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Future Approach of Carbon Nanotubes and Its Pharmaceutical Application

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ABSTRACT
Carbon nanotubes are nanoparticles with enormous application in the field of pharmaceuticals. It is used mostly in the drug delivery part for cancer treatment but other uses are not that much considered. It is used as a biosensor, used to find poisoning and many others. In this article, we are going to see the pharmaceutical uses and current approach to carbon nanotubes.
KEYWORDS: Carbon nanotubes

I. INTRODUCTION

The significant point of creating nanocarrier drug delivery system conveyance frameworks is to improve the helpful effect or lessen poisonousness of remedially dynamic materials. Carbon nanotubes can be single-walled or multiwalled which are presently delivered in generous amounts for an assortment of business applications[1]. Alternatively, carbon nanotubes (CNTs) are essentially tube-shaped particles made of carbon molecules. Carbon nanotubes are empty structures, open or shut at closes, with the dividers shaped by one-particle thick sheets of carbon, called graphenes[2]. The measurement of CNTs is in nanometer run, yet their lengths can arrive at a few micrometers... CNTs produced using a solitary graphene sheet brings about solitary walled nanotubes (SWNT) while a few graphene sheets make up multi-walled carbon nanotubes (MWNTs)[3]

As one kind of quasi-one-dimensional material, single-walled carbon nanotubes (SWNT) have been investigated as novel medication conveyance vehicles in vitro for cancer treatment[4]. Since the time their disclosure in 1991 by Iijima, there has been serious enthusiasm for these allotropes of carbon because of their one of a kind physical and chemical properties and potential applications in a wide scope of fields, from electronic gadgets and sensors to nanocomposite materials of high quality and low weight[5].pristine CNTs are not dissolvable. In recent years, the focus on CNTs has developed to include in biological applications, such as drug delivery transporters, selective cell destruction agents, biosensors, cellular growth substrates, and prosthetic implant materials[6]. Because of their high surface region, they are equipped for adsorbing or conjugating with a wide variety of therapeutic molecules. CNT can also be considered as nanocontainers. Many molecules, ions, or metals can be possibly inserted[7]. Hence, CNTs can be surface designed (i.e., functionalized) to upgrade their dispersibility in the fluid stage or to give the suitable utilitarian gatherings that can tie to the ideal helpful material or the objective tissue to evoke a therapeutic effect. CNTs may assist the joined remedial particle with penetrating through the objective cell to treat disease[8]and an ongoing case of CNTs with an assortment of practical gatherings pertinent to disease treatment. Here, we give a review of the helpful utilizations of CNTs with a significant spotlight on their utilization in the treatment of malignant growth[9].

Hostile to malignancy drugs stacked CNTs can collect medications at the disease destinations because of the improved entrance impact. Numerous malignant growth helpful operators have not been fruitful on account of their insufficient capacity to arrive at the objective tissue[10]. In this way, the advancement of CNTs - based medication conveyance framework could be compelling to convey hostile to malignancy tranquilizes in the objective tissue. Both single-walled carbon nanotube (SWCNT) and multi-walled nanotubes (MWCNT) are utilized in the tranquilizing conveyance framework. A few research works have been accounted for to convey hostile to disease drugs from both single-walled carbon nanotube (SWCNT) and multi-walled nanotubes (MWCNT)[11]. The malignant growth organic utilization of CNTs is at present underneath solid examination[12]. Carbon nanotubes (CNTs) are promising materials for detecting applications because of a few captivating properties[1]

II. MERITS

From the spearheading works with silicone elastic in the 1960s to nano time in the new thousand years, sedate conveyance frameworks have developed to a point where some endured clinical examinations[13]. To take matters further, a portion of these frameworks (e.g., liposomes and nanoparticles) sparkle out and urged the academic network to dispatch the period of commercialization[14]. Given how far medication conveyance frameworks have come, one can't resist pondering whether CNTs merit returning to the starting point or not. A current pattern in the biosensor field is the purpose of care applications, which are energized by the wide accessibility of PDAs. As of late, an expendable gadget for surface plasmon reverberation estimations dependent on mobile phone optics was illustrated[15]. As a general rule, what is normal from a tranquilize conveyance framework goes a long ways past what Ehrlich portrayed: a perfect conveyance framework should work in a manner to discharge the helpful specialists exclusively in a particular zone while keeping up potentially least or no collaboration with the insusceptible framework[16]. As ridiculous as these desires may show up in the present moment, we are unquestionably progressing nicely by methods for planning some new materials through derivatization. In such a manner, CNTs are worthwhile over other related structures, since they could believably be furnished with various (bio)molecules, every one of which fills an alternate need: focusing on specialists to decrease symptoms, medications to give remedial impacts, covertness operators to stay away from the safe framework, and analytic operators to screen a specific piece of the body, whenever required. Their subsequent benefit concerns clinical science since they have the limit of holding a few duplicates of medications[17]. In principle, it would seem that these benefits may be the way to accomplish considerable restorative records with sedate conveyance frameworks and CNTs hold the possibility to be as nearest to the enchantment projectile as we will ever be. For example, Heisner and associates manufactured triply functionalized SWCNs conjugated to doxorubicin against colon disease. In that, the framework comprises of carcinoembryonic antigen (a monoclonal antibody) to recognize tumor producers and fluorescein color to follow nanotubes inside cells. As the most focal component in this plan, doxorubicin is the anticancer operator, which represents the pharmaceutical activity of the framework. Following the utilization of this framework to human colon malignant growth cells, fluorescence perception using confocal microscopy uncovered that SWCNs–doxorubicin conjugate was taken up by dangerous cells and that upon the arrival of doxorubicin, SWCNs stayed in the cytoplasmic area of the disease cells, while dynamic pharmaceutical fixings (API) completely went to the core segment where doxorubicin applies its belongings[18]. This investigation alone demonstrates that different functionalizations are valuable to follow the bioactivity of pharmaceutical mixes.

