Brahmaputra basin has 10,106 glaciers occupying 20,542.75 sq. km of glaciated area. The 27 glaciated sub-basins in the Brahmaputra basin have been mapped.

It was observed that the percentage of accumulation area was highest in the Indus basin compared to the other two basins; however, it was almost similar for the Ganga and Brahmaputra basins. The ratio of accumulation to ablation area was also high in the Indus basin, and it was almost similar for the Ganga and Brahmaputra basins. This indicates that the glaciers of the Indus basin have larger feed area and hence are relatively more stable compared to the other two basins. The percentage of ablation area debris cover was almost similar for the Ganga and Brahmaputra basins, and low in the Indus basin. The ablation area ice exposed was highest in the Indus basin, and it was almost equal for the Ganga and Brahmaputra basins. Also, for these basins the accumulation–ablation area ratios were low and most of the glaciated areas had varying amounts of debris cover. The thick debris cover plays an important role by stopping the heat from sun rays in reducing the melting of glacier ice. However, the status of these glacier features depends on its altitude and latitudinal distribution.

The mean area under various glacier classes like accumulation area, ablation area, glacierets and snow fields, supra-glacier lakes and moraine-dammed lakes area have been studied for the three glaciated basins. The Indus basin has high mean accumulation, low mean ablation area along with low mean supra-glacial lake and mean moraine dammed lake area, which shows that this basin is more stable compared to the Ganga and Brahmaputra basins. It has been observed that low mean accumulation area of the Brahmaputra basin along with relatively higher mean area for supra-glacial lake and moraine-dammed lake could be serious for glacier health and stability, compared to the Ganga basin which has relatively high mean accumulation area and high mean ablation area.

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RESEARCH NEWS

Nanostructured carbon materials in water sterilization/purification

C. Srinivasan and R. Saraswathi

The discovery of fullerenes in 1985 by Smalley and co-workers[1] has opened the gate for the entry of several synthetic nanostructured carbon allotropes like carbon nanotubes (CNTs)[2–4], carbon nanohorns, cup-stacked CNTs, carbon nanotori, carbon nano-onions, nanobuds[5], graphene[6], carbyne[7], etc. into the wondrous world of carbon nanomaterials. These carbon nanomaterials with unique mechanical, thermal and electrical properties hold great promise for many technological applications.

It has been estimated that around 1.2 billion of the world's estimated 6.5 billion people lack access to clean water[8,9]. The UN prediction of 40% increase in population[10] by 2050 will further worsen the clean-water supply situation. As many parts of the world witness serious pollution of groundwater and surface water[11,12], the demand for safe, affordable, robust and sustained methods for water purification is increasing throughout the world[13]. The advocates of nanoscience and nanotechnology believe that nanotechnology can offer much promise for meeting this demand.

Two approaches are envisaged to tackle the problem of removal of bacteria and other organisms from water. In one method the pathogens are removed by filtration (size exclusion of bacteria) using a device with CNTs[14]. The other approach exploits the bactericidal property of silver nanowires (AgNWs) and uses a three-component system (*vide infra*) which inactivates bacteria[15].

In 2004 Srivastava *et al.*[14] reported fabrication of free-standing, monolithic, uniform macroscopic, hollow cylinders having radially aligned CNT walls, with diameter and length up to several centimetres. These cylindrical membranes act as filters and have been shown to be effective in the filtration of bacterial contaminants such as *Escherichia coli* or the nanometre-sized poliovirus (~ 25 nm) from water. One advantage of this method is that these macro filters can be cleaned for repeated filtration through ultrasonication and autoclaving.

In the second strategy, Schoen *et al.*[15] took advantage of the unique ability of AgNWs and CNTs to form complex multiscale coatings on cotton to produce an electrically conducting and high surface area device for the active, high-throughput inactivation of bacteria in water. As Ag is an effective bactericidal agent, AgNWs are used in the device. AgNWs also form an efficient electrical transport network in filters. CNT coatings offer good electrical conductivity over the entire area of the device. Figure 1 gives a summary of fabrication of this device. Cotton was soaked in the CNT ink prepared by dispersing CNTs in water containing the surfactant sodium dodecylbenzenesulphonate (Figure 1 *b*). The cotton was then rinsed with distilled water to remove excess surfactant. A solution of AgNWs was introduced on the cotton by means of a pipette. The resulting cotton material was used in destroying bacteria. The device was operated at an optimum bias of 20 V. The application of a moderate bias enhances the bactericidal character of the AgNWs. It was observed that when water containing *E. coli* was passed through the device nearly 90% of the bacteria were destroyed and the inactivated bacteria were present in the treated water.

