International Research Journal of Pharmacy and Medical Sciences
ISSN (Online): 2581-3277

Carbon Nanotubes as Novel Drug Delivery System

Elnazir Abakar Hassan mohamed*
Kl University
Email address: elnazir.e67822@gmail.com

Abstract— *Due to its superior qualities for usage in numerous applications, whether in medicine or other future scope, carbon nanotubes (CNTs) have been the subject of the most studies in the 21st century to date. Due to their tiny size and remarkable optical, electric, and magnetic capabilities when used alone or in combination with metal additions, these compounds have grown in popularity across a variety of fields. They are frequently explained as a graphene sheet that has been rolled up into a cylindrical shape. These are, in fact, graphene cylinders with an end-containment pentagonal ring around their circumference, measuring roughly 12 nm. The fields of medication transport, diagnostics, and biosensing all have potential therapeutic uses for carbon nanotubes. There are numerous ways to make CNTs, including chemical vapour deposition, laser ablation, and arc discharge. Because of their distinctive physical, thermally, electrical, and optical capabilities, CNTs are used in a variety of applications. They are utilised in fields such as biomedicine, drug delivery systems, detectors, implants, tissue engineering, and cancer prevention.*

Keywords— *Carbon nanotube, Functionalization, Dispersion, Properties, Structure*.

I. INTRODUCTION

Carbon nanotubes (CNTs) are one of the newest and most effective ways in pharmaceutical research and advancement in the present situation of novel drug delivery systems. A researcher by the name of Iijima initially investigated it in 1991.[1] One of the fullerenes group's members is CNT. CNTs are massive, pure carbon molecules that are long, thin, tubular, and cylindrical in form. They range in size from 2-3 nm. CNTs are also described as having sp2 hybridized carbon atoms in the form of tubular fullerene or cylindrical graphene. [2]CNTs are organized materials for a branch of tissue engineering that can be employed in a variety of pharmaceutical applications, including anticancer therapy, drug delivery, biosensors, and biomedical imaging. Additionally, CNTs are used for the intracellular delivery of proteins, deoxyribonucleic acid, plasmids, short interfering RNA, and small pharmacological entities[3]CNTs are an allotrope, which is a tubular-shaped material made of graphite. They are divided into three groups: single-walled (SWCNTs), dual walled, (DWCNTs). Multiwall

II. HISTORY

Scientists Lukyanovich and Radushkevich publish a research report in 1952's "Soviet Scholarly Journal of Physical Science" in which they present carbon strands with an empty graphitic nature and a size of about 50 nm. At the fifteenth yearly course on carbon in 1979, scientist John Abrahamson provided evidence of carbon CNT at Pennsylvania State College. A Soviet research team published the results of their synthetic and support plan for carbon nanoscale extension molecules in 1981. The carbon nanoscale extension molecule was encompassed by a heated catalytic lopsided of carbon monoxide (CO). At long last Multidisciplinary International Research Journal of Gujarat Technological University ISSN: 2581-8880 VOLUME 3 ISSUE 1 JANUARY 2021 98 during the year 1991 after all the exploration work Japanese researcher and specialist Iilima has found carbon nanotube by c*circular segment release strategy at NEC (Nippon electric organization).[4][5][6][i]

Advantage Of CNTs .[4][5]

1. Warm conductivity and strong electrical performance
2. Excessive elastic range
3. Exceptionally adaptive and flexible (18% lengthening before disappointment)
4. Wide angle perspectives
(5) Quality field emanation

Disadvantage Of CNTs.[4] [5]

1. There has been less testing because of more recent invention.
2. Reduced lifespan (1750 hours contrasted with 6000 hours for silicon tips)
The extractor cathode must be placed farther away since there are more options for field outflow because the cylinders are not very constrained.