Merits	Demerits
Unique mechanical properties offer in vivo stability	Non-biodegradable
An amazingly huge viewpoint proportion offers a format for the improvement of multimodal gadgets	Large available surface area for protein opsonization
Ability to promptly cross natural boundaries; novel conveyance frameworks	As-produced material insoluble in most solvents; need to surface treat preferably by covalent functionalization chemistries to confer aqueous solubility (i.e., biocompatibility)
One of a kind electrical and semiconducting properties; comprise progressed parts for in vivo gadgets	Bundling; large structures with less than optimum biological behavior
Empty, sinewy, and light structure with various stream elements properties; invaluable in vivo transport energy	Solid tissue resistance and aggregation; obscure boundaries that require toxicological profiling of material
Mass production–low cost; attractive for drug development	Great variety of CNTs types; makes standardization and toxicological evaluation cumbersome

METABOLISM

The non-biodegradability in the body and non-eliminate ability from the body question on the chance of their effective use in clinical practice, which has been constantly worried about. Functionalized SWCNTs appear to be metabolizable in the creature's body. For instance, SWCNTs with carboxylated surfaces have shown their interesting capacity to experience 90-day debasement in a phagolysosomal simulant, bringing about the shortening of length and collection of ultrafine strong carbonaceous garbage[19]. Unmodified, ozonolysis, aryl-sulfonated SWCNTs show no debasement under comparable conditions. The watched digestion marvel might be licensed to the one of a kind science of corrosive carboxylation, which, notwithstanding presenting the

responsive, modifiable COOH bunches on CNT surfaces, likewise actuates an inadvertent blow-back to the cylindrical graphic spine through neighboring dynamic locales that give purposes of assault to advance oxidative debasement [20]. A few tests showed that CNTs persevered inside cells for as long as 5 months after organization; short (< 300 nm) and very much scattered SWCNTs viably figured out how to get away from the RES lastly were discharged through the kidneys and bile pipes[21]. An ongoing examination uncovers that the biodegradation of SWCNTs can be catalyzed by hypochlorite and receptive radical intermediates of the human neutrophil compound myeloperoxidase in neutrophils. The wonder of CNT digestion can likewise be found in macrophages to a lesser degree. Sub-atomic displaying further uncovers that the connection between fundamental amino corrosive deposits on the chemical spine and carboxyl corrosive gatherings of CNTs is great to situate the nanotubes near the reactant site. Remarkably, when suctioned into the lungs of mice, the biodegradation of the nanotubes doesn't induce an incendiary reaction. These discoveries suggest that the biodegradation of CNTs might be a key determinant of the degree and seriousness of the incendiary responses in people presented to them. Nonetheless, further investigations are as yet required to make a proper determination[22].

FUNCTIONALIZATION OF CNTs

Regardless of every one of their benefits, these nanostructures are not impeccable either. Concerning their science, the key issue lies in that crude CNTs are insoluble practically in any dissolvable or milieu[23]. In light of solid van der Waals cooperations among tubes, related to their hydrophobic character, CNTs don't scatter in arrangement yet they rather structure packages or group totals. Without a doubt, this confusion could be settled just if the medium can wet these hydrophobic surfaces or the intermolecular attractions between singular cylinders are overwhelmed using any means[24]. Generally speaking, this condition comprises a significant obstruction on two checks. On one hand, the absence of dissolvability or failure to scatter—particularly, in water—endlessly limits their utilization in natural and biomedical applications, for an undeniable explanation. Then again, it blocks the entire idea of derivatization, which utilizes wet science and pertinent procedures[25]. Consequently, concocting methodologies to win these restrictions is essential concerning the science of CNTs and prepares for the use of these natural materials as medication conveyance frameworks. By and by, endeavors to scatter CNTs fall under four significant classifications: (1) surfactant-encouraged scattering, (2) dissolvable scattering, (3) the functionalization of CNTs sidewalls, and (4) biomolecular scattering. Among those techniques, the methodology of functionalization (either covalently or noncovalently) is all around presumed by the explanation that it might simultaneously practice impact on some different parts of CNTs, for example, diminishing cytotoxicity, upgrading biocompatibility, while empowering the conjugation of some other (bio)molecules and pharmaceutical operators[26].

