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NANOFLUIDS: AN EMERGING DRUG DELIVERY CARRIER

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ABSTRACT

Nanofluids are well-known for their uses in biology, medicine, and biomedicine. Given the rapid advancement of pharmaceutical nanotechnology in drug discovery, formulation, and the development of nanoparticulate novel drug delivery systems, high performance drug nanoparticle fluid suspensions (nanofluids) are expected to change the face of formulation research in the coming years. The technique of synthesis, characterization, stability, latest research, and applications of nanofluids are summarized in this review paper. It also recognizes the future potential of nanofluid technology in the pharmaceutical industry.

KEYWORDS: Nanofluids, biomedicine, nanoparticulate.

INTRODUCTION

Nanoscience and nanotechnology are concerned with the study and management of atoms and molecules at the nanoscale in order to generate effective materials. 'Nanotechnologies work with the boundary between the kingdom of specific atoms and molecules where quantum mechanics rules, and the macroworld, in which bulk properties of materials arise from the combined behaviour of a huge number of atoms and molecules,' writes Pietsch (2005) in a single statement. Nanomaterials having a size of less than 100 nm are generally deemed to be in the nanotechnology area. But, Micron-sized particles, are called as bulk materials. Nanofluids are a type of nanotechnology that incorporates a two-phase system, under which solids (nanomaterials) are suspended in liquids (base fluid). Engineered materials having nanoscale size are called as nanomaterials. Particles, rods, tubes, sheets, and

fibres are all examples of nanomaterials. Thermal diffusivity, thermal conductivity, density, viscosity, and specific heat capacity are physical characteristics of liquids. Nanomaterials are typically dispersed in liquids at low concentrations (up to 9%) to form nanofluids. Due to their low stability, higher quantities of nanoparticles in liquid might cause sedimentation.[1]

Metallic nanofluids and nonmetallic nanofluids are two types of nanofluids. Nonmetallic nanofluids are generated by adding nanoparticles of nonmetals like as the metal oxides, various allotropes of carbon (Graphene, CNT), and so on. Metallic nanofluids are generated by placing nanoparticles derived from metals likealuminium, copper, nickel, and so on.[2]

There are certain significant concerns that we must address in a two-phase system. The stability of nanofluids is amongst the most critical challenges, and achieving the appropriate stability of nanofluids remains a major challenge. The innovative methods for creating stable nanofluids will be discussed in this research, as well as the stability mechanisms.

Nanofluids have gained an increasing amount of research interest in recent years Nanofluids research is primarily motivated by a broad array of applications. Although few review papers on advances in nanofluid research have been published in recent years, the majority of the reviews are focused on experimental and theoretical research on nanofluidthermophysical characteristics and convective heat transfer. The goal of this work is to concentrate on new nanofluid preparation methods and stability mechanisms, as well as new application prospects for nanofluids and their heat transfer properties. Based on the study of these characteristics of nanofluids, we will try to identify some tough challenges that need to be resolved for future research.[3]

Nanofluids have recently been investigated for biological applications including as drug delivery and antibacterial treatments. There have also been numerous studies published on nanofluid-based combination systems, imaging and diagnosis (e.g., drug administration + imaging, high fever + imaging), and multimodal imaging (e.g., optical + MR imaging, PET + MR imaging). Several critical characteristics must be met in order for nanofluids to be used effectively and safely. Composition, size, crystallinity, and morphology must all be accurately characterised. Stability, non-agglomeration, and biocompatibility are also important characteristics.[4]

Preparation Methods for Nanofluids

Nanofluids are colloidal suspensions of nanometer-sized particles (1–100 nm) dispersed in basefluids including water, ethylene glycol, and engine oil.[5] The single-step preparation process and the two-step preparation process are the two main approaches for preparing nanofluids.[2]

