IOCM 2025 Conference

The 4th International Online Conference on Materials

3–6 November 2025 | Online

MDPI

ANTIBACTERIAL AND ANTICANCER PROPERTIES OF Ag, Ni, AND Co NANOCOMPOSITES OBTAINED *in situ* IN A HYBRID POLYMER-INORGANIC CARRIER

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INTRODUCTION & AIM

Designing nanomaterials with high activity toward biological systems is an emerging trend in nanotechnology. Metal-based nanosystems with particle sizes ranging from 10-100 nm, showed broad perspectives of application in biomedicine. For decades, major attention has been paid to silver NCs because of their lower reactivity and lower toxicity, as compared to many metals, high antimicrobial activity, and positive therapeutic effects in several diseases. Apart from antibacterial activity, AgNCs showed high virucidal efficiency, high anti-cancer activity, and high therapeutic efficiency in diseases, particularly, diabetes.

One recent step in the development of therapy based on MeNCs applications was the design of MeNCs with magnetic properties (Fe, Cu, Ni, Co) for targeted drug delivery in oncotherapy. The ability of targeting cancer-related pathways (MAPK/ERK pathway, p53 pathway, EGFR signaling, PI3K/Akt/mTOR pathway that regulate cancer cells growth, proliferation, differentiation, and metastatic processes) and elicit oxidative stress by targeting mitochondria shown for silver, gold, and magnetic NC (Fe, Cu, Co, Ni) makes these nanosystems promising as an anticancer medicine.

While bare metal nanoparticles exhibit low aggregation stability, their incorporation in polymer matrices of different chemical composition, besides particle stabilization, allows for a large variability of their surface properties. The bottom-up synthesis of MeNCs from metal nitrates within polymer matrices proved many advantages, as it allowed for obtaining small particle size at narrow size distribution, which improved their biological activity. Low nanoscale AgNCs synthesized in situ in the polymer-inorganic hybrid carrier SiO_2-grafted polyacrylamide (SiO_2-*g*-PAAm) by the group of Prof. Tatyana Zheltonozhskaya of the Institute of Macromolecular Chemistry, NAS of Ukraine, showed the prospective of many biomedical applications. The method of synthesis was spread to Ni and Co NCs, which recently were fully characterized [1, 2].

This work aimed at evaluating the antibacterial and anticancer properties of Ag, Ni, and Co nanocomposites synthesized *in situ* in SiO_2-grafted polyacrylamide matrix against most common bacterial pathogens and two cancer cell lines.

METHOD

Metal nanocomposites were obtained for this study from Prof. Dr. Tatyana Zheltonozhskaya, Institute of Macromolecular Chemistry NAS of Ukraine. Polymer-inorganic hybrid carrier SiO_2-*g*-PAAm with rav of SiO_2 core 7 nm, MvPAA ~800 kDa, and the number of grafts N=72 was synthesized for further synthesis of Me-polymer nanocomposites [1-3]. Low-nanoscale Ag, Ni, and Co nanoparticles embedded in the polymer-inorganic hybrid carrier SiO_2-*g*-PAAm were obtained by $NaBH_4$ reduction of Me nitrates in the presence of the polymer matrix [1, 2]. The mean MeNPs diameters (D_{av}) were evaluated based on TEM data: 1.9±0.9 (Co), 2.7±1.3 (Ni), 6.1±2.8 (Ag). The concentration of MeNC by metal (mg/ml) was: 0.05 (Ag), 0.1 (Ni), 0.1 (Co). The concentration of the polymer-inorganic hybrid matrix was 1.0 mg/ml.

Bacterial strains*:* *Staphylococcus aureus* ATCC 25923, *Escherichia coli* ATCC 25922, *Pseudomonas aeruginosa* ATCC 27853 were obtained from Gromashevsky Institute of Epidemiology and Infectious Diseases of the NAMS of Ukraine; the laboratory strain of *S. marcescens* KM-4 was obtained from the collection of National Taras Shevchenko University of Kiev (Ukraine).

Cell lines: Malignant cell lines B95-8 (marmosets' leucocytes transformed by Epstein-Barr virus) and Wish (the human amnion cells with marker chromosomes of HeLa) were used; MDCK cell line was used as the control.

Methods: To study antibacterial properties of MeNC, well diffusion and broth microdilution methods were applied . Cell viability was estimated by MTT test. ANOVA statistics was used for the reliability testing.

RESULTS & DISCUSSION

The antibacterial efficiency of AgNC

Of all MeNC studied, the antibacterial activity was inherent to AgNC only (Fig. 1, *1, 2*). NiNC produced no effects on bacteria (Fig. 1, *4*), and CoNC produced weak bacteriostatic effect (Fig. 1, *5, 6*). For AgNC the dependence of inhibition zones (D, mm) on cell concentration (CFU/ml) was studied.