THERAPEUTIC APPLICATION

A. Antimicrobial and Antifungal activity

The utilization of CNTs has been growing to incorporate remedial applications other than malignant growth. For example, surface-designed CNTs perhaps ready to catch pathogenic microscopic organisms in a fluid medium. In this way, CNTs themselves may have antimicrobial movement since microorganisms might be adsorbed onto the designed surfaces of CNTs[27]. Additionally, utilizing E. coli as a model microorganism, it has been accounted for that the electronic properties of SWNTs may manage their antibacterial action. The antibacterial effect was ascribed to carbon nanotube-instigated oxidation of the intracellular cancer prevention agent glutathione, bringing about the expanded oxidative weight on the bacterial cells and possible passing. Functionalized CNTs have been shown to have the option to go about as transporters for antimicrobial specialists, for example, the antifungal amphotericin B. CNTs can connect covalently to amphotericin B and transport it into mammalian cells. This diminished the antifungal toxicity as compared to the harmfulness of the free medication since 40% of the cells were slaughtered by the CNTs free plan contrasted with no cell passing by the CNTs definition[28]. It has additionally been accounted for that the antifungal movement was expanded utilizing the CNTs

B. Solid Phase Extraction Of The Drugs

Medications, for example, anti-infection agents, anxiolytics, against inflammatories, or antidepressants have additionally been extricated utilizing CNTs as SPE sorbents. From the investigation of the writing, unmistakably little amounts of CNTs (lower than those of ordinary SPE cartridges) can be utilized as SPE materials, and therefore, they may assume a significant job in scaling down of extraction strategies[29]. At times, these materials are more costly than regular SPE cartridges, in any case, a few works have additionally shown that exceptionally financial CNTs (with satisfactory SPE execution) are likewise accessible, and in this way, they may likewise speak to a decent monetary other option. Almost certainly, business CNTs-SPE cartridges will before long be accessible, however for this reason CNTs ought to be created at a bigger scope.

C. Preparation of Biocatalysts, Biosensors, and Biofuel Cells

Compound immobilizations on carbon nanotubes for the creation of biosensors and biofuel cells and the readiness of biocatalysts are quickly developing as new exploration areas[30]. To improve catalyst strength, proteins have commonly been concentrated with the chemicals immobilized on a strong help. Nanomaterials fill in as great supporting materials for chemical immobilization since they offer the perfect propertiesfor adjusting the key factors that decide the productivity of biocatalysts, including surface zone, mass exchange opposition, and powerful catalyst stacking. Utilizing non-covalent methodologies, proteins can be less denatured upon immobilization and the natural electronic structure and properties of CNTs are held. As of late, more consideration has been paid to the controlled immobilization of compounds on CNTs. With that in mind, explicit gatherings are presented onto CNTs like natural, polymeric, and organic particles[31]. Through useful gatherings, catalysts can be explicitly and decisively bound onto CNTs. It is likewise important to concentrate on how the connecting particles associate with compounds and influence the chemical structure and the course of action of proteins on CNTs.

D. Detection of Toxic Organophosphoric Compounds.

Organophosphorus mixes unfavorably influence CNS by repressing acetylcholinesterase which follows up on acetylcholine neurotransmitters[32]. Carbon Nanotubes are the anode materials and have the capacity of advancing electron move response at catalysts immobilization. Acetylcholine esterase is immobilized on Nanotubes surface and afterward, this immobilized Acetylcholine catalyzes the hydrolysis of thiocholine ester, shaping thiocholine. This hydrolysis of thiocholine can be identified by electrochemical strategies. There is a decrease in acetylcholinesterase synergist property when it interfaces with organophosphorus mixes and at the same time the oxidation of thiocholine hindered and this can be distinguished by amperometric investigation utilizing CNTs anodes

E. Detection Of Chemical Substances CNTs

display awesome adsorption properties given their high explicit surface region and nanoscale structures which give a huge number of destinations where the compound in vaporous structure can respond[33]. This adsorption of synthetic compounds on the CNTs surface after the CNT's electrical properties empower the CNTs to go about as a gas sensor. Analysts built up a gas sensor dependent on SWCNTs whose electrical conductance, on presentation to vaporous particles, changes rapidly (for example NO2, NH3[34]. They accomplished ultrahigh affectability recognition of NO2 gas utilizing composite film of SWCNTs pound doped with alkanethiol monolayer secured gold bunch (MPC).

F.Carbon Nanotubes As A Nanocomposite Material CNTs

CNTs can make nanocomposite materials for clinical gadget development[35]. Immaculate carbon nanotubes joined with nylon-12, structure a nanocomposite material that can be used to shape microcatheters for blood vessel cannulation[36]. The biocompatibility of such CNT-based microcatheter is more noteworthy contrasted with nylon onyl microcatheter and less cell infiltration and no provocative response watched.

