Chapter 12
Wastewater Treatment and Role of Green Synthesized Metal Oxide Nanocomposites

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ABSTRACT

Water pollution by metalloids is a global environmental concern. Owing to their propensity for bioaccumulation, water solubility, and interaction with environment, they are threatening both human and ecosystem health. Inherent limitations like low efficiency, sensitive operating conditions, and high capital and operating costs are associated with conventional removal methods which restricts adoption of these technologies on large scale. While adsorption is commonly recognized as both an effective and affordable remediation technology, many common adsorbents often have inherited limitations including non-renewability and high operating costs. Thus, limitations in conventional remediation technologies have headed to the rapid progression of new avenues for advanced treatment technologies for metalloid pollutant removal such as green nanotechnology. In contrast to many of the currently available adsorbents, nanoparticles often have unique properties such as tiny size, more active sites and big surface area, easy separation, and high reactivity that enhance removal efficiencies.

INTRODUCTION

Access to high quality water is indispensable for life. Worldwide, the excessive consumption of water (Vajnhandl & Valh, 2014), compounded with a general deterioration in the quality of both surface and ground waters due to anthropogenic activities such as agriculture, is a major threat to water security and ecosystem health. Seventy percent of fresh water is currently used for agriculture (Steinfeld et al., 2006) of which irrigation accounts for 66% of all water extractions (Scanlon, Jolly, Sophocleous, & Zhang, 2007; Tingey-Holyoak, 2014). Dairy farming, geothermal power utilization, contemporary use

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of arsenic-based pesticides and industrial activities are contributing anionic pollutants (phosphate, nitrate, nitrite, arsenate and chromium (VI)) to water bodies (Bundschuh & Maity, 2015; Kuppusamy et al., 2016). Elevated levels of these pollutants in turn are governing the production of algae and posing a threat to fresh water resources (Arshadi, Foroughifard, Etemad Gholtash, & Abbaspourrad, 2015). Annually exposure to poor water quality results in the death of more than five million people because of water-borne diseases (FAO, 2010).

In the previous few decades, the removal of anionic pollutants from water and wastewater has been extensively examined in order to safeguard standing water sources such as estuaries and lakes from eutrophication. However, these often costly techniques, are only effective for treating point-source pollution, and may involve synthetic toxic chemicals with potential to detrimentally impact the environment. There is therefore a need to explore cost-effective, efficient, and eco-friendly alternative treatment methods which can be deployed *in situ* to tackle more persistent diffuse pollution sources.

Of all the emerging techniques, green nanotechnology is perhaps the most promising; being, efficient, eco-friendly and cost-effective. Recently, large-scale bio-synthesis (green synthesis) of energy-efficient, low-cost and nontoxic metallic nanoparticles (MNPs) from plant extracts has generated considerable interest as a substitute for more traditional chemical and physical methods (Mittal, Chisti, & Banerjee, 2013; Qu, Alvarez, & Li, 2013). Plant extracts performs as both capping (stabilizing) and reducing agents. In plant extracts, the biomolecules, such as amino acids, proteins, enzymes, citrates, vitamins, flavonoids, organic acids, and polysaccharides are environmentally benign and mediate the metal ion bio-reduction (Iravani, 2011).

Many different types of plants (e.g. aloevera, azadirachta indica, eucalyptus, lemon grass, tea) are currently being widely used to prepare MNPs (Mittal et al., 2013). The source of the plant extracts greatly affects the final characteristics of the formed MNPs (Kumar & Yadav, 2009). Usually, bio-reduction via plant extracts, takes place at room temperature within a few minutes and simply involves mixing a liquid phase plant extract with the liquid phase solution mixture of the associated salt of metal. Unlike chemical procedures, which often require expensive instruments and end in the discharge of toxic chemicals to the environment, biological methods are more simple, eco-friendly and result in more monodispersed MNPs (Bindhu & Umadevi, 2013; Ibrahim, 2015). Some researchers have also reported the use of green NPs for wastewater treatment. For example, Wang et al. (2014) utilized *n*Fe, synthesized through eucalyptus leaf extracts for eutrophic wastewater treatment, obtaining removal efficiencies of 30.4%, 71.7%, and 84.5% for total P, total N and COD, respectively.

For practical removal of pollutants via NPs many different approaches are currently being investigated. Many researchers have simply used NPs in their raw form as nano adsorbents (Qu et al., 2013). However, to overcome the problems associated with NP regeneration and agglomeration many researchers have also prepared different composite structures; such as nanocomposite membranes and core-shell microspheres; with MNPs as nanofillers (Yin & Deng, 2015). The improved porous structure and mechanical strength makes these nanocomposites a more effective for pollutant removal from wastewater. Currently, the use of synthetic polymer hosts in nanocomposites are not preferred because of the associated high costs and toxic environmental effects. However as an alternative, biopolymer hosts are becoming more popular because of their renewability, low cost and environmentally friendly nature (Gehrke, Geiser, & Somborn-Schulz, 2015).

Recent literature (Lofrano et al., 2016) advocates that most of the common complications related with the use of NPs and polymer nanocomposites (i.e effect of other chemical species present in composite

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