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Application of Silica nanoparticles: A review

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ABSTRACT

The prefix nano in the terms Nanoscience and nanotechnology accounts for 1 billionth. The term nanotechnology was first coined by Richard Feynman, who is known as "Father of nanotechnology". Owing to its surface area to volume ratio, nanoparticles finds pivotal applications in the field of catalysts, electronic components, chemical sensor and pharmaceutical products . Two main approaches are used for the synthesis of nanoparticles: Top to bottom and bottom to top approach. Silica nanoparticles are promising agents in variety of areas like drug delivery, water purification, environmental bioremediation, disease diagnostic and therapeutics. In the present study, applications of silica nanoparticles in the field of water remediation, agriculture and therapeutics are discussed. Besides this its miscellaneous applications in cosmetic , food products and flame retardants are also covered. Hence the review concludes that silica nanoparticles are promising agents as adsorbents, nanopesticides, fertilizers, drug delievery agents, and thickeners in food products.

*KEYWORDS: **Silica nanoparticles, drug delievery, water remediation, flame retardants, anti-cancer agents***

1. INTRODUCTION

Nanoscience has been recently recognized as interdisciplinary science and it encompasses intact acquaintance on elementary traits of nano-sized entities. The prefix "nano" in the term Nanoscience or Nanoparticle accounts for one billionth or 10-9 units [1]. Michael Faraday first provided an insight on scientific elucidation of nanoparticles properties in his famous paper "Experimental Relations of gold and other metals to light" [2]. The term nanotechnology was first depicted by Richard Feynman who is known as Father of nanotechnology in 1959 in his lecture "There's plenty of room at the Bottom" [3]. Nanoparticles possess inimitable size and shape reliant chemical, physical, magnetic and optoelectronic traits changeable from that of bulk material due to its large surface area to volume ratio. As a result of these, nanoparticles have variety of interesting utilization like catalysts , electronic components, chemical sensor, pharmaceutical products and so on [4,5]. There are mainly two approaches for fabrication of nanoparticles: Bottom to top & Top to Bottom approach. Bottom to top approach involves self cohering of atoms to nuclei leads to formation of particles of erratic sizes. Laser pyrolysis, sol-gel method and hydrothermal methods are some examples of bottom to top approach. Top to bottom approach comprises of gradual controlled overwhelming of bulk substance into diminutive particles by size reduction. Electro-spraying, laser ablation, ball milling are the examples of top to bottom approach. Silver nanoparticles are antibacterial, anti-cancer, anti-microbial, anti-fungal and anti-ageogenic agents. They are also utilized as drug delivery agents, air and water disinfectants, cell imagining and anti-stain textile agents . Iron nanoparticles are anti-bacterial and anti-oxidant agents; they are also used as catalyst for environmental decontamination, dilapidation of ionic dyes and adsorbent for heavy metals. Gold nanoparticles functionalized with polyethylene glycol are as employed in drug and gene delivery agents . Copper nanoparticles are used in gas sensors, catalytic process to reduce toxic azo dyes Congo red and methyl orange, high temperature superconductors and solar cells. Copper nanoparticles also possess anti-microbial, anti-oxidant, and anti-cancer traits. Silica nanoparticles are promising agents in variety of areas like drug delivery, water purification, environmental bioremediation, disease diagnostic and therapeutic and so on [11-20]. In the present review , application of silica nanoparticles in the field of agriculture, water remediation and therapeutics are discussed.

2. APPLICATION OF SILICA NANOPARTICLES

Agriculture:

Si based nanoparticles find potential application as nanopesticides, nanoherbicides, fertilizers, drug delivery agents for protein and nucleotides in plants. Besides this, it also facilitates water retention in soil and mitigates the effect of environmental stress . Silica nanoparticles fabricated from agricultural waste sugarcane bagasse and corn corb exhibit antifungal activity against plant pathogenic fungi F. oxysporum and A. niger in Eruca sativa. The growth of inhibition for F. oxysporum and A. niger was found to be 73.42% and 58.92 % respectively. The application of silica nanoparticles to Eruca sativa also enhanced germination, protein and chlorophyll content in its leaves. The average diameter of these SiO2 nanoparticles was 17.23 nm . The exogenous application of silica nanoparticles on salt stressed Valencia sweet orange plant diminish harmful effect of excess NaCl by remodeling water status, photosynthesis and ion content. Along with this application of silica nanoparticles also promoted root growth and chlorophyll content in NaCl treated Valencia sweet orange plant as compared to control stressed plant . The combined foliar and soil application of silica nanoparticles to marigold plant enhanced plant biometrics, plant physiology, flower's characteristic and flowering period. The mentioned positive impact of silica nanoparticles arises due to its ability to boost plant-water correspondence, nutrient absorption, cell elongation, anti-oxidant potential and photosynthetic pigment . Silica nanoparticles comprising control release fertilizer facilitates deliberate liberation of nutrients, retaining appreciable amount of water and thus leading to better survival in drought circumstances . A. H. Alsaeedi et. al. revealed that the application of nanosilica promotes seed germination and growth development in Cucumis sativus. Diminutive size of nanosilica facilitates its easy permeability through the membrane and hence enhancing germination . Coriandrum sativum L. saplings grown in lead contaminated soil exhibited reduced plant biomass and vitamin C content while increased flavanoid and anti-oxidant enzyme activities. Application of foliar silica nanoparticles to Coriandrum sativum L plants grown in Pb tainted soil results in elimination of undesirable effect due to lead toxicity by regulating plant resistance system . Exogenous application of nano silicon to faba been plants led to enhancement of its crop water productivity and biological yields in arid climate . Silica nanoparticles also stimulates germination and growth of bean in Vicia faba L . NPK fertilizer in combination with silica nanoparticles is known to enhance maize production. Silica nanoparticles are optimistic insecticidal agent for management of Spodoptera littoralis pest . Azadirachtin loaded in silica nanoparticles possess pesticidal action against whiteflies (Bemisia tabaci) in green gram seeds [21-32].

Water remediation:

Silica nanoparticles synthesized using sugarcane waste ash as a precursor and cetyltrimethylammonium bromide as stabilizer is eco-friendly bioadsorbent for acid orange 8 dyes from aqueous solutions. The specific surface area of these nanoparticles was found to 131 m2 g-1 and adsorption capacity of 230 mg/g for acid orange 8 dye. These sugarcane waste derived nanosilica could be reused upto 5 times . N. P. Khumalo et.al. fabricated methyl functionalized mesoporous silica incorporated polytetrafluoroethylene/polyvinylidene fluoride membrane possessing 99% efficiency for removal of Congo red from aqueous solution . Mesoporous silica nanoparticles derived naturally occurring diatomite was successfully evaluated as bioadsorbent for removal of methylene blue from aqueous solutions. The adsorption of methylene blue on the surface of silica nanoparticles was best described by Langmuir adsorption isotherm model. Also these silica nanoparticles could be efficiently reused upto 5 cycles without significant loss of adsorption capacity . D. Maucec et. al. designed mesoporous silica supported TiO2 catalysts and mesoporous silica supported ZnO catalysts and examined their photo catalytic efficiency to uptake Reactive Blue 19 dye from wastewater. The removal efficiency of Reactive Blue 19 dye was higher onto silica supported ZnO nanoparticles as compared to silica supported TiO2 nanoparticles . M. Galangash et. al. prepared magnetic carboxyl-coated silica iron oxide nanoparticles and examined its potential to uptake malachite green from water. The adsorption of malachite green onto silica iron nanocomposite was best described Langmuir adsorption isotherm and pseudo second order kinetic model. The adsorption capacity for malachite green uptake was found to be 263.13 mg/g . Nanosilica supported poly β-cyclodextrin adsorbent facilitated uptake of bromophenol blue and crystal violet from aqueous solution at ambient temperature. The removal of these dyes from aqueous solution was in accordance with pseudo second order kinetic model . Monodispersed nanosilica fabricated using cetyltrimethylammonium bromide template is effective adsorbent for cationic dyes rhodamine B, methylene blue, methyl violet, malachite green, and basic fuchsin. The adsorption capacity of silica based adsorbent for above dyes was evaluated ranging from 14.70 mg/g to 34.23 mg/g within 2 to 6 minutes . Silica based fujasite nanocomposite is effective adsorbent to remove heavy metals Pb, Cr and Co from aqueous solution. It also exhibits remarkable photo catalytic activity to degrade methylene blue and methyl red dyes. The adsorption behavior of Cr, Co and Pb onto fujasite nanocomposite was in accordance with Langmuir adsorption isotherm . Silver decorated silica nanoparticles demonstrated exemplary adsorption capacity and photo catalytic activity for removal of methylene blue from aqueous solution. The maximum adsorption capacity was found to 55mg/g, The adsorbent revealed reusability upto 8 successive cycles of adsorption [33-41].

