IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Carbon Nanotubes: A review

Ms. Pooja Rokade*, Ms. Aishwarya Patil, Ms. Rutika Harshad, Dr. Santosh Payghan

Department of Pharmaceutics, Vasantidevi Patil Institute of pharmacy, Kodoli.

Tal –Panhala, Dist – Kolhapur(MS) ,416114

Abstract:

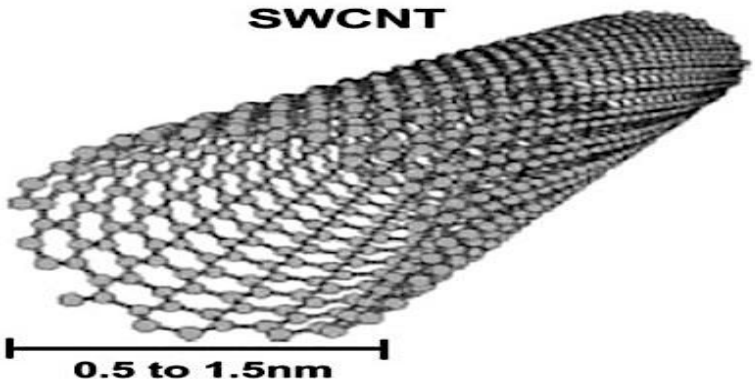
Carbon nanotubes (CNTs) are nanostructures derived from rolled graphene planes and possess various interesting chemical and physical properties. CNTs can be conjugated with various biological molecules including drugs, proteins and nucleic acid to afford bio-functionalities. In the future, CNTs can possible via with carbon fibre for high-end uses, significantly in weight-sensitive applications like Kevlar. in addition, CNTs are found to be a additional environmentally-friendly, flameproof additive to plastics. Current discoveries numerous sorts of carbon nanostructures have actuated analysis on their applications in various fields. They hold promise for applications in medication, gene, and drug delivery areas. many various production strategies for carbon nanotubes (CNTs) are introduced; functionalization, filling, doping, and chemical modification are achieved, and characterization, separation, and manipulation of individual CNTs are currently doable. Parameters like structure, expanse, surface charge, size distribution, surface chemistry, and agglomeration state similarly as purity of the samples have significant impact on the reactivity of carbon nanotubes. Otherwise, the strength and suppleness of carbon nanotubes build them of potential use in dominant different nanoscale structures, that suggests they're going to have a major role in technology engineering.

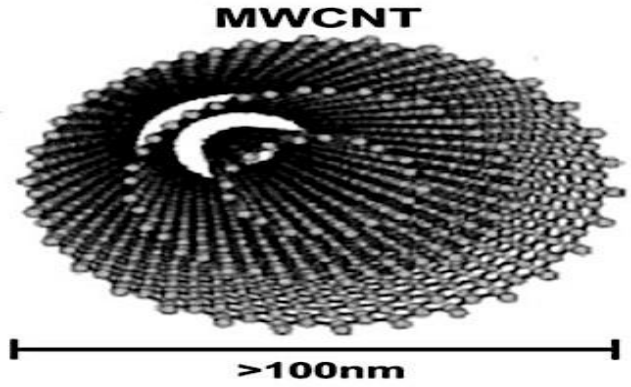
Keywords: Carbon nanostructures; Flexibility; Toxicity; Drug delivery; Nanotubes

Introduction:

