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Metal Oxide Nanoparticles: A Pharmaceutical Review

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Abstract

In the coming years, the growing demand for nanotechnology in various industries may result in a massive dispersion of nanoparticles in the environment. The expanding burden of nanoparticles in the environment has sparked concerns about their interaction with flora and wildlife. Several researchers have recently demonstrated the impact of nanoparticles on plant development and accumulation in food sources. This review looks at research of various methods involved in the development nanoparticles from various methods and their applications in different fields like health, food, feed, space, industrial, chemical and cosmetic industries. Various advantages and disadvantages of metal oxides nanoparticles were focussed.

Introduction

Nanotechnology and nanoparticles are an ever-growing field and had gained a lot of interest from chemist and scientists in the past few decades because of their uncountable applications in various fields [1]. The particles that are nanometer size are called nanoparticles. Their size range from 1-100nm. One nanometer is equal to one billionth of the basic unit(meter). The study of such particles is termed nanotechnology. The nanoparticles have tons of applications due to their unique physical and chemical properties. They are found in different shapes like sphere, cube, rod, plate etc., But, still, the nanoparticles have both advantages and disadvantages and are discussed under this context [2]. They have various applications in different fields like health, food, feed, space, industrial, chemical and cosmetic industries [3].

The metal oxide has surfaces that interact so effectively with the surrounding that in turn it improves all properties related to them. The increasing advancements in nanotechnology have a wide range of applications of metal oxide with it. In addition to this, the metal oxide nanoparticles surfaces possess charges that interact with target molecules and show certain effects[4]. There are many metal oxide nanoparticles synthesized such as zinc oxide nanoparticles, titanium oxide nanoparticles, tin oxide nanoparticles, silicon dioxide nanoparticles, zirconium oxide nanoparticles, nickel dioxide nanoparticles, aluminium oxide nanoparticles, cerium oxide nanoparticles, magnesium

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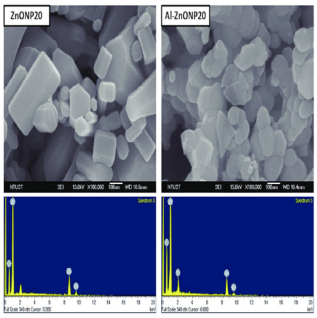
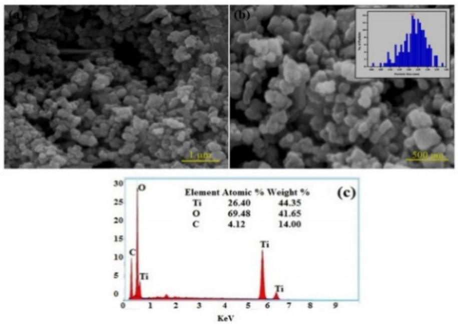
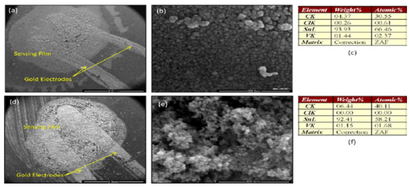
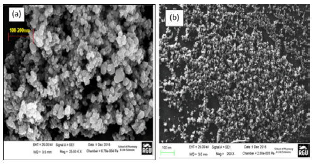
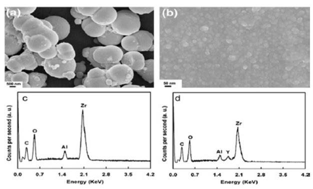
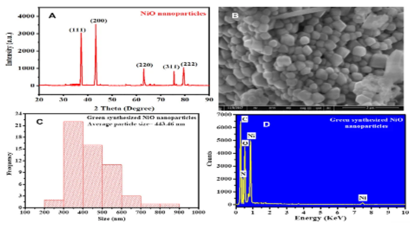
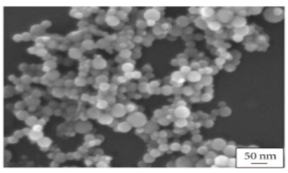
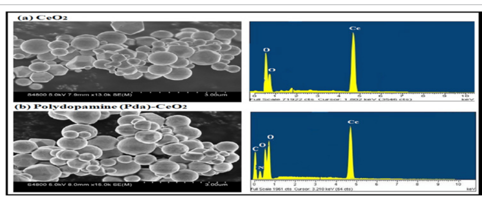
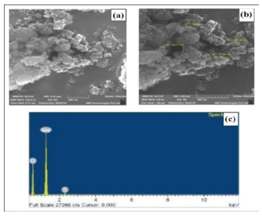
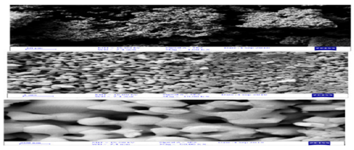
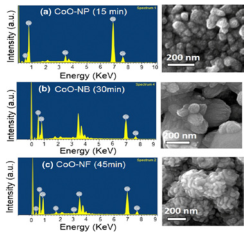
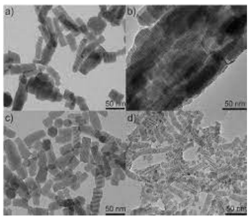
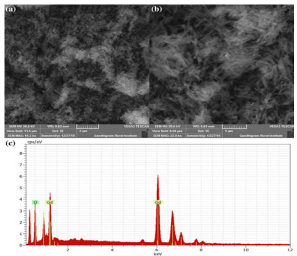
oxide nanoparticles, bismuth oxide nanoparticles, cobalt oxide nanoparticles, yttrium oxide nanoparticles, gadolinium oxide nanoparticles etc., [5,6].

