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Role of Metals in Preparation of Nanofluids

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ABSTRACT

Nanofluids are dispersion of nanoparticles in base fluids, it's a new challenge for thermal sciences given by nanotechnology Due to their excellent features, nanofluids find wide applications in enhancing heat transfer. These shows large increase of thermal conductivity in comparison with their base fluids. The particles used are generally metal or metal oxide which increases thermal conductivity & convection coefficient. Metallic nanofluids are prepared by dispersing nanoparticle made from metals such as aluminum, silicon ,iron, silver, gold, titanium, copper, nickel etc. and nonmetallic nanofluids are prepare by dispersing nanoparticles of nonmetals i.e. metal oxides, various allotropes of carbon for example; Graphene, CNTetc. Synthesis and stability of nanofluids are the two very primary parameters to study nanofluids.

Keywords- Nanofluids, metal oxide& metal oxide (Al_2O_3, Fe3O4, TiO_2, SiO_2, Cu_2O, ZnO, Ag, Au etc.), Nanoparticles.

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INTRODUCTION-

The term 'nanofluid' was firstly proposed by Choi and Eastman in 1995 while presenting the new way to enhance the thermal conductivity of heat transfer fluid (HTF).In the past, the effort to increase the thermal conductivity of fluid has been done by dispersing the solid particles in millimeter or micrometer-sizes into conventional HTF (water, ethylene glycol, oil, etc.) as base fluids.[1]

The kinds of nanoparticles used are usually metals (Cu, Au), metal oxide (Al_2O_3, TiO_2, Cu_2O, Fe_3O_4), and nonmetallic element (carbon). In the past few decades, rapid advances in nanotechnology have leads to introduction of new generation of coolants called "nanofluids".[2]

Metal nanofluid shows enhanced different thermophysical properties like thermal conductivity, heat transfer coefficient, viscosity and thermal diffusivity compared to those of base fluids like oil or water.[3]

Thermal conductivity of metals:- The thermal conductivity is the reciprocal of *thermal resistivity*, usually measured in kelvin-meters per watt ($K \cdot m \cdot W^{-1}$).When dealing with a known amount of material.

The thermal energy δQ, transmitted during an infinitesimal time interval dt through a thickness dx, in a direction normal to a surface of area (A), due to a temperature difference (dT):

$$\frac{\delta Q}{dt} = q(xt) = -KA\frac{\delta T(X,t)}{\delta x}$$

Where q is the called heat current. This equation is suitable to describe the heat transport along a specified direction (here denoted by x).

Heat Transfer Coefficient:-The heat transfer coefficient h is defined as the ratio of heat flux q (heat flow per unit area) to the difference between the temperatur(Ts) of the surface and that of the cooling medium, (Ta).

$$h = \frac{q}{Ts - Ta}$$

It is observed that heat transfer enhance by increasing nanoparticles fraction up to 1% volume concentration. At higher concentrations, heat transfer coefficient growth stops and starts to decrease[4]

Nanofluid is a composition of solid-liquid material which consists of nanoparticles of size 1-100nm which will be added to the base fluid in order to obtain the thermal conductivity. There were two types of solid material that can be used to prepare the nanofluid which are: (1) metallic solid and (2) nonmetallic solid.

All solid nanoparticles with high thermal conductivity can be used as additives of nanofluids. Metallic solid or metallic particles includes- Aluminum oxide, Iron oxide, Copperoxide, Titanium oxide, Silicon dioxide, silver oxide, gold, nickel etc.

Different fluids used for nanofluid preparation

Water-Tap water, distilled water, de-ionized water.

Mineral oils e.g; Paraffinic oils, Naphthenic oils, Aromatic oils.

Thermal Conductivity of additives and base fluids used in nanofluids are as follows:-[4]

Al-237W/m.K, Fe-83.5W/m.K,Cu-401W/m.K, Ag-428W/m.K, Au-318W/m.K,Al_2O_3-40W/m.K,CuO-76.5W/m.K,SiO_2-148W/m.K etc.

1. ALUMINUM OXIDE:

Synonyms:- Alumina

PROPERTIES:-

- It appear as a white powdery substance that has no odor.
- Is a compound made up of two component- aluminum and oxygen
- Though Al_2O_3 is an electrical insulator it has a relatively high thermal conductivity (30 $Wm^{-1}K^{-1}$)[3]for a ceramic material.
- Is insoluble in water

ADVANTAGES[5-8]

- Are readily available through established synthesis methods.
- Their vast surface area allows for readily conjugation with other molecules of various origins such as chemical and biological molecules.
- Can easily interact with the biological interfaces that allow for biological purposes.
- Are stable enough to be used in the various conditions, especially in the non-biological environments.