Properties of carbon nanotubes

1. Carbon nanotubes are nanoscopic-sized cylindrical tubes. Single-walled nanotubes (CNT-SW) and multi-walled nanotubes (CNT-MW) are the two different forms of nanotubes. Typical diameters range from a few nanometers (approx. 5 - 30nm, and even
2. The production method utilised determines the substructure of carbon nanotubes (also known as the "armchair" or "zigzag"), which in turn influences aspects like the presence of semiconductor properties. The raw materials have significantly better electric and thermal properties than do typical materials. A significant shift in the percolation curve towards lower material concentrations will be brought about, in particular, by the proper insertion of carbon nanotubes into a material matrix. These promising characteristics are based on the development of a network that makes use of the favourable length to diameter aspect ratio. Given that the base material has a tensile strength (11 - 63GPa) 20 times greater than steel, the development of networks also helps to enhance the mechanical characteristics within the matrix.

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3. Another intriguing characteristic of carbon nanotubes is that when other compounds bind to the carbon atoms, the electrical properties of the tubes substantially alters.
4. Nanotubes also have the ability to quickly pass through barriers like cell walls. It makes good sense that nanotubes can work like needles at the cellular level because of their long, thin shape, which gives them the appearance of microscopic needles. In order to deliver medications selectively to damaged tissue, medical researchers are making use of this feature by binding chemicals that are attracted to tumor cells to nanotubes

Why nanotubes are used in the human body

In the current world of medical research, carbon nanotubes are extensively studied in the areas of effective drug administration and biosensing techniques for the treatment of illness and health management. Carbon nanotubes have lately attracted interest in the realm of medicine since it has been demonstrated that CNT technology has the ability to improve drug release and biosensing techniques. The application of CNTs in biosensing and medication delivery systems has the potential to revolutionise medical practice. It has been demonstrated that fictionalising SWNTs improves their solubility and enables effective tumor targeting and medication administration It stops SWNTs from being cytotoxic and from changing how immune cells function. One of the main disorders being examined in terms of how it responds to CNT medication delivery is cancer, a category of diseases in which cells grow and divide improperly. Surgery, radiation therapy, and therapy make up the majority of modern cancer treatments. These treatments frequently cause discomfort and damage healthy cells in addition to having negative side effects. Using CNTs to deliver drugs Vehicles have demonstrated the ability to target specific cancer cells at a dosing lesser than that of traditional drugs[7], which is just as efficient in killing the cells but does not cause harm to healthy cells and drastically decreases adverse effects .[8] Diabetic patients typically use intrusive, frequently unpleasant blood glucose monitoring techniques. As an illustration, one technique utilizes a continuous glucose sensor built inside a tiny needle that must be put under the skin to check glucose levels every several days36. Another technique uses glucose-monitoring strips that need to have blood administered to them. These procedures can produce unreliable results in addition to being intrusive. It has been demonstrated that 7 percent of glucose readings from continuous glucose sensors differed by more than 50 percent, and 70 percent of them varied by more than 10 percent.[9] Single-walled and multi-walled nanotubes have the potential to be used in very sensitive noninvasive glucose monitors due to their high electrochemically accessible surface area, high electrical conductivity, and desirable structural properties.[10]

Filling up of nanotube

The nanotube created through procedures is closed at both ends. A proper chemical can be used to open the ends. One technique is acid treatment, which oxidizes the ends and leaves behind functionalities that contain oxide. The functional groups -COOH and -OH are the most typical.

CNTs in Drug Delivery and Cancer Therapy

A rapidly expanding field that now uses nanotube technologies is drug delivery. Dendrimers, polymers, and liposomes are currently employed drug delivery systems, however carbon nanotubes offer the chance to work with efficient structures that have high drug loading capacities and good cell permeation qualities. These nanotubes have a bigger interior volume that can be employed as a medication container, large aspect ratios for several functionalization attachments, and the capacity to be quickly absorbed by cells.[11]Carbon nanotubes can be produced with or without end caps due to their tube structure, which means that without end caps the interior, where the medicine is kept, would be easier to access. Currently, issues like lack of solubility, aggregating occurrences, and half-life exist with carbon nanotube drug delivery methods.[12] In order to further the study of carbon nanotubes, these problems are all being addressed right now and changed. The advantages of using carbon nanotubes as nanovectors for drug delivery still hold true where cell uptake of these structures was successfully proven where the effects were noticeable, demonstrating that the specific nanotubes can be less damaging when used as nenovehicles for drugs .[13] Additionally, it has been demonstrated that medication encapsulation improves water dispersibility, improves bioavailability, and reduces toxicity. In addition to offering security and controlled release for molecules that have been loaded, encapsulation of molecules also serves as a means of material storage.[12] All of them lead to a solid drug delivery foundation that might be improved upon by additional study and knowledge. These developments include higher water solubility, decreased toxicity, maintained half-life, and enhanced cell permeation and uptake.