One Step process

To make Cu/ethylene glycol nanofluids, Eastman et al.(Fig. 2) developed a one-step physical vapour condensation process. The one-step process involves manufacturing and spreading nanoparticles in the fluid at the same time. The steps of aeration, storage, transportation, and spreading of nanoparticles are removed in this approach, which reduces nanoparticle agglomeration and improves fluid stability. The one-step procedures can produce equally dispersed nanoparticles which can be suspended in the base fluid for a long time. Another effective approach for generating nanofluids employing various dielectric liquids fluids is the vacuum-SANSS (Submerged Arc Nanoparticle Synthesis System). The varied diagnoses are primarily impacted and dictated by the dielectric liquids' thermal conductivity qualities. The morphological shapes of the nanoparticles created are needle-like, polygonal, square, and circular. The approach prevents particle agglomeration, which is undesirable. Because the one-step physical approach cannot generatenanofluids in huge volumes and has a high cost, the one-step chemical method is rapidly modified. By reducing CuSO45H2O with NaH2PO2H2O in ethylene glycol under microwave irradiation, Zhu et al. introduced a new one-step chemical approach for synthesising copper nanofluids. Copper nanofluids that are well-dispersed and stable in suspension are obtained. This technology has also been used to make mineral oil-based nanofluids comprising silver nanoparticles with a limited size distribution. Korantin, which coordinates to the silver particle surfaces through two oxygen atoms generating a thick layer around the particles, could stabilise the particles. For almost a month, the silver nanoparticle suspensions were stable. A microwave-assisted one-step approach was used to create stable ethanol-based nanofluids comprising silver nanoparticles. Polyvinylpyrrolidone (PVP) was used as a colloidal silver stabiliser and a reducing agent for silver in solution in this approach. The establishment of coordination bonds or weak covalent contacts between the silver nanoparticles and the ODA molecules in the organic phase leads in phase transfer. For the manufacture of homogeneous and stable graphene oxide colloids, a phase transfer approach has been developed. After being modified by oleylamine, graphene

oxide nanosheets (GONs) were successfully transported from water to noctane, and the phase transfer process is depicted schematically in Figure 1.

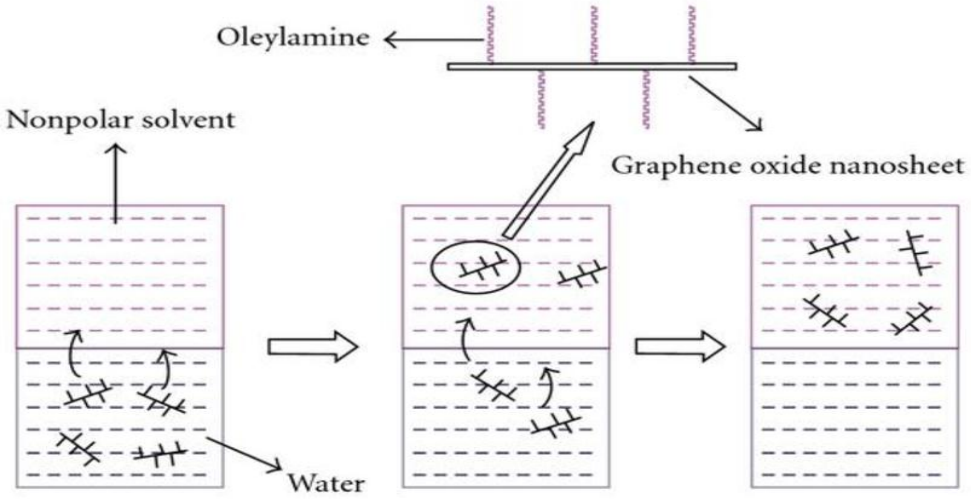

Figure 1:- Schematic illustration of the phase transfer process.[6]

The one-step solution, on the other hand, has some drawbacks. The most crucial is because due to inadequate reaction or stabilisation, residual reactants are remained in the nanofluids. It's impossible to understand the nanoparticle effect without taking this impurity effect into account.

