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Plant Mediated Green Synthesis of ZnO NPs and Their Potential Regenerative Applications: A Review

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Abstract: ZnO NPs (Zinc oxide nanoparticles) have variety of properties such as anti inflammatory, antifungal, antibacterial, anti-diabetic, wound healing and antioxidant. Green production techniques with the usage of alga, bacterium, fungus, plant etc. have been recently used worldwide. This is because the production of nanoparticles via chemical and physical ways includes hazardous substances, as well as having risky laboratory conditions. The review highlights the different synthesis techniques of ZnO NPs with a focus on the biosynthesis (green method) from various biological sources.

Keywords: Nanoparticles, Zinc Oxide, Green synthesis, Regeneration, Eco-friendly

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Introduction

Nanotechnology is the process of synthesizing the materials at nanoscale dimension and their application in various fields. Modern nanotechnology is the subject of obtaining nanomaterials of various metals with unique properties which allows their use in a huge level of commercial applications. Nanoparticles have very small size hence they have large surface area to volume ratio. Due to nanoscale dimension, they offer specific and enhanced properties like thermal conductivity, catalytic reactivity, chemical stability etc. (Khan *et al.*, 2016) . As they have antimicrobial activity, they are proved to be nano sized antibiotics (Ahmad *et al.*, 2003). They are also being integrated into many cosmetics, food, chemical and health industries (Rao and Gautam, 2016).

Amongst the key micronutrients of the human physiology, Zinc is semi-conducting substance that co-factors more than 300 enzymes and is crucial for performing essential cellular processes. Zinc deficiency could start the cancer while its high