G. Carbon Nanotubes In Tissue Engineering

The carbon nanotubes can be utilized for tissue building by imagining and improving cell execution and by following and marking cells[37]. As tissue designing advances, new apparatuses for better analyzing and assessing built tissues alongside new biomaterials to coordinate tissue development are required. Carbon nanotubes might be a significant tissue-building material for the improved following of cells, detecting of microenvironments, conveyance of transfection specialists, and platform[38]. Carbon nanotubes can likewise be fused into platforms giving basic support just as bestowing novel properties, for example, electrical conductivity into the frameworks may help in coordinating cell development. Potential cytotoxic impacts related to carbon nanotubes might be alleviated by artificially functionalizing the surface.

H. Detection Of Toxic Proteins, Micro-Organisms And Alkylating Agent Containing Sulphur And Nitrogen

By change in electrical signs, the CNTs can be utilized as an estimating stage for different poisonous proteins that will be immobilized on the CNTs[39]. Examining electron magnifying lens (SEM) and electrochemical chemiluminescence (ECL) can be utilized to test the obligations of proteins with antibodies on the CNTs stage. At long last, the location should be possible by incorporating these sensor tips to a solitary molding and preparing circuits and estimations examination of conductance and electrical signs got in the nearness of poisonous proteins. Alkylating operators (nitrogen mustards; ethylamines; alkyl sulphonates; triazenes; piperazines; nitrosoureas.) can be identified by DNA detecting as the natural acknowledgment component.

I.CNTs As A Carriers For Drugs, Genes, And Proteins

The procurement of multidrug obstruction represents a significant issue in chemotherapy, and new kinds of transporters have been effectively tried to defeat it[40]. As of late, poly(ethylene glycol)- conjugated (PEGylated) multiwalled carbon nanotubes (MWCNTs) are investigated as medication bearers to defeat multidrug opposition. Notably, malignancy cells overexpress folic corrosive (FA) receptors, and a few exploration bunches have structured nanocarriers with built surfaces to which FA subordinates can be connected. Besides, nonspherical nanocarriers (e.g., CNTs) have been accounted for to be held in the lymph hubs for longer timeframes contrasted with circular nanocarriers (e.g., liposomes). Along these lines, CNTs may be utilized for focusing on lymph node cancers as appeared by different examiners. CNTs based medication conveyance is a promising, new, productive, and elective transporter for high treatment adequacy and least symptoms for future malignant growth chemotherapy establishing low portion[41]. In certain investigations, attractive nanoparticles containing the anticancer cisplatin has been caught into folic-corrosive functionalized MWCNTs. An outer magnet was utilized to drag the nanotubes to the lymph hubs where the medication indicated discharge more than a few days and the tumor development restrained. The capacity of macromolecules (e.g., qualities) to cross the organic obstructions and be communicated inside an objective cell is especially testing, inferable from their hydrophilicity and enormous atomic size and in this manner utilization of viral or nonviral vectors to convey the quality and disguise it into the cell is vital. Nonviral vectors are less equipped than viral vectors and brief; be that as it may, they are far more secure. Confocal microscopy and stream cytometry have demonstrated a lot more prominent fluorescent action of protein and DNA when conjugated to SWCNTs when contrasted with the stripped macromolecules showing that CNTs are promising vectors for quality and protein. Cai and colleagues have acquainted a methodology with quality conveyance named "carbon nanotube skewering". Plasmid DNA with a fluorescent protein was immobilized onto nickel-installed CNTs. The detailing was "skewered" into Bal 17 B lymphoma cells utilizing an attractive field, which delivered high transfection in the objective cells. Functionalized SWCNTs have been planned as a transporter for siRNA for disguise into K562 cells and ensuing hindrance of the creation of cyclin A (2) and treatment of constant myelogenous leukemia[42]. It has been discovered that concealment of cyclin A(2) articulation utilizing siRNACNTs can advance apoptosis in the focused on the tumor. Streptavidin is a protein that has anticancer movement yet because of its extremely enormous atomic weight (roughly 60,000 KDa), it doesn't enter through cells. A conjugate of streptavidin with SWNTs-biotin has been created, which brought about the disguise of the protein in model malignancy cells by adsorption-interceded endocytosis.

J. Photothermal Therapy Of Cancer Using CNTs

CNTs can ingest light in the close to infrared (NIR) district, bringing about the warming of the nanotubes[43]. This one of a kind property of CNTs has been misused as a strategy to murder disease cells through warm impacts. CNTs show solid optical assimilation in the close to infrared (NIR) locales (NIR I: 700-900 nm, NIR II: 1–1.4 μm). NIR optical radiation has a dispersal profundity of 1.6 mm into natural tissue. CNTs produce heat by light assimilation and incite the warm annihilation of those malignant growth cells containing adequate CNT focuses. To maintain a strategic distance from harm to typical tissues, directed CNTs have been set up by the covalent warmth of tumor-specific ligands to the CNTs. The conjugated CNTs demonstrated great security under physiological conditions and produce an exceptionally explicit photograph warm executing of the focused on cells. The receiving wire hypothesis proposed that optical coupling of light with CNTs is most noteworthy when the length of the nanotubes is greater part the frequency of the episode light beam. Building the structure of MWNTs by making purposeful surface imperfections may improve the receiving wire properties of the nanotubes. Such designed "deformities" or dopants will cause dispersing in the voyaging flows and increment the warming of the nanotube.

