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# Carbon nanotubes: A new class of nanomaterials in various fields

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**Abstract**
This paper presents the function and application of carbon nanotubes and its derivatives (functionalized carbon nanotubes) in various fields. Carbon nanotubes applications in oil-spill, dye-adsorption, pesticides remediation, heavy and toxic metals absorptions, cancer diagnosis therapy, removal of toxic by-products and hydrogen storage are major fields of research. Extraordinary properties of carbon nanotubes make it a useful material for all of the above applications. The adsorption properties of carbon nanotubes make it a commendable material in surface chemistry. Thus, carbon nanotubes based materials provide a huge thrust to the pollutant absorbent industry and semiconductor devices. Based on the application of carbon nanotubes in controlling different pollutants by utilizing its adsorbent properties, this paper stresses upon the useful applications of carbon nanotubes in the context of adsorption of pesticides, herbicides, dyes, oil spill, toxic metals, hydrogen storage and cancer diagnosis.

**Keywords:** carbons nanotubes, pollutants, adsorption

## Introduction

Carbon nanotube is an allotrope of carbon. It is a cylindrical type nanostructure. It consists extraordinary thermal conductivity, mechanical strength and electrical properties. Because of these extraordinary properties the CNT are at least 100 times stronger than steel, but only one-sixth as heavy. It is also found as additive to other structural materials. Carbon nanotubes can conduct heat and electricity far better than copper. Mainly nanotubes are of two types one is single-walled carbon nanotubes (SWCNTs) and other is multi-walled carbon nanotubes (MWCNTs). Generally single-walled nanotubes have a diameter of one nanometer. Its structure can be abstracted by wrapping layer of graphene into a cylinder.

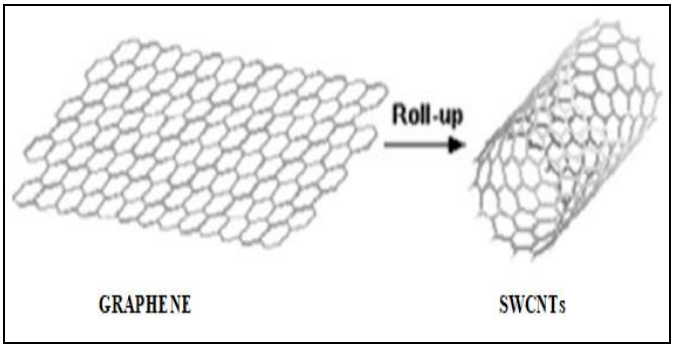


**Fig 1**

It is found that the rolling of a single graphene layer into a cylindrical shape produces the SWCNT, similarly the rolling of many concentric SWCNTs into a tubular shape gives the MWCNT.

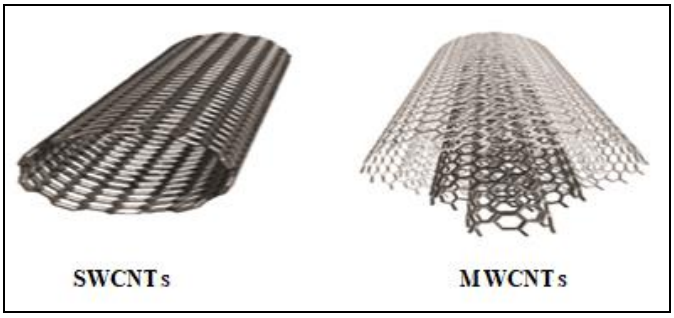


**Fig 2**

Carbon nanotubes was discovered in 1991 that was a new era in materials science. Because of unique physicochemical, electrical and mechanical properties the carbon nanotubes make itself suitable for potential applications as environmental adsorbents, sensors, membranes, and catalysts.