Nanotechnology could be a wide space of analysis and has been a modern and advanced producing technology rising worldwide. It deals with a spread of materials created at a mill micron scale through completely different chemical and physical ways[1]. of accelerating interest within the field of technology area unit the nanostructured materials, the inspiration of technology. Nanomaterials have dimensions below a hundred nm. This wide cluster of materials permits access to varied new decisions of magnetic, electronic, mechanical or optical properties. Nanotubes belong to a promising cluster of nanomaterials. The several alternative nanotubes supported B yet as atomic number 42 are explicit wide however, presently carbon nanotubes area unit far and away the foremost important cluster. Carbon nanotubes contain one or many concentric graphite-like layers with diameters within the vary of zero. 4 nm up to tens of nanometres [2]. the sphere of carbon nanotubes was discovered by Iijima within the year 1991 by Associate in Nursing early experimental observation of carbon nanotubes by TEM (Transmission electron microscopy) and also the succeeding reports of conditions for the synthesis of enormous quantities of nanotubes [3].Carbon nanotubes may be represented as atomic number 6 sheets that area unit rolled up into cylindrical shapes. The length of CNTs is within the style of micro-meters with a diameter of regarding a hundred nm [4]. Carbon nanotubes (CNTs) area unit thought-about as a by-product of each carbon fibres and atomic number 6 with molecules composed of sixty atoms of carbons organized specifically muffled tubes[5]. There are a unit 2 styles of carbon nanotubes that are classified in line with the amount of carbon layers' gift in them. Single-walled carbon nanotubes (SWCNTs) accommodates single graphene layer with diameter varied between zero.4 and a pair of nm and frequently happens as hexagonal-packed bundles. Multi-walled carbon nanotubes (MWCNTs) includes of 2 or many cylinder, every created of graphene sheets. The diameter varies from one to three nm [6]. CNTs may be synthesized by 3 completely different ways arc discharge technique, optical device ablation technique and chemical vapor deposition technique. Arc discharge technique uses the extreme temperature i.e., (>3000 C) necessary for evaporating carbon atoms into a plasma, forming each multi- and single-walled CNTs. The existence of a chemical change agent isn't obligatory for MWNT, whereas throughout the preparation of individual SWNT, chemical change agent is needed like metal, Yttrium, Nickel, Iron etc. Chemical vapour deposition technique involves the organic compound sources like metal, methane, alkene etc. optical device ablation technique involves the vaporization of atomic number 6 in Associate in Nursing electrical chamber heated at 1200 C. The atomic number 6 purity ensures a high-level purity for the ensuing product and a high changing magnitude relation. For biomaterial functions, the high purity level could be a concern; so, the large process is additionally utilized to boost the standard of carbon nanotubes materials and to get specific

characteristics like length, alignment, etc.[5,6]. MWCNTs were 1st discovered by Iijima by Arc discharge technique. This technique is that the most ancient technique used earlier for the assembly of carbon fibres [7,8]. in place emulsion chemical change was utilized by khan et al., 2016 for the no-hit synthesis of fullerene (CNT) composites in an exceedingly mixture system with poly (styrene) or PS to create nanostructured brush. CNTs were first functionalized with monounsaturated fatty acid following salinization with (3-amino propyl) triethoxysilane to create cross-linking properties[9].CNTs exhibit glorious chemical and physical properties like high durability, ultra-light weight, special electronic structures and high chemical and thermal stability. owing to these exceptional properties, scientists have developed Associate in Nursing huge interest in these nanomaterials. Among carbon nanomaterials, carbon nanotubes area unit most exploited for varied applications. the most applications of fullerene embrace biomolecule, drug, and drug delivery to the targeted organs, biosensor diagnostic and analysis [10 - 19]during this paper, a summary of various clinical applications of CNTs like illness diagnosing and drug targeting area unit reviewed. It in brief describes the applications associated with chemistry detector, deoxyribonucleic acid based mostly detector, electricity detector, gas sensor. a number of the medicine as well as antifungal activity of CNTs also are being mentioned.





Carbon Nanotubes: Structures, Types and Preparation:

Carbon nanotubes (CNTs) consist completely of carbon atoms organized during a series of condensed benzol rings rolled up into a cannular structure. This novel artificial nanomaterial belongs to the family of fullerenes, the third chemical phenomenon kind of carbon together with carbon and diamond that are each natural sp2 (planar) and sp3 (cubic) forms, respectively [20,21,22]. supported the quantity of layers, structures of CNTs are classified into 2 types: single-walled carbon nanotubes (SWCNTs) and multiwalled carbon nanotubes (MWCNTs)

SWCNTs comprises one graphene cylinder with diameter variable between zero.4 and 2 nm, and frequently occur as polygonal shape compact bundles. MWCNTs comprises 2 to many homocentric cylinders, every product of one graphene sheet encompassing a hollow core. The outer diameter of MWCNTs ranges from two to one hundred nm, whereas the inner diameter is within the vary of 1–3 nm, and their length is zero.2 to many μm [19,21]. From a chemical reactivity purpose of read, CNT are often differentiated into 2 zones: the guidelines and also the sidewalls. a very important issue that controls these distinctive properties comes from a variation of tube structures that are caused by the rolling of the graphene sheet into a tube. There are 3 distinct ways that for the molecule to try and do the rolling, relying upon its direction: armchair, zigzag, and chiral. elaborated explanations of CNTs structures are often found in many recent review articles cited herein[20,21,22].

Structures and characterizations of SWCNTs and MWCNTs are summarized in Table [19] Three main techniques typically used for SWCNTs and MWCNTs production are: Arc-Discharge technique (using arc vaporization of 2 carbon rods), optical device Ablation method (using graphite), and Chemical Vapour Deposition (using organic compound sources: CO, methane, ethylene, acetylene). once preparation, CNTs are submitted to purification by acid refluxing, chemical agent power-assisted sonication, or air chemical reaction procedure so as to eliminate impurities like amorphous carbon, fullerenes, and transition metals introduced as catalysts throughout the synthesis[21,22,23]. Pristine CNTs are currently synthesized and marketed by several chemical corporations.

