Facile green synthesis of Ag/AgCl nanoparticles derived from *Chara* algae extract and evaluating their antibacterial activity and synergistic effect with antibiotics

Khalil T.Hassan[a] Ibraheem J.Ibraheem[b] Omar M.Hassan[c] A.S.Obaid[a] Hameed HusseinAli[b] Thaer AbdulqaderSalih[c] Mohammed S.Kadhim[d]

[a] Department of Physics, College of Science, University of Anbar, Ramadi 30001, Iraq

[b] Department of Chemistry, College of Science, University of Anbar, Ramadi 30001, Iraq

[c] Department of Biology, College of Science, University of Anbar, Ramadi 30001, Iraq

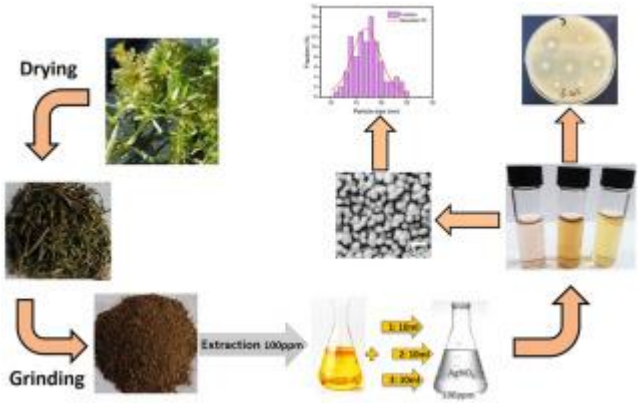
[d] Material Science & Advanced Material Research Center, University of Technology, Baghdad 10011, Iraq

Abstract

Here, we present a pathway for the green synthesis of Ag/AgCl nanoparticles derived from freshwater *Chara vulgaris* algae. The formation of Ag/AgCl NPs is confirmed by XRD, UV–Vis spectroscopy, and SEM techniques. The volume with an aqueous extract of *Chara vulgaris*: $AgNO_3$ ratio 3:1 possessed optimal synthesised Ag/AgCl NPs. A plasmon absorbance peak, at 395 nm was observed in the UV–vis spectrum. XRD patterns confirmed the highly crystalline FCC structure of Ag/AgCl NPs. SEM imaging of Ag/AgCl NPs indicated nanoparticles of size 16.99 ± 0.3 nm. The antibacterial activity of Ag/AgCl NPs was evaluated against *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumonia*, and *Pseudomonas aeruginosa*. Combining Ag/AgCl NPs with antibiotics causes growth inhibition of both Gram-positive and Gram-negative bacteria. The fractional inhibitory concentration index (FICI) is used to evaluate the synergistic antimicrobial effect of combining nanoparticles with antibiotics. The combinations of Ag/AgCl NPs with Gentamicin, Erythromycin and Vancomycin show a partial synergistic activity against *E. coli*, *K. pneumoniae* and *P. aeruginosa*, respectively. The combination of Ag/AgCl

NPs with antibiotics could potentially prohibit the development of resistant bacteria against antibiotics.

Graphical Abstract



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Keywords Green synthesis ;Silver/silver chloride nanoparticles (Ag/AgCl NPs) ;*Chara vulgaris* algae ;Antibacterial activity