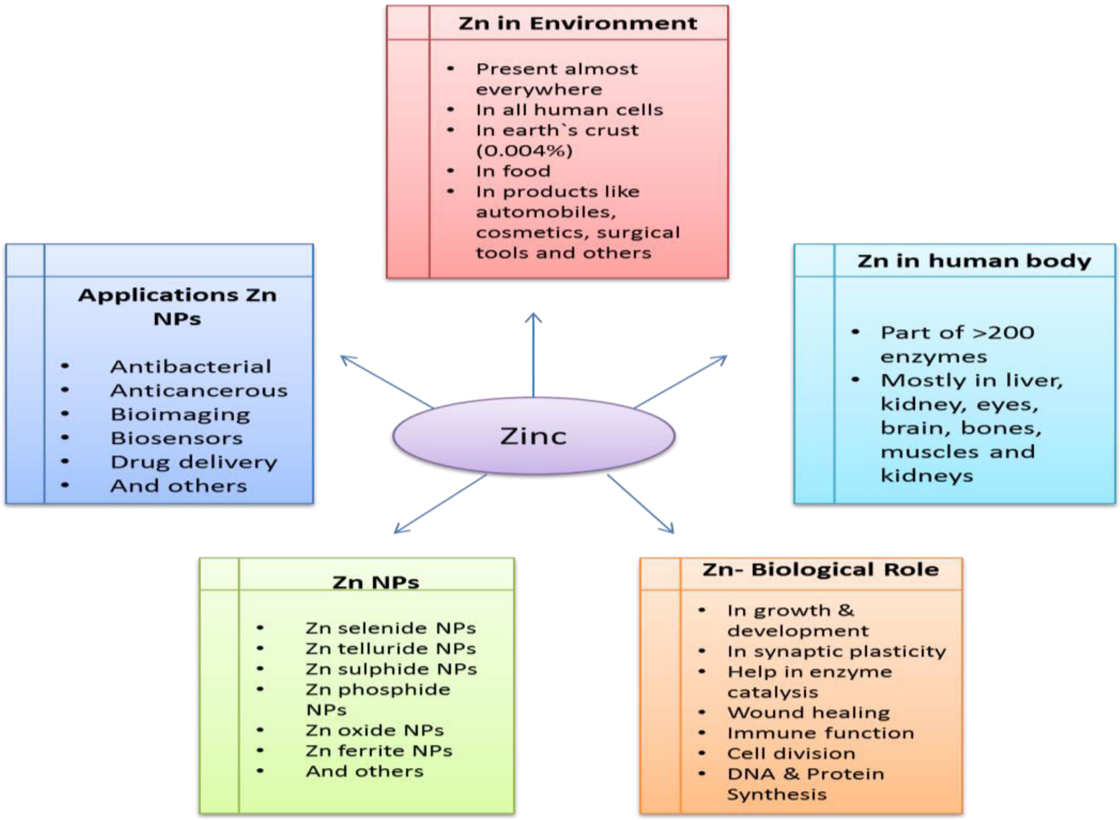

Fig. 1: Brief description of Zinc metal, their role in environment, human body and general biology and various forms of Zinc NPs with their applications (source: Ahmad *et al.*, 2003).

dose also has hazardous effects that could be fatal. The toxicity could result by imbalance of Zinc-mediated proteins as well as oxidative stress which lead to hydroxyl radicals, other ROS and NO (nascent oxygen). Among many NPs, that are synthesized from other metals, Zinc NPs are the most significant and versatile substances. ZnO NPs shows photocatalytic, antibacterial and anticancer characteristics due to their lower size and a higher surface reactivity. Furthermore, they have higher selectivity, better stability and are more biocompatible and easily synthesizable than other metallic NPs. Additional evidence from recent studies is their use in textile, medical, and wastewater treatment etc. (Ali *et al.*, 2018).

This review discusses the significance of zinc for biological systems, different methods of nanoparticles synthesis with a focus on ZnO NPs. The review contains a thorough description of ZnO NPs, their production (mainly by green method) and their industrial application (Fig. 1).

Various Approaches of Nanoparticles Production:

Two approaches are generally used for nanoparticle synthesis-- Top Down approach and Bottom Up approach (Fig. 2). In the top down approach, the macroscopic particles are converted in small NPs by reduction. In this large dimension patterns are synthesized at first and then milled them to nano sized materials. As this approach is costly and slow, it could not be used for high level production of NPs (Arasu and Soniya, 2010).

In the bottom up approach, the production of NPs takes place from automated assembly of already miniaturized atomic components. It is comparatively cheap approach which includes creation by green, physical as well as chemical methods (Rashid *et al.*, 2017). In the physical synthesis, small nanoscale particles are attracted by means of physical forces and different well-

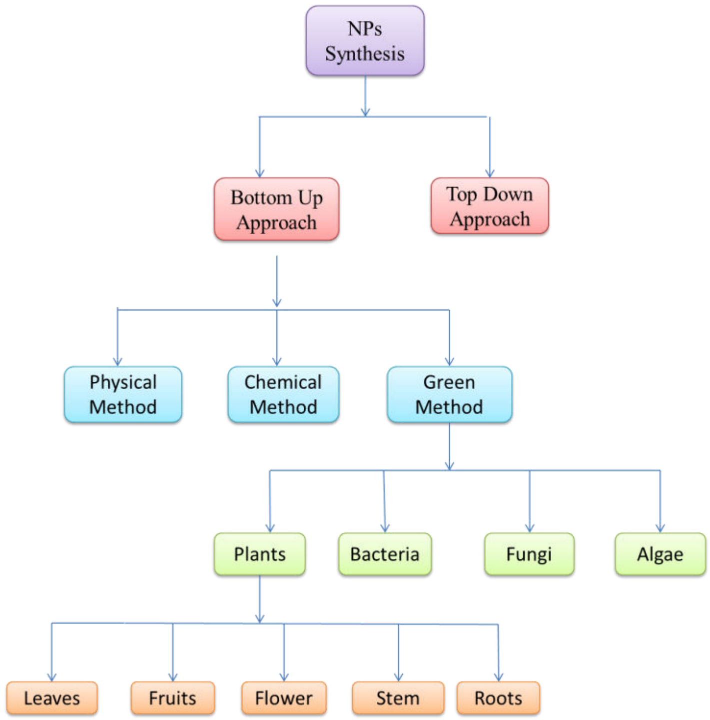

Fig. 2: Different methods of NPs synthesis.