Types of carbon nanotubes (CNTs):

The carbon nanotubes are of two types namely:

- Single walled carbon nanotubes (SWCNTs)
- Multiple walled carbon nanotubes (MWCNTs)

Single-wall carbon nanotubes (SWCNTs):

SWCNTs comprises one cylindrical carbon layer with a diameter within the vary of zero.4-2 nm, betting on the temperature at that they need been synthesized. it had been found that the upper the expansion temperature larger is that the diameter of CNTs [24]. The structure of SWCNTs is also arm chair, zigzag, chiral, or volute arrangements[25]. The SWCNTs have associate ultra high expanse as massive as 1300 M2/g, that renders sufficient area for drug loading and bio conjugation [26]. In drug delivery, SWCNTs square measure famous to be additional economical than MWCNTs. this can be because of the explanation that SWCNTs have ultra high expanse and economical drug-loading capability. It has been found that a SWCNT antineoplastic drug complicated encompasses a for much longer blood circulation time than the antineoplastic drug on its own. This results in additional prolonged and sustained uptake of the drug by

growth cells via the improved permeability and retention impact. Once the functionalized of SWCNT releases the drug into a particular space, it's step by step excreted from the body via the biliary pathway and at last within the faecal matter. This suggested that SWCNTs square measure appropriate candidates for drug delivery and a promising nanoplatform for cancer medical specialty.

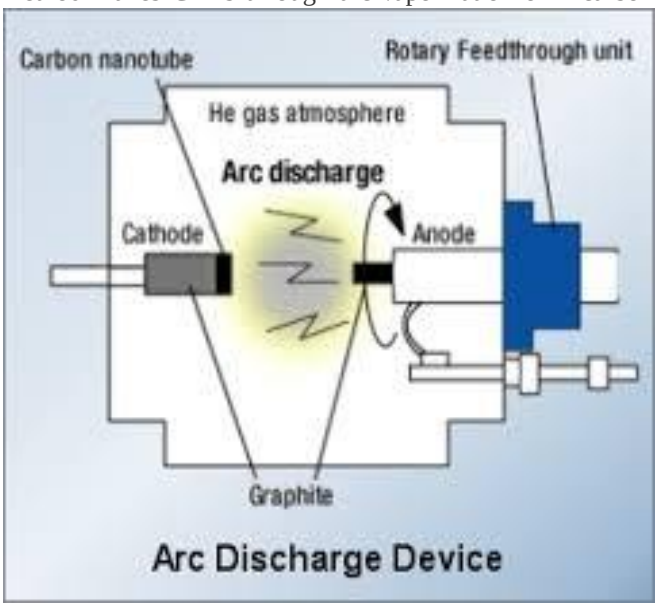
Multiple walled carbon nanotubes (MWCNTs)

MWCNTs comprises many homocentric cylinders, every manufactured from a single printed symbol sheet encompassing a hollow core. The outer diameter of MWCNTs ranges from 2-100 nm, whereas the inner diameter is within the vary of 1-3 nm, and their length is one to several micrometers [27]. The sp2 sexual union in MWCNTs, a delocalized negatron cloud on the wall is generated that is responsible for the interactions between adjacent cylindrical layers in MWCNTs leading to a less versatile and a lot of structural defects [28]. MWCNTs structures will be split into 2 categories supported their arrangements of atomic number 6 layers: one has a parchment-like structure that consists of a graphene sheet rolled up around it and also the alternative is understood because the Russian doll model wherever layers of graphene sheets area unit organized among a coaxal structure [29] Decoration of multiwall carbon nanotubes (MWCNTs) consists of depositing nanoparticles on the MWCNT walls or ends, warranted by physical interaction with potential applications in contact action, biosensors, biomedical, magnetic knowledge storage, and electronic devices. the varied strategies used for this purpose embody precipitation, reaction at high temperature, or chemical decomposition of a metal precursor

Synthesis:

