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Review

Application of common nano-materials for removal of selected metallic species from water and wastewaters: A critical review

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ABSTRACT

Wastewater treatment and water purification have always posed challenges to mankind and this problem has become severe with escalating population and industrialization. This topic has attracted the global scientific community. Activated carbon adsorption became popular choice for water purification but its high cost prompted scientific workers to search for its alternates. In that series, several materials including minerals, waste materials, cellulosic materials, etc. were also applied as adsorbents. Recently, especially after advent of nano technology, there was a shift toward application of nano materials as 'adsorbents' and the term was coined as 'nano adsorbents'. Present review has been focussed on the application of common nano materials for the removal of metallic species which are found in aqueous environment. The 'most common' metallic species are As, Cd, Cr, Cu, Pb, Hg, and Ni. Sb, Pd, Pt, U and Th are the other miscellaneous metallic species where nano particles are applied for their removal from aqueous solutions and water. We have critically discussed the articles published recently on this topic.

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1. Introduction

Water pollution is one of the most serious problems posing human health risks and which causes detrimental effect to humanity and other life forms. In recent years the world's rapid economic improvement is gaining momentum and has led to climbing wages, as well as to a fast urbanization and an uncontrolled populace development. Therefore, the planet has experienced an assortment of pressing environmental challenges such as climate change and global warming, extreme era of robust waste, and water pollution, leading to serious environmental degradation and contributes a major share to the overall imbalance of the ecosystem. It is a well-known that clean water is vital for healthy living. Satisfactory supply of pure and clean drinking water is an essential need for all people on the earth, yet it has been perceived that millions of individuals worldwide are denied of this. Water resources onto every part of the planet are undermined by over abuse and poor administration as well as by environmental pollution. The principle wellspring of water contamination might be ascribed to release of untreated waste, dumping of modern industrial effluents and run-off from rural fields. Moreover, indifferent behaviour of man towards nature and his activity at surface, unintentionally by farming, local effluents, surprisingly by sub-surface or surface disposal of sewage, industrial wastes, and geometrical growth of population has led to adverse effects on water quality. Unfortunately, due to rapid increase in industrialization, uncontrolled population growth, civilization, rural, and domestic practices, and various other land and ecological progressions, water quality of the water resources is getting deteriorated continuously. Therefore, in the present situation, water pollution affecting all living creatures, etc. has become a serious issue of global concern for government authorities, academicians, scientists and environmentalists.

Many natural, inorganic and organic constituents have been accounted for as water contaminants. A number of them have serious symptoms and acute toxicities with a couple of them being deadly poisonous and carcinogenic posing threat to the ecosystem of the earth as a whole. The various types of water pollution problems result in the scarcity of water all over the world, in terms of quality and quantity, and pose serious threats to people's well-being. Therefore, providing clean and safe water is a major challenge for the global community [1–3]. As water resource has increasingly become scarce recently, it is evident that the world is now facing formidable challenges not only in maintaining good quality of water supply, but also in complying with the increasingly stringent requirement of environmental legislation for clean drinking water.

As protected and clean water is a nexus vital asset and sustains life on Earth, preserving the aquatic environment and its resources against pollutants is critical to safeguard living organisms. In this regard, mere reliance on conventional solutions is not sufficient, as they are ineffective, time-consuming, and costly. Robust and technological improvements are required for purifying water economically with less chemicals/energy consumption, while addressing environmental impacts in the long term. While the impacts could be minimized using existing treatment techniques, novel and cost-effective technologies are increasingly in demand in the commercial market. As innovations are the only pathways through which long-term improvement could be sustained, new, practical, and local solutions need to be developed not only to overcome barriers to water and sanitation provision, but also to tackle global water pollution problems in sustainable ways. Therefore, new and more advanced approaches are continually being examined to supplement existing traditional water treatment methods.

For a couple of decades, distinctive techniques have been produced and utilized for treatment of contaminated water. The most paramount strategies are screening, sedimentation, filtration, micro-and ultra filtration, centrifugation, crystallization, precipitation, oxidation, floatation, coagulation, solvent extraction, dissipation, refining, reverse osmosis, particle diffusion, electrolysis, electro-dialysis, gravity separation, adsorption, and so on. Adsorption is acknowledged as one of the most suitable water strategies because of its simplicity of operation and the accessibility of an extensive variety of high adsorption limit and large scale sections [4]. Moreover, adsorption can likewise be utilized for source diminishment and recovery for consumable, mechanical, and other water purposes. Despite these facts, adsorption has specific limits, for example, it couldn't attain a decent status at business levels. Presumably, it is because of the absence of suitable adsorbents of high adsorption capacity and business scale sections. Furthermore, a single adsorbent can't be utilized for various types of pollutants It was observed that, regardless of a few impediments, it will be an exceptional water treatment innovation in the near future. Much work has been carried on the abatement of different contaminants from water by utilizing adsorption method. Initially, activated carbon [5–8] was utilized for the removal of contaminants from water, which has been supplanted by some low cost adsorbing materials. A number of other adsorbents, e.g. fly ash [9–11], chitosan [12–13], kaolinite [14], zeolite [15–16], montmorillonite [17], sphagnum moss peat [18], wollastonite [19], bentonite [20], sawdust [21], sea weeds [22], soya cake [23], red mud [24] and alumina [25–27] have been incorporated by various workers and reported for the removal of metallic pollutants from aqueous solutions and wastewaters. In the last two decades, nanotechnology has undergone a full-fledged advancement with its requisitions in essentially all branches of science and technology. In this arrangement, water remediation is not denied of nanotechnology.

Nanotechnology is an emerging science with wide applications in the remediation of environmental pollutants. Advances in nano-scale science and engineering are providing unprecedented opportunities to develop more cost effective and environmentally acceptable water purification processes. In recent years, a great deal of attention has been focused on the synthesis and application of nano-structured materials as adsorbents to remove toxic and harmful compounds from water and wastewater. Resurgence to synthesize and manipulate nano-particles finds use in improving water quality in the environment. In perspective of the vitality of water quality and increasing applications of nanotechnology, endeavours have been made to talk about different parts of water remediation by adsorption utilizing nano-adsorbents.

Several reviews have been published so far on the application of nano-materials for water remediation, this work mainly highlights the works that have been carried out during last mostly five years with emphasis on the removal of certain heavy and toxic metals.

1.1. Adsorption

Adsorption is a mass transfer process which involves the accumulation of substances at the interface of two phases, such as, liquid–liquid, gas–liquid, gas–solid, or liquid–solid interface through the physical forces (physi-sorption) or sometimes through weak chemical forces (chemi-sorption). The adsorption from solution on to a solid occurs as a result of the driving forces of lyophobic character of the solute, relative to the particular solvent, or a high affinity of the solute for the solid. The molecule which gets adhered on the solid surface is called the adsorbate and the solid surface is termed as adsorbent. The process of adsorption is influenced by various parameters such as initial metal ion concentration, temperature, nature of adsorbate and adsorbent, pH, contact time, particle size, etc. All adsorption performance processes depend on solid-liquid equilibria and on mass transfer rates. The adsorption operation can be batch, semi-batch and continuous. The state of equilibrium is achieved in this vary process when the concentration of pollutant on the solid and in the solution become constant. At this state of equilibrium, the relationship between amount of solid adsorbed and in solution is called an adsorption isotherm. Adsorption isotherms are important for the description of interaction of adsorbate with adsorbent and are critical in optimizing the use of adsorbents. The adsorption is performed for determination of different adsorption parameters. The most common models are Langmuir, Freundlich, Temkin, Sips, etc. [28–37], which have been tabulated in Table.1. These are diverse well-known