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# Engineered Carbon Nanomaterials: The Chance or the Risk in the Future?

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## Engineered Carbon-based Nanomaterials

Nanomaterials, defined as "a field that takes a material science-based approach to nanotechnology", are materials with morphological features on the nanoscale, and especially the materials that have special properties stemming from their nanoscaled dimensions. The diversity of nanomaterials is enormous, including nano-glasses, metals and alloys, carbon-based nanomaterials, biological nanomaterials, nanocomposites, nano-ceramics, nano-polymeric materials and so on. Advancements in the field of nanotechnology have the potential for improving diagnostic, therapeutic, and preventive medical products, as well as in applications for food packaging, processing, and preservation. The United States Food and Drug Administration has already approved some nanotechnology-based products and expects a significant increase in the use of nanomaterials in drugs, devices, biologics, cosmetics, and food. Carbon-Based Nanomaterials (CNMs), such as buckminsterfullerene ($C_{60}$), carbon nanotubes and graphene oxide, etc, has received much attention. The rapid increase in the worldwide production and use of CNMs has led to an annual production that reached 4065 tons in 2010 and would further increase to 12300 tons in 2015 [1]. The possibilities of their environmental release and the associated implications have received much attention. Recently, more and more research tried to focus on the environmental fate, transport, adsorption, dispersion and toxicity of CNMs in the nature [2-6]. We have got some useful information about the CNMs in the environment, unfortunately, little is known about their ability of interaction with organic or inorganic materials, and the effect of carbon nanomaterials on the contaminants.

## Characters of CNMs in the Environment

More and more studies on the characters of CNMs were published in the recent year, such as the aggregation ability and stability of CNMs in the aqueous phase, transport ability of CNMs, especially for the transport ability of CNMs, which may affect the transport ability of contaminants. Thus far, only a few studies have been conducted to understand the transport of carbon nanomaterials in saturated porous media. Some homogeneous materials, such as glass beads and pure sand were used to study the transport ability [7-9]. However, even among these homogeneous porous materials, the transport properties can vary significantly. For example, Lecoanet and Wiesner [9] found that varying Darcy velocity from 120 m/d to 34.6 m/d had little influence on the migration and deposition of nC60 in a glass-bead column. Nonetheless, Li et al. [10] reported that changing pore-water velocity had a significant effect on $nC_{60}$ transport in sand columns, especially for the columns packed with finer sands. Zhang et al. [11] examined the effects of several important environmental factors on $nC_{60}$ transport in saturated porous media. Decreasing flow velocity from approximately 10 to 1 m/d had little effect on $nC_{60}$ transport in Ottawa sand (mainly pure quartz), but significantly inhibited the transport in Lula soil (a sandy, low-organic-matter soil). The difference was attributable to the smaller grain size, more irregular and rougher shape, and greater heterogeneity of Lula soil. Another research studied by Qi et al. [12] conducted column experiments and a modeling study to understand the effects of several environmental factors on the aggregation and transport of Graphene Oxide Nanoparticles (GONPs) in saturated quartz sand. The GONPs were negatively charged and stable under the test conditions, and the Derjaguin–Landau–Verwey–Overbeek (DLVO) calculation indicated that deposition of GONPs was under unfavorable attachment conditions. The GONPs exhibited high mobility even at an ionic strength of 25 mM NaCl. The transport of GONPs was insensitive to the changes of pH, but the presence of 10 mg/L Suwannee River Humic Acid (SRHA) considerably enhanced transport of GONPs.

## Effect of CNMs on the Contaminants

As the carbon-based materials, CNMs has the basic characters of the adsorption ability similarly with the conventional carbon materials, but with higher surface area and more surface functional groups, the adsorption abilities of CNMs are more complicated. Until now, a sort of study on the adsorption ability of CNMs has been published. For example, some studies have shown that Carbon Nanotubes (CNTs) exhibit strong adsorption affinities for several important classes of organic compounds, such as polycyclic aromatic hydrocarbons, hydroxyl-, nitro-, and amino-substituted aromatics, tetracyclines, and sulfonamides, to mention a few [7-9]. A common observation is that adsorption affinities between CNTs and organic molecules can be significantly enhanced via nonhydrophobic interactions, including p–p electron coupling/stacking, p–p electron donor–acceptor (EDA) interactions, n–p EDA interactions, and Lewis acid–base interactions [5,13,14]. The type and number of functional groups of adsorbate molecules can markedly affect the significance of adsorption-enhancement effects. For instance, both electron-donating groups, such as $-NH_2$ and –OH, and electron-withdrawing groups, such as $-NO_2$ and –C=O, can considerably enhance p–p EDA interactions [5,14]. Similarly, functional groups of adsorbate molecules possessing lone-pair electrons, such as $-NH_2$, can allow n–p EDA interactions with the graphitic surface of CNTs [14,15]. For another important carbon nanomaterials, graphene oxide, the study on the adsorption of GO was also too little and only a few studies have been conducted to understand the adsorptive interactions between environmentally relevant organic contaminants and GO, and only GO powder (rather than true colloidal GONPs) has been used as the adsorbent [16-18].

With the studies shown before, we found that most of the work was related to the transportation of CNMs, their adsorption of contaminants and the stability of CNMs in the water, but little researches were focus on the effect of CNMs to the human being.

CNMs will be used more and more in the future and more CNMs homolog will be produced. We believe that their effects on the contaminants, the organism, or the human being are waiting for the systematic studies.

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