Arc Method

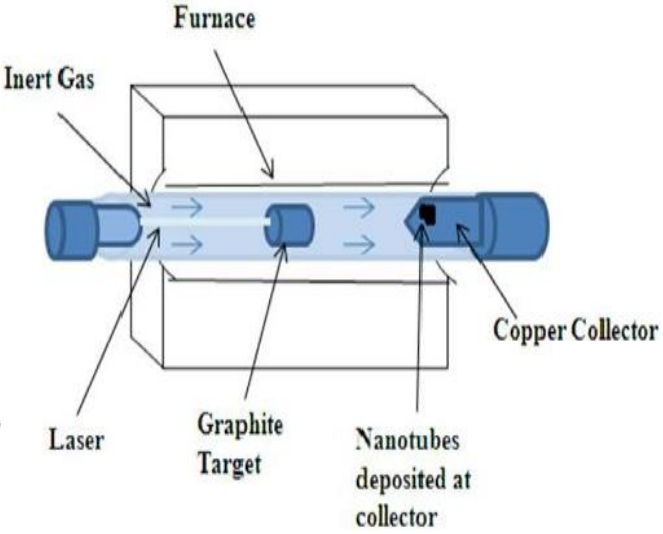
The carbon arc lamp discharge methodology, initial utilised for making C60 fullerenes, is one among the foremost common and simplest way to make CNTs, as a result of it's easy. Yet, the technique creates a sophisticated mixture of elements. It conjointly needs further purification to isolate the CNTs from the soot and therefore the residual chemical process metals existing within the unpolished product. The method makes CNTs through arc-vaporization of 2 carbon rods set finish to finish in an exceedingly location that's stuffed with depression and noble gas. The discharge evaporates the surface of 1 of the carbon electrodes, and creates a little rod-shaped deposit on the opposing conductor. the assembly of CNTs in high harvest depends on the uniformity of the plasma arc, and therefore the temperature of the deposit growing on the carbon conductor.[30-38]



Hipco methodology could be a variety of arc methodology synthesis methodology achieved beneath air mass and was established at Rice University to supply prime quality single-walled carbon nanotubes (SWCNT) from the gas-phase reaction of iron carbonyl with air mass CO2 gas. folks use iron pentacarbonyl to form iron nanoparticles that provides a nucleation surface for carbon monoxide gas transformation into carbon throughout the event of the nanotubes. Synthesis creates prime quality materials however in mere tiny quantities and they're not out there to be distributed within the amounts required commercially.[30-38]

Laser ways:

Carbon nanotubes were initial synthesized in 1996, with a dual-pulsed optical maser and made yields of >70 skyscraper purity. optical maser vaporization ready samples of carbon rods with a 50:50 catalyst mixture of Nickel and Cobalt at 1200 ℃ in flowing noble gas. it had been then followed by



heat treatment in an exceedingly vacuum at one thousand ℃ to eradicate the C60 and different fullerenes. the primary optical maser vaporization pulse was trailed by a succeeding pulse, to vaporize the target additional systematically[30-38].

The utilization of 2 consecutive optical maser pulses reduces the quantity of carbon collected as soot. The second optical maser pulse disbands the larger particles ablated by the initial one. It then feeds them into the developing carbon nanotube structure. the fabric created by this method is shown as a mat of "ropes", regarding ten to twenty nm in diameter and up to one hundred µm or additional long .[30-38] Each rope contains a bundle of single-walled nanotubes, in parallel to a typical axis. By having totally different growth temperature, the catalyst configuration and different method parameters, the typical carbon nanotube diameter and size alignment becomes numerous[30-38].

Arc-discharge and optical maser vaporization are presently the most ways for obtaining small quantities of prime quality CNTs. Yet, the 2 ways face some issues. First off, they involve the evaporation of the carbon supply. So, it's unknown the way to boost production to the economic level mistreatment these ways. Second, vaporization ways grow CNTs in extremely twisted forms, combined with unwanted kinds of carbon and/or metal varieties. Hence, the CNTs created are arduous to purify, gather and handle for developing nanotube-device design for helpful implications[30-38.]

Applications of Carbon Nanotubes in Pharmacy and medication:

The functionalization of CNTs makes them helpful during a vary of different applications. Their structure means the tubes have Associate in Nursing inner Associate in Nursing an outer core which might each be changed by different useful teams. therefore the CNTs are often designed for very specific functions. within the space of biomedicine, the applications of CNTs area unit investigated in particularly four main fields: drug delivery, medicine imaging, biosensors and scaffolds in tissue engineering[39].

Drug delivery

Specific drug delivery is a necessary methodology employed in medication to deliver pharmacy to the particular place within the body wherever it is required. the strategy shows nice promise in cancer medical aid since one amongst the largest challenges in treating cancer is that the severe facet effects caused by the therapy.