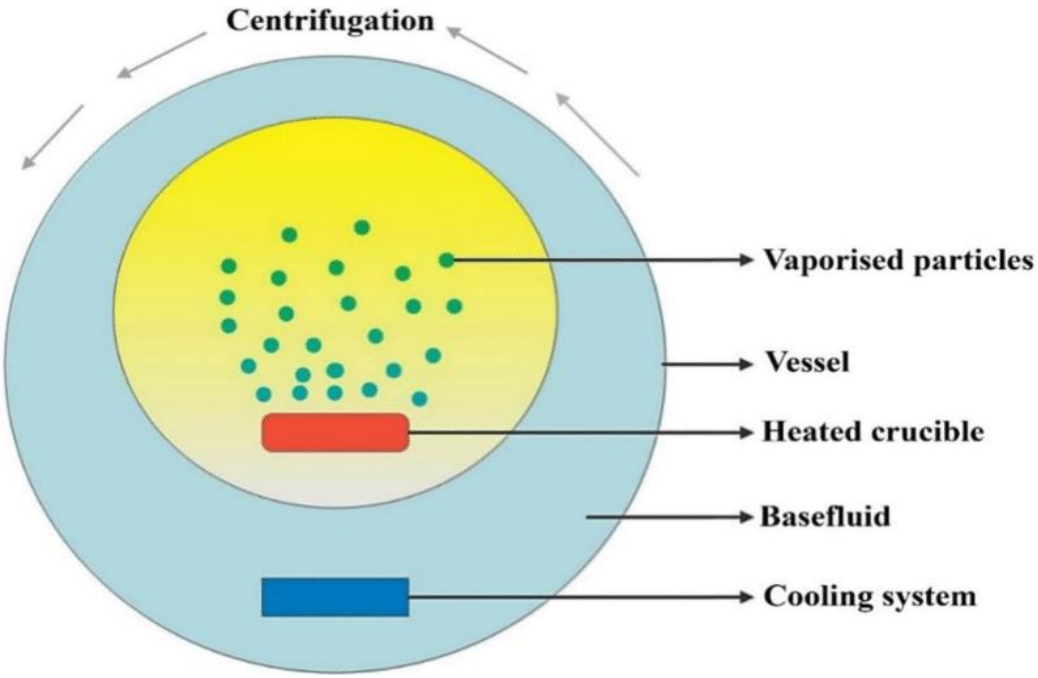

Figure 2: Eastman et al. one-step method for nanofluids fabrication. Reproduced with permission from [146]. Cambridge University Press, 2011.[7]

Two Step Process

The most common approach for preparing nanofluids is the two-step procedure. Chemical or physical processes are utilised to manufacture dry powders from nanoparticles, nanofibers, nanotubes, or other nanomaterials used in this method. Aggressive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenising, and ball milling will then be used to disseminate the nanosized powder into a base fluid. Becausenanopowder synthesis methods have previously been successfully applied to commercial production levels, the two-step process is the most cost-effective way to create nanofluids on a wide scale. Nanoparticles have a propensity to agglomerate due to their large surface area and surface properties. Surfactants are a typical strategy for improving the stability of nanoparticles in fluids. Surfactant functionality at high temperatures, on the other hand, is critical, especially in high-temperature applications.[3]

In a two-step procedure, the drying, transporting, and preservation of nanoparticles cannot be evaded. However, a two-step approach can be used to make nanofluids on a vast scale.[5]

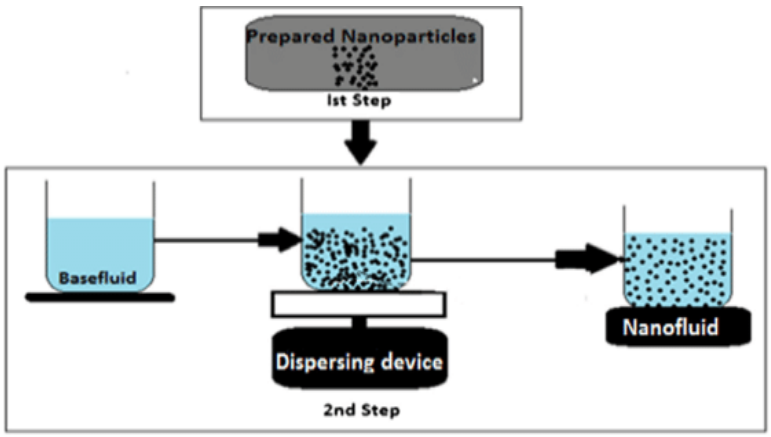

Figure 3: Preparation of nanofluids using two step method.[8]

Other Methods

Different methods (other than these two procedures) have been expressed in other literatures. For the synthesis of gold, silver, and platinum nanoparticles, Feng et al. applied an aqueous organic phase transfer approach. The phase transfer approach can also be used to make kerosene-based Fe3O4 nanofluids with thermal conductivity that is not time dependent. The surface Fe3O4 can be grafted with oleic acid to enable it suitable with kerosene. To make copper nanofluids, Wei et al. built a continuous flow microfluidic microreactor. Adjusting factors like concentration, flow rate, and additives can change the microstructure and features

of nanofluids. Furthermore, an unique precursor conversion process using ultrasonic and microwave irradiation can also be used to prepare aqueous CuOnanofluid. Under this process, the precursor, Cu $(OH)_2$, is entirely transformed to CuO in water. Ammonium citrate is used to limit nanoparticle development and aggregation, leading to a stable CuO aqueous nanofluid with greater thermal conductivity compared to those which is made by using other dispersion methods.[2]

Stability of Nanofluid

The fundamental obstacle in using nanofluids in applications is their stability, and there are certain significant issues to be dealt with in a two-phase system. Because of the reduced particle size and large surface area, particle interactions become more prominent. Each particle in a nanofluid system is subjected to a variety of interactions. These interactions can occur in particle–particle systems as well as particle–liquid systems (Ilyas et al. 2014). The attracting and repulsive forces that originate or act on the particle surface cause these interactions. In general, attractive molecular forces predominate over other types of interactions, causing particles to approach one other. Agglomeration is the formation of a mass of particles as a result of attraction forces. The aggregation effect refers to the change of particulate material into bigger entities as a result of interactions. The stability and homogeneity of nanosuspensions are harmed by agglomeration in nanofluids.. Different forms of stable and unstable nanofluids are shown in Fig.1.

