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APPLICATIONS OF GREEN NANOPARTICLES FOR THE MANAGEMENT OF PLANT DISEASES: A REVIEW

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Abstract

Nanotechnology is not new in science, but utilization of the nano-based solutions for the agriculture is advance and valuable step. Nanoparticles are now widely in use due to their extreme small size and stability. Nps are prepared through various methods such as chemical, thermal and green routes, but the most effective and eco-friendly method for the synthesis of these Nps is the biological method. Green synthesis of the nano-scale particles is the most effective and becoming favorite due non-toxic nature. Nanoparticles are commonly being in use in agriculture, due to their eco-friendly and non-toxic nature. Zinc oxide nanoparticles (ZnO NPs) are being in use as pesticide, fertilizer and insecticide. Due to small size these particles are applicable as fungicide, pesticide and as fertilizer.

INTRODUCTION

Nanotechnology is now considered to be a proven state-of-the-art technology with numerous branches embedded in industrial fields such as chemical, pharmaceutical, mechanical, and food processing industries. Nanotechnology also plays an interesting role in the areas of computing, power generation, optics, drug delivery, and environmental sciences (Ramsden, 2016). Actually, nanotechnology is based on the nano-sized material having different application in science world such as physical, chemical and biological

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system, individually molecule and atoms into nano-sized material and uses these particles into these systems. This technology solves the problems and fulfils our needs for which we are trying for long time (Nasrollahzadeh et al., 2019). It has wide application in agriculture, pharmaceuticals, biomedicines, food, cosmetics and other domains (Sinha et al., 2017; Balaure et al., 2017). Nanotechnology improves the seed germination and modify target gene, nano-biosensors as well as minimize the secretion related with agriculture (Hayle et al., 2017). This technology is the combination of art and science that utilize the matter in to nanoscale sizes, specify and then use them for our desire purpose by controlling their shape and structure (Abobatta, 2018).

Nano technology is the 6th revolt technology of 21th century (Mousavi and Rezaei, 2011). It is an applied technology that evolves at the atomic level and then adapts it into a nano structure with distinctive properties. The main interest of this technology in the domain of agriculture and medical science (Bayda et al., 2020; Imani and Safaei, 2019). It has made it capable to recognize the basic properties of an object at atomic molecular and super-mol level. Beside biotechnology the nanotechnology plays the remarkable role in the science world. Biotechnology provides the role model and biosynthetic elements to nano technology while nanotechnology provides different technological techniques to explore and create bio-active compounds (Keat et al., 2015).

The formation and functions of materials whose atoms exist at nanoscale and have size less then 100 is known as nanotechnology. At the molecular and a sub molecular level, this technology studies electrical, optical and magnetic activity as well as structural behavior. It has capability to revolutionize a variety of medical and biotechnological instruments and methods by making them more efficient, low cost, safe and easy to use (Hasan S, 2015). Nanoparticles have distinctive properties because of their small size, so they range of applications but they also possess serious enviroental hazards. In the recent decade the ecotoxicity of environment increases regardless their benefits they also cause the harm to environment (Reboredo et al., 2021).

There are different types of Nanoparticles including metal nano-particle, ceramic nono-particles and polymeric nano-particle have been generated and studied. They have demonstrated and influence in a compass of fields including homogenous and heterogeneous catalysis, nano-medicine and imaging (Pedon et al., 2017). Their synthesis techniques have been refined to paragon with accurate command over particle size and shape (Pedon et al., 2017). In recent year's ceramic nanocomposite have taken alots of attention when it is compared with ordinary ceramic matrix composites due to their competent of increasing thermal, mechenical and electrical properties (Palmero, 2015; Rathod et al., 2017). Nanosphereand Nano capsules, which have different formation structures, but both are nanoparticles. Polymeric NPs have a lot of applications in terms of delivering drugs to accurate areas for the treatment of diseases (Musumeci et al., 2019).

Zinc oxide nanoparticles are important in a variety of a pplications, such as gas devices, biodevices, chemical sensors, superconductors, optoelectronic devices, varistors,

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cosmetics, photocatalysts, diodes, field emitters, and piezoelectric devices as well as solar energy conversion. These particles are commonly in use for the manufacture of variety of medicine, food products and products for commercial use. ZnO Nps are multifunctional material due to having unique physical and chemical properties, such as high chemical stability, high electrochemical coupling coefficient, broad range of radiation absorption and high photostability. Moreover these are also recommended to use in variety of cosmetic products being nontoxic (Segets et al.., 2009).