Types of metal oxide nanoparticles.

Sl. No	Type	Morphological images
1.	Zinc oxide nanoparticles	
2	Titanium oxide nanoparticles	
3	Tin oxide nanoparticles	
4	Silicon dioxide nanoparticles	
5	Zirconium oxide nanoparticles	
6	Nickel oxide nanoparticles	
7	Aluminium oxide nanoparticles	
8	Cerium oxide nanoparticles	

9	**Magnesium oxide nanoparticles**	
3	**Bismuth oxide nanoparticles**	
4	**Cobalt oxide nanoparticles**	
5	**Yttrium oxide nanoparticles**	
6	**Gadolinium oxide nanoparticles**	

Zinc oxide nanoparticles: The zinc oxide nanoparticles are prepared by the green synthesis method. They possess larger bandwidth and higher binding energy. They possess semiconducting, high catalytic, optic, UV filtering, anti-inflammatory wound healing, drug delivery, anticancer, antidiabetic, antibacterial, antifungal and agricultural properties [7]. They produce reactive oxygen species(ROS) which cause damage to the cell wall, increases cell permeability and causes cell toxicity which causes weakness of mitochondria, the flow of intracellular fluid to the extracellular matrix and oxidative stress which hinder cell growth and cell survival enhancing antimicrobial activity[8].

Titanium oxide nanoparticles: it possesses very good photocatalytic properties and produce Reactive Oxygen Species (ROS) and acts as an antimicrobial agent. The efficiency of these nanoparticles differ greatly on gram-positive and gram-negative bacteria is thin and they are most efficient against antimicrobial agents when compared to gram-positive bacteria that have thicker cell wall [9]. The titanium oxide nanoparticles then attack and damage the cytoplasmic region of the cell which leads to the death of the cell [10].

Nickel oxide nanoparticles: nickel oxides nanoparticles are synthesized by the chemical precipitation method. The main application of nickel oxide nanoparticles is in the production of electrochromic, films, magnetic materials, p-type transparent conducting films, gas sensors, catalysts, alkaline, batteries, cathode and solid oxide fuel cells anode and antimicrobial agents [11]. The nickel oxide nanoparticles increase the ROS generation and damage most of all the cell organelles which finally leads to the cell organelles which finally leads to the cell organelles which finally leads to the programmed cell death. So the nanoparticles are effective antimicrobial activity [12].

Cerium oxide nanoparticles: It possesses both cytotoxic and cytoprotective nature. The cytotoxic effects are used in cancer therapy and against bacteria for antimicrobial activity. The cytoprotective nature is due to the antioxidant properties of cerium oxide nanoparticles [12]. The radical scavenging activity is useful in the wound healing process. This property of cerium oxide nanoparticles is due to small particle size by a reduction in the size of particles [14].

Advantages of metal oxide nanoparticles:

1) They possess photocatalytic activity, the degradation of any dye in aqueous media by nanoparticles. Is termed as the photocatalytic effect in control of environmental pollution [15].

2) They have nitrate sensing properties. Certain nanoparticles possess the ability to sense the nitrate present in their environment. It helps in analysing the nitrate concentration [16].

3) They posses antiproliferative activity. The metal oxide nanoparticles can stop the proliferation of cells in breast cancer widely used for cancer therapy [17].

4) They are used in invitro haemolytic activity determination. The metal oxide nanoparticles possess the ability to cause lysis of red blood cells. The assay is carried out for

its determination [18].

They have antifungal properties. They can inhibit the growth of fungus used as therapy in fungal infection [19,1].