The following principles are responsible for particle aggregation (Elimelech et al. 2013).

• In a fluid media, suspended particles must be moving in such a way that they stay in contact with one another. Fluid motion, Brownian diffusion, or sedimentation can all contribute to these collisions.

• Interactions between particles must be such that colloidal particles are not damaged. Because they do not form aggregates, particles with dominating repulsive interactions are known to be stable.[1]

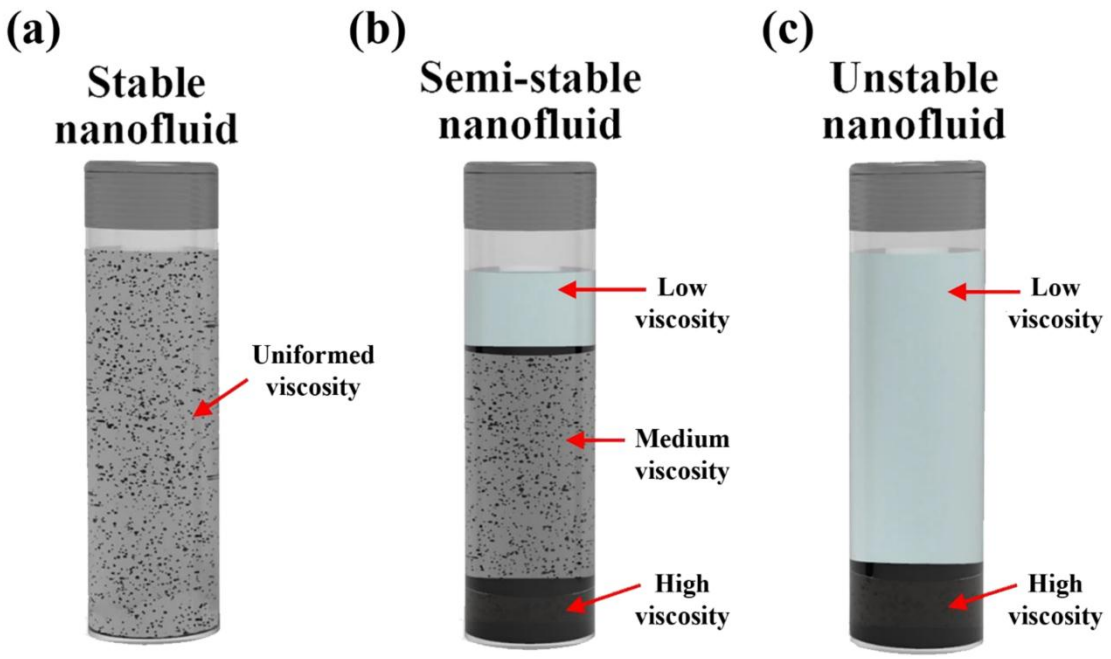

Fig.1: Different forms of stable and unstable nanofluids.[17]

Mechanism of Stabitity

The most important concern, stability, might be impeded by particle aggregation. The combination of attracting and repulsive forces between particles causes nanoparticles to aggregate. If attractive forces win out over repulsive forces, particles form clusters, As a result, increasing repulsive forces over attractive forces can help avoid particle aggregation and maintain stability. Electrostatic stabilisation and steric stabilisation are two ways for enhancement of stability. These two mechanisms are briefly explored here.[2]

Electrostatic stabilization

A key source of kinetic stability is the presence of an electric charge on the surfaces of particles. Adsorption of ions to the electrophilic metal surface causes electrostatic stabilisation. Adsorption forms an electrical double/multi-layer between the nanoclusters, resulting in a Columbic repulsion force. Electrostatic stabilisation is a pH-sensitive technique with restricted use.

Steric stabilization

Steric stability is achieved by attaching macromolecules such as polymers or surfactants to the surfaces of nanoparticles (grafting or chemisorption). The large adsorbents that operate as a steric barrier, preventing particles from colliding, are responsible for the stabilisation.

Because it prevents nanoparticle aggregation due to the steric effect, PVP's protective role is responsible for the stability of graphite nanofluids.