K.Adsorption And Photo-Catalytic Performance

CNTs can be broadly used in photograph catalysis, catalysis, and adsorption process[44]. These properties have been extrapolated in the expulsion of contaminations from watery arrangements and conditions. This drove the manufacture of Nanosensors, which have several uses in Pharmaceuticals and Development forms. Nanocomposites offer synthetically latent surfaces with high explicit surface zones for physical adsorption and give more adsorption locales. The nearness of a modest quantity of CNTs can upgrade the photocatalytic action of TiO_2[45]. Carbon covered TiO_2 have been acknowledged for their high movement in the disintegration of Polyvinyl liquor, rhodamine B, and methyl orange in water under UV illumination.

TOXICITY

Harmfulness OF CNTs Despite the generally exhibited capability of CNTs in sedate conveyance, research demonstrates these particles can conceivably cause antagonistic impacts in light of their little size and outrageous perspective proportion[46]. The poisonousness is identified with properties of the CNT material, for

example, their structure (SWCNT versus MWCNT), length and perspective proportion, surface territory, level of accumulation, degree of oxidation, surface topology, bound practical group(s), and technique for assembling (which can leave impetus deposits and produce polluting influences)[47]. The general methodology has been to consider and treat CNTs as harmful because nanosized particles are uniquely more poisonous than bigger estimated particles. In any case, debate encompasses the translation credited to CNT poisonousness information[48]. Poisonousness of CNTs is additionally identified with their focus and the portion to which cells or life forms are uncovered. Sufficient adjustment and care in the previously mentioned boundaries prompt progressively useful and low harmful CNTs.

On the other hand, it has been broadly stressed by ensuing articles that genuine poisonous impacts were experienced, particularly during the aspiratory and intravenous organization of these develops[49].A rundown of variables that have been found to affect the level of harmfulness of CNTs[50]follows underneath:

Factors found to affect CNT toxicity

- Concentration/portion of CNTs.
- SWCNTs or MWCNTs
- Length of the cylinders
- Catalyst buildups leftover during combination or functionalization
- Degree of collection Oxidisation
- Functionalisation.

While numerous investigations show clashing outcomes on a portion of these properties, two appear to yield the most simultaneous outcomes; focus and functionalization [51]. Different investigations have been directed concerning the impact of portion fixation on cell feasibility. The two boundaries used to screen this test are a grouping of portion and brooding time[52]. It has been demonstrated utilizing rodent erythrocytes (red platelets) that at MWCNT groupings of 25 µg/mL no unfavorable impacts to the cells were watched[53]. At centralizations of 50 µg/mL, in any case, erythrocyte hemolysis (breaking of the cell layer) was expanded. One likely clarification is that at this higher focus the MWCNTs agglomerate, which seems to quicken the hemolysis procedure[54]. A few papers concur that high portion focuses and delayed hatching times both increment the instigated poisonousness and along these lines decline cell feasibility. Exploration has indicated cell suitability diminishes fundamentally in human bronchial epithelial cells.[55]The pattern shows how DNA harm increments impressively with portion grouping of SWCNTs (non-functionalized SWCNT). The fixation and brooding time of a portion is a zone of nanotechnology in malignancy treatment which requires a lot further examination, as it will be imperative to enhance these for the treatment and destruction of dangerous developments just as to limit the body's presentation to the medication (should it demonstrate to have a level of harmfulness). The focal point of a huge assemblage of examination has been how much functionalization influences CNT harmfulness. This is likewise liable to be one of the territories of exploration that gets most consideration since a dynamic and detached focusing on is legitimately identified with the sort and level of functionalization of the CNT. It has been shown that expanding the level of functionalization of an SWCNT can drastically diminish its cytotoxicity. [56]The official executive for the Center for Biological and Environmental Nanotechnology (CBEN) has expressed concerning this investigation "...it's a similar answer: change the surfaces. This is a significant exhibit that there are general patterns in natural reactions to nano-particles". Long side-chain useful gatherings on SWCNTs can bring down harmfulness and have been appeared to expand the CNTs biocompatibility with cells. This property of CNTs for malignancy treatment has all the earmarks of being especially encouraging, as the functionalization of CNTs is basic for latent and dynamic disease treatment[57].

RECENT PATENTS WITH CNTs IN DRUG DELIVERY SYSTEM

As of late, CNTs are one of the most explored medicate conveyance vehicles among the submicron bearers and they offer us one more opportunity to fix maladies through pinpoint sedate conveyance. Supported by shocking advancement, the academic network turned its consideration on bettering the medication conveyance profile of these materials and decreasing their conceivable cytotoxicity[14]. From this point of view, numerous licenses related to CNTs have been given regarding the matter of their union, functionalization, cleaning techniques, epitome methodologies, and toxicological profiles. A general perspective on licenses applicable to CNTs is introduced in Table 12.3, which surely features an astounding thought for CNTs and uncover precisely where we remain in this field.

