



Manganese oxides and their application to metal ion and contaminant removal from wastewater



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ABSTRACT

Manganese oxides are ubiquitous in soil, sediment and aquatic environment. Over the years, manganese oxides and their composites have proved to be effective as adsorbents for the removal of metal ions and contaminants from water/wastewater. Because of their unique chemical and physical properties, they have attracted widespread attention as excellent adsorbents. This review reports on recent research on the synthesis, characterization, and application of manganese oxides and their composites for wastewater treatment. The adsorption characteristics, including experimental conditions and mechanisms involved in the pollutant removal processes, are discussed. The review provides an overview of the research related to manganese oxides and their application, including future areas of research and limitations in the current body of research.

1. Introduction

Pollution of surface and groundwater due to metal ions and contaminants is a worldwide problem today [1–3]. The problem is particularly severe in many developing countries where proper waste disposal systems are scarce. Because of unplanned urbanization, industrialization, agricultural activities and excessive use of chemicals, significant quantities of pollutants enter into the environment [2]. At present, research has focused on the removal of metal ions, metalloids, dyes, natural organic matter (NOM), radioactive pollutants and miscellaneous contaminants [4]. Excessive concentrations of these contaminants are detrimental to human health and other living organisms [1]. Consequently, removal of them to an acceptable level is a global challenge for environmental researchers.

To date numerous physical, chemical and biological procedures have been used for removing metal ions and contaminants including adsorption [5], solvent extraction [6], chemical precipitation [7], membrane filtration [8], ion-exchange [9], coagulation and flocculation [10], photocatalysis [11], and biological treatment [3,12]. Among them, adsorption is of particular interest to researchers because of the potential for high removal performance, ease of application and a simple recovery processes.

Among available adsorbents, manganese oxides (MnOs) have proved effective scavengers of metal ions and contaminants due to their high specific surface area (SSA), range of surface charge, polymorphic nature, natural availability, ease of preparation from available reagents in large scale, and environmental friendliness [13–15]. Accordingly, numerous research groups have focused on the development of MnOs and manganese-based composites for the environmental pollutants clean-up from wastewater [5,16–23]. There are, however, several drawbacks that may limit potential application. Some of the MnOs are poorly crystalline, vary significantly in particle size and have low solubility at acidic pH. Furthermore, they tend to coalesce into larger particles because of electrostatic interactions or van der Waals forces. As a result, their effectiveness as sorbents can be significantly decreased or even lost. Therefore, to improve their applicability in real wastewater treatment situations, some researchers have modified their physical and chemical properties by combining them with other suitable materials to produce composite adsorbents [24,25]. The most common additives utilised are activated carbon [26], graphite [27], carbon nanotubes [28], other natural materials [24,29], a synthetic polymer host [30], and miscellaneous additives [25,31].

Several reviews have reported on the synthesis and characterization of MnOs and their composites [32–35]. For instance, Liu et al. [35]

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