A Rapid and Sensitive Colorimetric Method for the Detection of Several Toxic Heavy Metal

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Abstract

Gold nanoparticles are versatile nanomaterials that have been widely used in many applications, including cancer diagnosis, drug delivery and biosensing. Here, we developed a rapid and sensitive colorimetric method for the detection of several toxic heavy metals. Our simple room temperature synthesis of gold nanoparticles utilizes ascorbic acid as a reducing and capping agent to produce catalytically active gold nanoparticles in a matter of a few minutes. Our results show a high selectivity for 4 toxic metals (i.e., aluminum, lead, mercury, and chromium) over a dozen potential interfering metal cations. A detection limit down to ~ 300 ppb based on a visual color change was achieved, but much lower values (single ppb or less) can be detected with the use of a conventional UV-vis spectrophotometer.

Introduction

Exposure to several heavy metals can cause behavior problems and learning disabilities particularly in young children but can also affect the health of adults. There is an urgent need to develop innovative methodologies and detect these toxic metals in drinking water, before exposure. Gold nanoparticles (AuNPs) and their chemical functionalization have attracted enormous scientific and technological interest due to their ease of synthesis, chemical stability, and unique optical properties, and have been used as biosensors for different purposes, including the detection of heavy metals. This property is due to the aggregation of gold nanoparticles around the metal which typically gives a color change proportional to the concentration. Parameters such as size and shape of gold nanoparticles, ionic strength, solution pH, and the type of ligands conjugated to the AuNPs, affect the effectiveness of the gold nanoparticles, and their detection sensitivity. Here, we developed a simple, rapid, and sensitive colorimetric method to detect several toxic heavy metals such as Al(III), Pb(II), Cr(VI) and Hg(II).

Materials and Methods

All experiments reported herein were carried out using ultrapure water having a resistivity of 18.2 MΩ cm. Fresh aqueous stock solutions of chloro-auric acid and ascorbic acid were prepared before each experiment. The acid serves as both a reducing agent and as a capping agent providing electrostatic stabilization of the nanoparticles. The stock solutions of the nanoparticles were placed in the refrigerator (4 °C) for one hr before use. Testing of samples was performed 3 to 5 times to ensure reproducibility.

Discussion

Our results show that visual colorimetric detection of Al(III), Pb(II), Cr(VI) and Hg(II) can be achieved using gold nanoparticles, down to a 300-ppb level, in a matter of 2 to 3 days. Our assay appears to be sensitive and semi-selective, since no changes are observed upon exposure to over a dozen other cations. Longer exposure time leads to complete precipitation of the gold nanoparticles after > 3 days. The presence of 100 µM Ca(II) or Mg(II) did not interfere with our assay, but higher concentrations of led to faster precipitation. Therefore, water filtration to soften hard water is required before testing. None of the water samples (residential and tap) that we have tested show any color change, suggesting the absence of > 300 ppb toxic heavy metals. Thus, our assay demonstrate an easy, rapid, and instrument-free visual detection of 4 toxic metals at concentrations > 300 ppb.

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Results