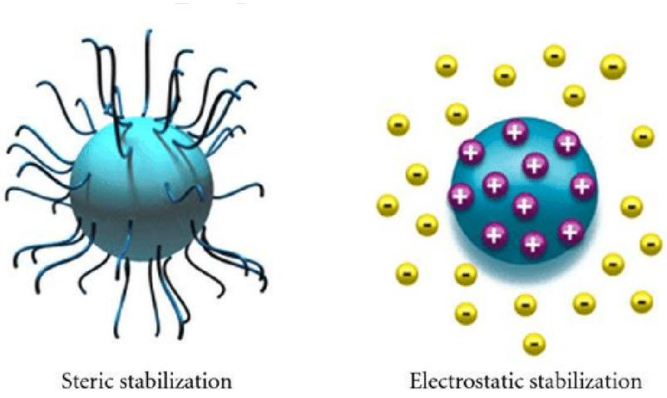

Fig 2: Stability mechanism of nanofluid[9]

Techniques to Enhance The Stability of Nanofluids[8]

Chemical treatment

1. Addition of surfactants

Nanoparticles and basefluids are often required for the creation of nanofluids. Nanofluid stability is determined by the nature of the nanoparticles as well as the basefluid. Basefluids can be polar or non-polar, and nanoparticles can be hydrophobic or hydrophilic. Hydrophilic nanoparticles, such as oxides, will disperse easily in polar basefluids like water, while hydrophobic nanoparticles, such as CNTs, will disperse easily in non-polar basefluids like oils. When hydrophobic nanoparticles must be dispersed in polar basefluids but hydrophilic nanoparticles must be dispersed in non-polar basefluids, surfactants must be added to stabilise the nanofluids. Surfactants serve as a link between nanoparticles and basefluids, allowing nanoparticles and basefluids to communicate with one another.

Depending on the charge on the head group of surfactants, various types of surfactants are available. 1st table When exposed to high temperatures, surfactants may change their characteristics or form foam. They may alter the purity of the heat transfer medium or fluid under investigation[10,11], or they may reduce thermal conductivity by introducing thermal resistance between nanoparticles and basefluids. Table 2 lists the different surfactant and nanofluid combinations that have been described in the literature. Surfactants provide nanofluids stability, as seen in the table, however the period of stability is only specified in a few examples.

Table 1: Surfactant list with some examples.[8]

Type of surfactant	Examples
Anionic	Sodium dodecylbenzenesulphonate (SDBS), Sodium dodecyl sulphate (SDS)
Cationic	Cetyltrimethyl ammonium bromide (CTAB), Benzalkonium chloride
Non-ionic	Gum arabic (GA), Polyoxyethylene (10) nonylphenyl ether
Amphoteric	Lecithin, Sodium lauroamphoacetate

Table 2: The stability period of several nanofluidsand surfactants in combination.[8]

Nanoparticle/Basefluid	Surfactants	Stability period
SWNTs/Water	GA	Over few months
SWNTs/Water	SWNTs/Water	3 Months
SWNTs/ Water	Humic acid	More than 10 days
Stainless steel/Water	SDS	10 days
Stainless steel/Water	SDBS	10 days
TCNTs/Decene	Oleylamine	2 months
Cu/Water	CTAB	Not reported
MWNTs/Water	SDS	Long term stability
MWCNTs/Water	Triton X-100	Not reported
CuO/Water	Rokanol K7	Not reported

2. Change of pH

The isoelectric point (IEP) is the pH value at which a molecule bears no net electric charge and hydration forces are minimal. When the pH of nanofluids approaches or equals the IEP, they become unstable. The zeta potential is zero, repulsive forces between nanoparticles floating in basefluid are zero, and coagulation is a possibility at the isoelectric point.[8] High hydration forces between nanoparticles are required to increase the stability of nanofluids.[12] Because very high or low pH values might harm the heat transfer surface due to corrosion, especially at high temperatures, stablenanofluid must have a pH of around 7.

3. Surface Modification Techniques: Surfactant-Free Method

A good way to obtain long-term nanofluid stability is to use functionalized nanoparticles. It depicts the method without the use of a surfactant. The deposition layer does not form on the heated surface after the pool boiling process, which is one of the nanofluids' distinguishing features. Because of their lack of contamination to the medium, good fluidity, low viscosity, high stability, and high thermal conductivity, the nanofluids produced have potential uses as coolants in sophisticated thermal systems. Surfactant-free nanofluids incorporating double- and single-walled CNTs were created via a wet mechanochemical process. The hydroxyl groups had been imported onto the treated CNT surfaces, as evidenced by the infrared spectra

and zeta potential studies. Chemical treatment of carbon nanotube surfaces to functionalize their surfaces is a typical way for increasing the stability of carbon nanotubes in solvents.[16]

Physical treatment

1. Ultrasonication

Ultrasonication is a widely used physical method for dispersing clumped nanoparticles into a basefluid. The effect of ultrasonication on MWCNTs/Distilled water nanofluid was investigated by Sadri et al.[14] During the ultrasonication process, bubbles developed and then collapsed. Furthermore, the heat generated during the ultrasonication process raised the temperature of the nanofluid, impacting properties such as density, viscosity, thermal conductivity, and stability. Amrollahi et al.[13] investigated the influence of ultrasonication on thermal conductivity and sedimentation in a CNT/Ethylene glycol nanofluid, finding that longer ultrasonication times result in uniform MWCNT dispersion. Ultrasonic devices based on probes operate at a very high frequency. As a result of the separation of extremely small metal particles from the surface of the metal probe, there is a risk of contamination of nanofluids. This could have a negative impact on nanofluid stability. Nanoparticles in nanofluids have the potential to degrade the surface of heat transfer equipment during use. Detection and removal of such particles from nanofluids has received no attention to far.