Destroying cancer cells specifically

Carbon nanotubes have numerous biological applications and can be utilized in combination with near-infrared radiation to selectively kill cancer cells.[14] It is well known that living organisms are highly permeable to NIR light, which ranges in wavelength from 700 to 1,100 nm. Mono carbon nanotubes (SWNTs), which have a substantial optical absorbance in this particular spectral window as an intrinsic characteristic, have been demonstrated to be useful for optically stimulating nanotubes inside living cells to produce multipurpose nanotube biological carriers. They used oligonucleotides that were carried by nanotubes within active Hela cells. Upon endosomal rupture brought on by NIR laser pulses, the oligonucleotides translocated into the cell nucleus. Due to severe local heating of SWNT in vitro from constant NIR light, cell death occurred. Functionalization of SWNT with a folate moiety resulted in the specific killing of tumor cells. SWNTs selectively internalize within folate receptor tumour marker-labeled cells and cause NIR-triggered cell death without affecting receptor-free normal cells. As a result, new classes of innovative nanomaterials for drug delivery and

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cancer treatment can be created using carbon nanotubes' delivering abilities, appropriate functionalization chemistry, and intrinsic optical properties.[14]

Mode of break down of CNTs in the body.

Since they did not degrade in biological or natural environments, carbon nanotubes were once thought to be biopersistent. Recent studies have demonstrated that experimental animals exposed to carbon nanotubes by inhalation or injection into the abdominal cavity experience significant irritation. Lung function is hampered as a result, and there's a chance that cancer will develop because to this and the tissue alterations (fibrosis) exposure brings about. For instance, worrying studies from other researchers from a year or two ago revealed that carbon nanotubes are quite comparable to asbestos fibres, which are themselves biopersistent and can cause lung cancer (mesothelioma) in humans a long time beyond exposure. For the first time, a team of Swedish and American researchers has demonstrated that the white blood cell enzyme myeloperoxidase (MPO) may degrade carbon nanotubes. Their findings—which are reported in Nature Nanotechnology—contradict the conventional wisdom that carbon nanotubes are not broken down in the human body or in the natural world. The new knowledge of how MPO breaks down carbon nanotubes into water and carbon dioxide, according to the researchers, may be useful in the field of medicine. As a result, this study marks a milestone in nanotechnology and nanotoxicology since it demonstrates conclusively that endogenous MPO may degrade carbon nanotubes. Neutrophils, a type of white blood cell that expresses this enzyme, employ it to combat dangerous microorganisms. However; the scientists have now discovered that the enzyme also affects carbon nanotubes, dissolving them into water and carbon dioxide. Additionally, the researchers demonstrated that mice that were given carbon nanotubes that had been broken down by MPO no longer developed inflammation.

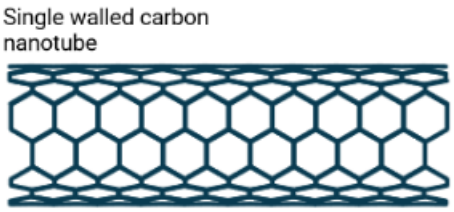
Factors Affecting CNTs[15]

The following is a list of factors found to influence the degree of toxicity of CNTs;

- The CNTs' dosage or concentration
- SWCNTs or MWCNTs
- the length of the tubes
- any catalyst remnants left over after synthesis or functionalization
- the degree of accumulation
- oxidation
- functionalization
- and other factors