DISADVANTAGE[8,9]

- Shows environmental biotoxicity.
- Can decrease the growth rate of Ceriodaphniadubia through induction of oxidative stress.

APPLICATIONS OF ALUMINIUM OXIDE NANOFLUIDS[10-14],

- Drug delivery:- have been used in the form of ordered mesoporous for improved oral delivery of anti-blood pressure drug Telmisartan as a poor-water soluble compound..
- Cancer therapy:- induce cell death in human prostate cancer cells, changing the zeta potential of cell surface boosting the efficacy of cancer vaccines
- Anti-microbial effects: strong anti-microbial activities against E. coli and S. epidermis
- Immunotherapy: leishmania vaccine to induce autophagy in macrophages, as potent vaccination adjuvant
- Biosensing: have been considered as novel platforms for detection of different molecules, used to sense bovine serum albumin.
- The streptokinase- have a sustained release action and it has thrombolytic activity.

TOXICITY[15,16]

- It's free metal cation, Alaq3+, highly biologically reactive and causes toxicity.
- Biologically reactive aluminum is present throughout the human body and it can be acutely toxic.
- Direct exposure to Al_2O_3 NPs leads to phytotoxicity mostly in wheat roots culminating in morphological, cellular, and molecular alterations.

HOW TO OVERCOME TOXICITY:

- By using insoluble form of aluminum oxide as soluble form causes more toxicity
- By reduction in dose

➢ **PREPARATION OF ALUMINIUM OXIDE-NANOFLUIDS**[17,18]

Al_2O_3 Nanoparticles (45nm in size)+ distilled water

↓

1%, 3%, 5% concentrations prepared in 100 ml distilled water

↓

Ultrasonicate for 3-4 hrs

↓

Stable nanofluids obtained and more evenly dispersed in distilled water

2. FERROUS OXIDE:

Synonym: Hematite,

PROPERTIS:

- Have diameters between 1 and 100 nanometers.
- Has main two forms are magnetite (Fe_3O_4) and its oxidized form magnetite (γ-Fe_2O_3).
- Has superparamagnetic properties [19]

ADVANTAGES:-

- Used in cellular therapy such as cell labelling, targeting and as a tool for cell-biology research to separate and purify cell populations;
- Tissue repair, drug delivery, hyperthermia, magnetic resonance imaging(MRI)
- The particles in this size range (6-15nm) are rapidly removed through renal clearance.

DISADVANTAGES[19,20]

- Decreases the coherence needed to form an MRI image (T2 relaxation agent), results in iron serves to darken the regions of the image where it is present (the bone marrow in the image below).
- Susceptible to Oxidation

APPLICATIONS OF IRON OXIDE[21]

- Used in the magnetic nanotherapy which is controlled by external electromagnetic field ,ROS mediated local toxicity in the tumor during chemotherapy with antitumor magnetic complex and lesser side effects in normal tissues.
- Contrast agents for Magnetic Resonance Imaging (MRI)
- Drug carriers for target specific drug delivery

- As gene carriers for gene therapy
- As therapeutic agents for hyperthermia based cancer treatments
- Also used as magnetic sensing probes for in-vitro diagnostics (IVD)
- Nano-adjuvant for vaccine and antibody production.

TOXICITY OF IRON OXIDE[22,23]

- Cytotoxicity induced by production of free radical
- Increase in expression of genes involved in cell signaling, including integrin subunits, tyrosine kinases and several members of the protein kinase C family.
- Caused severe damage in liver and lung tissues.
- Pulmonary fibrosis.

HOW TO OVERCOME TOXICITY:-

- The toxicity can be reduced by substitution with surface-saturated uncoated SPION.

PREPARATION OF FERROUS OXIDE NANOFLUID[24,25]

Fe_3O_4 nanoparticle (size ~10 nm)sterically stabilized with oleic acid

⬇

Dispersed in octane (oil phase)

⬇

Crude emulsion prepared (ferrofluid oil)

⬇

Shearing

⬇

Ferrofluid oil + water + surfactant in the ratio of 5:90:5

⬇

Fe_3O_4 nanofluid obtained

⬇

Characterized by X-ray diffraction, TEM, TGA, FTIR, Magnetometer

3. TITANIUM DIOXIDE:-

Synonym:-Titania

PROPERTIES:-

- Has a good thermal stability
- Is soluble in hot concentrated sulfuric acid, hydrochloric acid, nitric acid, but it is insoluble in dilute alkali, dilute acid.
- Is a semiconductor, its conductivity increased rapidly with increasing temperature, but it is very sensitive to hypoxia.
- Is hydroscopic, but not too strong.