defined, large, stable nanostructures are formed. In this method the use of huge area for set up of equipments, expensive machinery, elevated heat and pressure is needed which prove to be a big drawback (Chandrasekaran *et al.*, 2016). In the chemical method, poisonous substances which can prove unsafe for the atmosphere as well as the individual, is used. Few of the deadly compounds that are used in physical as well as chemical synthesis approaches might remain in synthesized NPs and therefore can prove to be harmful in arena of their applications (Dhandapani *et al.*, 2014). Addition of extra capping as well as stabilizing agents are necessary in both chemical as well as physical methods (Agarwal *et al.*, 2017). In the green synthesis, NPs are synthesized from living systems like bacteria, fungi, algae, plants etc. These biological systems allows large quantity production of NPs at a time, which are without any extra contaminations (Abdul Salam *et al.*, 2014). Green/ Biosynthesis involves use of plants and microorganisms of biomedical importance. This is harmless, environmental, biota friendly and economical NP synthesis method (Yuvakkumar *et al.*, 2014). These natural strains of microorganisms and extracts of various parts of the plant have certain phytochemicals which have ability of reducing, capping and stabilizing agent (Auld, 2001).

***Uses of Zinc Oxide Nanoparticles*:**

ZnO NPs are one of the popular NPs used from last few years. This is because of their application in optics, electronics and biomedical field. Many types of NPs made form inorganic oxides of metals are being synthesized and continuously being used like TiO_2 NPs, CuO NPs, ZnO NPs etc. Among all, Zinc oxide nanoparticles are economical to create and can be synthesized simply (Jayaseelan *et al.*, 2012). US FDA has found that ZnO is the GRAS metal oxide (Pulit-Prociak *et al.*, 2016) and so ZnO NPs are widely used in research. Different ZnO nanomaterials have been reported like nanoflake, nanoparticles, nanoflower, nanofibers, nanobelt, nanotubes, nanowire, nanopores, nanorod etc. Because of the UV clarifying characteristics of ZnO, they have been employed on large scale in commercial production of cosmetic items for skin protection like sunscreen lotions (Wodka *et al.*, 2010). They have variety of biomedical uses such as antifungal, antibacterial, antidiabetic, anticancer, drug delivery and in dental field. They can be used widely for elastic as well as dye manufacturing, for eliminating arsenic as well as sulfur from aquatic bodies and they also have property of adsorption of protein. They are also actively used in agricultural field for eradication of unwanted water plants which are sturdy for any type of disposal practices such as physical, mechanical as well as chemical methods (Rajeshkumar, 2016).

Development of nanotechnology is extremely rapid in recent years and therefore becoming notable, and leads to the formation of ZnO NPs having novel features (Espitia *et al.*, 2012). ZnO NPs specifically with dimensions <100 nm offer excellent catalytic characteristics (Khan *et al.*, 2019). There has many ZnO NPs production approaches which determines their physical-chemical properties, such as laser synthesis, ultrasonography, sol-gel technology, hydrothermal techniques, microwave-aided incineration, electrochemical depositions, coprecipitation, anodization, and electrophoretic deposition etc. (Bharat *et al.*, 2019).

The capability of using ZnO NPs as sunscreens is considered to be their key benefit. Between 200 and 400 nm, zinc oxide particles scatter and reflect light, giving skin a white appearance. Although ZnO NPs typically range in size from 40 to 100 nm, they absorb as well as disperse UV light and primarily captivate visible wavelengths and make sunscreens undetectable upon skin therefore subsequently develop that qualities which customers want (Osmond and McCall, 2010). They are also utilised in garments as efficient UV blockers. Textile coatings produced with bigger particles are more air permeable when compared with ZnO nanoparticles (Yadav *et al.*, 2006). Additionally, these coatings have an antimicrobial purpose. The material's self-cleaning is made possible by properly modified nanoparticles.