CNTs Classification

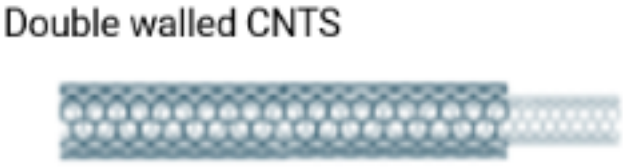
Single-walled CNTs



SWCNTs are organised from an unique actual sheet that is entirely moved over CNTs and has a circuit of 1-2 nm. The detailed process affects the SWCNTs' spectrum of application. The production of nanotubes from the SWCNTs blend needed a unique driving force. Because SWCNTs needed the appropriate reform overextension and unusual air condition, mass unification is problematic when used in tandem with SWCNTs. It requires a catalyst for its synthesis. Insufficient purification and a simple structure characterise SWCNTs. Being twisted is simple. [16][17][18]

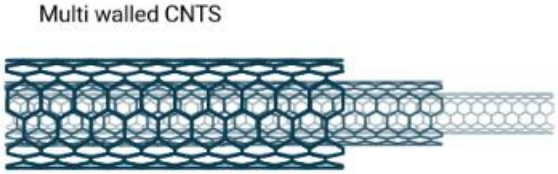
Double-walled CNTs

This CNT, as implied by the name, is made up of two concentric CNTs in which the outer shell of the carbon chamber is entirely enclosed within the interior chamber (outer cylinder is enclosed within inside cylinder) [7] For its production, no catalysts is required. High purity and structural complexity characterise MWCTs. Twisting is difficult . [18]



Multi-walled CNTs

The thickness of the graphene layers in MWCNTs ranges from 2 to 50 nm, depending on the number of the cylindrical graphene molecules present, and they are spaced apart by 0.34 nm. Since MWCNTs have more virtue than SWCNTs, they can be delivered by the mass union in the amalgamation of MWCNTs without the need for any additional propulsion .[16][17][18]



III. PRODUCTION METHODS OF CNTS

There are five common kinds of methods, including the Laser Ablation method. CVD technique & arc discharge (chemical vapour deposition)

1.ARC Discharge method

This technique is used for large-scale manufacturing. The most popular and straightforward approach for creating carbon

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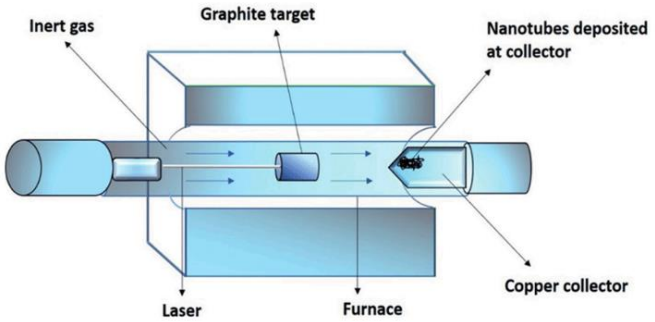
nanotubes is the one used to create C60 fullerence. This technique mixes components and requires separating nanotubes from the catalytic and smooth metals that are already present in the crude product. An ARC-vaporization experiment involves two carbon rods that are placed end to end and spaced apart by roughly 1 millimetre in an enclosure that is filled with inert gas (helium or argon) at reduced pressure, or between 50 and 700 mbar. With a direct current of 50 to 100A and a voltage of about 20V, two electrodes will discharge at a high temperature. One of the carbon rods is vaporised by the discharge, and the other rod develops a little shaped deposit.[19]Specific growth of SWCNTs or MWCNTs is achievable based on the precise procedure, and the normal yield is between 30 and 90%.

