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Silica nanoparticles with amino or amino/phenyl groups and adsorbed Cu(II) ions as antibacterial and antifungal agents

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In this work we studied the effect of aminosilica nanoparticles on gram-positive (*Staphylococcus aureus* ATCC 25923) and gram-negative bacteria (*Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853), and fungi (*Candida albicans*). We used one-step Stöber synthesis to obtain two types of silica samples with composition $SiO_2/\equiv Si(CH_2)_3NH_2$ and $SiO_2/\equiv Si(CH_2)_3NH_2/\equiv SiC_6H_5$. These materials were characterized by SEM, FTIR spectroscopy, TGA, elemental and XPS analyses, showing that they feature particles of ~280 and ~320 nm in size with 2.0 and 2.2 mmol/g of amino groups. According to XPS, the state of surface amino groups in these samples is different, which results in varying antibacterial properties. Silica particles with amino groups showed the highest antimicrobial activity in the concentration of 1.0%. After 60 min contact, survival index (SI) of *S. aureus* was 24.0%, *E. coli* – 60.9%, and *C. albicans* – 34.5%. Antibacterial effect of bifunctional amino-/phenyl silica particles was observed only on gram-positive bacteria. After 60 min contact with 0.001%v/v suspension, SI of *S. aureus* was 34.3%. Bifunctional sample showed antifungal and gram-negative bacteria antimicrobial effects only after increasing the exposure time to 120 min (SI of *C. albicans* 43.7%, *E. coli* – 1.8%, *P. aeruginosa* – 39.0%).

The synthesized silica particles form stable complexes with copper(II) ions in water suspensions. Therefore, the suspensions with different concentrations were prepared and tested against the above-mentioned bacteria and fungi. These samples had improved antibacterial and antifungal activity, especially bifunctional sample with 2.2 mmol/g of Cu(II) ions. After contact for 120 min with such sample, SI of *S. aureus* decreased 28 times, *E. coli* – 500 times, and *C. albicans* – 5.3 times.

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