Patent number	Title	Date of publication	References
US20120058170A1	Drug delivery by carbon nanotube arrays	March 8, 2012	Gharib et al. (2012)
WO2012057511A2	Method for preparing a highly dispersive carbon nanotube for	May 3, 2012	Khang et al. (2012a)

	reducing in vivo immunotoxicity		
WO2012060592A3	Carbon nanotube-polymer composite coating film suppresses toxicity and inflammation and has improved biocompatibility and adjusted surface strength	August 16, 2012	Khang et al. (2012b)
US20120220921A1	Immunologically modified carbon nanotubes for cancer treatment	August 30, 2012	Chen (2012)
US20130034610A1	Hydrophobic nanotubes and nanoparticles as transporters for the delivery of drugs into cells	February 7, 2013	Dai et al. (2013)
EP2594289A2	Use of carbon nanotubes for preventing or treating brain diseases	May 22, 2013	Jeong et al. (2013)
US8764681B2	Sharp tip carbon nanotube microneedle devices and their fabrication	July 1, 2014	Aria et al. (2014)
EP2797605A4	Targeted self-assembly of functionalized carbon nanotubes on tumors	July 8, 2015	Scheinberg et al. (2015)
US20150238742A1	Drug delivery and substance transfer facilitated by a nano-enhanced device having aligned carbon nanotubes protruding from the device surface	August 27, 2015	Gharib et al. (2015)
US8029734B2	Noncovalent sidewall functionalization of carbon nanotubes	October 4, 2011	Dai and Chen (2011)

III. CONCLUSION

Although a huge measure of essential exploration has been finished on CNTs during the previous decade, little of this has been deciphered into human applications. No CNT-based medication has arrived at clinical trials. There is still an absence of good creature toxicity studies to get leeway for human investigations for security and pharmacokinetics of CNTs. Especially missing is information about the digestion of CNT, which is a troublesome subject for study. The majority of the momentum action as in research on other nanomaterials is for applications in disease, especially for drug conveyance. There is a more noteworthy requirement for use of CNT in creating therapeutics for CNS problems. This is getting less consideration since safety issues are more basic in the sensory system. The observation and result of this review article show that carbon nanotubes have a promising effect in the drug delivery system and it is helpful for any future references.

REFERENCES

[1]. Balasubramanian K, Burghard M. Biosensors based on carbon nanotubes. *Anal Bioanal Chem* (2006); 385: 452–468.

[2]. Jain K K. Advances in the use of functionalized carbon nanotubes for drug design and discovery. *Expert Opin. Drug Discov*. (2012); 7(11):1029-1037.

[3]. Elhissi AMA, Ahmed W, Hassan UI, Dhanak VR, and Emanuele AD. Carbon Nanotubes in Cancer Therapy and Drug Delivery. *Journal of Drug Delivery*; Volume 2012: 10 pages.

[4]. Liu Z, Chen K, Davis C et al. Drug Delivery with Carbon Nanotubes for In vivo Cancer Treatment. *Cancer Res* 2008; 68(16):6652-6660.

[5]. Dizaj SM, Mennati A, Jafari S et al. Antimicrobial Activity of Carbon-Based Nanoparticles. *Adv Pharm Bull* 2015; 5(1): 19-23.

[6]. Heister E, Brunner EW, Dieckmann GR et al. Carbon Nanotubes a Natural Solution Applications in Biology and Medicine. *ACS Appl Mater Interfaces* 2013; 90pages.

[7]. Prato M, Kostarelos K, Bianco A. Functionalized Carbon Nanotubes in Drug Design and Discovery. *Accounts Of Chemical Research* 2008; 40(1): 60-68.

[8]. Pantarotto D, Briand JP, Prato M, Bianco A. Translocation of bioactive peptides across cell membranes by carbon nanotubes. *C h e m. C o m m u n.* , 2 0 0 4; 1 6 – 1 7.

[9]. Bhirde A, Patel V, Gavard J et al. Targeted Killing of Cancer Cells in Vivo and in Vitro with EGF-Directed Carbon Nanotube-Based Drug Delivery. *American chemical society nano* 2009; VOL. 3(2): 307–316.

[10]. Capek I. Dispersions Based on Carbon Nanotubes – Biomolecules Conjugates. *Carbon Nanotubes – Growth and Applications* 2011; 75-96.