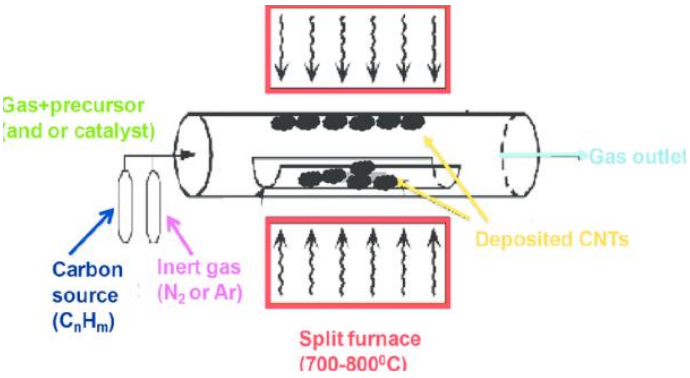
2. Laser Ablation method

Smalley's team at Rice University published the initial report on this synthesis in 1995Using a pulsed or continuous laser, a carbon target is warmed to 1200°C in an oven before being vaporised. The primary difference between continuously and pulsed lasers is the requirement for a much higher light intensity (100KW/cm2 as opposed to 12KW/cm2) for the pulsed laser to function. Helium or argon gas is loaded into the burner in order to keep the pressure at 500 Tor. A initially very hot vapour plume forms, expanding rapidly and cooling. Little carbon particles and atoms soon condense to form bigger clusters, possibly including fullerences, as the vaporised species cool. Once they unite with the carbon clusters, the catalysts also begin to condense., and stop the carbon clusters from closing into the cage structure. The usual yield is up to 70%, and when catalysts connect to them, they may even open cage structures. Van der Wall forces are used to bundle the SWCNTs that are created in this situation .[19]



By irradiating a solid (or occasionally liquid) surface with a laser beam, a process known as laser ablation, photoablation, or laser blasting can remove material from it. The substance is heated by the absorbed laser energy at low laser flux and evaporates or sublimates. The substance is normally transformed into a plasma at high laser flux. If the laser intensity is strong enough, it is feasible to ablate material with a continuous wave laser beam instead of the more common pulsed laser. While relatively long laser pulses (e.g. nanosecond pulses) can heat and thermally alter or damage the processed material, ultrashort laser pulses (e.g. femtoseconds) cause only minimal material damage during processing due to the ultrashort light-matter interaction and are therefore also suitable for micromaterial processing.[Excimer lasers of deep ultra-violet light are mainly used in photoablation; the wavelength of laser used in photoablation is approximately 200 nm.

3. Chemical vapour deposition (CVD)



It can be done by placing a source of carbon (such as methane, carbon monoxide, or acetylene) in the gaseous state and applying energy to a gaseous carbon molecule using a resistively warmed coil or plasma, for example. The power source is employed to split the molecule into reactive carbon atoms. When the substrate is heated and covered with a catalyst (Ni, Fe, and CO), the carbon diffuses towards that surface and binds there. CVD production is a 2 procedure that starts with the production of the catalyst and ends with the real synthesis of CNT. A transition metal is typically sputtered onto a substrate to create the catalyst, which is subsequently thermally or chemically annealed to promote catalyst particle nucleation. Clusters are formed on the substrate as an outcome of the thermal annealing, from which the nantoube will grow. The etchant may be ammonia. The constant temperature[19] ranges are 650 to 900oC, and the usual yield is 20 to 100%.

4.Flame Synthesis Method

SWCNTs are produced using fuel sources and a small metal aerosol catalyst in a controlled flame environment. [20] [21] Single-walled nanotubes have been observed in the post-flame region of a premixed acetylene/oxygen/argon flame operated at 50 Torr (6.7 kPa), with iron pentacarbonyl vapour serving as the catalyst source.. The formation and coalescence of nanotubes into clusters are seen to occur between 40 and 70 mm above the burner (or in around 30 milliseconds).

5.Silane Solution Method

The silane solution method was used to make carbon nanotubes. In a silane solutions of a metal catalyst, preferably Co:Ni in a 1:1 ratio, a substrate, such as graphite or stainless steel mesh, was submerged. The substrate was next supplied a feedstock gas including a source of carbon, such as ethylene, and the catalyst was placed there while the substrate was warmed by an electrical charge running through it. As a result of a reaction between the catalyst and the gas, CNTs supported on the conductive substrate are created. [22]

Purification of Carbon nanotubes

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Purification is necessary because nanotubes can include a lot of carbonaceous contaminants that are added during manufacture. These are the several techniques for doing this:[23]

1. Air Oxidation

This technique enables the reduction of the quantity of metal catalyst and amorphous carbon. The recommended temperature for this is 673 K for 30 seconds.