They possess antimicrobial activity. The smaller particle size and high surface area of metal oxide nanoparticles cause the production of ROS or free radicals which causes damage to the bacterial cell wall and cell components [18].

They have antiviral activity. The metal oxide nanoparticles synthesised by the green synthesis method confirmed that they had antiviral properties against the new castle disease virus (NDV) [19].

Semiconducting metal oxide nanoparticles can be easily produced at a low cost that acts as gas sensing materials. These semiconducting metal oxide nanoparticles have high sensitivity due to the high surface-to-volume ratio [20].

The anti-inflammatory property of metal oxide nanoparticles blocks inflammation assisting enzymes and hence possesses anti-inflammatory activity [21].

UV filtering property of metal oxide nanoparticles. The metal oxide nanoparticles due to larger surface area are potential agents to filter the polluted water and removes the water impurities [22].

Disadvantages of metal oxide nanoparticles

1. The toxicity of metal oxide nanoparticles and their effects mainly depends on their size, shape and metal ion. The dissolution rate is directly related to toxicity. The metals with a higher dissolution rate are highly toxic. The agglomeration and dispersal contribute to the toxicity of the metal or metal oxide nanoparticles [23].

2. The metal/metal oxide nanoparticles and cell surfaces possess charges which interact with each other by interactive forces to form the agglomeration. Various methods are incorporated to outlook the process of aggregation like laser diffraction technique, the stroke- Einstein equation is applicable and branauer- enmett teller(BET) technique [24].

3. If the particle size of metal oxide nanoparticles decreases the surface area of atoms exposed also increases. Inturn the toxic reactions also increases drastically. The fate of nanoparticles is of two ways either accumulation or degradation. The accumulation of nanoparticles remain active for a long period and the degradation of nanoparticles produce ROS (reactive oxygen species) [25].

Metal/metal oxide nanoparticles	Activity	References
Ag nanoparticles	Antibacterial, antifungal, prevent wound inflammation form of topical administration (transdermal drug delivery).	26
Au nanoparticles	Antioxidant properties, skin immunization and optimising transdermal delivery system	27
SnO nanoparticles	Photocatalytic degradation of dye.	28
ZrO_2 nanoparticles	Application biosensors, cancer the raphy ,implants and dentistry	29
SiO_2 nanoparticles	Signal amplication for DNA sensing	30
Al_2O_3 nanoparticles	Used as energy storage materials and in fabrication of aluminium ion cells	31
MgO nanoparticles	Antimicrobial and Antibiofilm activity	32
BiO nanoparticles	Ionic insulating and conductors	33
Co_2O_3nanparticles	Free radical scavenging property, antioxidant properties and reducing powers, inhibition of α-amylase and protein kinase.	34
Y_2O_3 nanoparticles	Host materials for rare-earth dopants, biological imaging, photodynamic therapies, polarizer, phosphor, laser host material, cancer therapy, biosensor and bioimaging, antibacterial, antioxidant properties.	35
Gd_2O_3 nanoparticles	Theranostics agents	36

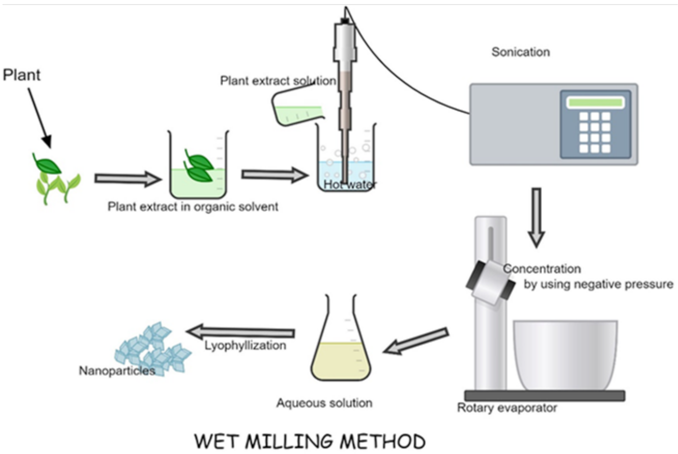


Figure 1: Schematic representation of process of wet milling method.

Methods of preparation of metal oxide nanoparticles containing plant extracts

1) Wet milling method: The plant extraction solution is made in a organic solvent which is volatile. The solution made is sprayed into hot water under ultrasonication. The solution is further concentrated in its aqueous form under reduced pressure. The aqueous solutions were freeze dried. The nanoparticles in its powdered form can be obtained [37].

