Chapter 28
Functionalized Magnetic Nanoparticles for Environmental Remediation

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ABSTRACT

Water pollution by anthropogenic activities is proving to be of critical concern as the heavy metals affect aquatic organisms and can quickly disperse to large distances. This poses a risk to both human health and the aquatic biota. Hence, there is a need to treat the wastewater containing toxic metals before they are discharged into the water bodies. During recent years, magnetic nanoparticles came to the foreground of scientific interest as a potential adsorbent of novel wastewater treatment processes. Magnetic nanoparticles have received much attention due to their unique properties, such as extremely small size, high surface-area-to-volume ratio, surface modifiability, multi functionality, excellent magnetic properties, low-cost synthesis, and great biocompatibility. The multi-functional magnetic nanoparticles have been successfully applied for the reduction of toxic metal ions up to ppb level in waste-treated water. This chapter highlights the potential application of magnetic nanoparticles for the removal of heavy metals.

INTRODUCTION

Industrialization and urbanization coupled with rapid population growth has lead to an increased disposal of heavy metals into the aquatic environment. Contamination of heavy metals in the surroundings has done great harm to human and other organism due to their high toxicity and carcinogenicity (Gautam, 2012; Gautam et al., 2013; Gautam & Chattopadhyaya, 2013; Lin et al., 2012; Smith, 2009; Srivastava

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& Majumder, 2008; Santos & Judd, 2010). United States Environmental Protection Agency (USEPA) has classified heavy metals as priority pollutants. Heavy metal pollution in the aqueous solutions has become a serious threat today and of great environmental concern as they are non-biodegradable and thus persistent in the nature. Lead (Pb), cadmium (Cd), chromium (Cr), nickel (Ni), cobalt (Co), zinc (Zn) and copper (Cu) are such metals, which are frequently present in polluted water from various industrial processes, such as catalysts, mineral processing, electrical apparatus, painting and coating and agricultural materials (Keane, 1998; Monier et al., 2010; Swayampakula et al., 2009). They accumulate in living cells of biological systems throughout the food chain, which has humans at its top, multiplying the threat. Therefore, their toxic effect is more pronounced in animals at higher trophic levels (Ahluwalia & Goyal, 2007). Thus, it is necessary to control presence of heavy metals in the aqueous environment.

These potentially toxic and relatively accessible metals to the biological systems have attracted the keen attention of the scientists and researchers. These toxic metals occur in very small quantities in the Earth's crust. These are further arbitrarily divided on the basis of their densities. Those having densities less than 5 g/cm^3 are designated as "light metals", while those having densities more than 5 g/cm^3 are designated as "heavy metals". Thus metals like Hg, Cd, Cr, Cu, Ni, Fe, and Pb are generally known as toxic heavy metals. Unexpectedly, even metalloids like selenium (Se), arsenic (As), and antimony (Sb) are also considered under this category, thereby making the term heavy metals misleading. Among the metallic species, Pb, Cd, Hg, Cr, Ni, and As have drawn greater attention for their environmental impacts as they can enter the human beings via food chain and often exceed the toxic levels before they produce visible toxic effects. World Health Organization has, recently, recognized the health hazards of toxic metals in food chain even at low concentrations. Environmental Protection Agency's "Top 20 Hazardous Substance Priority List" has ranked mercury as 6th, cadmium 7th, chromium 8th, and nickel 13th, while quoting arsenic as the king of poisons.

SOURCES OF HEAVY METALS IN THE ENVIRONMENT

Various industries generate heavy metal containing wastewater includes the tanning, battery, glassware, ceramics, electroplating, fertilizer, mining, paints, and photographic industries. These wastewaters contain heavy metals such as chromium, lead, cadmium, arsenic, copper, iron, manganese, nickel, mercury, and cobalt, among others. The amount and the number of metals present in any wastewater are related directly to the operations carried out in an industry. For example, tanneries discharge chromium in wastewater; copper, chromium, zinc, and cadmium are widely generated from metal plating; the production of electrical equipment and mining, smelting, and fossil fuel combustion contribute to mercury pollution; and lead is generated from a number of industrial and mining sources. Most of the wastewaters contain higher concentration level of heavy metal than the safe permissible limit that might result in lethal and costly repercussions in public health. Table 1 summarizes the anthropogenic sources of heavy metals in the environment.

Arsenic is ubiquitous and ranks 20th in natural abundance, comprising about 0.00005% of the earth's crust, 14th in the seawater, and 12th in the human body (Mohan & Pittman, 2007). It's concentration in most rocks ranges from 0.5 to 2.5 mg/kg, though higher concentrations are found in finer grained argillaceous sediments and phosphorites. Since its isolation in 1250 A.D. by Albertus Magnus (Mandal & Suzuki, 2002), this element has been a continuous center of controversy. Arsenic is mobilized by natural weathering reactions, biological activity, geochemical reactions, volcanic emissions and other anthro-

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