2.Acid Refluxing For the reduction of metallic particles and amorphous carbon, strong acid is used (HCl, HNO3, and H2SO4).

3.Surfactant aided sonication

Characterization

The techniques currently employed for characterising CNTs are as follows:

- RAMAN Spectroscopy is a good option for a reliable and effective SWCNT presence test.
- Evaluation of intricate structures using transmission electron microscopy (TEM).
- Scanning electron microscopy (SEM) - less susceptible to sample processing and uniformity than TEM, SEM gives a broad perspective of sample structures.

Functionalization of CNTs

CNTs are a substance that is either scarcely or almost completely insoluble in solvents. The solubility of tubes, especially those found in aqueous phase, has to improve in order to integrate CNT technology with biological backgrounds. Many different solubilization and dispersion techniques are looked at, and basically two strategies are discussed.[24] The first strategy consists of a process that involves surface-active chemicals, peptides, polymers, nucleic acids, and oligomers functionalizing CNTs through non-covalent bonds. The advantage of this method is that the nanotube's aromatic surface's electrical structure is protected. For the application of CNTs as biosensors, its characterization is of crucial significance. The second strategy is based on the functionalization of covalent bonds in CNTs. To start, CNTs are split and then put through the oxidation process, producing several CNTs and their derivatives with various types of molecules. The wall-sides of nanotubes operate without contributing reactions. When moieties are added to the CNTs' outer surface, it causes repulsion between the individual CNTs, which allows them to disperse naturally in solvents. [25]

Displacement has been obtained using four fundamental methods;

Non-covalent bond functionalization

Numerous pharmacological molecules, whether tiny or large, are non-covalently adsorbed onto the CNTs' wall layer. Therefore, CNTs function as nano-reservoirs to absorb the drug molecule through cell interactions. The type of adsorption is hydrophobic. The chain's adsorbed molecules and the CNTs interact by stacking one on top of the other. If the drug molecules are lipophilic, the hydrophobic force can be used to load them onto the CNTs. Chemical processing causes the adsorption of charged molecules by ionic interactions when a voltage is applied to the surface of CNTs.[18]

Covalent bond functionalization

When functionalizing CNTs by covalent means, the mixture of medicinal molecules or functional groups is relatively safer. Enhanced dispensability in the aqueous media is the result of covalent functionalization of CNTs, which is caused by the oxidation of CNTs by strong acids. As an alternative, they can be made water-soluble by coating CNTs' external walls and tips with hydrophilic groups. Drugs like methotrexate and responses to 1,3-cycloaddition use CNTs that have been covalently functionalized often. The site of the functionalization and the manner of addition can only be accurately determined by carefully analysing the characteristics of covalently functionalized CNTs. [26]

Dispersion of CNTs using surfactant

In polymeric resources, surface-active chemicals are employed to disperse nanotubes. To reduce the lump disposition of nanotubes in water and other comparable solvents, surface-active compounds such polyethylene glycol, sodium decyl sulphate, and dodecyl benzene sodium sulfonate are commonly used. The presence of benzene rings contributes to the high dispersive efficiency of CNTs. The interaction of the benzene ring with the sidewall of CNTs through P-stacking is necessary to increase the ratio of surfactants that are adsorbed. The method by which weak Van der Waal's bonds are defeated by surface-active agents micelles is shown in the image.[27]

LIMITATION OF CNTs

• CNTs are not soluble in a wide range of solvents, but they work well in an organic environment that is probably water-based.

• CNTs can only be produced if they are essentially and synthetically reproducible bunches with identical properties.

• CNTs have difficulty maintaining high-quality, least-polluting impacts.