Blood cancer

Leukemia may be a cancer that begins within the bone marrow (the soft inner a part of some bones), however in most cases, moves into the blood. Associate in Nursing intense targeted delivery of daunorubicin (Dau) to acute lymphoblastic leukemia was achieved by Taghdisi et al., they developed a tertiary complicated of Sgc8c aptamer (this aptamer targets cancer of the blood biomarker supermolecule aminoalkanoic acid kinase-7),daunorubicin, and SWCNT named as Dau-aptamer SWCNTs. Flow cytometric analysis viewed that the tertiary complicated was internalized effectively into human lymphocyte cancer of the blood cell (MOLT-4 cells) however to not U266 malignant neoplasm cells. Release of Dau-loaded nanotubes were pH-dependent. in a very slightly acidic solution of pH 5.5. Dau was discharged from complicated in seventy two h at 37 ºC, while Dau-aptamer-SWNTs tertiary complicated was pretty stable when a similar incubation at pH 7.4.[40]

Breast cancer

Over expression of human cuticular protein receptor a pair of (HER2), conjointly called c-erbB-2 or HER2/neu, is approximately 20-25% liable for invasive carcinoma. Liu et al., studied SWNT delivery of paclitaxel (PTX) into xenograft growths in mice with higher tumor suppression efficacy than the clinical drug formulation Taxol. The PTX conjugated to PEGylated SWNTs showed high water solubility and maintains alike toxicity to cancer cells as Taxol in vitro. SWNT-PTX affords for much longer blood circulation time of PTX than that of Taxol and PEG ylated PTX, resulting in high tumor uptake of the drug through EPR result. The strong therapeutic effectualness of SWNT-PTX is shown by its ability to slow down growth growth even at a lower drug dose [41].

Liver cancer

Polyamidoamine dendrimer changed CNTs (dMWCNTs) were fictional for the economical delivery of antisense c-myc oligonucleotide (asODN) into carcinoma cell line HepG2 cells. As ODN-dMWCNTs composites were incubated with HepG2 cells and confirmed to enter into tumour cells among fifteen min by optical maser confocal research. These composites inhibited the cell growth in time and dose dependent means that and down regulated the expression of the c-myc cistron and C-Myc supermolecule. These composites exhibit largest transfection efficiencies and inhibition effects on tumour cells in comparison to CNTNH - asODN and dendrimer (asODN) alone. [41]

Lymph node metastatis

Yang et al., compared the in vitro and in vivo potential therapeutic impact of gemcitabine (GEM) loaded magnetic MWCNTs (mMWCNTs) thereupon of gemcitabine loaded magnetic-carbon particles (mACs). The result reflects that mACs and mMWNTs effectively increased GEM toxicity in vivo and strangled lymphatic tissue metastasis, particularly once using high dose agents and/or applying deep-seated in vivo magnets. Systems provide the chance to reinforce therapeutic effects and reduce side-effects related to chemotherapeutic agents by utilising the synergistic effects of magnetic targeting and bodily fluid therapy. Due to the super magnet behaviour of mMWCNTs-GEM, their magnetic moments tend to align on the applied field leading to web magnetization that greatly affects the interaction of mMWCNTs-GEM with the cellular membrane and therefore they were found to be superior than mACs-GEM in no-hit inhibition of lymphatic tissue metastasis when following subcutaneous administration underneath the impact of magnetic field.[42]

Gene therapy

CNTs will deliver an outsized quantity of therapeutic agents, including DNA and ribonucleic acid, to the target illness sites, Gene therapy and ribonucleic acid have bestowed an excellent potential for antitumor treatment. The wire formed structure (with a diameter matching that of DNA/siRNA) and their outstanding flexibility, CNTs will influence the conformational structure and the transient conformational changes of DNA ribonucleic acid, which can additional enhance the therapeutic effects of DNA is ribonucleic acid. The treatment of a personality's respiratory organ malignant neoplastic disease model in vivo mistreatment siRNA sequences, that light-emitting diode to toxicity and necrobiosis using amino-functionalized multiwalled carbon nanotubes (MWNT-NH3+). this can be believed to activate biologically in vivo by triggering associate degree apoptotic cascade that ends up in in depth necrosis of the human growth mass followed by a concomitant prolongation of survival of human respiratory organ tumor-bearing animals.[43]

Immune therapy

Chemotherapy faces the problems of accumulative toxicity and drug resistance, anti-tumor therapy sometimes has few adverse effects, smart patient tolerance, and therefore the potential to improve the prognosis considerably. CNTs have additionally shown the potential to spice up the antigenicity of the carried proteins or peptides. Xu et al., studied that MWNTs conjugated to neoplasm lysate supermolecule can enhance the effectuality of AN anti-tumor immunotherapy that employs neoplasm cell immunogen (TCV) during a mouse model bearing the H22 liver disease.[43]The study showed that MWNTs conjugated to neoplasm lysate supermolecule enhanced the precise anti-tumor reaction and therefore the cancer cure rate of a TCV therapy in mice.[44]

Biomedical applications:

