Journal of Environmental Analytical Chemistry

Kanchi, J Environ Anal Chem 2014, 1:2
DOI: 10.4172/2380-2391.1000e102

Editorial Open Access

Nanotechnology for Water Treatment

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Rec date: Apr 14 2014; **Acc date:** Apr 17 2014; **Pub date:** Apr 19 2014

Introduction

Nanotechnology is among the most revolutionary technologies in the world. The term nanotechnology describes a range of technologies performed on a nanometer scale with widespread applications as an enabling technology in various industries. Unlike other technologies, which have often sprung directly from a particular scientific discipline, nanotechnology spans a wide spectrum of science. Nanotechnology encompasses the production and application of physical, chemical, and biological systems at scales ranging from individual atoms or molecules to around 100 nanometers, as well as the integration of the resulting nanostructures into larger systems. The principal way nanotechnologies might help alleviate water problems is by solving the technical challenges that removing water contaminants including bacteria, viruses, toxic metals, pesticides and salts. Numerous scientists' claims that nanotechnologies offer more affordable, effective, efficient and durable ways of achieving specific nanoparticles for water treatment will allow manufacturer to prepare less toxic particles using classical methods.

A common problem in developing countries is drinking water that is contaminated with bacteria and viruses, which are the main cause of water-borne diseases. Due to change in climatic conditions, growing pollution, water will become even scarer, especially in developing countries. Moreover, in these countries, available water is often unsafe to drink. The interesting facts are shown in Table 1.

Figures	Facts
3.4 Millions	In developing countries people dies from water-related diseases every year
63 Millions	In developing countries like Bangladesh, India and Nepal people suffers with Arsenic pollution
6 Km	Women's from Africa and Asian continent walk to fetch water
80 %	Water related deaths in children between age 0-14 years
40 %	Water related deaths are due to Diarrhoea

Table 1: Water related facts of developing countries

Significance of Nanotechnology in Wastewater Treatment

Modern advances imply that several issues relating water quality could be determined or significantly increased the usage of nanomaterials and related stuff which resulted the growth of nanotechnology. Novel routes in the development of new nanomaterials to desalinate water are among the most thrilling and gifted technologies. Different materials science research teams in the world are exploiting specific nanomaterials targeting the analyte and making the entire system effective, economical and rapid for the treatment of waste waters. On the other hand treatment of industrial wastewater with newly synthesized nanomaterials is another potentially useful application. Most of the remediation technologies available today, while effective, very often are costly and time consuming, particularly pump-and-treat methods. The capability to remove toxic compounds from surface and sub-surface and other environments are very difficult to access in situ, and doing so rapidly, efficiently and within reasonable costs is the ultimate goal. Hence, nanotechnology based waste water treatment effectively eliminates the contaminants and helps in the recycling process to get purified water, which leads to reduction in labour, time and expenditure to industry and solves the various environmental issues.

Nanomaterials are mainly categorised into various groups based on their physical and surface properties. Nanomaterials include carbon nano-adsorbents (CNTs), metal nano-adsorbents (Al_2O_3 NPs, ZNO NPs, TiO_2 NPs and CeO_2 NPs), metallic nanoparticles (Au & Ag NPs), mixed oxide nanoparticle (Fe-Ti NPs), polymer nano-adsorbents, nanofibers, nanoclays. Additionally, it also utilizes the existence of nanoscopic pores in zeolite filtration membranes, as well as nanocatalysts. Metallic/metal oxide nanoparticles such as Titanium oxide nanoparticles and palladium nanoparticles are used as Nanosensors for the analysis of organic and inorganic pollutants in the water systems.

Wastewater treatment processes are designed to achieve improvements in the quality of the wastewater. The various treatment processes may reduce: (i) Suspended solids (ii) Biodegradable organics (iii) Pathogenic bacteria (iv) Nitrates and phosphates. Wastewater treatment is classified into three types: (a) Primary (b) Secondary and (c) Tertiary treatments. Based on the type of treatment and stage of purification, nanomaterials are selected for the effective removal of contaminants from the water systems. Nanotechnology can also be adopted for the removal of sediments, chemical effluents and charged particles. Nanofiltration is a new type of pressure driven membrane process and used between reverse osmosis and ultrafiltration membranes. The most different speciality of nanofiltration membranes is the higher rejection of multivalent ions than monovalent ions. Nanofiltration membranes are used in softening water, brackish water treatment, industrial wastewater treatment and reuse, product separation in the industry, salt recovery and recently desalination as two pass nanofiltration systems. Carbon nanotubes are unique nanomaterials which can eliminates wide range of contaminants including organic, inorganic, oil, turbidity, bacteria and viruses. Although their pores are significantly smaller carbon nanotubes have shown to have an equal or a faster flow rate as compared to larger pores, possibly because of the smooth interior of the nanotubes. Nanofibrous alumina filters and other nanofiber materials also remove negatively charged contaminants such as viruses, bacteria, and organic and inorganic colloids at a faster rate than conventional filters.