Pharmacology of CNTs

Biodistribution and pharmacokinetics for nanoparticles are based on their physiochemical properties, such as size, morphology, clumping, chemical composition, surface functionalization, and dissolution .[28][29] Two investigations that have been reported on the biodistribution of CNT used water soluble CNT that is compatible with bodily fluids. None of the studies mention fatalities or hazardous adverse effects. According to Wang et al.[30] , the mode of administration had no discernible effect on the CNT biodistribution, and the 125Iodine tagged numerous hydroxylated SWNT swiftly distributed throughout the entire body without causing any harm to the tissues. The fact that 94% of the nanotubes were eliminated into urine and 6% into faeces, as was seen in this research, is crucial from a safety standpoint. The biodistribution characteristics for both forms of functionalized [111In] DTPA-SWCNT were remarkably comparable, according to a different study [31] that used functionalized SWCNT and MWCNT and focused on the iv mode of delivery. With a greater blood circulation half-life of 3.5

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hours, both types of nanotubes were discovered to be quickly eliminated from all tissues. According to results using transmitted electron microscopy, both DTPA-functionalized CNTs are excreted intact into the bladder and urine via the renal pathway.

Toxicity of CNTs

The deleterious effects of nanomaterials are generally attributed to a number of traits, including two that are especially notable: (a) the large surface area and (b) the intrinsic toxicity of the surface. [28] Nanostructures that are smaller than 100 nm have a propensity to be more detrimental to the lungs (the portal of entry), can migrate after deposition, can elude phagocytic defences, and can change the structure of proteins. Consequently, might trigger inflammatory and immune responses and may impact how normally tissues operate[32]The total surface area and number of cylindrical, fiber-like particles are both extremely high in milligramme quantities of CNT. This overall surface area will also depend on how tightly the nanotubes are bunched together and how much they are gathered together in solution .[33] The level of surface functionalisation and the toxicity of the different groups of functions both contribute to the intrinsic toxicity of CNT. Amorphous carbon and metallic nanoparticles (catalysts: Co, Fe, Ni, and Mo) can induce very unfavourable side effects and are commonly seen in batches of unprocessed, unfunctionalized CNT after manufacture. [28] The structural characteristics of nanostructures, such as the fibre form, length, and CNT accumulation state, are discussed by Donaldson et al. in their study [34]., might also affect the immunological reaction after exposure to CNT and the local deposition of those particles in the lungs.

The toxicity of CNTs can be divided into following

1.Cytotoxicity of functionalized group

Functionalized carbon nanotubes are non-cytotoxic, according to studies, and they maintain the functionality of primary immune cells .[35] This entailed the preparation of two different types of f-CNTs (functionalized CNTs) using the 1, 3-dipolar cycloaddition procedure and the oxidation/amidation therapy.

A. In vitro cytotoxicity

Using the MTT assay and calcein/propidium iodide (PI) staining, it was discovered that SWCNTs and MWCNTs were hazardous to human astrocytoma and lung cancer cells in vitro .[36] The findings indicated that numerous tests be used to thoroughly examine the harmful effects of carbon nanotubes in order to avoid the potential issue of artifactual results caused by interference from nanomaterials with the dye markers used.

B. Cytotoxicity of SWCNTs and MWCNTs

For comparison, researchers looked at SWCNTs, MWCNTs (MWNT10), and fullerene (C60) on normal alveolar macrophage cells taken from adult guinea pigs .[37] Findings showed that nano particles with various geometric shapes exhibit fairly varying cytotoxicity and bioactivity in vitro, even though their respective toxicity in vivo may not accurately reflect them. In order to explore the morphological and spectral properties of the MWCNT water solutions, as well as to determine MWCNT cytotoxicity in vitro, S.V. Prylutska et al. [38] examined the procedures of the creation of high-stability multi-walled CNT (MWCNT) water solutions. N.A. Monteiro-Riviere and coworkers. Investigated the ideal surfactant that harms human keratinocytes as little as possible, prevents nanotube aggregation without compromising cell viability, and induces inflammation as measured by IL-8 production. Most papers to date have addressed the toxicity of CNT, examining possible negative impacts on human health and the environment, with a focus on worker safety and public health in CNT manufacturing facilities. IVIVC and CNT bioavailability in the body require additional study. In order to create highly potent and effective drug forms that are also highly likely to be well-tolerated by patients, it is also critical to advance our knowledge of the processes behind CNT metabolism, decomposition, clearance, and bioaccumulation. Maynard et al. in a tiny manufacturing facility.[39] looked at the routes that workers might be exposed to particles released into the air from unrefined SWNT material. They discovered that handling unprocessed material results in glove deposits of 0.26–6.0 mg per hand and airborne particle concentrations of 53 g/m3.