CNTs will have several applications owing to the advantageous properties that build them associate applicable material for medical specialty application as they're a lot of biocompatible as compared to others, quick lepton transfers dynamics, ultra-light weight, chemical immobility, high durability, wide variety of medication and antifungal properties, act as macromolecule carriers, contains exposed practical teams etc. They additionally hold semi and golden semi conductive properties that build them an appropriate material for numerous applications like clinical medicine, food safety, environmental watching. CNTs additionally play a major role within the fabrication of sensors for police work numerous infective bacterium and helps within the treatment of cancer in addition. CNTs even have a large variety of antimicrobial activities.[44,45]

Antifungal activity of CNTs:

It demonstrated the anti-fungal activity of Invitro through the agar well diffusion process. Here is the chitosan-based method used with MWCNT to demonstrate the anti-fungal activity of Aniger, C. trobicalis and C. Neoformans [46]. Nano-composites have shown great potential in which polymer chitosan inhibits grain germination, germ expansion and radial growth. [44] Chitosan promotes morphogenesis of the cell wall that inhibits fungal growth. Chitosan inhibits the germination of extracts from the long-term expansion of the tuberculosis and radial growth [47]. Chitosan promotes morphogenesis of the cell wall that inhibits fungal growth. Chitosan interacts with DNA after entering the cell wall as it is small in size and exposed to small experiments. After being synthesized with DNA the process of transcription and translation is also inhibited which will ultimately affect the production of enzymes and proteins needed for the growth of fungal hyphae [48]. Extracts from Polymer and MWCNT have shown unique killing functions than parent chitosan. MWCNTs have the ability to detect electrostatic interactions with the cell membrane and modify their penetration. The findings of Chitosan and MWCNTs were found to be significantly stronger compared to C. Trobicalis compared to C. Neoformans and superpowers were observed in the event of A. niger. Active carbon nanotubes have been found to be effective in combating Candida problems. The study was conducted by zari et al. (2003) [49] show the anti-rot effect against various fungi. A. niger, A. fumigatus, C. albicans, P. chrysogenum, S. cerevisiae, F. Culmorum, M. canis, T. mentagrophytes, T. rubrum and P. P. lilacinum. One-walled nanotubes dispersed with performance-based tetra-arylbimesityl by adding a carboxy group used for the demonstration of anti-E activity. Coli, S. aureus and C. albicans [50].

Conclusion:

Nanoparticulate as drug delivery systems is meant to improve the pharmacologic and therapeutic properties of conventional medicine. The incorporation of drug molecules into nanocarrier will shield a drug against degradation yet as offers potentialities of targeting and controlled unleash. In comparison with the standard style of medicine, nanocarrier-drug conjugates are more practical and selective; they'll reduce the toxicity and alternative adverse facet effects in traditional tissues by accumulating medicine in target sites. In consequence, the required doses of medicine are lower. However, so far, the scientific paradigm for the doable (adverse) reactivity of nanoparticles is lacking and that we have very little understanding of the basics of the interaction of nanoparticles with living cells, organs and organisms. A abstract understanding of biological responses to nanomaterials is required to develop and apply safe nanomaterials in drug delivery within the future. Furthermore a detailed collaboration between those operating in drug delivery and particle production is important for the exchange of ideas, ways and power to manoeuvre this issue ahead.

Reference:

(1) S. Kumar, R. Rani, N. Dilbaghi, K. Tankeshwar, K.H. Kim, Carbon nanotubes: anovel material for multifaceted applications in human healthcare, Chem. Soc. Rev. (2017) 158–196.

(2) A.G. Mamalis, L.O. Vogtländer, A. Markopoulos, Nanotechnology andnanostructured materials: trends in carbon nanotubes, Precis. Eng. (2004) 16–30.

(3) S. Iijima, Helical microtubules of graphitic carbon, Nature 354 (6348) (1991) 56.

(4) D. Tasis, N. Tagmatarchis, A. Bianco, M. Prato, Chemistry of carbon nanotubes,Chem. Rev. (2006) 1105–1136.

(5)S. Polizu, O. Savadogo, P. Poulin, L.H. Yahia, Applications of carbon nanotubes based biomaterials in biomedical nanotechnology, J. Nanosci. Nanotechnol. (2006) 1883–1904.

(6)H. He, L.A. Pham-Huy, P. Dramou, D. Xiao, P. Zuo, C. Pham-Huy, Carbon nanotubes: applications in pharmacy and medicine, BioMed Res. Int. (2013).

(7) R.H. Baughman, A.A. Zakhidov, W.A. De Heer, Carbon nanotubes–the route toward applications, Science (2002) 787–792.

(8) V.N. Popov, Carbon nanotubes: properties and application, Mater. Sci. Eng. R Rep.(2004) 61–102.

(9) M.U. Khan, K.R. Reddy, T. Snguanwongchai, E. Haque, V.G. Gomes, Polymer brush synthesis on surface modified

carbon nanotubes via in situ emulsion polymerization, Colloid Polym. Sci. (2016) 1599–1610.