Therapeutic applications

Silicon derived material and their oxides as nanoparticles are promising therapeutic substances in medical applications due to their biocompatible characteristic . Mesoporous silica nanoparticles are optimistic oral drug delivery system for poorly soluble hydrophobic drug telmisartan. Mesoporous silica nanoparticles inflate oral bioavailability by enhancing drug dissolution rate and drug permeability . Mesoporous nanosilica functionalized with polyethyleneimine/polyethylene glycol are effective nano-carriers for doxorubicin along with P-glycoprotein siRNA in multi-drug resistant human breast cancer xenograft. These polyethyleneimine/polyethylene glycol functionalized silica nanocarrier system enhanced drug permeability and retention effect by 8% at the tumor site . S.S. Park et. al. fabricated Mesoporous nanosilica functionalized with Pt and carboxylic group to study drug molecule release behavior of cisplatin. These cisplatin loaded mesoporous nanosilica functionalized with Pt and carboxylic group demonstrated good anti-cancer potential against A549, A2780, and MCF-7 cancer cell lines . Quan et. al. fabricated lactosaminated mesoporous silica nanoparticles as a carrier for targeted anti-cancer drug delivery. Docetaxel loaded lactosaminated mesoporous silica exhibited pronounced anti-cancer activity against hepatoma cell lines HepG2 and SMMC7721 . Graphene oxide wrapped squaraine loaded mesoporous nanosilica finds potential application in in vitro florescence imaging. Graphene oxide based mesoporous nanosilica possess tribological property and outstanding permanence in aqueous media . Organometallo silica nanoparticles fabricated using tetraethylorthosilicate and [Ir(dfppy)2(dasipy)]PF6 precursors are luminescent bio-markers as well as controlled delivery trajectories for A549 (lung carcinoma) and HeLa (cervix carcinoma) cell lines . Silica derived vaccines revealed enhanced proliferative reciprocating resulting it in adequate delivery agents for DNA vaccines [42-49].

Other Applications:

Silica nanoparticles are anti-caking substances and enhance absorbency of cosmetic formulations . They are also used as fillers to raise the bulk of cosmetic formulations due their effective manufacturing expenses and hydrophobic character . Amorphous silica nanoparticles are utilized as thickeners and carriers for fragrances and flavors in food products . R. Zhu et. al. revealed improved selectivity of bisphenol coated silica nanoparticles column for solid phase extraction of bisphenol A from cosmetic samples as compared to that of C-18 solid phase extraction column available in market . Thiol customized silica nanoparticles have been successfully employed as adsorbent for extraction drugs and pesticides . Silica nanoparticles capped with flame retardants facilitates uniform dispersion of flame retardants along with silica nanoparticles in polyester matrix and hence improving flame retardant property of polyester material [50-55].

3. CONCLUSION

Nanomaterials possess distinct physical, chemical and optical properties owing to its large surface area. Fabrication of nanoparticles mainly involves two approaches : Top to bottom and bottom and top approach. Silica nanoparticles are anti-cancer agents, drug delievery agents and alos finds potential application in in vitro florescence imaging. Silica nanoparticles are effective adsorbents to uptake methylene blue , acid orange, crystal violet, methyl violent and rhodamine B dyes from aqueous media. Silica nanoparticles are employed as thickeners in food products and fillers in cosmetics. In the field of agriculture , nanosilica is employed as herbicides , pesticides and fertilizers . Hence silica nanoparticles are promising agents in the field of therapeutics, water remediation, cosmetics and agriculture.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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