2. Homogenization

It is not always required to use ultrasonication to break up the agglomerates. To create stable nanofluids, a high shear homogenizer was used. Hwang et al.[15] used a high-pressure homogenizer to make carbon black/water nanofluids by adding SDS at a pressure of 1241 bars. The nanofluid that resulted was determined to be stable. With the combined effects of cavitation and high shear force, it was also determined that high pressure homogenization is the most efficient way for breaking the agglomerates of carbon black present in the nanofluid. Fedele et al. used a two-step process that included ultrasonication and high-pressure homogenization to make CuO/Water, TiO2/Water, and SWNTs/Water nanofluids. In comparison to ultrasonication, the high pressure homogenizer approach was shown to be more effective, as evidenced by size measurement of nanoparticles within the nanofluid following production.

Pharmaceutical Applications of Nanofluids

Antibacterial activity of nanofluids

Organic materials degrade under higher temperatures or pressures. Antibacterial materials are notorious for being unstable. Metals and other inorganic materials, on the other hand, are organic. Metal oxides have received a lot of consideration in recent years owing to their capacity to endure the last decade. Process conditions are quite difficult. The antibacterial action of zinc oxide (ZnO) nanofluids indicates that they exhibit bacteriostatic action against E. coli (E. coli). At high ZnO concentrations, electrochemical studies show a direct contact among ZnO nanoparticles and the bacterium membrane. In antibacterial activities of suspensions of ZnO nanoparticles, Jalal et al reported a reduction in E. coli growth. Bacterial survival ratios fall as ZnOnanofluid concentrations and time increase. Further research has verified that ZnO nanoparticles have a broad spectrum of antibacterial properties on a variety of different microbes. The size and presence of normal visible light may affect the antibacterial activity of ZnO. According to recent study, the inhibitory effect of ZnO nanoparticles against E. coli O157:H7 rises as the concentration of ZnO nanoparticles increases. The cell membrane components, such as lipids and proteins, were altered by ZnO nanoparticles. ZnO nanoparticles have the ability to distort bacterial cell membranes, resulting in the loss of intracellular components and, eventually, cell death, and are thus regarded an efficient antibacterial agent for agricultural and food safety.[18]

Copper oxide (CuO) nanoparticles were found to have antibacterial activity against four bacterial strains in an antibacterial activity study. Nanoparticles have a unique characteristic of penetrating the cell membrane without impediment since their size was smaller than the pore size of bacteria. It's possible that these nanoparticles created stable compounds with key enzymes within cells, impairing cellular function and eventually killing them.[19] Antibacterial action against dangerous pathogens is a common feature of these nanoparticles. ZnO, CuO, and iron oxide (Fe2O3) nanoparticles have outstanding antimicrobial action against Gram-positive and Gram-negative bacteria. ZnO outperformed the other two metal oxide nanoparticles in this investigation in terms of antibacterial efficacy against both Gram-positive and Gram-negative bacteria. ZnO nanoparticles were shown to have good bactericidal potential, whereas Fe2O3 nanoparticles had the least bactericidal activity. The antibacterial activity of ZnO, CuO, and Fe2O3 was proven in this sequence.[20]

Biomedical Applications

Polymerase chain reaction (PCR) is one of the most widely used molecular diagnostic techniques in biomedical applications. It can amplify DNA samples to detectable signal levels in a short amount of time, as well as amplify a single or few copies of a piece of DNA by many orders of magnitude, resulting in hundreds to millions of copies of a specific DNA sequence. The effectiveness of the PCR may be hampered by primer–dimer and GC-rich areas of the template, as well as the heating/cooling ratio of the PCR system. Two essential components of PCR should be examined to improve PCR efficiency and yield: reagent and equipment. The Taq DNA polymerase, primers, and template are among the reagents. At 72°C, the Taq DNA polymerase from the thermophilic bacteria Thermusaquaticus showed the most activity. PCR efficiency has also been observed to be affected by primer design, buffer concentration, and the presence of primer–dimer. PCR machines with fast heating-cooling responses have recently been created. The nanoparticle (NP) is a novel material and has several physical characteristics which are as comparison to bulk materials Furthermore, AuNPs, in addition to their interaction with DNA, interact with other biological molecules, particularly DNA polymerase is a kind of DNA polymerase. Because of the binding, characteristics of AuNPs in the presence of proteins, interaction of AuNPs with DNA or Polymerase is a versatile enzyme that may be used in a number of situations. immunoassay. It's logical to conclude that interactions between AuNPs and polymerase can be employed to control and improve the PCR process. The interaction between DNA polymerase and AuNPs produced the decreased PCR amplification induced by excess AuNPs, and raising the polymerase concentration in the system may overcome the amplification limiting effect.[21]