2) Synthesis by reduction reaction: Nanoparticles can be prepared by using plant extract by pouring into its respective sulphates. The pH of the aqueous solution needs to be adjusted using suitable alkali which also acts as reaction accelerator. The whole mixture is then heated with continuous stirring until there is change in colour of solution. The mixture is then centrifuged to obtain the pellets. The pellets obtained are then washed and air dried at low temperature. The powder of nanoparticles is obtained [38].

The physical, chemical and biological methods are encorporated for synthesis of nanoparticles.

The physical method involves,

Technique	Method	Reference
Furnace evaporation	The metal acetates along with alkaline solution is boiled, filtered. The precipitated is ovened and powder is muffle furnaced to obtain nanoparticle.	40
Laser induced pyrolysis	The flowing gas and sample is heated. The energy is absorbed from laser to obtain.	41
Laser evaporation	The sample is heated at elevated temperature which results in vapours which further forms nanoparticles.	42
Flame	Nanoparticles are generated by using flame heat to produce monomers	43
Thermal plasma	The temperature of plasma at 10^{4} °c can decompose the reactants to produce nanoparticles	44

The biological method are also used for synthesis of nanoparticles. The green synthesis approach is used widely because of its ease and less complicated procedure and by utilization of plant, fungi, bacteria, algae, yeast and actinomycetes.

Sl no.	Organism	Species	References
1.	Bacteria	Escherichia coli., lactobacillus casei, bacillus cereus, aeromonas sp. SH10 phoeocystis, bacillus, anyloliquefaciens, bacillus indicus, bacillus cecembensis, enterobactergangotriensis, corynebacterium sp. SH09 and shewanellaonlidensis.	45
2.	Yeast	Saccharomyces cerevisiae.	46
3.	Plants	Aloe vera(aloe barbadensis miller), oat(avenasativa), alfalfa(medicagosativa), tulsi(osmium sanctum), lemon(citrus limon), neem (azadirachtaindica), coriander (coriandrumsativum), mustard(brassica junucea) and lemon grass(cymbopogen flexuous)	47

It is an important method for the synthesis of the metal/ metal oxide nanoparticles by using the functional groups extracted from bacteria, yeast, plants and fungi act as reducing agent along with solvents.

The chemical method of nanoparticles involves methods like chemical vapour depostition(CVD)method, sol-gel method, spinning and sputtering [48,49].

Sl no.	Method	Inference	Reference
1	Chemical vapour deposition	The heated substrate will be deposited by solids in its vapour state and the chemical reaction occurs to produce nanoparticles	50
2	Sol-gel method	The metal alkoxide is dissolved in solvent to prepare a gel by heating or stirring and dried to get gel that is further powdered.	51
3	Spinning	The SDR(spinning disc reactor) that consists of rotating disc and spinning produces nanoparticles.	52
4	Sputtering	The solid state in vapourized state undergoes collisions at very high velocity to form nanoparticles	53

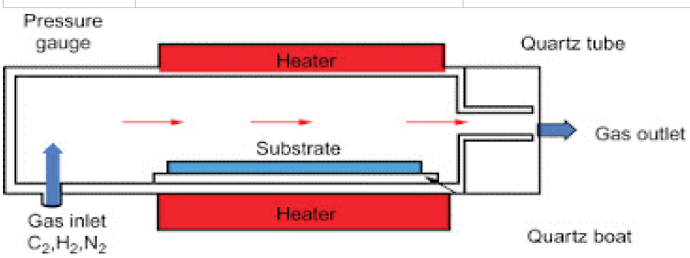


Figure 2: Concept of Chemical vapour deposition method.

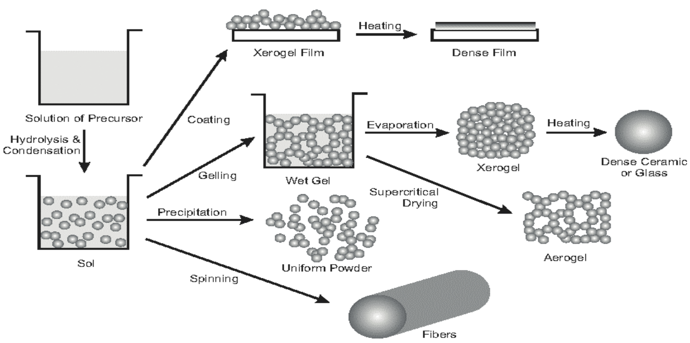


Figure 3: Schematic representation of sol gel approach.

Conclusion

Based on review of articles metaloxide nanoparticles synthesised by various methods and it can be taken for further application studies. Need to concentrate on toxicity levels of metals is the prime importance. Few methods are very cost effective in the preparation of metal oxide nanoparticles like green synthesis method.

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