Nanoparticles made by chemical, physical or biological processes (in biological techniques plants and microbes' techniques are most popular) as shown in figure 1. In biofabricated procedures highlight the use of natural vegetation by the use of microbes, microalgae, natural vegetation, plants, enzymes and plants extract that provide inexpensive, and reliable method with notoxity, ecofreindly, a stable nature and environment friendly results, (Menon et al., 2019). Green source-mediated synthesis allows nanoparticle size and produce because of plants function in stabilizing and reducing agents. Green nanoparticles have a much least inhibitory effect as compared to chemically formed nanoparticles.

Application of ZnO Nps

There are numerous applications of zinc oxide nanoparticles in almost all areas of sciences. These particles are applied in chemical, physical and biological areas widely, it plays an important role in a very wide range of applications, ranging from tyres to ceramics, from pharmaceuticals to agriculture, and from paints to chemicals. It covers almost all disciplines of science Figure 1 around the globe (Radzimska and Jesionowski, 2014).

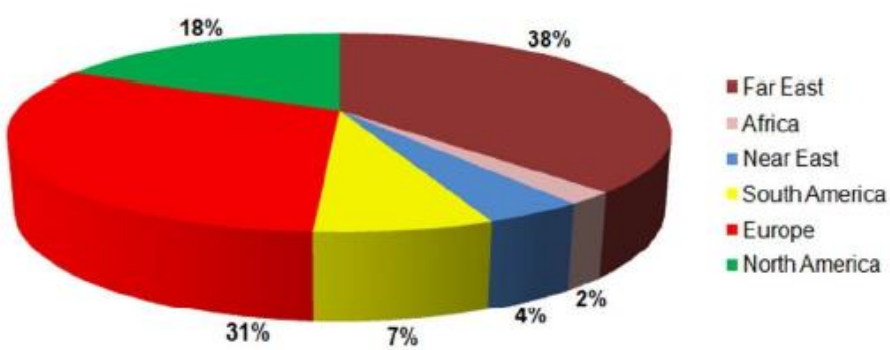

Figure 1 : Applications of ZnO (Radzimska and Jesionowski, 2014)

APPLICATION OF ZINC OXIDE NANOPARTICLES IN AGRICULTURE

Nanotechnology has a dominant position in transforming agriculture and food for both production and protection. Nanotechnology has a great potential to modify conventional agricultural practices with better production. Most of the agrochemicals applied to the

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crops are lost and do not reach the target site due to several factors including leaching, drifting, hydrolysis, photolysis and microbial degradation (Shang et al., 2019). These particles are used for the synthesis of pesticides and fertilizers in a controlled fashion with high site specificity thus reducing collateral damage. Farm application of nanotechnology is gaining attention by efficient control and precise release of pesticides, herbicides and fertilizers.

Anti-bacterial activity potential:

ZnO is the universal Nanoparticles that are anti-bacterial and inhibit the growth of micro-organisms by disrupting the cell membrane of the bacteria.The oxidation stress demage lipids, carbohydrates, protein and DNA (Reshma et al., 2017). The changes in the lipids eventually stop the junction of cell membrane and the activity of bacteria. However, ZnO generate hydrogen peroxide that has been suggested to describe the antibacterial properties. Since ZnO is amphoteric in nature so, it react with both acids and alkalis Zn positive ions. The free Zn ions immediately ions bind with the biomolecules like proteins, carbohydrates and all the functional activity of bacteria cease (Fatehah et al., 2014). Toxicity of Zinc oxide, zinc sulphide seven molecule of water has been examined on *vibrio fischeri* zinc sulphide and water is more toxic (Halbus et al., 2020). In the recent last year the activity of ZnO Nps, discovered on four gram positive and gram negative bacteria named as *staphylococcus aureus, Escherichia coli, salmonella typhimurium, kebsilla pneumoneae* (Figure 2)

