Chapter 13
Ecotoxicity and Toxicity of Nanomaterials with Potential for Wastewater Treatment Applications

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ABSTRACT

Nanotechnology holds the promise of develop new processes for wastewater treatment. However, it is important to understand what the possible impacts on the environment of NMs. This study joins all the information available about the toxicity and ecotoxicity of NMs to human cell lines and to terrestrial and aquatic biota. Terrestrial species seems more protected, since effects are being recorded for concentrations higher than those that could be expected in the environment. The soil matrix is apparently trapping and filtering NMs. Further studies should focus more on indirect effects in biological communities rather than only on effects at the individual level. Aquatic biota, mainly from freshwater ecosystems, seemed to be at higher risk, since dose effect concentrations recorded were remarkable lower, at least for some NMs. The toxic effects recorded on different culture lines, also give rise to serious concerns regarding the potential effects on human health. However, few data exists about environmental concentrations to support the calculation of risks to ecosystems and humans.

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INTRODUCTION

Surface and ground water resources are continuously facing profound changes and quality deterioration, caused by anthropogenic activities, such as, mining operations, manufacturing and agro-industries. With the industrial development, the generation and accumulation of waste products has tremendously increased and one of the major challenges is the proper management and safe disposal of the vast amount and array of such solid and liquid wastes. Industrial wastewaters are one of the major sources of direct and often continue input of pollutants into aquatic ecosystems (Kanu & Achi, 2011). Due to the lack of effluent treatment facilities, proper treatment methodologies and disposal systems, huge amounts of industrial wastewater, containing high loads of organic and inorganic chemicals with high toxicity and recalcitrant properties, are being discharged into aquatic environments. Depending on the type of industry, the wastewater produced can contain different pollutants such as dyes, phenolic compounds, surfactants, pharmaceuticals, pesticides, organic solvents, chlorinated by-products, metals and microorganisms, which can cause the increase in biological oxygen demand (BOD), chemical oxygen demand (COD) and total dissolved solids (TDS) in the receiving water systems promoting their deterioration.

In the last few years, nanomaterials (NMs) with their unique proprieties have been extensively studied for water and wastewater treatment. Nanotechnology holds the promise of enhancing the performance of existing treatment technologies but also offers the potential for developing new treatment solutions (Qu, Alvarez, & Li, 2013). In 2011, the European Commission (EC) has adopted the following definition for NMs: "a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1–100 nm"(EC, 2011). Within this definition, several NMs have received considerable attention for wastewater treatment, namely metal (silver (Ag), gold (Au)) and metal or metalloid oxides of titanium (TiO_2), silica (SiO_2), iron (Fe_2O_3), cerium (CeO_2) (García et al., 2011; Jarvie et al., 2009; Kaegi et al., 2011). Due to their reduced size, NMs display unique physical, chemical and biological proprieties compared to their bulk counterparts (Stone et al., 2010; Zhang & Fang, 2010). At the nanoscale, the specific surface area and the surface/volume ratio increases, leading to an increase in the number of surface atoms and therefore contributing for enhanced optical, electrical and magnetic properties (Mohmood et al., 2013). The properties that make NMs suitable for wastewater treatment, in particular, include high surface areas with more active sites available for adsorption; high reactivity and catalytic potential for use in photocatalysis process, antimicrobial activity, high mobility in solution, as well as, super magnetism proprieties for particle separation (Hariharan, 2006; Qu, Brame, Li, & Alvarez, 2013; Sánchez et al., 2011). Therefore, these unique characteristics can be useful for efficient removal of metals or to degrade persistent organic compounds.

Although there are great advances with the use of nanotechnology for wastewater treatment, health effects and environmental impacts associated to NMs are attracting considerable concern in the scientific field and regulatory agencies. The unique proprieties of NMs, which make them so appealing, can also be responsible for ecotoxicological effects. Hund-Rink & Simon (2006) for example, were one of the first authors reporting the effects caused by the potential formation of reactive oxygen species (ROS) during UV-irradiation of TiO_2 NMs used as photocatalysts on *Daphnia magna* and *Desmodesmus subspicatus* (Hund-Rinke & Simon, 2006). Also, it was recognized that the nanosize of these materials can favour the cross through cell membranes and their interaction with cellular components (Colvin, 2003). In the last two decades, some reviews were published joining data about the toxicity of NMs to several organisms (Baun, Hartmann, Grieger, & Kusk, 2008; Menard, Drobne, & Jemec, 2011; Navarro et al.,