(10)J. Che, T. Cagin, W.A. Goddard III, Thermal conductivity of carbon nanotubes,Nanotechnology (2000).

(11) S.K. Smart, A.I. Cassady, G.Q. Lu, D.J. Martin The biocompatibility of carbon nanotubes Carbon (2006), pp. 1034-1047

(12) P.R. Dey, N.I. Das Carbon nanotubes: it's role in modern health care

(13) B. G. P. Singh, C. Baburao, V. Pispati et al., "Carbon nanotubes. A novel drug delivery system," *International Journal of Research in Pharmacy and Chemistry*, vol. 2, no. 2, pp. 523–532, 2012.

(14) W. Zhang, Z. Zhang, and Y. Zhang, "The application of carbon nanotubes in target drug delivery systems for cancer therapies," *Nanoscale ResearchLetters*, vol. 6, pp. 555–577, 2011.

(15) L. Jiang, T. Liu, H. He et al., "Adsorption behavior of pazufloxacin mesilate on amino-functionalized carbon nanotubes," *Journal of Nanoscience and Nanotechnology*, vol. 12, pp. 1–9, 2012.

(16) W. Yang, P. Thordarson, J. J. Gooding, S. P. Ringer, and F. Braet, "Carbon nanotubes forbiological and biomedicalapplications," *Nanotechnology*, vol. 18, Article ID 412001, 12 pages, 2007.

(17) R. Hirlekar, M. Yamagar, H. Garse, M. Vij, and V. Kadam,"Carbon nanotubes and its applications: a review," Asian Journalof Pharmaceutical and Clinical Research, vol. 2, no. 4, pp. 17–27,2009

(18) Z. Liu, X. Sun, N. Nakayama-Ratchford, and H. Dai,"Supramolecular chemistry on water-soluble carbon nanotubesfor drug loading and delivery," ACS Nano, vol. 1, no. 1, pp.(50-60) 2007.

(19) E. Bekyarova, Y. Ni, E. B. Malarkey et al., "Applications ofcarbon nanotubes in biotechnology (21) biomedicine,"Journal of Biomedical Nanotechnology, vol. 1, no. 1, pp. 3–17, 2005.

(20) M. S. Digge, R. S. Moon, and S. G. Gattani, "Applications ofcarbon nanotubes in drug delivery: areview," International Journal of PharmTech Research, vol. 4, no. 2, pp. 839–847, 2012.

(21) J. Zha, H. He, T. Liu, S. Li, and Q. Jiao, "Studies on the interactionof gatifloxacin with bovine serum albumin in the presence ofcarbon nanotubes by fluorescence spectroscopy," Spectroscopyand Spectral Analysis, vol. 31, no. 1, pp. 149–153, 2011

(22) Z. Chen, D. Pierre, H. He et al., "Adsorption behavior ofepirubicin hydrochloride on carboxylated carbon nanotubes,"International Journal ofPharmaceutics, vol. 405, no. 1-2, pp. 153–161, 2011.

(23) Klumpp C, Kostarelos K, Prato M, Bianco A. Functionalized carbon nanotubes as emerging nanovectors for the delivery of therapeutics, Biochem Biophys Acta 2006; 1758:404-412.

(24) Danailov D, Keblinski P, Nayak S, Ajayan PM. Bending properties of carbon nanotubes encapsulating solid nanowires, J Nano Sci Nanotechnol. 2002; 2:503-507.

(25) Zhang B, Chen Q, Tang H, Xie Q, Ma M, Tan L et al. Characterization and biomolecule immobilization on the biocompatible multi-walled carbon nanotubes generated by functionalization with polyamidoamine dendrimers. Colloids Surf B Biointerfaces 2010; 80:18-25.

(26) Saito N, Haniu H, Usui Y, Aoki K, Hara K, Takanashi S, et al. Safe clinical use of carbon nanotubes as innovative biomaterials Chem Rev 2014; 114(11):6040-6079.

(27) Rastogi V, Yadav P, Bhattacharya SS, Mishra AK, Verma N, Verma A et al. Carbon Nanotubes: An Emerging Drug Carrier for Targeting Cancer Cells, Journal of Drug Delivery. 2014, 23.

(28)Xia ZH, Guduru PR, Curtin WA. Enhancing mechanical properties of multiwall carbon nanotubes via sp3 interwall bridging, Physical Review Letters 2007; 98:245501- 245504.