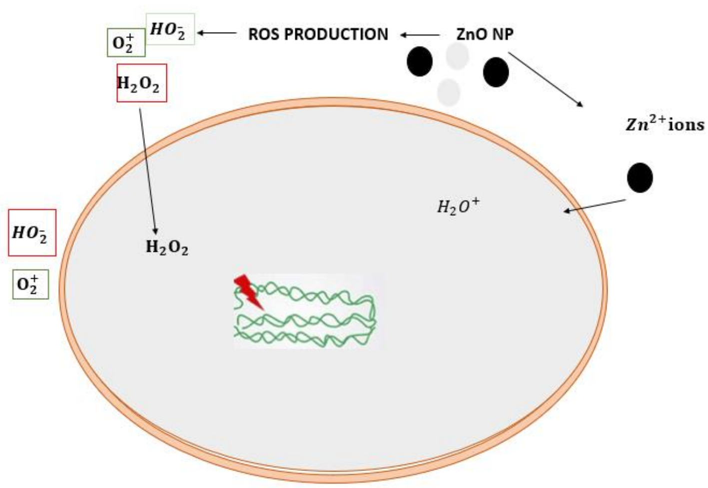

Figure 2: Presenting mode of action of ZnO NPs against bacteria

(1) ZnO NPs allow to leave Zn ions that inter into the bacteria and disturbs the enzyme mechanisms (2) ROS production that become the reason destruction of cells components like Lipids, DNA and Proteins and cause loss of cell integrity.

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Fertilizer:

ZnO-NPs isa suitable for use as a foliar-applied fertilizer for enhance the Zn concentration in wheat grain. We observed that the application of ZnO-NPs enhanced the grain Zn concentrations from 18 mg·kg−1 in the control to 30 mg·kg−1 when put in two times and to 40 mg·kg−1 when put in four times (sun et.al 2020). ZnO NPs application a bit change in the amino acids content of rice grains, but had no notable impact on total number of amino acids content (Guoying et.al 2021)Foliar application of ZnO-NPs also enhance the improvement of other elements in the grain and enhanced the nutritional quality of the grain (sun et.al 2020).These observation displays that ZnO NPs are a good fertilizer for increasing Zn within the wheat grain and can also potentially be used to increase human nutrition (sun et.al 2020). Compared with formal fertilization, ZnO NPs increased Zn concentration of brown rice by 13.5-39.4%, it has no harmful impact on the health of human. ZnO NPs application at bunching stage have a greater positive effect in improving Zn concentration of brown rice than at base and agriculture stage (Guoying et.al 2021).

Pesticidal applications of ZnO:

Nanotechnology based products are used to increase the production of crop as well as protection of crop. In the past time farmers use the over-dose of the dangerous insecticides, fungi and herbicides in order to protect the crop. Approximately 90% pesticide have no their proper target sites, so they absorb in the soil and vanish the enviroent which makes them non effective for the pest management (Levard et al 2012). They increase the crop protection expenses, but also damage the environment with the toxic material. The effective management of pest needs the active ingredient at the target in order to reduce the concentration for assurance of improved plant protection from pest and subsequent crop close (Khan et al 2011; Levard, et al 2012). In recent era we use nanotechnology to develop the nano-based pesticides in the crop protection (Figure 3). In the nano formulation of the pesticides enclose nanoscale particles which contain the active ingredient for the target site with functional pesticidal properties.The nano capsulation pesticides contain the active ingredient along with the coated material and designated as internal phase of core material and capsulation material are referred as external phase the coating nanomaterial Nano pesticides enhance the yield increasing the pesticide efficiency by modeling transport potential of pesticide (Wohlleben et al., 2017).

The promising application of the nano engineered particles are also established in the weed and management system. Inorganic NPs such as Ag, CaO, MgO, SiO2, TiO2, and ZnO they all play the important role in the plant protection together with bacterial diseases and microbial activity (Nuruzzaman et al., 2016). For example, ZnO nano particles are being reported to provide improved growth control of Alternaria alternate, Rhizopus stolonifer, Mucor plumbers and penicillium expansum (Haq et al., 2019).