ADVANTAGES OF TiO_2 NANOFLUIDS[26,27]

- Widely used in the printing, cosmetics, air purification, etc., and it is recognized safe material without any toxicity for human beings.
- Has good chemical stability, resistance to acid, alkali, and most organic solution erosion.
- Are produced on larger industrial grade which makes them relatively economical.
- Have good dispersability in the polar and nonpolar base fluids when we add proper dispersant.

DISADVANTAGES OF TITANIUM DIOXIDE:-

- A whitish unsightly tint formed when it comes to Ultra-Violent Rays.
- It also leads to the generation of harmful radicles which in most times appear free in their forms via a mechanism known as photocatalytic as they are exposed to direct light.

APPLICATIONS OF TITANIUM DIOXIDE[28, 29]

- Possess good photo catalytic properties, used as antiseptic and antibacterial compositions
- Degrading organic contaminants and germs
- As a UV-resistant material
- Used in cosmetic products such as sunscreen creams, whitening creams, skin milks, etc

TOXICITY:-

- TiO_2 NPs induce phototoxicity upon UV irradiations.
- **Neurotoxicity:-**Brain tissues are more susceptible to oxidative stress-induced damage
- **Respiratory Toxicity:-**The exposures of NMs via inhalation may affect the respiratory tract, resulting in an increased risk of lung cancer, fibrosis, blockage of interalveolar areas, and presence of inflammatory cells
- The changes of serum biochemical parameters (ALT/AST, LDH) and pathology (hydropic degeneration around the central vein and the spotty necrosis of hepatocytes) of liver indicated that the hepatic injury induced due to exposure to mass different-sized TiO_2 particles.

HOW TO OVERCOME TOXICITY:-

- Use of silica-coated rutile TiO_2 NPs inhibit the most soluble and cellular mediators of allergic asthma.
- Reduction in particle size and dose reduces toxicity.

PREPARATION OF TITANIUM DIOXIDE NANOFLUIDS[30]

1) Vapor deposition:-

Bulk solid material for nanoparticles (in low pressure container filled with inert gas) Heated and evaporated

↓

Vapor of raw material cooled and settled in base fluids (base fluid- ethylene glycol)

↓

Pulsed wire evaporation technique is used (25 KV voltage applied for few milliseconds)

↓

Plasma was interacted by argon oxygen to condensed into nanoparticles

↓

TiO_2 Nanofluids obtained

2) Submerged arc method

The submerged arc method provide higher temperature for the preparation of TiO2 nanofluids.

1. Bulk TiO2 solid was vaporised by the arc discharge method in vaccum
2. Gaseous TiO_2 was rapidly cooled into fine solid by an isolated liquid
3. TiO_2 nanofluid obtained

4. COPPER OXIDE:

Synonyms:-Cuprous Oxide,

PROPERIES[31]

- Is introduced as working fluid of direct absorption solar collector.
- Absorbed energy fraction of Cu_2O nanofluid is 4 times more than that of base fluid.
- Thermal conductivity increased with the increase of volume fraction.
- Thermal conductivity improvement of 13.7% is obtained by 100 ppm Cu_2O nanofluid.
- Copper forms two oxides: tenorite (CuO) and cuprite (Cu2O).

ADVANTAGES

- Copper (I) oxide (Cu_2O) is a less expensive material for the fabrication
- It is also Non-toxic
- Enhance mass transport and catalysis
- Enhance solubility

DISADVANTAGES:

- Exposure to higher doses can be harmful; can irritate your nose, mouth, and eyes, and cause headaches, dizziness, nausea, and diarrhoea.
- Increase in copper concentration in blood and urine increased the ceruloplasmin levels may be leads with conditions such as chronic liver disease

APPLICATIONS OF COPPER OXIDE:-

- It is effective against both, susceptible and antibiotic resistant microorganisms
- Has wide range of antifungal and antibacterial properties.
- Inhibits biofilm and the development of microorganisms on the surface of materials coated with Cu_2O NPs.
- Labeling of antibodies, enzymatic chromogenic approach by ELISA (Enzyme Linked Immunosorbent Assay).