The previously described antibacterial action of ZnO at the nanoscale is still another benefit. Ointments and lotions containing zinc oxide are frequently applied to wounds to hasten healing. It is also utilised in temporary dental fillings (Kolodziejczak-Radzimska and Jesionowski, 2014). There is evidence that ZnO NPs are extremely effective against microorganisms that cause food poisoning, leading to its widespread usage as a preservative and a food packaging component (Akbar and Anal, 2014). Zinc oxide has photocatalytic abilities; yet, it has poor stability but nanoscale zinc oxide particles (ZnO NPs) show larger stability, better crystallinity, and fewer defects, allowing for successful application in the breakdown of different materials, such as organic contaminants (Hariharan, 2006).

ZnO NPs are frequently used for the manufacturing of a variety of cross-linked rubber goods because of their superior heat conductivity (Xu *et al.*, 2019). The heat conduction ability of lone rubber is fairly less, hence the adding of a stuffing of ZnO NPs ensures high thermal conductivity and maintains its elasticity also. In addition to this, ZnO NPs increase elasticity as well as speed of the vulcanization procedure of rubber (Kadum Abd-ali, 2020). Due to the status of ZnO NPs as a semiconductor and its capacity of emission of light under influence of electromagnetic radiation it has been used in variety of ways in electronics and electrical engineering. Addition of ZnO NPs in sensors leads to their increased sensitivity for revealing of Carbon monoxide (CO) as well as other gases (Liu *et al.*, 2007).

The size, shape and other characteristics like solubility, aggregation, pH etc. have a significant impact on their properties. Nevertheless, the advancement of nanotechnology enables to drastically alter the properties of ZnO NPs to obtain desired effects (Altunbek *et al.*, 2014).

Production of Zinc Oxide nanoparticles via various biotic bases that is biosynthesis/green production gaining very much popularity in recent years therefore different work also done by researchers across the country. In this review we focused mainly on ZnO NPs produced by using plants and their different parts and the valuable work done in this field is summarized in Table 1.

Zinc Oxide Nanoparticles' Role in various Types of Regeneration:

Because Zinc Oxide Nanoparticles has strong collagen-producing as well as bio-mineralization properties, they are employed in the scaffolds for many type of tissue regeneration (Table 2). The periodontal (gum) regeneration was studied by Münchow *et al.* (2015) using novel and unique ZnO-loaded electrospun membranes of rod shape and 65 nm thickness. With increasing ZnO NP concentrations, these membranes demonstrated antibacterial activity, but they were not toxic to human dental stem cells of pulp. The findings suggested that low concentration ZnO-loaded electrospun membranes containing ZnO NPs may possibly used for Directed Regeneration of Tissue/ Bone (Münchow *et al.*, 2015).

The Poly Urethane (PU)/Poly Lactide Blend (PLDL) polymer membrane films fixed with 0.001% ZnO NPs (<100 nm) is used for the development and enlargement of Stem Cells of human adipose stroma as well as OECs (Olfactory Ensheathing Cells) was investigated by Marycz *et al.* (2016). They demonstrated that the ZnO NPs-containing films enhanced cell proliferation while reducing ROS and NO levels by raising SOD activity in all of the test cells. Additionally, these films inhibit programmed cell death (PCD) by reducing the expression of genes linked to PCD in both OECs and ASCs. According to the findings, this specific film could be used for regeneration and cell recovery. But the higher concentrations (0.01% and 0.05%) caused the aggregation of cultured cells and gives totally opposite results. Therefore, to avoid the negative effects caused due to higher dose of ZnO NPs and to provide greater tissue regeneration, ZnO NPs must be used ideally at lesser concentration (Marycz *et al.*, 2016).

Forero *et al.* (2017) investigated the use of a nano sized copper-zinc alloy containing gelatin/ chitosan/ nano-hydroxyapatite framework (<150 nm) for regeneration of bone tissue. They demonstrated that frameworks induced osteogenic differentiation as well as enhanced the spread as well as increased the union of Mouse Embryonic Fibroblasts (MEFs). In addition, next to the live hypodermic implant, the nano fusion framework/scaffolds encouraged the development of granulation in tissue and stimulated the growth of the surrounding tissues. Their study suggested that the nano fusion framework/scaffolds might be a good applicant for use in the bone tissue regeneration (Forero *et al.*, 2017).

