presence of more than one metal center in multinuclear complexes allows them to bind DNA more efficiently.

The values of the minimum inhibitory and minimum bactericidal concentrations of the studied complexes, at which suppression of the visible growth of the tested microorganisms and fungi and the bactericidal effect of the complexes is observed, vary in the range of 62.5–125 μmol/dm^3 (Table 2).

However, it must be taken into account that despite the wide range of antimicrobial activity of solutions of the complexes, the minimum effective concentration for bacteria and fungi is different. This is explained by the difference in the structure of cell walls, differences in ongoing metabolic processes, and the spatial organization of colonies. In turn, gram-negative bacteria are highly resistant to unfavorable conditions due to the presence of an additional outer membrane.

The values of the minimum inhibitory concentration and minimum bactericidal concentration of the palladium complex (μ-S)[$Pd_2(SCH_2CH_2NH^+_3)_2Cl_4$] are shown in the Table 2.

Table 2. The values of the minimum inhibitory concentration and minimum bactericidal concentration of the palladium complex (μ-S)[$Pd_2(SCH_2CH_2NH^+_3)_2Cl_4$]

Microorganisms and fungi	Minimum inhibitory concentration/minimum bactericidal concentration, μmol/dm^3						
	500-250	125	62,5	31,2	15,6	7,8	3,9
Basillus subtilis B4647	- / -	- /	+	+ /	+ /	+ /	+ / +
Aspergillus brasiliensis	- / -	-	+	+	+	+	+ /
(niger) F679	- / -	- /	+ /	+ /	+ /	+ /	+
Pseudomonas aeruginosa	- / --	-	+	+	+ + /	+	+ /
B8243		+ /	+ /	+ /	+ + /	+ /	+
Escherichina coli		+	+	+ + /	+	+	+ /
		+ / +	+ /	+		+ /	+
			+			+	

«-» – suppression of the growth of microorganisms and fungi; «+» – growth of microorganisms and fungi.

Conclusion

Mono- and binuclear complexes of palladium and platinum containing bridging and terminal sulfur, chlorine and nitrogen ligands have been synthesized. Screening of the antibacterial and antifungicidal properties of the studied complexes showed high activity of the binuclear complex of palladium (II) of the sulfur bridge type and the binuclear complex of platinum (II) of the chloro bridge type. The high lability of the complexes contributes to a strong chemical interaction of the complexes with the DNA of bacterial cells. An increase in the number of coordination centers leads to an increase in antimicrobial activity. By changing the structure of the complex, the composition and charge of the internal sphere, the number of coordination centers, the nature and denticity of the ligands, it is possible to achieve a higher toxic effect of the complexes-*(μ-S)[$Pd_2(SCH_2CH_2NH^+_3)_2Cl_4$]* and *(μ-Cl)[$Pt_2(SCH_2CH_2NH_2)_2Cl_2]\cdot 3H_2O$* against bacteria and fungi.

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