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Quaternary Trimethyl Chitosan Chloride Capped Bismuth Nanoparticles with Positive Surface Charges: Catalytic and Antibacterial Activities

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Abstract
Quaternary trimethyl chitosan-stabilized bismuth nanoparticles (QTMC-BiNPs) with positive surface charges were uniquely synthesized and fully characterized. In the synthesis, Quaternary Trimethyl Chitosan (QTMC), a water-soluble derivative of chitosan (CTS) was prepared using two-step reductive methylation. The new biopolymeric functionalized ligand was further used as capping agent for the synthesis of QTMC-BiNPs which was applied as antibacterial and catalytic agents. The reaction was carried out at room temperature without the use of energy consuming or high-cost instruments. The QTMC and nanocomposites were characterized by proton nuclear magnetic resonance (1H NMR), attenuated total reflection Fourier-transform infrared, UV–visible, X-ray diffraction, X-ray photoelectron spectroscopy and energy dispersive X-ray spectroscopic techniques. The topology and morphology of the composites were examined with scanning electron microscopy and high-resolution transmission electron microscopy. Thermogravimetric and differential thermal gravimetric analysis were also conducted. The degree of quaternization and degree of dimethylation values of 63.33 and 11.75%, respectively obtained for QTMC confirmed that the main product is a quaternary derivative. The average particle size of QTMC-BiNPs was evaluated to be between 30 and 45 nm. The QTMC-BiNPs revealed clear and uniform lattice fringes with an estimated interplanar d-spacing of 0.32 nm confirming the formation of highly crystalline nanocomposites. A further insight into the antibacterial activities of this nanomaterial were carefully examined on Escherichia coli (E. coli) and Staphylococcus aureus (S. aureus) using resazurin based microdilution method for Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC). The obtained results revealed that both bacteria pathogens were effectively inhibited/killed by the QTMC-BiNPs at very low concentrations. The MIC of 15.63 and 125 µg/mL were recorded against E. coli and S. aureus, respectively while the MBC of 31.25 and 500.00 µg/mL were estimated against E. coli and S. aureus, respectively. An extensive evaluation of the catalytic capability of the nanocomposites towards the reduction of 4-nitrophenol to 4-aminophenol was also carried out with highly promising result.

Author Keywords
Antibacterial activity; Bismuth nanoparticles; Catalytic activity; Chitosan; Quaternary trimethyl chitosan

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