ZnO NPs (80-100 nm) were recently studied by Yousefi *et al.* (2018) to see how they would affect tendon repair in a rabbit model. After eight weeks of application, they saw the NPs at the repair site completely absorbed. In addition, the NPs reduced the formation of adhesions across the tendon and not any evidence of local infection was found. The NPs demonstrated a rapid healing procedure through enhanced angiogenesis and rearrangement of collagen fibril, pointing to its capability to use in the cure of acute ligament wounds (Yousefi *et al.*, 2018).

Chen (2018) investigated the use of 500 nm, sheet-shaped ZnO nanofibers (0.1% wt./wt.)/ polyvinyl alcohol/ chitosan as a framework for the development and growth of Human Foetal Osteoblasts (HFOs). They demonstrated that this framework enhanced osteogenic mineralization by encouraging calcium discharge and activity of an enzyme named alkaline phosphatase for three weeks, but did not improve human foetal osteoblasts adhesion and proliferation.

A nanofibrous framework made up of PolyCaproLactone (PCL), ZnO nanofibres (rod shaped and 318.19 nm thickness) (1- 30 weight %) and nano-hydroxyapatite (nHA) was created by Shitole *et al.* (2019) for the regeneration of tissue of bone by using MG-63 (Osteosarcoma) cells of Human. The framework containing Zinc Oxide performed best in terms of antimicrobial property against the gram- positive as well as gram- negative bacteria, cell viability, mechanical power and biomineralization. The level of cells multiplying was, however, reduced by scaffolds containing ZnO up to 15% or 30% by weight, and

Table 1: ZnO NPs Synthesized using various plants

S. No.	Scientific Names of Plants used	Common Names of Plants used	Plant part taken	Shape of nanoparticles synthesized	Size of Nanoparticles synthesized (nm)	Ref.
1	*Azadirachta indica*	Neem	Leaves	Spherical	18	Elumalai and Velmurugan (2015)
2	*Azadirachta indica*	Neem	Leaves	Spherical	9.6-25.5	Bhuyan *et al*, (2015)
3	*Azadirachta indica*	Neem	Leaves	Hexagonal	10–30 , 9–40	Madan *et al.* (2016)
4	*Agathosma betulina*	Buchu	Leaves	Quasi-spherical	15.8, 12–26	Thema *et al.* (2015)
5	*Aloe vera*	Korphad	Leaves	Spherical, Oval, Hexagonal	8–20	Ali *et al.* (2016)
6	*Aloe vera*	Korphad	Leaves	Spherical, Hexagonal	25–65	Qian *et al.* (2015)
7	*Coptidis rhizoma*	Hu anglian	Rhizome (dried)	Spherical, Rod shaped	2.9–25.2	Nagajyothi *et al.* (2014)
8	*Phyllanthus niruri*	Bhuiamla	Leaves	Hexagonal-wurtzite	25.61	Anbuvannan *et al.* (2015a)
9	*Pongamia pinnata*	Indian beech	Leaves	Spherical	10-120	Sundrarajan *et al.* (2015)
10	*Trifolium pratense*	clover (red)	Flowers	-	<60–70	Dobrucka and Długaszewska (2016)
11	*Rosa canina*	wild rose	Fruits	Spherical	13.3, 11.3 , 25–204, 21–243	Jafarirad *et al.* (2016)
12	*Eichhornia crassipes*	Water hyacinth	Leaves	Spherical	32 ± 4	Vanathi *et al.* (2014)
13	*Ocimum basilicum*	Purple ruffles	Leaves	Hexagonal-wurtzite	<50 , 14.28	Abdul Salam *et al.* (2014)
14	*Solanum nigrum*	Black nightshade	Leaves	Quasi-spherical	20–30, 29.79	Ramesh *et al.* (2015)
15	*Anisochilus carnosus*	Kapurli	Leaves	Quasi-spherical	56.14, 49.55, 38.59, 20–40, 30–40	Anbuvannan *et al.* (2015b)
16	*Cocus nucifera*	Coconut palm	Coconut sap	Predominantly Hexagonal Sphere-shaped,	20–80, 21.2	Krupa and Vimala (2016)
17	*Gossypium herbaceum*	Cotton	Cellulosic fibre	Rod, Spherical	13	Aladpoosh and Montazer (2015)
18	*Moringa oleifera*	Horseradish tree	Leaves	Round	24, 16–20	Elumalai and Velmurugan (2015)