The earth is continuously being contaminated with a large number of toxic substances from both caused by nature and humans. There are several polluting activities which directly or indirectly in one way or the other way pollute the Earth. In daily life activity people uses many chemicals without proper evaluation of their environmental risks and human health impacts. The discharge of untreated industrial effluent into water and soil, the indiscriminate use of pesticides and fertilizers in agriculture, the unfettered use of harmful chemicals in every day life, the lack of proper public cleanness systems in developing countries and the combustion of fossil fuel are some of the primary causes of contamination of water, soil, and air. The materials like zeolite, clay minerals, and agricultural/industrial waste based adsorbents

often experience drawbacks in practical applications because of poor contaminant removal capacity, lack of contaminant interaction specificity, and environmental instability [1].
In recent decades, CNTs have attracted the attention of scholars worldwide because of their unique properties. The Carbon nanotubes have large specific surface area, light weight, high porosity, and strong interactions with a various range of contaminants. Some of techniques such as chemical vapor deposition (CVD), laser ablation, and arc discharge have been employed for CNT synthesis [2]. Out of these technique of CNT synthesis, CVD is the best technique [3].

**Toxic heavy metal**
The CNTs are materials that attractive for adsorbing contaminants from water and wastewater. These nanotubes can adsorb toxic materials such as Pb, Cd, Hg (II), Cr (VI), 1,2-dichlorobenzene etc. from wastewater. Functionalized MWCNTs are used for the adsorption of Hg (II) from wastewater. For this purpose MWCNTs have amino- and thiol-functional group. Hadavifar *et al.* [4]. found that the thiol-functional group are more effective than amino-functional group for adsorption of Hg (II) from wastewater. Magnetic MWCNTs are used for the removal of Cr (VI) [5].

**Oil spill adsorption**
The management of oil spill in the sea is more difficult than that of a land because of sea waves and wind. Because of large surface area, high porosity and extraordinary thermal conductivity, mechanical strength, electrical properties, CNTs act as good adsorbents for oil spills under oceanic conditions [6]. It is also found that there is strong interaction between oil particles and CNTs network, so there is no possibility of complete desorption of all adsorbed oil particles.

**Dyes**
Organic dyes are used in large quantity in many of industries such as textiles, food products, cosmetics, paper manufacturing and pharmaceuticals etc. So, their quantities are increasing day-by-day in wastewaters. This large amount of dyes in water bodies have adverse effects on the ecosystem and human health. Compared with other adsorptive materials, CNTs have high affinity for organic dyes. Some of CNT-based materials are used for dye removal without any modification and some materials are used with functional group modification. Zare *et al.* [7]. Found that the functionalization of CNTs can enhance adsorption capability of organic dyes. Oxidized MWCNTs are the most effective in removing methylene orange and methylene blue dyes from water. MWCNT without any modification is suitable for removing malachite green, maxilon blue, alizarin red and Congo red from water matrices. The salinity levels of both land and sea water are constantly increasing day-by-day. It was found that CNTs played an important role in decreasing the salinity level and also played role in purification of drinking water [8]. Figure given below shows the most common techniques used to remove dyes from wastewater.