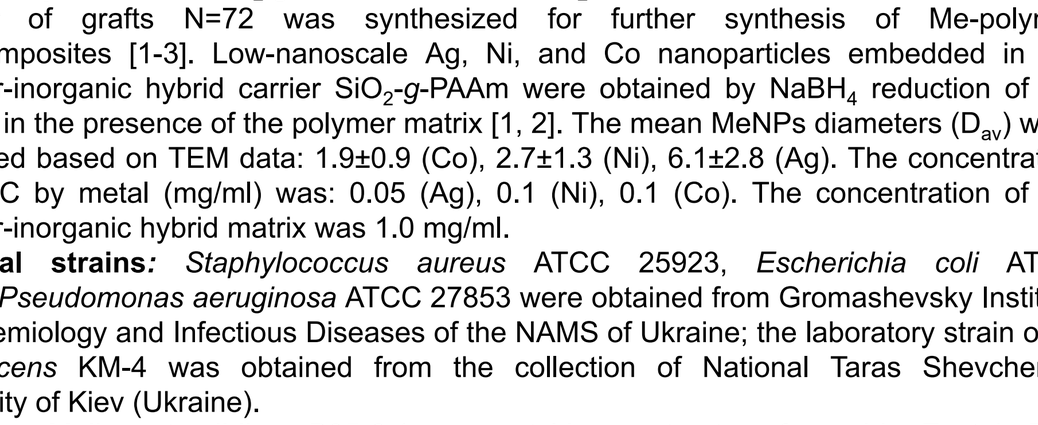

Figure 1. The antibacterial efficiency of AgNC (1, 2), hybrid matrix SiO_2-*g*-PAAm (3), NiNC (4), and CoNC (5, 6).

To assess antibacterial activity, the dependence of inhibition zones (D, mm) on Ag concentration (C_{Ag}) was studied at constant CFU/ml. (Fig. 2). As the antibacterial efficiency decreased with the increase of cell concentration (Fig. 2A),IC_{50} were found at $1.5 \cdot 10^4$ CFU/ml from the dependences of inhibition zones on C_{Ag} (Fig. 2B). The minimal inhibition concentrations (MIC) were found by serial dilutions. Resulting maximal diameters of the inhibition zones, IC_{50}, and MIC were summarized in the Table 1.

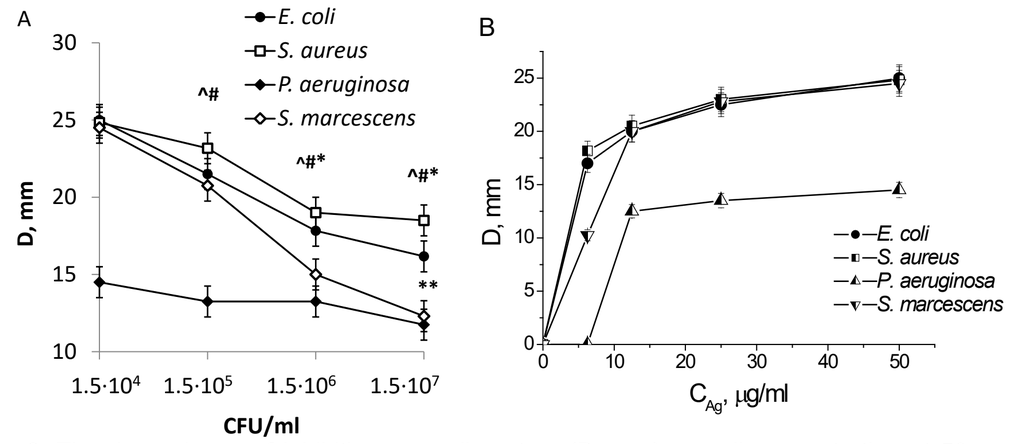

Figure 2. The dependence of inhibition zone diameters (D, mm) on cell concentration at 50 µg/ml AgNC by metal (A); the concentration dependences of inhibition zones on AgNC concentration by metal (C_{Ag}) at $1.5 \cdot 10^5$ CFU/ml (B). M±m, N=3; * - P<0.05 as compared with *E. coli* at $1.5 \cdot 10^4$ CFU/ml; # - P<0.05 as compared with *P. aeruginosa* at $1.5 \cdot 10^4$ CFU/ml.