Every year, two million people die from waterborne diseases and billions more suffer from illness. Much of this ill-health and suffering can be prevented. The WHO drinking-water guidelines, released on 4 July 2011, call on governments to improve the quality of their drinking water (http://www.who.int/en/). The removal/destruction of *E. coli* gains importance from the following statement (http://www.who.int/en/): 'Countries in the WHO European Region have reported significant numbers of infections from verocytotoxin-producing *E. coli* O104 : H4, resulting in a large number of cases of bloody diarrhoea and haemolytic uraemic syndrome in Germany, and in 15 other countries in Europe and North America. More recently, another cluster of cases in the region of Bordeaux, France, as well and a single case in Sweden, have been reported.'

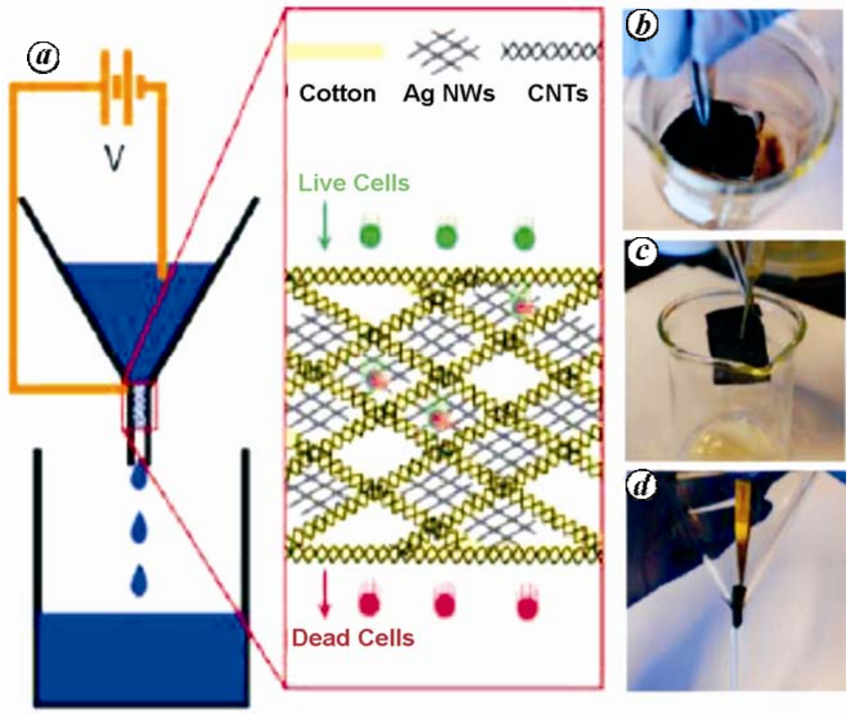

Figure 1. Schematic fabrication and structure of cotton, silver nanowire (AgNW)/carbon nanotube (CNT) device. ***a***, Schematic active membrane device proposed. ***b***, Treatment of cotton with CNTs. ***c***, Treatment of device with AgNWs. ***d***, Integration of treated cotton into funnel. Reprinted with ACS permission from Schoen *et al.*[15]. Copyright (2011) from American Chemical Society.

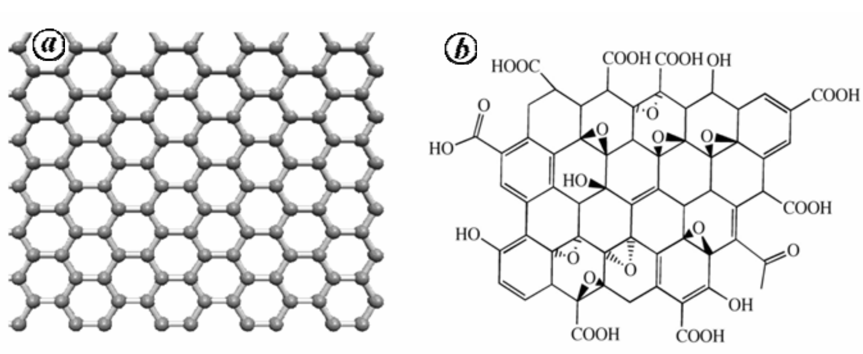

Figure 2. Structures of (***a***) graphene and (***b***) graphite oxide.

