

# Water-soluble multi-walled carbon nanotubes decorated with guanidinylated hyperbranched poly(ethyleneimine) derivatives with enhanced antibacterial performance

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Recently, antibacterial properties of carbon nanotubes (CNTs) have received special attention by the research community. It is known that the aqueous dispersibility can critically influence antibacterial efficiency, as highly dispersed CNTs enhances their interaction with cells, leading to increased antibacterial properties. For this purpose, many attempts have been made to increase the aqueous dispersibility of CNTs such as modification of their surface using various oxidation processes, or dispersed them into aqueous solutions containing various surfactants or polymers at high concentrations. In this study, oxidized multi-walled carbon nanotubes (oxCNTs) were functionalized with guanidinylated hyperbranched polyethyleneimine derivatives (GPEI5K and GPEI25K) through electrostatic interactions and van der Waals forces, affording the hybrids oxCNTs@GPEI5K and oxCNTs@GPEI25K that can successfully form stable aqueous dispersions for at least six months. Their structural characterization using a variety of techniques, revealed the successful and homogenous anchoring of GPEIs on the oxCNTs' surface. Moreover, the antibacterial activity of oxCNTs@GPEIs was evaluated against gram- and gram+ bacteria. It was found that both hybrids exhibited an enhanced, dose-dependent antibacterial activity against both test organisms. The obtained IC-50 values were much lower compared to oxCNTs, revealing that the attachment of GPEIs strongly induces the antibacterial properties of the hybrids. These improved properties were attributed to the polycationic character of the oxCNTs@GPEIs, which enables the effective interaction of the hybrids with the bacteria membranes, facilitating their internalization into the cells as revealed by SEM microscopy (Fig. 1). These results suggest that oxCNTs@GPEIs can be very attractive candidates as antibacterial agents, able to be used for applications in the disinfection industry.

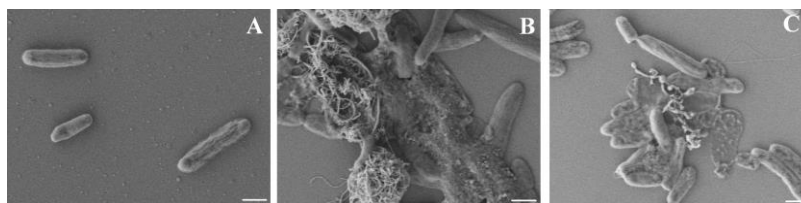


Figure 1: SEM images of Escherichia coli bacteria: untreated cells (A) and cells after incubation with oxCNTs@GPEI5K (B) and oxCNTs@GPEI25K (C) at 50% inhibitory concentrations. The scale bar is 1  $\mu\text{m}$ .