Medical application

In laboratory experiments, it was discovered that nanotubes attached to a chicken-produced antibody were effective at removing breast cancer tumours. Nanotubes carrying antibodies are drawn to the proteins made by a particular type of breast cancer cell. An infrared laser is then used to burn the tumour and the nanotubes that were attached to it.[19]

1. Functionalized SWCNTs have increased solubility and enable efficient medication delivery for tumour targeting. It prevents immune cell activity from being altered and SWNTs from being cytotoxic. Another application of carbon nanotubes in medicine is the detection of chemicals or species. According to several studies on the electrochemical reactivity of carbon nanotubes, these substances have the ability to fortify biomolecules and promote the movement of electrons within proteins. It has been found that proteins containing heme benefit from the facilitation of electron transport by carbon nanotubes. The heme centre of biomolecules in heme-containing proteins may be accessed by carbon nanotubes, which is normally undetectable by the glass electrodes.

2.Moreover, carbon nanotubes can serve as blood arteries for the delivery of medications to their intended targets. The drug doses can be decreased when the medicine distribution is carried out in that manner (and it is less expensive for the pharmaceutical corporations). There are 2 equally successful strategies: either a) attaching the drug to the back or side, or b) actually putting the medicine within the nanotube.

3.CNTs are perfect for synthetic muscles because of their high contraction to elongation ratio when exposed to an electric field.[40]

4.Synthetic muscles could be created using CNTs because of their high degree of contractility.[19]

5.When the nanotubes work like a needle at the cellular level, osteoblastic activity, propagation, and bone production are increased.[41]

6.In order to deliver medications exactly to sick cells, this feature is employed to bind chemicals that are attracted to tumor cells to nanotubes. By binding ethylene glycol molecules to nanoparticles of nanotubes, WBCs are prevented from identifying the nanoparticles as foreign substances, letting the nanoparticles to circulate in the bloodstream longer enough to bind to cancer tumour treatment.
7.Inhaled to elicit an immunological response to combat respiratory infections.
8.To aid transplanted bone marrow recipients in the development of their blood cells.
9.In an animal study, magnetic fields cause nanoparticles with drugs loaded on them to disperse and lessen blood artery blockages.
10. New nanovectors for the transport of pharmaceuticals include functionalized carbon nanotubes. Carbon nanotubes as nanocarriers: mechanical properties of carbon nanotubes enclose helical copper nanowires; toxicological to pharmacological aspects.
11. CNTs are extensively utilised in the fields of efficient drug administration and biosensors technology for the diagnosis and monitoring of disorders.
12. Lipid-functionalized CNTs are highly water soluble, which makes them more desirable as drug carriers since it makes it easier for them to flow through the body and reduces the chance that they may impede the pathways to vital organs. CNTs have shown the capacity to target particular tumour cells at a dosage lower than that of conventional medications (does not harm normal tissue and significantly decreases adverse effects). [19]

IV. CONCLUSION

It is more dependable to utilise as carbon nanotubes perform better than we had anticipated and have a straightforward mechanism with a long lifespan. Its capability to treat 100% of the region and be body-friendly make it an advantage over other cancer drugs, which cannot guarantee 85% of the therapy. The adaptable qualities of CNTs have made them stand out in all sectors, particularly in medical, where they have helped humanity tremendously. Nevertheless, CNTs are unable to realise their full potential due to a lack of technology for mass production and a high cost of production. Prior to the discovery of the enzyme MPO (Myeloperoxidase), which can break down Carbon Nanotubes into both water and carbon dioxide and so declare them to be body-friendly, the accumulation of Carbon Nanotubes and their significant toxicity had occupied scientists' attention.

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