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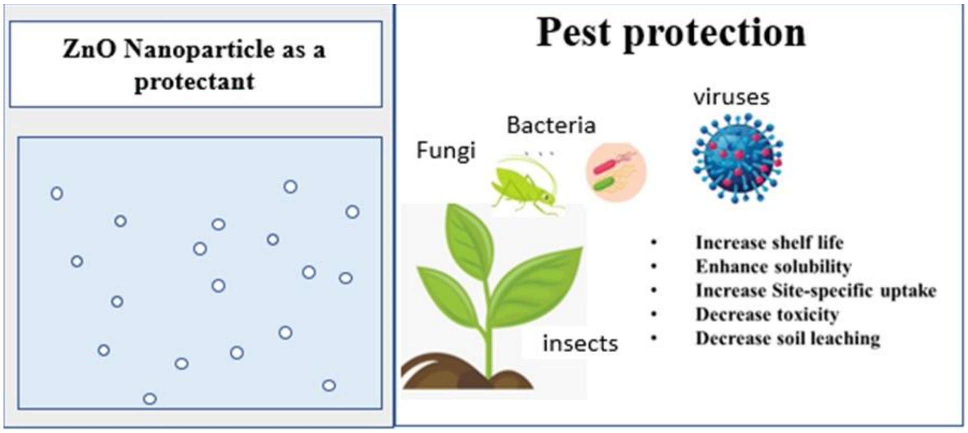

Table 1: Characterization and applications of Zinc oxide nanoparticles (Zno Nps)

Sr No	Salt	Plant Extract	Part of Plant Used	Size of Nps (nm)	Shape	Characterization	Activity	References
1.	Hydrated zinc nitrate	Agthosma Betulina	Leaves	15.8	Spherical	Spectroscopy, X-rays diffraction, IR and Raman spectroscopy	Photolytic activity	Thema et al, 2018
2.	Zinc nitrate	Calotropis Gigantean	Leaves	30-35	Spherical, and hexagonal	SEM, X-ray diffraction	Photocatalytic activity	Vidya et al,2013
3.	Zinc nitrate	Orange fruit peel	Aqueous extract	-	Deepened on parameter	UV Light	Antibacterial activity	Thi et al, 2020
4.	Zinc nitrate	Orange	Leaves, roots, seed	14	Spherical	XRD, TEM, FTIR	Anti-bacterial activity	Xu et al, 2021
5.	Zinc nitrate	Hibiscus Sabariffa	Flower extracts	30 to 8	Semi circular	XRD, FTIR	Photocatalytic activity	Robles et al, 2019
6.	Sodium chloride	Sanbuscus nigra L	Fresh shoots	500	Crystal structure	XRD, field emission electroscope, TEM	exhibited low toxicity on A549 cancer cells	Cao et al, 2021
7.	Zinc nitrate hexa hydrated	Dysphonia ambrosioides	Dry leaves	5-30 Commercial size range 15-35	Quasi-spherical (circles), irregular shape	X ray diffraction (XRD). Field emission electron microscopy. TEM, FTIR and thermogravimetry (TG).	Structural characterization	Chimal et al, 2021
8.	Zinc acetate dehydrate	Pomegranate peel	Food waste, cotton	…….	Irregular shape	XRD, AFM, SEM, ICP-Ms	In-situ synthesis of cotton fabric	Verbič et al, 2021
9.	Zinc nitrate	Parthenium hysterophous	Fresh leaves	10	spherical	XRD, FT-IR, TEM, SEM	Anti-microbial activity	Umavathi et al, 2021