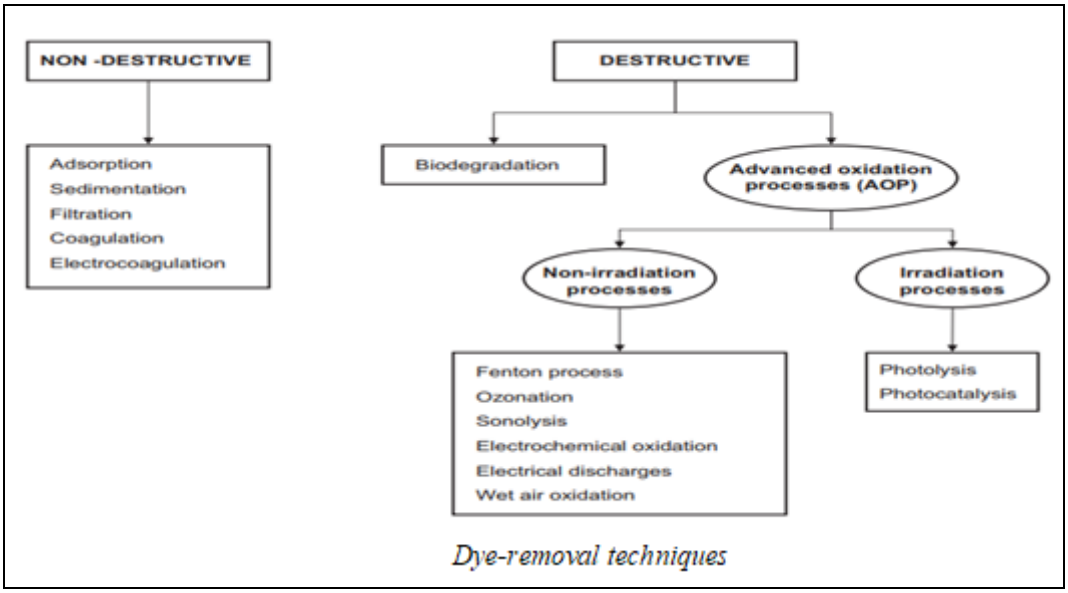


**Fig 3**

**Pesticides**
Pesticides are a diverse group of chemical compounds, which are used to eliminate pests in agriculture and households. However, their widespread use, as well as their high toxicity, generates risks to humans and the environment. CNT, a member of the carbon nanomaterial family, having mainly two types structure - SWCNT and MWCNT has sparked considerable research attention. CNT and modified CNT materials have been widely employed for the treatment of pesticide-contaminated water. Oxidative modification of CNTs increased the surface area and pore volume, which resulted in higher adsorptive removal performance. Deng *et al.* [9]. Reported that the adsorption of diuron by oxidized MWCNTs was most favored at pH ≥ 7.0. CNTs and their types also significantly influence pesticide availability to plants. Hamdi *et al.* [10]. Found that the pesticides (chlordane and p,p'-dichlorodiphenyldichloroethylene) in roots and shoots of lettuce crop was reduced by 88% and78%, respectively,

with the use of non-functionalized CNTs, with the use of amino functionalized CNTs the same were reduced by 57% and 23%, respectively. The semiconducting SWCNTs due to lack of electron density also favored high pesticide adsorption. Some of the pesticides with their favorable adsorbent are shown in table.

**Table 1**

| Pesticides/herbicides | Adsorbent | Surface area ($m^2 g^{-1}$) |
|---|---|---|
| Diquat dibromide | MWCNTs | 233 |
| Isoproturon | MWCNTs | 162 |
| Atrazine | SWCNTs | 407 |
| Diuron | MWCNTs | 258 to 427 |
| Dicholbenil | MWCNTs | 83-558 |
| Phenoxy acid herbicide | SWCNTs | 94-541 |

**Cancer Diagnosis**

Now-a-days, cancer is a life challenging disease to almost all populations of the world. Cancer is a group of diseases involving abnormal cell growth. Besides the development of advanced treatment like chemotherapy methods, an effective treatment is not yet found. Breast cancer is the most common cancer in women of the world. Lung cancer and prostate cancer is common in men. Different types of nanomaterials have been involved in cancer therapy and diagnosis. Out of all the techniques, surgery is one of the oldest treatments for cancer. Another treatment for cancer is radiation. In this radiation method, high-energy rays are used to destroy cancer cells. Chemotherapy is one of the most common treatment for cancer. In this, drugs are used to terminate cancer cells and prevent their proliferation. One of the most significant problem of cancer treatment methods is the low selectivity of the techniques. Recently, carbon nanotubes (CNTs) have attracted a lot of attention in the field of cancer diagnosis and therapy. CNT was found as an agent for cancer therapy and diagnosis because of their properties such as large surface, conjugation ability and encapsulation of drugs [11]. The limitation of CNT such as hydrophobicity and toxicity level can be lowered by functionalization of different chemical groups on CNTs. Because of the low selectivity and specificity of cancer treatment strategies which is the main problem of current methods, CNTs are used for cancer diagnosis.

| Cancer type | Incidence (million) |
|---|---|
| Lung | 1.825 |
| Breast | 1.677 |
| Colorectum | 1.361 |
| Prostate | 1.112 |
| Stomach | 0.952 |
| Liver | 0.782 |
| Bladder | 0.430 |

**Hydrogen Storage**

Now-a-days, it is well known that hydrogen is an important source of energy carrier. Hydrogen ($H_2$) has attracted a great deal of attention as an energy source. The importance of $H_2$ as an energy source is increasing day-by-day because it as a fuel creates neither air pollution nor greenhouse gas emissions. Recently, carbon nanotubes were reported to be very promising candidates for $H_2$ storage. It was reported that the SWCNTs can be easily produced and show reproducible and humbly high hydrogen storage at room temperature [12]. Figure given below shows the schematic diagram for $H_2$ adsorption.