19	*Parthenium hysterophorus*	Congress weed	Leaves	Sphere-shaped, Hexagonal	27 ± 5, 84 ± 2	Rajiv *et al.* (2013)
20	*Plectranthus amboinicus*	Mexican mint	Leaves	Rod	88, 50–180	Fu and Fu (2015)
21	*Vitex negundo*	Nochi	Leaves	Spherical	75–80 , 38.17	Ambika and Sundrarajan (2015b)
22	*Vitex negundo*	Nochi	Flowers	Hexagonal	38.17, 10–130	Ambika and Sundrarajan (2015a)
23	*Santalum album*	Sandalwood	Leaves	Rod	100 , 70–140	Kavithaa *et al.* (2016)
24	*Nephelium lappaceum*	Hairy Lychee	Fruit peels	Like needles	50.95	Yuvakkumar *et al.* (2014)
25	*Calatropis gigantea*	Giant Milkweed	Leaves	Hexagonal crystal	30–35	Kodi *et al.* (2013)
26	*Sphathodea campanulata*	Fire Tree	Leaves	Spherical	20–50	Ochieng *et al.* (2015)
27	*Citrus sinensis*	Orange	Fruit peels	Hexagonal prisms with rounded corners, sponge-like Irregular, Oval spheres,	24.3, 22.6, and 12.7	Luque *et al.* (2018)
28	*Corymbia citriodora*	Lemon-scented gum	Leaves	Polyhedron	64	Zheng *et al.* (2015)
29	*Calotropis procera*	Milkweed (Rui)	Fruit and leaves	-	120–169	Salem *et al.* (2015)
30	*Cardiospermum halicacabum*	Balloon vine	Leaves	Spherical	10-20	Duan *et al.* (2020)
31	*Mangifera indica*	Mango	leaves	Spherical, Hexagonal-quartzite	45-60	Rajeshkumar *et al.* (2018)
32	*Veronica multifida*	speedwell, bird's eye, gypsyweed	leaves	Irregular to nearly hexagonal, Quasi-spherical	10–100	Doğan and Kocabaş (2020)
33	*Cydonia oblonga*	quince	Seeds	-	25	Tabrizi Hafez Moghaddas *et al.* (2020)
34	*Musa acuminate*	Edible bababa	Peel	Triangular	30–80	Abdullah *et al.* (2020)
35	*Melia azedarach*	White cedar	Leaf	Spherical	33–96	(Dhandapani *et al.* (2020)
36	*Euphorbia hirta*	Asthma plant	Leaf	Spherical	20–25	Ahmad and Kalra (2020)
37	*Cassia alata*	Ringworm bush	Leaf	Spherical	60–80	Happy *et al.* (2019)