Nano drug delivery

Colloidal drug delivery methods have been developed during the last few decades to increase the efficiency and specificity of medication activity. Nanoparticles open numerous doors and generate novel biomedical applications due to their tiny size, customizable surface, enhanced solubility, and multi-functionality. Nanoparticles' unique characteristics allow them to engage with complicated biological activities in innovative ways. Nontoxic carriers for medication and gene delivery applications are gold nanoparticles. The gold core in these systems provides stability, while the monolayer enables for fine control of surface characteristics like as charge and hydrophobicity. The interaction of gold nanoparticles with thiols is another appealing characteristic, since it allows for efficient and selective intracellular release.[22-23]

Carbon nanotubes (CNT) have developed as a novel alternative and efficient method for therapeutic chemical transportation and translocation. CNT may be loaded with bioactive peptides, proteins, nucleic acids, and medicines, and then delivered to cells and organs. Because functionalized carbon nanotubes are non-immunogenic and have minimal toxicity, they have a lot of potential in nanobiotechnology and nanomedicine.[24-25] Pastorinet al. used the 1, 3- dipolar cycloaddition of azomethineylides to create a new approach for functionalizing CNTs with two distinct chemicals. The addition of molecules that target specific receptors on tumour cells will aid in the improvement of anticancer drug response.[26] Graphene-based medication delivery systems have gotten a lot of interest in recent years. Sun et al. were the first to disclose the use of nano-graphene oxide (NGO) for cellular imaging and drug delivery in 2008. They created functionalization chemistry to improve NGO solubility and compatibility in biological settings. To load doxorubicin, a commonly used cancer medication, onto NGO functionalized with antibody for selective killing of cancer cells in vitro, simple physicosorption through -stacking may be utilised. The utilisation of functional nanoscale graphene oxide as a new nanocarrier for the loading and targeted delivery of anticancer medicines has been discovered.[27] Controlled loading of two anticancer drugs onto folic acid-conjugated NGO via Π-Π stacking and hydrophobic interactions revealed that NGO overloaded with the two anticancer drugs showed specific targeting to MCF-7 cells (human breast cancer cells with folic acid receptors) and extraordinarily high cytotoxicity when compared to NGO loaded with either doxorubicin or camptothecin alone. PEGylated (PEG: polyethylene glycol) Nanographene oxide (glycol) might be utilised. for the delivery of cancer drugs that aren't soluble in water drugs. NGO that has been PEGylated easily complexes. containing an aromatic molecule that is insoluble in water SN38, a camptothecin analogue, was obtained by Van der Waals interaction that is noncovalent. The NGO-PEG-SN38 complex is highly soluble in water and retains the potency of free SN38 dissolved in organic solvents. Yang et al. discovered that the GO-Fe3O4 hybrid could be loaded with doxorubicin hydrochloride, an anti-cancer medication, with a high loading capacity. This GO-Fe3O4 hybrid exhibited super paramagnetic properties, allowing it to cluster in acidic circumstances and reversibly redisperse in basic ones. This material's pH-activated regulated magnetic activity makes it a viable option for controlled targeted medication delivery.[28-29]

Cancer Treatment

Surgery, chemotherapy, and radiation are all options for cancer treatment.

Chemotherapy, radiation therapy, and hyperthermia are some of the treatments available. There are three types of clinical hyperthermia: (1) localised hyperthermia, (2) regional hyperthermia, and (3) whole-body hyperthermia.

Hyperthermia is the heating of particular tissues or organs (41–46°C) for tumor/cancer treatment using radio frequency, microwave, or laser wavelengths. Within malignant tissues, blood vessels are poorly formed and have a lower heat resistance than healthy tissue. Becausetumour cells have a greater rate of metabolism than normal cells, they are more sensitive to heat, making hyperthermia a viable cancer therapy. Cancer cells are destroyed at lower temperatures than healthy tissue, but only a tiny portion of the tumour may not be heated. The two most obvious explanations are either an insufficient concentration of magnetic nanoparticles implanted or a locally elevated amount of blood flow due to a nearby blood artery. A new endeavour is utilising numerous characteristics of specific nanofluids to be used in cancer imaging and medication delivery. This project includes using iron-based nanoparticles as medication or radiation delivery vehicles in cancer patients. Magnets will be utilised to direct the particles up the bloodstream to a tumour using magnetic nanofluids. It will enable doctors to provide high local doses of medicines or radiation without causing damage to adjacent healthy tissue, which is a common side effect of standard cancer treatments. Furthermore, because magnetic nanoparticles are more adherent to tumour cells than non-malignant cells, they are an attractive choice for cancer therapy.[30]