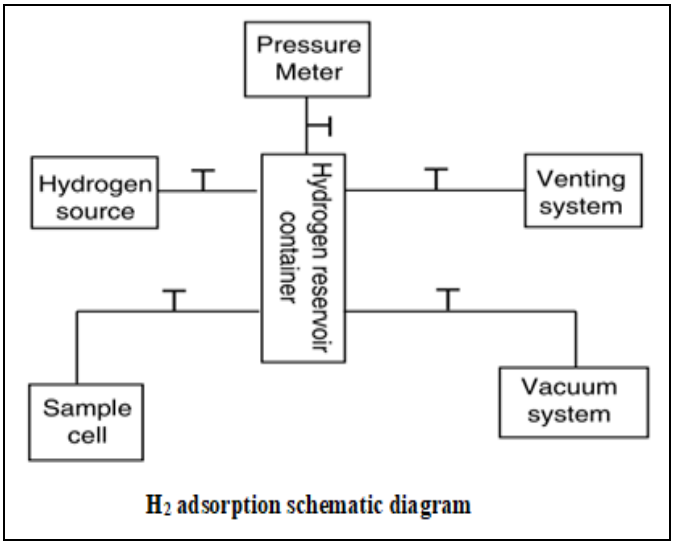


**Fig 4**

**CNTs as gas sensor**

A number of gaseous molecules are present in our environment some of them are toxic in nature such as $NO_x$, $H_2S$, $SO_2$, $NH_3$ etc. A device which detects the presence of gaseous molecules is called gas sensor. Gas sensor should be very sensitive towards particular gaseous molecule with high response time. These are used to monitor environment pollution which arises because of emission of toxic gases from industries. Because of large surface area of carbon nanotubes and tremendous electrochemical properties, CNTs are used as a sensor for many gaseous molecules. $NH_3$ and $NO_2$ gases are toxic in nature these are easily detected by sensing with carbon nanotubes with high response and better recovery time than others sensors [13]. $H_2S$ and $SO_2$ gases are corrosive in nature. $SO_2$ gas is emitted from burning of petroleum and coal products which plays an important role in acid rain and also causes respiratory problems. $SO_2$ gas was strongly adsorbed on CNTs than activated carbon [14].

$CO_2$ is a greenhouse gas which is responsible for global warming. So detection of $CO_2$ is very useful to monitor environment pollution. Adsorption of $CO_2$ on SWCNTs is twice than that of activated carbon [15] and hence CNTs can detect presence of $CO_2$ gas more accurately than activated carbon so it is novel sensor for detection of $CO_2$.

**Electrochemical Devices**

As the name suggest electrochemical devices have electrodes which are used for migration of ions. There are a number of electrochemical devices such as electrochemical capacitor which are used to storage charge these are mainly divided into two parts redox capacitor and electrochemical double layer capacitors. Supercapacitors have very large charge storage power than simple capacitor. Because of high electrical conductivity and better mechanical strength CNTs were used as electrode for these electrochemical devises [16].

Supercapacitors having CNTs as electrodes are mainly used in hybrid electric vehicle because of their large storage power than ordinary capacitors which were used in ordinary batteries. Actually in supercapacitors two CNTs electrodes were used which are separated by insulating materials [17]. Stability of nanotubes actuators at very high temperature is due to the high thermal stability of CNTs these nanotubes electrochemical actuators are used as piezoelectric stacks because of their functioning at very few volts [18].

**Conclusions**

From the carbon nanotubes based study, it has been concluded that the adsorbent properties of CNTs can be exploited for the controlling of different pollutants, which cannot be controlled by different controlling agents. Its special properties for hydrogen storage and cancer diagnosis make it superior in nanomaterial field. CNTs and its derivatives can be further modified by use of different synthetic methods for control of various pollutants.

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