Chapter 1
Waste Management Using Nanotechnology

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ABSTRACT

Waste management represents a challenge due to the rapid increase in waste production and the emergence of new waste types. Overcoming the issue involves using innovative technologies such as nanotechnology. Nanotechnology uses nanomaterials, which are materials that have at least one dimension less than 100 nm. Due to their small size, these materials increase reactivity in processes such as adsorption and oxidation/reduction. The application of nanotechnologies is significant in the production of new materials to replace current raw materials, and in providing novel solutions for waste recycling and disposal. Furthermore, nanofiltration is effective in the treatment of metals, toxic waste, and nonbiodegradable materials of leachate. Nanomaterials, however, represent a safety risk for the environment, and a serious threat to human health due to their small size and long suspension time. This chapter deals with the use of nanotechnology in waste management, including reduction, recycling, treatment, and disposal phases.

INTRODUCTION

Waste is an unavoidable by-product of numerous human activities. The rapid urbanization, prosperity, and the increase of population have caused an enormous increase in the production of several types of waste materials. In fact, the global production of waste is expected to reach 2.59 and 3.40 billion tonnes per year by 2030 and 2050, respectively (Kaza et al., 2018). In the USA, the municipal waste materials generated in 2018 was 265.22 million tonnes (EPA, 2020). Waste is generated from several sources such as residential, commercial, construction and demolition, and industrial. For example, solid waste is produced at every stage of industrial processes. Most industrial waste sources are petrochemicals, chemical and pharmaceutical industries, fertilizer and agricultural chemical production, plastic manufacturing and many others.

DOI: 10.4018/978-1-6684-8117-2.ch001

Generally, waste can be classified into two main categories: hazardous waste and non- hazardous waste (Arni & Elwaheidi, 2020; Reddy, 2011). Hazardous waste consists of more than a single chemical or substance that has specific characteristics such as ignitability, corrosively, reactivity and toxicity. On the other hand, non-hazardous waste includes mineral processing materials, coal ash, oil, and other waste materials that lack the characteristics of hazardous waste.

Various components of waste cause health and environmental problems. Health problems include infections and chronic diseases, which are the result of the exposure to toxic chemicals and biological contaminants. The environmental impacts of solid waste include pollution, acidification, and water toxicity. Therefore, procedures and practices were established for efficient management of urban solid waste and to use it to extract reusable components and produce energy (Reddy, 2011). Waste management, therefore, implies the use of adequate technologies whose application depends on local, regional, and national capabilities that include regulations, policies, economic priorities, and practical local limits (infrastructure) (Arni & Elwaheidi, 2020).

The standard management practices include source reduction, recycling, and processing/disposal through different technologies such as composting, combustion/incineration, gasification, anaerobic digestion, and landfill (Arni & Elwaheidi, 2020). Nanotechnology is an emerging technology that is being employed everywhere in many sectors. The sectors include electronics (laser diodes and fiber optics transistors), medicine (drug delivery, test systems, and diagnostic systems), energy (lighting, fuel cells and solar cells), cosmetics (sunscreen, lipsticks and creams), textile (surface coating and coloring), food-drink (as packaging additives), military (neutralization of chemical weapons), automotive (catalysts, painting and sensors), and construction (insulation and flame retardants) (Bayda et al., 2019; Imani & Safaei, 2019; Safaei et al., 2019; Solano et al., 2021). The technology can be likely utilized in environmental protection and particularly in waste management. It is an interdisciplinary science that includes nanophysics, nanochemistry, nanomaterials and several other sciences. The technology uses nanomaterials, which are materials that have at least one dimension less than 100 nm.

Due to their small size, these materials increase the reactivity in processes such as adsorption, oxidation/reduction, and as catalysis of organic and inorganic contaminant materials (Dermatas et al., 2018). Typical applications of nanotechnology include nanocomposite packaging systems, which are used in meal bags to decrease the amount of waste (Pushparaj et al., 2022). Numerous additional applications of nanotechnology in waste management are reported in the scientific literature (Part et al., 2018; Walser et al., 2012).

This chapter investigates the potential role of nanotechnology in the management of waste. In particular, employment of nanotechnology in enhancing waste reduction and recycling will be discussed, with a focus on use in treatment and disposal phases of waste management.

WASTE MANAGEMENT

Globally recognized sustainable waste management strategies aim primarily to prevent waste generation and to reduce its harmfulness. However, where this is not possible, waste materials should be subjected to the "4Rs" processes: reduce, reuse, recycle, and resource recovery, which collectively ensure waste reduction. Landfill disposal is considered if none of the 4Rs is applicable and thus ranked as lowest in priority (Arni & Elwaheidi, 2020; Kaufman & Themelis, 2009; Rosenzweig et al., 2018). Figure 1a illustrates the steps of waste pre-treatment processes, starting from post-consumer waste until waste pre-