Magnetic nanoparticles are employed because, in comparison to other metal nanoparticles, they have the ability to handle and manipulate nanofluids using magnetic force.[31] This combination of focused distribution and controlled release will be extremely effective. Because the medication is encapsulated and physiologically inaccessible during transit, it reduces the risk of systemic toxicity. circulatory system The magnetic nanoparticle-containing nanofluid also acts as a super-paramagnetic fluid, absorbing energy in an alternating electromagnetic field to produce a controllable hyperthermia. Hyperthermia can induce a selective radiation impact on malignant cells by increasing chemotherapy effectiveness. Traditional cancer treatment approaches have certain negative effects, however nanofluids and nanoparticles have numerous uses in the biomedical business. Iron-based nanoparticles might be utilised as medication or radiation delivery vehicles without causing harm to surrounding healthy tissue. Using magnets outside the body, such particles might be directed through the bloodstream to a tumour. Nanofluids might potentially be utilised to

make surgery safer by providing efficient cooling around the operating area, increasing the patient's chances of survival and lowering the risk of complications. Magnetic nanoparticles in biofluids can be utilised as medication or radiation delivery vehicles, opening up new cancer therapy options. At AC magnetic fields that are acceptable to humans, magnetic nanoparticles absorb far more power than microparticles. Magnetic nanoparticles stimulated by an AC magnetic field are more sticky to tumour cells than normal cells, making them potential for cancer treatment. The combined impact of radiation and hyperthermia is due to the heat-induced failure of the repair process immediately following radiation-induced DNA damage.[32]

Nano cryosurgery

Cryosurgery is a procedure that uses freezing to remove unwanted tissues. Because of its significant therapeutic benefits, this treatment is gaining popularity. Cryosurgery is fast becoming a viable alternative to traditional cancer treatments, despite the fact that it is not yet a standard therapeutic option. Magnetite Fe3O4 particles are likely the most effective and suitable particle for increasing freezing because of their high biological compatibility. Particles less than 10 m are tiny enough to allow efficient transport to the tumour location, either by encapsulation in a bigger moiety or suspension in a carrier fluid.[33] At a high temperature threshold, introducing nanoparticles into the target through a nanofluid will effectively enhance the nucleation rate.

Other applications of nanofluids

Nanofluids are broadly used in all other fields. The following are some of the most popular uses for nanofluids.

Heat Transfer Applications: Industrial cooling, nuclear reactor coolant, geothermal energy extraction, and other energy sources.

Automotive Applications: Car radiator coolant.

Electronic Applications: Microchip cooling, microscale fluidic applications.

The Current and Future Scope of Nanofluids

Nanofluids are significant because they may be utilised in a wide range of applications, including heat transmission and detergency. Nanofluids require further study in terms of production and uses before they can be used as expected. Nanofluids may be replicated on a

large scale and employed in a variety of applications if the science and engineering behind them is completely understood and their full potential explored. In biomedical engineering and the biosciences, colloids, which are also nanofluids, will become more widely used.[34] However, numerous new findings and advances concerning the properties of nanofluids in the examined applications have been found, and researchers are one step closer to building more efficient and smaller systems.

Limitations of Nanofluids

There are minimal constraints to nano fluids. The long-term stability of nano fluid is a critical concern. For long periods of time, nano fluids may not be physically or chemically stable. Nanofluids have poor boiling properties. This places severe restrictions on the design of nanofluid cooling systems and can lead to overheating.[34]

Lower specific heat: According to the research, nanofluids have a lower specific heat than base fluid. When compared to base fluids, CuO/ethylene glycol nanofluids, SiO_2/ethylene glycol nanofluids, and Al_2O_3/ethylene glycol nanofluids have lower specific heat. To remove more heat, the optimum coolant should have a higher specific heat value.

High cost of nanofluids: One of the factors that may limit the use of nanofluids in industry is their higher production costs. Nanofluids can be made using one-step or two-step processes. Both procedures, however, necessitate the use of advanced and complex equipment.

CONCLUSION

With such a broad range of uses and applications for nanofluids technology in engineering, it's no surprise that it's attracting interest for its usage in pharmaceutical research. Nanofluid technology has a lot of potential in the pharmaceutical sector. The goal of the future is to create stable and effective nanofluids using non-toxic or biodegradable nanoparticles. Nanofluid technology is predicted to become an important element of pharmaceutical technology in the future. The nanofluidic medication delivery method has the potential to become a trademark of pharmaceutical nanotechnology.

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