TOXICITY:-

- Small sized nanoparticles are much toxic than larger ones.
- The toxicity of nanoparticles is increase by a positive charge which facilitates interactions between cells and nanoparticles[32].

HOW TO OVERCOME TOXICITY:-

- By use of coating agents.
- EDTMP coating could effectively reduce the ion shedding and oxidative stress on the surface of toxic metal oxide.

PREPARATION OF COPPER OXIDE NANOFLUID[33,34]

- 25 ml of ethylene glycol solution (0.1 M) of copper sulfate pentahydrate ($CuSO_4{\cdot}5H_2O$) was mixed with 5 ml of ethylene glycol solution (0.01 M) of polyvinyl pyrrolidone (PVP-K30) in a 100-ml beaker, followed by magnetic stirring for 30 min.
- 25 ml of ethylene glycol solution (0.25 M) of sodium hypophosphite ($NaH_2PO_2{\cdot}H2O$) was added and stirred for 15 min.
- The mixture is put into a microwave oven to react for 5 min under medium power.
- The color of the mixture converted from blue to dark red after the reaction. After cooling to room temperature, Cu nanofluid was obtained.

5. SILICON DIOXIDE:-

SYNONYM:-Silica, Vitreous Silica,

PROPERTIES[35]

- Are divided into two types of particles P-type and S-type according to their structure. The P-type particles are characterized by numerous nanopores having a pore rate of 0.61 ml/g.
- The S-type particles have a smaller surface area than the p-type. The P-typenano-silica particles have great ultraviolet reflectivity when compared to the S-type.
- Have good Stability, lower toxicity.

ADVANTAGES:-

- Has highest efficiency.
- It is thermally stable upto1100°C.

DISADVANTAGES:-

- It needs thick layer (crystalline).
- Brittle Limited substrates
- Production of silicon nanoparticles is expensive
- Some processing wasteful because has short life cycles.
- Toxic substances are produced and are used in manufacturing.

APPLICATIONS OF SILICON DIOXIDE NANOFLUIDS[36]

- Used as a solid medium for protein immobilization, protein binding and separation. The iron oxide acts as magnetic core can respond to external magnetic field, and used for fast particle separation, while the silica shell gives biocompatibility, stability, and a platform for protein entrapment.
- **Nucleic acid detection and purification**:-Silica nanoparticles used for DNA detection, separation and purification, DNA biosensors by hybridization with target complementary DNA or RNA probes to obtain variable fluorescent intensity.
- **Drug and gene delivery**:-Mesoporous nanoparticles used as a carrier for drugs and genes delivery. The pores holds the drug molecules and addition agents like gold nanoparticles, are required as caps to close the pores. To release the drugs, some molecules that can break the covalent bond so that pores get open.
- **Imaging contrast agents construction**:-play an important role in medical imaging, used to encapsulate contrast agents particles, such as organic dyes, quantum dots, gold nanoparticles, iron oxide, also incorporated as contrast agents, and drug/gene/protein delivery.

TOXICITY:-

- ➢ Affect pregnancy and breastfeeding
- ➢ Small vessel vasculitis, autoimmune diseases, kidney damage, and rheumatoid arthritis.
- ➢ DNA damage associated with oxidative stress.
- ➢ Direct interaction with DNA, oxidative DNA damage, depletion of anti-oxidants, cell cycle arrest, and abnormal expression of genes.

HOW TO OVERCOME TOXICITY:-.

- Genotoxicity of SNP can be overcome by reduction in nanoparticles size range. SiNPs in the size range of 25–80 nm exert no or little genotoxicity

PREPARATION OF SiO_2 NANOFLUIDS[37]

The Sol-gel Method:-

12.68 ml TEOS +2.82 ml conc. ammonia+84.5 ml water(30:4.5:1)

↓

Two phases occur

↓

Stirring for 1hr

↓

Sol get formed

↓

Dialyzed against ultrapure water at pH 8 by using dialysis tube membrane

↓

Solution filtered through regular filter paper

↓

Acidify with addition of conc. Nitric acid to pH 3

↓

SiO_2 nanofluids form

6. ZINC OXIDE:-

SYNONYM:-Zinc White

PROPERTIES[38]

- Occur as a white powder that is insoluble in water.
- Has an antibacterial as well as deodorizing property.