Parameters	*S. aureus*	*E. coli*	*P. aeruginosa*	*S. marcescens*
D, mm	24.8 ± 0.8	25.0 ± 1.0	15.0 ± 1.0#	24.0 ± 1.0
MIC, µg/ml	12.5	12.5	25#	25#
IC50, µg/ml	4.43	4.5	11.9#	7.6#
MIC, µg/ml*	0.25-4	1-8	8-32	4-16
MIC, µg/ml**	8-64	4-32	32-128	

Table 2. Growth inhibition zone diameters (D), MIC, and IC_{50} values of growth inhibition found from the concentration dependences (Fig. 1B) for AgNC and bacteria strains: *S. aureus* ATCC 25923, *E. coli* ATCC 25922, *P. aeruginosa* ATCC 27853, *S.marcescens* KM-4 at $1.5 \cdot 10^4$ CFU/ml; M±m, n=3. # - P<0.05 as compared with *S. aureus*; * - data found for tetracycline (*) and streptomycin (**) [EUCAST].

The anticancer activity of MeNCs

The anticancer effectiveness of MeNPs was evaluated by IC_{50} values obtained from the dose-response curves (Fig. 3). NiNC exhibited the highest toxicity: IC_{50} was 1.9 and 2.5 µg/ml for B95-8 and Wish cells, respectively, and 20.6 µg/ml was for MDCK cells (Fig. 3A). Malignant cells B95-8 and Wish were the least sensitive to AgNC (IC_{50} 9.2 µg/ml for both cell types). CoNC exhibited moderate toxicity to B95-8 and Wish cells (IC_{50} were 6.3 and 5.31 µg/ml, respectively).

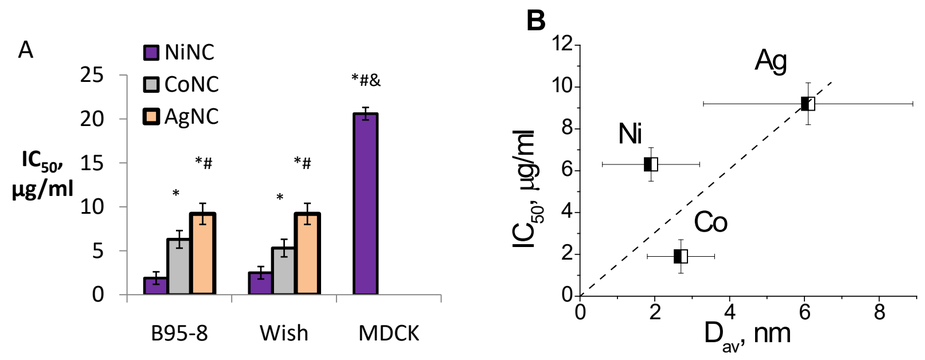

Figure 3. The half-inhibition concentrations IC_{50} against B95-8, Wish, and MDCK cells (A); IC_{50} vs. mean particle diameters (D_{av}) of AgNC, NiNC, and CoNC (B). M±m, n=3. * - p<0.05 compared to NiNC; # - p<0.05 compared to CoNC (A, B); & - p<0.05 compared to AgNC.

Based on IC_{50}, following series of cells' sensitivity to MeNC was observed: MDCK << B95-8=Wish. Within each cells' group, their sensitivity was dependent on the metal type: AgNC<CoNc<NiNC. Ag particles were reliably larger than Ni and Co ones, but no reliable correlation between the metal particles' size and their anticancer activity was established (Fig. 3B). Thus, the differences in MeNC toxicity should depend on different cytotoxicity mechanisms triggered by each metal type, which require more detailed studies in the future.

CONCLUSION

Highly stable nanocomposites of low nanoscale Me particles Ag, Ni, Co (MeNCs), in SiO_2-*g*-PAAm matrix exhibited high antibacterial and anticancer activity and low toxicity to the control MDCK cells, which makes them promising for further development of antibacterial and anticancer preparations.

B95-8 = Wish >> MDCK

Ni > Co > Ag/SiO_2-*g*-PAAm

E. coli* = *S. aureus* > *S. marcescens* > *P. aeruginosa

REFERENCES

1. Zheltonozhskaya T.B., Permyakova N.M., Fomenko A.S. et al. The process of nickel nanoparticle formation in hydrophilic polymer/inorganic matrices. Mol. Cryst. Liq. Cryst. 2021. 716:13-28.
2. Zheltonozhskaya T.B., Permyakova N.M., Kravchenko O.O., Maksin V.I., Nessin S.D., Klepko V.V., Klymchuk D.O. Polymer/inorganic hybrids containing silver nanoparticles and their activity in the disinfection of fish aquariums/ponds. Polymer-Plastics Technology and Materials. 2021. 60:4, 369-391.