(29) Madani SY, Naderi N, Dissanayake O, Tan A, Seifalian AM. A new era of cancer treatment: carbon nanotubes as drug delivery tools. Int J Nanomedicine. 2011; 6(1):2963- 2979. 19. Uc-Cayetano EG, Aviles F, Cauich-Rodriguez JV, Schonfelder R, Bachmatiuk A, Rummeli MH et al. Influence of nanotube physicochemical properties on the decoration of multiwall carbon nanotubes with magnetic particles. Journal of Nanoparticle Research 2014; 16:2192

(30) M. Wilson *et al*, Chapman and Hall (2002) Nanotechnology: Basic Science and Emerging Technologies", ISBN 1-58488-339-1

(31) P. F. Harris, Cambridge University Press (1999) "Carbon Nanotubes and Related Structures: New Materials for the Twenty-first Century", ISBN 0-521-55446-2

(32) R. Saito *et al*, Imperial College Press (1998) "Physical Properties of Carbon Nanotubes", ISBN 1-86094-093-5

(33) J. M. Daenen *et al*.Wondrous World of Carbon Nanotubes (Internet Reference)

(34) T. W. Ebbesen and P. M. Ajayan, "Large-scale synthesis of carbon nanotubes," Nature, vol. 358, no. 6383, pp. 220–222,1992.

(35) M. S. Dresselhaus et al, Academic Press (1996) "The Science of Fullerenes and Carbon Nanotubes : Their Properties and Applications", ISBN 0-12221-820-5

(36) T. W. Ebbesen ed., CRC Press (1996) "Carbon Nanotubes – Preparation and Properties", ISBN 0- 84939-602-6

(37) M. S. Dresselhaus *et al* eds., Springer-Verlag (2000) "Carbon Nanotubes: Synthesis, Structure, Properties, and Application ISBN 3-54041-086-

(38) T. W. Ebbesen, Ann. Rev. Mater. "Carbon Nanotubes" Sci. 24, 235 (1994); Physics Today 381, 678 (1996)

(39) Beg S, Rizwan M, Sheikh AM, Hasnain MS, Anwer K, Kohli K. Advancement in carbon nanotubes: basics,

biomedical applications and toxicity, J Pharm Pharmacol. 2011; 63:141-163.

(40) Taghdisi SM, Lavaee P, Ramezani M, Abnous K. Reversible targeting and controlled release delivery of daunorubicin to cancer cells by aptamer-wrapped carbon nanotubes, Eur J Pharm Biopharm. 2011; 77(2):200-206

(41) Liu Z, Tabakman SM, Chen Z, Dai H. Preparation of carbon nanotube bioconjugates for biomedical applications, Nat protocols 2009; 4:1372-1382.

(42) Xu D, Guo G, Gui L, Tang Y, Shi Z, Jin Z. Controlling growth and field emission property of aligned carbon nanotubes on porous silicon substrates, Appl. Phys Lett 1999; 75(4):481-483.

(43) Meng J, Meng J, Duan J, Kong H, Li L, Wang C et al. Carbon nanotubes conjugated to tumor lysate protein enhance the efficacy of an antitumor immunotherapy Small 2008; 9:1364-1370.

(44) S.K. Smart, A.I. Cassady, G.Q. Lu, D.J. Martin The biocompatibility of carbon nanotubes Carbon (2006), pp. 1034-1047

(45) P.R. Dey, N.I. Das Carbon nanotubes: it's role in modern health care

(46)] H.S. Rathore, S. Mittal, S. Kumar, S. Synthesis, Characterization and antifungalactivities of 3d-transition metal complexes of 1-acetylpiperazinyldithiocarbamate, M (acpdtc) 2, Pestic. Res. J. (2000) 103–107.

(47) A. El Ghaouth, J. Arul, A. Asselin, N. Benhamou, Antifungal activity of chitosan onpost-harvest pathogens: induction of morphological and cytological alterations inRhizopus stolonifera, Mycol. Res. (1992) 769–779.

(48) M. Benincasa, S. Pacor, W. Wu, M. Prato, A. Bianco, R. Gennaro, Antifungal activityof amphotericin B conjugated to carbon nanotubes, ACS Nano (2010) 199–208.

(49) H. Zare-Zardini, A. Amiri, M. Shanbedi, M. Memarpoor-Yazdi, A. Asoodeh, Studyingof Antifungal Activity of Functionalized Multiwalled Carbon Nanotubes byMicrowave-assisted Technique, Surface and Interface Analysis, 2013, pp. 751–755.

(50) E.L. Ursu, I. Rosca, L.G. Bahrin, L. Clima, D. Bejan, M.C. Sardaru, A. Rotaru,Aqueous dispersion of single-walled carbon nanotubes using tetra-phenylbimesitylene derivative via noncovalent modification and improved antimicrobiology activity, J. Nanosci. Nanotechnology.(2019)