ADVANTAGES:-

- Helps in lowering skin inflammation associated with rashes, allergies or irritation
- Provides broad-spectrum sun protection which prevents burns ,protection from skin cancer/neoplasias
- Improving wound healing and preventing bacterial infections
- As aid in recovery of burns and damaged tissue, treat acne, prevent bacterial infections.

DISADVANTAGES[39, 40]

- Cause irritation, swelling, itching, or tingling.
- Cause allergic reactions
- Leads to genotoxicity and cytotoxicity, ROS generation immunomodulatory, apoptotic responses.

APPLICATIONS OF ZINC OXIDE[41,42]

- ➢ Nanorod sensors, spintronics.
- ➢ Used in sun blocks and can often be seen on the nose and lips of lifeguards at the beach.
- ➢ Found in medical ointments to treat skin irritations.
- ➢ Great antimicrobial effect against multiple foodborne pathogens and food contaminants, for example entero

toxigenic *E. coli*, *Botrytis Cinerea*, and *Penicillium expansum.*

- Have been valued in various applications, such as sunscreens, toothpastes, and cosmetics especially because of their ability to absorb ultraviolet radiation.

TOXICITY[43]

- Cytotoxicity, genotoxicity
- Increasing concentration greatly affect liver enzyme
- Increasing zinc oxide nanoparticles concentration affects sperm quality and quantity
- Affect the histopathology of liver and kidney
- Increasing concentration affect oxidant and antioxidant parameters.

HOW TO OVERCOME TOXICITY[43,44]

- The presence of silica coating effectively reduces the toxicity of ZnO NPs and maintains the antimicrobial properties of ZnO NPs.

PREPARATION OF ZNO NANOFLUIDS[44,45]

ZnO Nanoparticles + ethylene glycol or water

⬇

0.1%, 0.5% concentration prepared

⬇

5%wt PVP, OR 1%wt PVA added into mixture to form more stable suspension

⬇

Stir on magnetic stirrer

⬇

Ultrasonicate to re-dispersion of nanoparticles

⬇

ZnO nanofluid obtained

7. SILVER OXIDE:-

SYNONYM:-Ag

PROPERTIES[46]

- Have particles size between 1 nm and 100 nm in size.
- Their extremely large surface area permits the coordination of a vast number of ligands.

ADVANTAGES:-

- Ecofriendly
- Involving living organism
- Less energy is used to synthesis nanoparticles

DISADVANTAGES[47]

- Short life up to (20 min)
- Release of sweet smelling amines
- Formation of by-items
- High cost of power
- Require long maintenance time

APPLICATIONS OF SILVER OXIDE[47,48]

- **Diagnostic Applications:** used as biosensors and in quantitative detection.
- **Antibacterial Applications:** incorporated in various cosmetic preparation for their antibacterial properties.
- **Conductive Applications:** as conductive inks and integrated into composites which enhance thermal and electrical conductivity.
- **Optical Applications:** to harvest light for enhanced optical spectroscopies including metal-enhanced fluorescence (MEF) and surface-enhanced Raman scattering (SERS).

TOXICITY:-

- Due to release of silver ions in cells as both silver nanoparticles and silver ions have been reported to have similar cytotoxicity
- Exposure to silver nanoparticles leads to inflammation, genotoxicity and cytotoxicity, allergic reactions.

HOW TO OVERCOME TOXICITY:-

- Can be reduced by surface aggregation on the plasma membrane of the cells without changing the specific surface functionalization.
- If coated with citrate particles of the same diameter reduce the toxicity induces by silver oxide nanoparticles.

PREPARATION OF SILVER OXIDE NANOFLUIDS[49,50]

Reduction of $AgNO_3$ done by polyvinyl pyrrolidone (PVP), used as stabilizing agent, having Ag concentrations of 1% by volume.

⬇

Silver oxide nanoparticles obtained with size range of 30–60 nm

⬇

Silver oxide nanoparticles added into base fluid (ethanol)

⬇

Characterization by UV-Vis spectroscopy, FTIR, X-ray diffraction, TE

8. GOLD NANOFLUID:-

SYNONYM:-Au

PROPERTIES[51]

- Possess number of surface ligands which allowing flexible design and multi-functionality by incorporating mixed ligands for optimal properties.
- Is inert and is also biocompatible.
- High chemical stability so potential applications in optics, catalysts, sensors, and biology

ADVANTAGES:-

- Has higher absorption with less bone and tissue interference achieving better contrast with lower X-ray dose.
- Clear the blood more slowly permitting longer imaging times. Gold nanoparticles of size 1.9 nm in diameter, were injected intravenously into mice and images recorded over time with a standard mammography unit.
- Used as X-ray contrast agents which overcome some significant limitations of iodine-based agents.