38	*Coccinia abyssinica*	Anchote	Tuber	Hexagonal	10	Safawo *et al.* (2018)
39	*Urtica dioica*	Stinging nettle	Leaf	Spherical	22	Bayrami *et al.* (2020)
40	*Prunus domestica*	Plum	Fruit	Cylindrical	60-80	Singhal *et al.* (2020)
41	*Artemisia annua*	Sweet sagewort	Bark	Spherical	20	Wang *et al.* (2020)
42	*Aloe vera*	Chinese aloe	Leaf	Oval	24	Rasli *et al.* (2020)
43	*Morus nigra*	Black mulberry	Leaf	Rod, hexagonal and spherical	-	Tang *et al.* (2020)
44	*Paris polyphylla*	Satuwa	Leaf	Spherical	-	Xu *et al.* (2020)
45	*Calliandra haematocephala*	Blood-red Tassel-flower	Leaf	Flower	19	Vinayagam *et al.* (2020)
46	*Azadirachta indica*	Neem	Leaf	Spherical	20–40	Singh *et al.* (2019)
47	*Prosopis juliflora*	Mesquite	Leaf	Hexagonal	65	Sheik Mydeen *et al.* (2020)
48	*Nyctanthes arbortristis*	Night flowering	Flower	-	12–32	Jamdagni *et al.* (2018)
49	*Cinnamomum tamala*	Indian bay leaf	Leaf	Spherical, Hexagonal	26.57	Agarwal *et al.* (2019)
50	*Zizyphus jujube*	Common jujube	Fruit	Spherical	29	Golmohammadi *et al.* (2020)

Table 2: Applications of ZnO NPs in Tissue Regeneration

S. No.	**Various forms in which Zn NPs used**	**Size of the ZnONPs synthesized (nm)**	**Shape of the ZnONPs synthesized**	**Therapeutic Target Tissue**	**Observation/Result**	**Ref.**
1.	Biosynthesized from leaves extract of *Cymbopogon citratus*	50±4	Hexagonal Rod like	Tissue culture of *Panicum virgatum* (Switchgrass)	Regeneration potential improved as compare to control by addition of ZnO NPs	Shafique *et al.* (2020)
2.	ZnO NPs	30	-	Callus of *Solanum lycopersicum* (Tomato)	Most % of callus induction observed with iron oxide NPs and most regeneration rate recorded using ZnO NPs	Alharby *et al.* (2016)
3.	Nano hydroxyapatites substituted with Zn2+ (0.2%)	Length 20-50 nm, thickness 5-20 nm	Needles or Rods	Bone tissue	Synthesis of nano ms-HAP materials, used for bone healing as well as regeneration	Garbo *et al.* (2020)
4.	Zn-substituted forsterite nanoparticles	fiber diameter 542 ± 148	cylindrical and belt-like fibers	osteosarcoma cells (MG-63) of bone	Ternary PCL/SF/Mg1Zn1SiO4 scaffold has a probable	Bigham *et al.* (2021)

		nm			ability of regeneration of bone tissue	
5.	cit-Zn-Hap (Citrate Zn doped Hap) NPs	length along the longest axis is 41-60 nm	Rod	BMSCs (Stromal cells derived from Human bone marrow)	synthesized cit-Zn-Hap NPs promotes osteogenic differentiation therefore can be used as material for artificial bone regeneration	Fernandes *et al.* (2020)
6.	Ch/ G/ nHAp/ nCuZn nano composite scaffold	-	-	Mouse embryonic fibroblasts (MEFs) cells	Tissue granulation which grown under the nanocomposite framework offers a vascularized complex for next collagen deposition as well as regeneration of tissue	Forero *et al.* (2017)
7	Nanocrystalline zinc-doped carbonated hydroxyapatite (Zn-cHA)	< 210 µm	-	Bone tissue of Wistar rats	Nanostructured Zn-doped cHA showed limited osteo conductivity independent of the Zn in cHA.	Martinez-Zelaya *et al.* (2019)
8	HA/ZnO NPs	< 80	spherical	Human osteoblast cells (HOB)	Density, compressive strength and fracture toughness increased when HA modified with ZnO NPs	Heidari *et al.* (2020)
9	Zn- doped PCL-MBGNs Fibers (mesoporous bioactive glass nano particles)	Diameter around 240-385 nm	fibers	murine stromal cells (ST- 2)	Incorporation of mesoporous glass NPs doped Zn^{2+} cations under the fibers have ability to synthesize a all-in-one biomaterial appropriate for delivery of drugs as well as tissue engineering	Neščáková *et al.* (2021)
10	Zn-nBGC (nanoBioGlass Ceramics)	708 d.nm	bulbous	Murine mesenchymal stem cells [mMSC (C3H10T1/2)]	Zn-nBGC enhanced osteogenic effect therefore bone regenerative property also	Paramita *et al.* (2021)
11	ZnO NPs	20	-	Persuaded nodule from buds of apex of date palm	When adding ZnO NPs and HA to medium best result obtained in case of number of roots per shoot and their regeneration	Al-Mayahi (2021)
12	Zero valent Zinc nanoparticles comprising PCL electrospun mats	35	-	Human primary fibroblasts	Dilutions of Zinc nanoparticles like 5 and 10% promot regeneration of neurons, show comparely non-toxic effect on fibroblasts	Aydemir Sezer *et al.* (2017)