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10	Zinc acetate	Syzygium cumini	Leaves	10-12.55	Crystal structure	XRD, SEM, FTIR	Photocatalytic	Sadiq et al, 2021
11	Zinc chloride, sodium Hydroxide	Brassica oleracea L. var. italic	Broccoli leaves	17	Hexagonal	XRD, EDX, TEM, FTIR.	Photolytic activity	Osuntokun et al, 2019
12	Zinc acetate dehydrated	Eriobutria japonica	Seed	50	Hexagonal wurtzite	XRD, EDX, FTIR.	Photocatalytic activity	Nazir et al, 2021
13	zinc acetate dehydrates	Myristica fragrans	Fruit	41.23	Spherical and ellipitical	XRD, TEM, TGA	Antibacterial Assay	Faisal et al, 2021
14	Zinc acetate	Syzygium cumini	Leaves	10-12.55	Crystal structure	XRD, SEM, FTIR, UV-vis spectrophotometer	Photocatalytic activity	Sadiq et al, 2021
15	Silver nitrate, zinc acetate dehydrate	Prosophis fracta	Seed	16-26	Spherical shape	UV- visible spectroscope, X-ray diffraction.	Antibacterial activity	Khatami et al, 2018
16	Zinc nitrate	Prunus Dulcis	Almond gum	30	Hexagonal shape	x-ray diffraction	Antimicrobial activity	Anand et al, 2019
17	Zinc acetate dehydrate	Solanum Rantonnetii	Leave	12	uniform spherical	SPR, XRD FTIR	antifungal activity	Radoli et al, 2020
18	Zinc nitrate hexahydrate	Tilia Tomentosa	Leave	22	single-phase hexagonal structure	XRD, SEM,	Photochemical activity	Altaf et al 2021
19	Zinc nitrate hexahydrate	Ailanthus altissima	Fruits	5-18	Crystalline nature	SEM XRD	Antibacterial activity	Shashanka et al 2020
20	Zinc chloride	Capsicum annuum)	Pepper	11	crystalline	SEM XRD	antioxidant activity	Awwad et al, 2022
21	Sodium hypochlorite (NaOCl)	Sambucus nigra	Shoot	98	hexagonal	XRD, FEG, SEM, EDX analysis	Applied in cancer therapy	Rosado et al, 2021
22	Zinc nitrate	Orange	Peel	10	spherical	XRD, EDX, XPS	Gas sensor	Coa et al, 2021
23	Zincnitrate hexahydrate	Limonia acidissima	Leaf	12-53	spherical	FTIR, EDAX, AFM, XPS, ATR	Antibacterial activity against Mycobacterium tuberculosis	Gonçalves et al, 2021
24	Zinc acetate dehydrate	Pomegranate	Peel	37.6	spherical	SEM, FTIR, ICP-MS		Kalpana et al, 2018
25	Zinc nitrate	Parthenium hysterophorus	Leaf	10	spherical	UV, FTIR, XRD, TEM	Anti-microbial activity	Verbič et al, 2021
26	Zinc acetate dehydrate	Pseudomonas aeruginosa	Bacterial stain	15	spherical	TEM, FTIR, XRD	Activity against	Ogunyemi et al, 2019

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							pathogenic microbes	
27	Zinc acetate dehydrate	Myristica fragrans	Fruit	0.04ppm	Crystalline	FTIR, UV, XRD, SEM	Energy conservation, textile, electronics, health care	Abdo et al, 2021
28	Zinc nitrate hexahydrate	Cordia myxa	Leaves	wurtzite shaped	25	UVS, CFE-SEM, FTIR, ATR	Anti-bacterial activity	Faisal et.al, 2021
29	Zinc chloride	kaolinite and coconut	Husk	Crystalline	20	EMP, XRD, FTIR	Removal of ciprofloxacin (CIP) and tetracycline (TET)	Saif et al, 2019
30	Zinc acetate	Arthrospira platensis	Metabolites	spherical	30	FTIR, TEM, EDX, SEM	Anti-microbial activity	Egbedina et al,2021
31	Zinc nitrate	Calotropis Gigantean	Leaves	Spherical, and hexagonal	30-35	SEM, X-ray diffraction	Anti-microbial activity	El-Belely et al, 2021
32	Zinc nitrate	Hibiscus sabariffa	Flower	8 to 30	Semi circular	XRD, FTIR	Photocatalytic activity	Vidya et al,2013
33	Zinc nitatre	Parthenium hysterophous	Leaves	10	spherical	XRD, FR-IR, TEM, SEM	Antimicrobial activity	Robles et al, 2019
34	Zinc acetate dihydrate	Pomegranate	Food waste	0.201	Irregular shape	XRD, AFM, SEM, ICP-Ms	In-situ synthesis of cotton fabric	Verbič et al, 2021
35	Zinc nitrate	Dysphonia ambrosioides	Dry leaves	15-35	Quasi spherical	XRD, field emission electron microscopy. TEM, FTIR and thermogravimetry (TG)	Structural characterization	Chimal et al,2021
36	Zinc nitrate	Parthenium hysterphorous	Leaf	10	Spherical	XRD, FTIR, SEM	Anti-microbial and vegetative growth	Umavathi et al, 2020
37	Zinc acetate dihydrate	Pseudomonas aeruginosa	Biomass filtrate	379	Irregular shape	UV-vis spectroscopy, TEM, FTIR, XRD	Activity against pathogenic microbes	Abdo et al, 2021
38	Zinc acetate	Lemon	Bulb (Juice)	21.5	Spherical	FTIR, XRD, TEM	Degradation of dyes	Davar et al, 2020