In 2004, physicists from Manchester University first isolated graphene by mechanical exfoliation of small mesas of highly oriented pyrolytic graphite[6]. Within the last few years, graphene has received special attention from the scientific world due to its unique mechanical and electrical properties. Therefore, the race to prepare graphene in large quantities is unabated. One important method involves the oxidation of graphite to graphite oxide (GO), exfoliation in solution and subsequent reduction by a variety of reducing agents. GO is readily obtained by modified Hummers method[16]. The success of the developed CNT device[14] for filtration of *E. coli*, prompted Gao *et al.*[16] to employ an inexpensive material like GO to remove heavy metal ions like mercuric ion and dyes. It has to be pointed out that graphene is composed of only sp^2 hybridized carbon atoms that impart hydrophobic character. On the other hand, 60% of the carbon atoms in GO are sp^3-hybridized and oxidized, mostly in the form of alcohols, epoxides and also as lactols, whereas the remaining 40% of the carbon atoms remain sp^2-hybridized, mostly as unfunctionalized alkene or aromatic carbons, but also as carbonyl groups in lactols, esters, acids, and ketones[16] (see Figure 2). The oxygen-containing functional groups not only impart hydrophilicity, but also exhibit limited complexing capacity with mercuric ions. It is therefore not surprising that Gao *et al.*[16] preferred the amphiphilic GO as a material for purification of water.

It is a well-known fact that for more than six millennia India and some other countries use sand–gravel filtration bed to get clean water. In the municipal water supply such a bed is invariably employed. Although ordinary sand is effective in removing biological waste from polluted water, it cannot eliminate heavy metals. Therefore, Gao *et al.*[16] converted conventional sand granules to 'core-shell' adsorbent granules in which the GO coating imparts nanostructural features on the surface of sand granules. The process involves mixing of the water-dispersible GO colloids with sand, followed by a mild heat treatment causing the nanosheets to adhere to each other over the sand surface, likely through van der Waals interaction. The

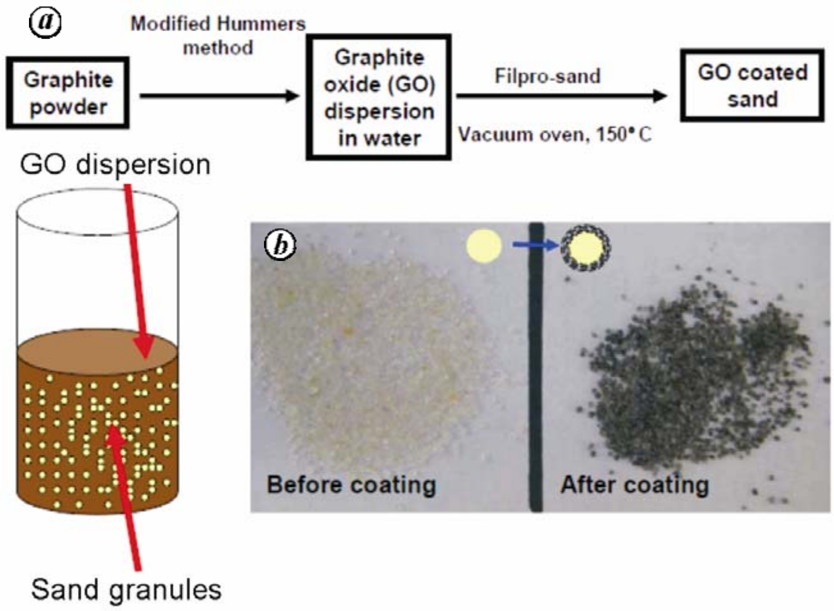

Figure 3. ***a***, Flow chart and schematic illustration for the preparation of GO_{SAND}. ***b***, Photographic images of sand and GO_{SAND} product. (Inset) Idealized schematic of conversion of regular sand to GO_{SAND}. Reprinted with ACS permission from Gao *et al.*[16]. Copyright (2011) from American Chemical Society.

resulting material is termed GO_{SAND}. Figure 3 *a* provides details of the process of preparing GO_{SAND}. From Figure 3 *b* one can easily visualize the change in colour of the sand from yellowish-white to blackish-grey after the coating process. In the inset of Figure 3 *b* is shown the idealized schematic of the many-layer GO coating and the resultant GO_{SAND} filtration granules.

EDAX analysis and Raman spectral studies of the modified sand confirm many-layer GO coating. The efficiency of GO_{SAND} in the adsorption of contaminants like Hg^{2+} and Rhodamine B dye from water was examined using the GO-coated sand in typical bed-packed experiments and by comparing the performance with ordinary (i.e. GO-uncoated) sand bed. The adsorption capacity of sand granules toward Hg^{2+} was saturated within 10 min of filtration and at the same time the GO_{SAND} maintained the adsorption capacity for more than 50 min of fluid flow. More important is the fact that treated water had less than 1 ppb of Hg^{2+}. When the experiments were carried out with water containing the dye molecule, the dye molecule evolved through the GO_{SAND} column after 100 min, while it was after 20 min that the dye evolved in the sand column.

The experimental results obtained by Gao *et al.*[16] certainly establish that this novel 'core-shell' adsorbent system that contains nanostructured GO coating (GO_{SAND}) can sequester heavy metal or organic contaminants at a five-fold higher capacity than regular sand and will enable exploitation of GO as a novel material for low-cost water purification processes.

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