13	ZnS NP (Zinc Sulphide nanoparticles)	90	spherical	Rat skin fibroblasts	ZnS NP promoted skin regeneration instead of fibrotic healing in both studies (in vitro and in vivo)	Han *et al.* (2020)

it was discovered that these scaffolds were cytotoxic because of lots of ROS generation. As a result, the scaffold that contains 10% or less ZnO NPs could be thought of as a capable environment friendly material for bone tissue engineering (Shitole *et al.*, 2019).

Cho *et al.* (2020) evaluated the 100 – 300 nm thickness ZnO-coated poly-caprolactone/nano-hydroxyapatite scaffold's ability to promote cell growth and inhibit bacterial growth. Due to its improved cell proliferation and antimicrobial activities and best mechanical properties, they found that the framework with a 100 nm thickness ZnO coating might be the superior scaffold for regeneration of bone.

The ability of nanoHydroxyApatite/ZnO scaffolds and PolyCaproLactone/ ZnO scaffolds to regenerate bone tissue in human osteoblast cells has also been demonstrated. After being submerged in the body fluid, the nHA/ ZnO framework was found to be more rough than pure HydroxyApatite as well as high apatite deposited than on the HydroxyApatite surface. Additionally, the nHA/ZnO scaffold demonstrated superior biomineralization and biocompatibility properties. PolyCaproLactone/ZnO 0.2-1% frameworks, on the other hand, offer a nano-spongy medium for increased cell linkage and improved cell multiplication (Heidari *et al.*, 2020; Harikrishnan and Sivasamy, 2020).

Conclusion

More than 300 enzymes depend on zinc, making it a crucial element. The brief overview of an inorganic metal zinc, its all-in-one compound like ZnO as well as their applications are elaborated in this review. Numerous intriguing properties of zinc compounds and nanostructures include great stability under light, biocompatibility, biodecomposability, a broad array of absorption of UV etc.

Additionally, recent developments in biosensors of electrochemistry because of various nano compounds such as nanoflake, nanoparticles, nanoflower, nanofibers, nanobelt, nanotubes, nanowire, nanopores, nanorod etc. have made great attention in uses for the environment, agriculture, and biomedicine. Additionally, prominent features include a broad range of antipathogenic activities (for example, against foodborne microbes), ease of fabrication, enhanced analytical performance, non-toxicity, biological compatibility, greater sensitivity, high-electron transfer rates, high resistance to harsh processing conditions and low cost.

Bio/green production of nanoparticles by environment-friendly attitude has becoming the zone of attentive research in the recent years. Biomaterials act as agents which reduce as well as stabilize during synthesis of nanoparticles. Future prospect of NPs biosynthesis includes an interpretation of secondary metabolites which play role in production of nanoparticles through tools of bioinformatics, development of accurate pathway occurred in the blockage of harmful microbes and development of small laboratory level work in an industrial level work. The NPs made from plants are very much applicable in arena of cosmetics, food, chemical, space, feed, health sectors.

As Zinc have slow degradation speed and higher density, so it is most appropriate in regeneration of bones, cartilages, tooth, spines and tendons. All those studies on ZnO NPs used for regeneration mentioned earlier in literature review specified that they can be used inside the frameworks for gum, bone, tendon and nerve regeneration. ZnO NPs are currently being used very limitedly and in the early stages of tissue engineering. Therefore, more research should be done on ZnO NP`s ability to regenerate tissue.

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