[11]. Liu C, Zhang B, Yang F et al. Carbon nanotubes in cancer diagnosis and therapy. *Biochimica et Biophysica Acta* 2010; 29–35.
[12]. Dineshkumar B, Krishnakumar K, Bhatt AR et al. Single‐ walled and multi‐ walled carbon nanotubes based drug delivery system: Cancer therapy. *Indian J Cancer* 2015;52:262-4.
[13]. Hofmann S, Sharma R, Ducati C et al. In situ Observations of Catalyst Dynamics during Surface-Bound Carbon Nanotube Nucleation. *Nano Lett*. 2007; Vol. 7(3): 602-608.
[14]. Turk CTS, Alpturk O. Carbon Nanotubes For Drug Delivery. *Nanoconjugate Nanocarriers for Drug Delivery* 2010; 348-386.
[15]. Kruss S, Hilmer AJ, Zhang J et al. Carbon nanotubes as optical biomedical sensors. *Advanced Drug Delivery Reviews* 2013; 18 pages.
[16]. Min YS, Bae EJ, Oh BS, Kang D, Park W. Low-Temperature Growth of Single-Walled Carbon Nanotubes by Water Plasma Chemical Vapor Deposition. *J. AM. CHEM. SOC.* 2005;127:12498-12499.
[17]. Kushwaha S, Ghoshal S, Rai AK, Singh S. Carbon nanotubes as a novel drug delivery system for anticancer therapy. *Brazilian Journal of Pharmaceutical Sciences* 2013; vol. 49(4):630-634.
[18]. Heister E, Neves V, Tilmaciu C et al. Triple functionalization of single-walled carbon nanotubes with doxorubicin, a monoclonal antibody, and a fluorescent marker for targeted cancer therapy. *CARBON;*47(2009): 2152–2160.
[19]. Zhang W, Zhang Z, Zhang Y. The application of carbon nanotubes in target drug delivery systems for cancer therapies. *Nanoscale Research Letters* 2011; 6:555: 1-22.
[20]. Kolosnjaj-Tabi J, Hartman KB, Boudjemaa S et al. In Vivo Behavior of Large Doses of Ultrashort and Full-Length Single-Walled Carbon Nanotubes after Oral and Intraperitoneal Administration to Swiss Mice. *American chemical society* 2010; VOL.4(3): 1481–1492.
[21]. Thakare VS, Das M, Jain AM et al. Carbon nanotubes in cancer theragnosis. *Nanomedicine* (2010); 5(8): 1277–1301.
[22]. Kagan VE, Konduru NV, Feng W et al. Carbon nanotubes degraded by neutrophil myeloperoxidase induce less pulmonary inflammation. *Nature Nanotechnology* 2010; VOL (5): 354-359.
[23]. Herrero MA, Prato M. Recent Advances in the Covalent Functionalization of Carbon Nanotubes. *Molecular Crystals and LiquidCrystals* 2008; 483:1: 21-32.
[24]. Revathi S*, Vuyyuru M, Dhanaraju MD. Carbon Nanotube: A Flexible Approach For Nanomedicine And Drug Delivery. *Asian J Pharm Clin Res* 2015; Vol 8(1): 25-31.
[25]. Botticelli A, Russier J, Venturelli E et al. Peptide-based Carbon Nanotubes For Mitochondrial Targeting. *The Royal Society of Chemistry* 2013; 15(41): 1-10.
[26]. Foldvari M, Bagonluri M. Carbon nanotubes as functional excipients for nanomedicines: II. Drug delivery and biocompatibility issues. *Nanomedicine: Nanotechnology, Biology, and Medicine* 2008; 4 (2008): 183–200.
[27]. Gurjar PN, Chouksey S, Patil G et al. Carbon Nanotubes: Pharmaceutical Applications. *Asian Journal of Biomedical and Pharmaceutical Sciences*2013; 3(23): 8-13.
[28]. Lamberti M, Pedata P, Sannolo N et al. Carbon nanotubes: Properties, biomedical applications, advantages and risks in patients and occupationally exposed workers. *International Journal of Immunopathology and Pharmacology* 2015; Vol. 28(1): 4–13.
[29]. Ravelo-Pérez LM, Herrera-Herrera AV, Hernández-Borges J et al.Carbon nanotubes: Solid-phase extraction.*Journal of Chromatography A*2010; 1217 (2010): 2618–2641.
[30]. Plata D, Hart J, Reddy C et al. Early Evaluation of Potential Environmental Impacts of Carbon Nanotube Synthesis by Chemical Vapor Deposition. *Environ. Sci. Technol* 2009; 43: 8367–8373.
[31]. Apetreia I.M, Rodriguez-Mendezb M.L, Apetreic C, de Sajad J.A. Enzyme sensor based on carbon nanotubes/cobalt(II) phthalocyanine and tyrosinase used in pharmaceutical analysis. *Sensors and Actuators B*; 177 (2013): 138– 144.
[32]. Baird C.L, Myszka DG. Current and emerging commercial optical biosensors. J. Mol. Recognit. 2001; 14: 261–268.
[33]. Pantarotto D, Partidos C.D et al. Immunization with Peptide-Functionalized Carbon Nanotubes Enhances Virus-Specific Neutralizing Antibody Responses. *Chemistry & Biology* 2003; Vol. 10: 961–966.
[34]. Hassan A.F.M, Smyth L, Rubio N et al. Carbon nanotubes' surface chemistry determines their potency as vaccine nanocarriers in vitro and in vivo. *Journal of Controlled Release*; 225 (2016): 205–216.
[35]. Prakash S, Malhotra M, Shao W et al. Polymeric nanohybrids and functionalized carbon nanotubes as drug delivery carriers for cancer therapy. *Advanced Drug Delivery Reviews*; 63 (2011): 1340–1351.
[36]. Koyama S, Haniu H, Osaka K et al. Medical Application of Carbon-Nanotube-Filled Nanocomposites: The Microcatheter. *small* 2006; 2(12): 1406 – 1411.
[37]. Kumar O, Singh Y, Rao V.K, Vijayaraghavan R. Carbon Nanotubes: Detection of Chemical and Biological Warfare Agents. *Defence Science Journal* 2008; Vol. 58(5): 617-625.

