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Mini Review

Magnetic Graphene Oxide Composites are the Solutions for Sustainable Remediation of Ecosystems

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Introduction

Heavy metals are one of the primary contaminants in the environment [1]. Exposure to heavy metals, even at trace levels, is believed to be a high health risk for humans [2,3]. Heavy metals are naturally occurring throughout the earth's crust [4]. But most of the environmental contamination results from the anthropogenic activities such as mining and smelting operations, industry, and domestic and agricultural use of metals and metal-containing compounds. Migration of these contaminants into non-contaminated areas as dust or leachates through the soil and spreading of heavy metals containing sewage sludge are a few examples of events contributing towards contamination of the ecosystems [5]. Hence, water is the one of the major routes through which heavy metals and radionuclides may enter the human body [6,7]. The sources of water pollution are shown in Figure 1. The conventional wastewater purification techniques including chemical coagulation, photo degradation, precipitation, flocculation, activated sludge, membrane separation and ion exchange are limited to the removal of heavy metals at trace levels [7-9]. However, adsorption is one of the best methods for the purification of water, owing to its low cost and easy handling of materials [7,10-12]. Moreover, adsorption approaches using commercial activated carbon, micro-filtration and membrane techniques are effective, but their use is limited by the complicated installation process involved coupled with the high maintenance costs of the systems [7,13]. Hence, these drawbacks have necessitated the search for an alternative method which is inexpensive, renewable and cost-effective for the removal of heavy metals from aqueous solutions. Many scientific groups have prepared graphene or graphene oxide (GO) based hybrid nanocomposites for various potential applications [14-17]. The study of literature survey and stability of the GO-based nanocomposites prompted us to survey on graphene oxide and reduced graphene oxide-based inverse spinel nickel ferrite nanocomposites for the removal of heavy metals and radionuclides from water with the purpose of reducing their environmental impact.

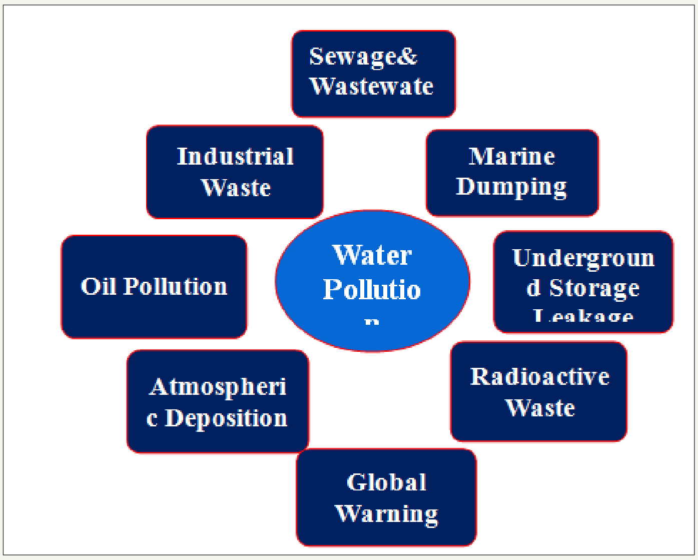

Figure 2: Schematic depict for sources of water pollution.

Graphene Oxide Based Nanocomposites for Radioactive and Toxic Metal Remediation

Recently, the field of nanoscience has blossomed, and the importance of nanotechnology will increase as miniaturization becomes more vital in the areas of computing, sensors, biomedical, water purification and other applications. Advancements in this discipline depend largely on the ability to synthesize nanoparticles of various materials, sizes, and shapes, as well as to assemble them efficiently into complex architectures. That means, nanomaterials applications are mainly depend on their physicochemical properties which leads to develop a special structural featured nanoparticles. However, the scientists are examining materials with improved physicochemical properties that are dimensionally more suitable in the field of nanoscience and technology. In this regard, the discovery of graphene or graphene-based nanocomposites is an important addition in the area of nanoscience, playing a vital role in modern science and technology.

Graphene, a two-dimensional sp^2 carbon monolayer in a unique honeycomb-like network [18,19]. It has attracted dramatic attention due to its numerous merits such as enormous specific surface area (2630m2/g), high thermal and electrical conductivity (~5000 W/m.K and 6000S/cm), large Young's modulus (~1.0TPa) and high optical transmittance (~97.7%) [14,15,18-21]. Moreover, graphene oxide (GO) or graphene-based material shares merit like those of the bare. However, due to the presence of decorated hydroxyl, carboxyl, and epoxy functional groups on the basal plane and plane edge, GO is more easily dispersed than graphene, making its synthesis, processing, and usage more convenient [22,23]. Also, the durable hydrophilicity of GO guarantees that it is a good candidate for many applications, including drug delivery, brutal cell treatment and water purification [23-25]. To enrich the functionalities, graphene and GO are always used to host various nanomaterials due to their large surface area [22,24,25].

The incorporation of inorganic NPs to GO excellently improved its performances in different applications [26-29]. Moreover, GO is a good candidate for constructing GO-based metal oxide composite materials. For example, Co_3O_4-anchored graphene nanocomposites that serve as potential electrode materials for super capacitors exhibit an excellent specific capacitance [25]. TiO_2-graphene nanocomposites display a much higher photocatalytic activity and stability for the degradation of benzene in the air [30]. Graphene-Fe_3O_4 nanocomposites exhibit improved reversible capacity and cyclic stability of the lithium ion battery [31,32]. Recently, many researchers prepared GO-based metal oxide nanocomposites, such as Fe_3O_4/GO [33,34], Magnetic reduced GO [35,36], Mn_3O_4/GO [37-39] and other hybrid [40-42] nanocomposites are used for the adsorption of various organic and inorganic pollutants from water. Sreeprasad et al. [41] and Maaz et al. [42] have been reported nickel ferrite-GO composite is a promising reacting media because Ni^{2+} in the nickel ferrites shows unique property such as high catalytic efficiency with high charge (electron) transfer capacity than iron ferrites. Therefore, it has been used for adsorption of toxic heavy metals [32]. Besides, graphene-based materials possess the ability of adsorbing organic pollutants and heavy metal ions owing to their potential adsorbent materials [42,29]. However, the limitations in separation and the following recycling process have significantly restricted their applications [29,39-43]. Nevertheless, the introduction of magnetic NPs to the graphene/GO can improve the graphene's dynamic adsorption behavior as well as overcoming the separation and recycling problem. Previous reports have proved the magnetic NPs/graphene or GO composites amazing removal response for pollutants, like chromium [44,45], copper [46,47], arsenic [33,48], cadmium [49], lead [50], cobalt and organic dye [51-53].

For the synthesis of GO-based magnetic nanocomposites, GO is the candidate used as a template to the in-situ production of magnetic NPs by interacting with the functionalized oxygen-containing groups [51,52]. A further reduction process is performed to obtain few layered graphene or reduced GO (r-GO) nanocomposites of an enhanced magnetization [52]. Recently, we reported on the synthesis of graphene oxide based inverse spinel nickel ferrite nanocomposites for the removal of heavy metals, Co(II), Pb(II), Cr(III), As(III) and As(V) and radionuclides, U(VI) and Th(IV) from aqueous solutions, thereby reducing potential effects on human health and environmental risks [53-58]. The reported results demonstrated that the magnetic GO-based nanocomposites, are promising, economic and could be separated by external magnetic field, and were recycled and re-used for up to five cycles without any significant loss of adsorption capacity towards heavy metals and radionuclides from aqueous environment.

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