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Hyperthermia, Cytotoxicity, and Cellular Uptake Properties of Manganese and Zinc Ferrite Magnetic Nanoparticles Synthesized by a Polyol-Mediated Process

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Abstract: Manganese and zinc ferrite magnetic nanoparticles (MNPs) were successfully synthesized using the polyol method in ethylene glycol and were found to have high saturation magnetization values (90–95 emu/g at 4 K) when formed by ~30-nm crystallites assembled in an ~80-nm multicore structure. Hyperthermia data revealed a sigmoidal dependence of the specific absorption rate (SAR) on the alternating magnetic field (AMF) amplitude, with remarkable saturation SAR values in water of ~1200 W/g_{Fe+Mn} and ~800 W/g_{Fe+Zn} for the Mn and Zn ferrites, respectively. The immobilization of the MNPs in a solid matrix reduced the maximum SAR values by ~300 $W/g_{Fe+Mn, Zn}$ for both ferrites. The alignment of the MNPs in a uniform static magnetic field, before their immobilization in a solid matrix, significantly increased their heating performance. Toxicity assays performed in four cell lines revealed a lower toxicity for the Mn ferrites, while in the case of the Zn ferrites, only ~50% of cells were viable upon their incubation for 24 h with 0.2 mg/mL of MNPs. Cellular uptake experiments revealed that both MNPs entered the cells in a time-dependent manner, as they were found initially in endosomes and later in the cytosol. All of the studied cell lines were more sensitive to the $ZnFe_2O_4$ MNPs.

Keywords: manganese and zinc ferrite magnetic nanoparticles; ethylene glycol; polyol method; magnetic hyperthermia; specific absorption rate; cancer cell uptake; endocytosis; cytotoxicity; biodegradation

1. Introduction

The last decades have shown an exponentially increased interest in the applications of magnetic nanoparticles (MNPs) in various fields [1]. Biomedical applications of magnetic nanoparticles include targeted drug delivery, magnetic hyperthermia (MH), contrast agents for magnetic resonance imaging (MRI), biological separation, neural stimulation, biosensing, and gene transcription [2]. On the basis of the fact that iron oxide MNPs, mainly magnetite (Fe_3O_4) and maghemite (γ-F_2O_3), possess high