Singlewalled carbon nanotubes (SWCNTs) are distinguished from multiwalled carbon nanotubes (MWCNTs) by their number of layers, and many researchers are focusing due to its unique structure, excellent properties and variety of potential applications. Van der Waals force of attraction makes CNTs to form aggregation due to entanglement of hundreds of individual CNTs [1,2] which provides large external surface area for the adsorption of analytes [3-6]. TiO_2 NPs is using as a photo degradator of organic pollutants. In fact, TiO2 NPs have been successfully used in environmental technology for the treatment of waste water and ground water, for the removal of organic wastes. Ceria NPs has distinct properties of strong size dependent and would be show significant quantum size effect [7]. However, the synthesis of CeO_2 NPs [8] below 10 nm is a challenging task for the scientist in the field of material science. ZNO NPs have attracted the interest of several scientists in recent years due to its remarkable properties. ZNO NPs offer a great benefits applied to a catalytic reaction process because of their large surface area and high catalytic activity. Al_2O_3 NPs are high in surface area, more reactivity and greater adsorption capacity hence; it has been employed successfully for the separation and determination of toxic metals of environmental importance [9]. Nanotechnology has spurred efforts to design and produce nanoscale components for incorporation into devices. Magnetic nanoparticles are an important class of functional materials, possessing unique magnetic properties due to their reduced size (below 100 nm) with potential for use in devices with reduced dimensions. Polymer adsorbents are gaining more attention in sample pre-treatment step. Organic polymers are the system into which inorganic nanosized particles can be incorporated to enhance their physical, chemical, mechanical and sorption properties. Nanopolymer sphere, for example Dendrimers are tailored adsorbents that are capable to eliminate organic and inorganic species. The interior walls of dendrimers are hydrophobic in nature and useful for sorption of organic compounds while the exterior branches can be tailored (e.g., hydroxyl- oramine-terminated) for adsorption of heavy metals. Nanoclays are the naturally occurring particles with nanometer scale, and considered as a nanomaterials of geological origin. Nanoclays exhibits different structures which include tetrahedral silicates and octahedral aluminium layers, and the variety of the clays depends on the arrangement and composition of these layers [10].

Instrument based Wastewater Analysis with Nanomaterials

Recently several advancements came into light on applications of nanomaterials in analytical chemistry for detection of organic and inorganic pollutants using different instruments as depicted in Figure 1. For instance two examples were discussed in this paper. A new synthesized Schiff base, 3- (4-methoxybenzylideneamino)-2-thioxothiazolodin-4-one was synthesized for the development of Carbon Paste Electrode (CPE) on the Multi-Walled Carbon Nanotubes (MWCNTs) for the concurrent detection of mercury(II) and lead(II) by Square Wave Anodic Stripping Voltammetry (SWASV). This fabricated electrode showed fair sensitivity and selectivity due to easy and fast electron transfer rate between the electrode surface and the metal ions. To improve the selectivity, stability of the complex and detection limits, different experimental parameters such as pH, deposition potential and deposition time were optimized. Under optimal conditions the limits of detection, were found to be 9.0×10^{-4} and 6.0×10^{-4} μ mol L^{-1} for mercury (II) and lead (II) respectively with a 90 as a preconcentration factor. In addition, the modified electrode displayed excellent reproducibility and selectivity, making it appropriate for the simultaneous analysis of mercury (II) and lead (II) in different wastewater systems [11]. Palladium-graphene nanocomposite and ions liquid was fabricated and tested as a sensor for chlorophenols. The Pd-graphene nanocomposite was prepared via a sonoelectrochemical route, and the possible formation mechanism was proposed. TEM, SEM, XRD and Raman spectrum were used for the characterization of structure and morphology of the nanocomposite. The experimental results showed that Pd nanospheres comprised of small Pd NPs were uniformly attached on graphene sheets. The EC properties were investigated by CV and Differential Pulse Voltammetry (DPV), which indicated that the Pd-graphene nanocomposite had high activity for chlorophenol oxidation. Herein, 2-chlorophenol was selected as the model molecules. The results showed that graphene played an important role in the fabrication of the chlorophenols sensor. The nanocomposite with large electrochemical active surface led to the excellent electrocatalytic activity, and ionic liquid further enhanced the catalytic activity of Pd-graphene for chlorophenols in several secondary effluent samples from a wastewater treatment plant [12].

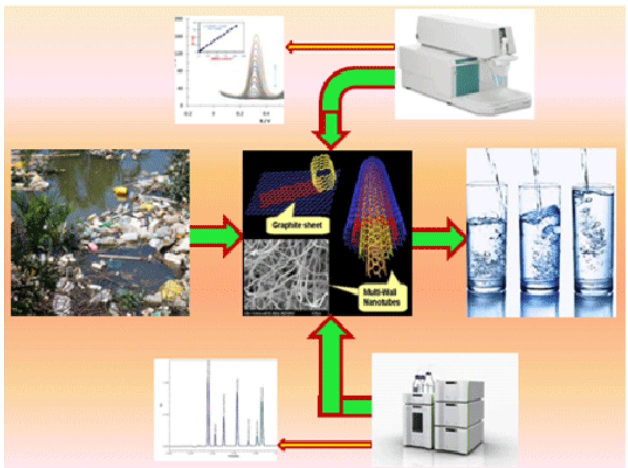

Figure 1: Instrumental Analysis with Nanomaterials

Conclusion

Nanotechnology research and development is a promising novel technology, for the treatment of wastewaters which is vital to human beings. These technologies are economical, reliable, rapid and durable to treat wastewaters by eliminating specific types of pollutants from water. Nanotechnology applications for sustainable water supplies are including water filtration, water treatment, desalination, and using such techniques as sensors, nanoparticles, and catalysts.

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