DISADVANTAGES[51]

- The high cost of gold.
- Clear the body more slowly than some small molecules which leading to longer-term whole-body retention in some cases.

APPLICATIONS OF GOLD NANOFLUIDS[51,52]

- **Nano-drug delivery:-**provide nontoxic carrier for gene and drug delivery
- Heat transfer application, energy storage
- In optical filter

TOXICITY [53,54]

- Shows genotoxicity and cell toxicity.
- Hepatotoxicity in mice with healthy or damaged livers was examined in mice.

HOW TO OVERCOME TOXICITY:-

- Modified thiol–PEG (SH-PEG) is an excellent candidate for stabilizing gold NPs in physiological condition and long lasting circulation in the blood
- Replacing cetyltrimethyl ammonium bromide (CTAB) by PEG on the surface of nanoparticles reduced the toxicity of nanoparticles (6.5 nm×11 nm).

PREPARATIONOF GOLD NANOFLUIDS[55]

Au nanoparticles +Surfactant (capping agent) + water or organic solvent

↓

Stabilization (by 1-methylimidazilium)

↓

Stable Au nanofluid obtained

↓

Characterized for their optical, catalytic, biological & thermal property

9. NICKEL OXIDE NANOFLUIDS:-

SYNONYM:-Ni

PROPERTIES[56-57]

- Can be easily altered by changing their shape, size and chemical properties.
- Have unexpected optical properties, and produce quantum effects.
- Is electrically conductive.
- Are available as nanofluid and in passivated, ultra high purity, high purity, coated and dispersed forms.

ADVANTAGES[58]

- Possess high specific surface area and therefore more heat transfer surface between particles and fluids.
- Are highly stable with predominant Brownian motion of particles.
- Due to reduction in particle clogging as compared to conventional slurries it promotes system miniaturization.
- Possess adjustable properties, including thermal conductivity and surface wettability, by varying particle concentrations.

DISADVANTAGES:-

- Due to limited service life deep discharge reduces service life.
- Requires complex charge algorithm
- It is unable to absorb overcharge well; trickle charge must be kept low
- Generates heat during fast-charge and high-load discharge

APPLICATIONS OF NICKEL OXIDE NANOFLUIDS[59]

- Nano drug delivery:-helps in increasing residence time of drug by controlled release of drug over extended period of time.
- Cancer therapeutics:-efficiently used in cancer imaging and drug delivery.
- Smart fluids:-used as energy resource for heat valve to control the flow of heat.
- Used for their thermal properties as coolants in heat transfer equipment such as heat exchangers, electronic cooling system and radiators
- Propellant and sintering additive, bio detection of pathogen
- Drug and gene delivery , protein detection
- Probing of DNA structure ,tissue engineering
- Tumor destruction via heating (hyperthermia)

TOXICITY:-

- ROS production can cause serious and heritable damages to DNA, chemical changes in histones or other proteins, which plays important role in the formation of DNA, unwind the helical structure of DNA and exposed DNA to any change.
- Nickel nanoparticle-induced cell death.

HOW TO OVERCOME TOXICITY[60]**:-**

- Modifying bioavailability –by changing solubility
- By changing the surface contact charge
- Modification in particle size.

PREPARATION OF NICKEL NANOFLUIDS[61]

- Nickel oxide nanoparticles are prepared using the ultrasonic irradiation technique

NaOH solution (0.1M, 100ml) +nickel chloride (0.1M, 50ml) aqueous solution +PEG (0.5ml)

↓

Mixture exposed to ultrasonic irradiation (20 KHz, 200 W) for 3 hrs

↓

Precipitate formed

↓

Precipitate was washed with ethanol and water to separate the impurities

↓

Annealed it in 4000 C for one hour.

↓

Morphological and structural characterizations of annealed powder.

↓

Ultrasonic irradiation

NiO nanoparticles suspended in ethylene glycol (uniform suspension obtained)

CONCLUSION

The different metals and metal oxide plays an important role in preparation of nanofluids. Nanofluids have various applications - as coolent, heat transfer fluid, drug delivery , cancer treatment ,antibacterial ,antiviral activity ,gene therapy, diagnostic application etc. Nanoparticles exert some toxic effect which can be overcome by various treatments.

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