[38]. Collins P.G, Bradley K, Ishigami M, Zettl A. Extreme Oxygen Sensitivity of Electronic Properties of Carbon Nanotubes. *Science* 2000; VOL 287: 1800-04.
[39]. Cheung W, Pontoriero F, Taratula O et al. DNA and carbon nanotubes as medicine. *Advanced Drug Delivery Reviews*; 62 (2010): 633–649.
[40]. Yang F, Jin C, Yang D et al. Magnetic functionalized carbon nanotubes as drug vehicles for cancer lymph node metastasis treatment. *European Journal Of Cancer*; 47(2011): 1873–1882.
[41]. Lodhi N, Mehra N.K, Jain N.K. Development and characterization of dexamethasone mesylate anchored on multi-walled carbon nanotubes. *Journal of Drug Targeting* 2013; 21(1): 67–76.
[42]. Karchemski F, Zucker D, Barenholz Y, Regev O. Carbon nanotubes-liposomes conjugate as a platform for drug delivery into cells. *Journal of Controlled Release* 2012; 160 (2012): 339–345.
[43]. Gannon C.J, Cherukuri P, Yakobson B. I et al. Carbon Nanotube-enhanced Thermal Destruction of Cancer Cells in a Noninvasive Radiofrequency Field. *Cancer* 2007;110(12):2654–65.
[44]. Saleh T.A, Gupta V.K. Photo-catalyzed degradation of hazardous dye methyl orange by use of a composite catalyst consisting of multi-walled carbon nanotubes and titanium dioxide. *Journal of Colloid and Interface Science*; 371 (2012): 101–106.
[45]. Saleh T. The influence of treatment temperature on the acidity of MWCNT oxidized by HNO3 or a mixture of HNO3/H2SO4. *Applied Surface Science*; 257 (2011): 7746–7751.
[46]. Firme C.P, Bandaru P.R. Toxicity issues in the application of carbon nanotubes to biological systems. *Nanomedicine: Nanotechnology, Biology, and Medicine*; 6 (2010): 245–256.
[47]. Shi Kam N.W, Liu Z, Dai H. Carbon Nanotubes as Intracellular Transporters for Proteins and DNA: An Investigation of the Uptake Mechanism and Pathway. *Angew. Chem. Int. Ed*. 2006; 45: 577 –581.
[48]. Jain A.K, Mehra N.K, Lodhi N et al. Carbon nanotubes, and their toxicity. *Nanotoxicology* 2007; 1(3): 167-197.
[49]. He H, Dramou P, Xiao D et al. Carbon Nanotubes: Applications in Pharmacy and Medicine. *BioMed Research International*; 2013:1-12.
[50]. Kayat J, Gajbhiye V, Tekade R.K, Jain N.K. Pulmonary toxicity of carbon nanotubes: a systematic report. *Nanomedicine: Nanotechnology, Biology, and Medicine*; 7 (2011): 40–49.
[51]. Mehra N. K, Jain N. K. Functionalized Carbon Nanotubes and Their Drug Delivery Applications. *Nanostructured Drug Delivery*; 4(2014): 328-369.
[52]. Bussy C, Kostarelos K. Carbon nanotubes in medicine and biology — Safety and toxicology. *Advanced Drug Delivery Reviews*; 65(2013): 2061–2062.
[53]. Kaiser J.P, Roesslein M, Buerki-Thurnherr T, Wick P. Carbon Nanotubes – Curse or Blessing. *Current Medicinal Chemistry*; 18(2011): 2115-2128.
[54]. Bottini M, Bruckner S, Nika K et al. Multi-walled carbon nanotubes induce T lymphocyte apoptosis. *Toxicology Letters*; 160 (2006): 121–126.
[55]. SaiTeja N, Jawahar N. A Review of Carbon Nano Tubes Synthesis and Its Application as Potent Carriers in Cancer Therapy. *International Journal of Current Pharmaceutical Review and Research*; 9(2): 28-33.
[56]. Azizian J, Tahermansouri H, Biazar E. Functionalization of carboxylated multiwall nanotubes with imidazole derivatives and their toxicity investigations.*International Journal of Nanomedicine*; 5(2010):907–914.
[57]. Zhang Y, Bai Y, Yan B. Functionalized carbon nanotubes for potential medicinal applications. *Drug Discovery Today*; 15 (2010): 428-435. Drug Discovery Today _ Volume 15, Numbers 11/12 _ June 2010Drug Discovery Today _ Volume 15, Numbers 11/12 _ June 2010

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