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39	Zinc nitrate	Aspalathus linearis's	Natural extract	9	Plethora shape	XRD, RAMAN, XRP, EM	Reducing/oxidizing agent	Kanay et.al, 2018
40	Zinc nitrate hexa hydrate	Tilla tomentosa	Leave	22	Single phase hexa gonal	XRD, FTIR	Photochemical activity	Shashank et al, 2021
41.	Zinc nitrate Zn (NO3)2	Daphne oleoides	Leaf	38	Spherical	GC-MS, Field Emission Scanning Electron Microscopy, FTIR, XRD, EDS	Antibacterial. Against pathogenic bacteria	Gupta et al,2018
42	Zinc acetate	Catharanthus roseous	Dried leaves	50-92	Hexagonal Wurtzite	UV-Visible Spectroscopy-Ray Diffraction, Foureior Transform Infrared Spectroscopy, SEM, EDX, TEM	Antimicrobial	Elshayb et al, 2021
43.	Zinc sulfate	Phaeophyta (brown algae)	Algae	31.4	Spherical	XRD, TEM, Selected Area Diffraction, Zetasizer Nano, Malvern Instrument	Plant growth, high yield	Abdelbaky et al, 2022
44.	zinc acetate	Pelargonium ordoatissimum (L.)	Aqueous leaf	21.	Spherical and hexagonal	UV-spectroscopy, dynamic light scattering, FTIR, XRD, EDX, TEM,	Antioxidant, Antibacterial, Anti –inflammatory.	Nadeem et al, 2018
45.	Zinc acetate	Silybum marianum (wild plant)	Tissues, seeds	30.8-4.0	spherical	XRD, FTIER, SEM	Antibacterial potency, antioxidant	Nadeem et al, 2018
46.	Zinc nitrate hexahydrate	Cinnamomum uverum	Bark	280	Hexagonal wurtzite	X-ray diffraction, sac caning electron microscopy, transmission microscopy	Antimicrobial/antibacterial agent against harmful pathogens	Hashmi et al, 2016
47.	Zinc acetate	Olive (oleo europaea)	Leaves	41	Spherical	FTIR, TEM, XRD	Antioxidant	Faisal et al, 2021
48.	Zinc acetate	Meristic fragrant	Fruit	41.23	Spherical, elliptical	SEM, TEM, FTIR	Antibacterial	Jayachandran et al, 2021
49.	Zinc nitrate hexahydrate	Cayratia pedata	Leaf	52.24	agglomerated	Field emission electron saccaing microscope, FTIR, energy dispppersive spectrum, XRD	Immobilization of cysteine functionlized enzyme	Matinise et.al, 2017

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							immobilization	
50.	Zinc nitrate hexahydrate	Moringa oleifreria	Leaves	32	Crystalline	CV, XRD, SEAD, Cbarxheter	Electrochemical activity	Matinise et.al, 2017
51	zinc nitrate,	Nelumbo nucifera	Leave	3-4	crystalline	UV-vis spectroscopy, XRD, EDX analysis, TEM and FESEM	Photophysical activity	Narayana et.al, 2021
52	zinc nitrate hexahydrated	Deverra tortuosa	aerial parts	1–100	crystallite structure	UV-Vis spectroscopy, FTIR, XRD and HR-TEM	Cytotoxic Activities	Selim et al, 2020
53	zinc acetate	Hyssops officinalis L.	Dry powerder	20-40	spherical	transmission electron microscopy, field emission scanning electron microscopy, X-ray powder diffraction and Fourier transforms infrared spectroscopy techniques	Antiinflammaotry activity	Ghasim et al, 2018
54	Zinc acetate dehydrate	Raphanus sativus var. Longipinnatus	Leave	12-15	partial crystal spherical shape	UV–vis, FTIR, particle size analysis, SEM, XRD	Anticancer activity	Umamaheswari et al, 2021
55	zinc acetate dihydrate ((CH3COO) 2Zn·2H2O),	Spartina alterniflora	biochar	5-40	fluffy structure with variable-sized pores,	SEM, TEM, FT-IR, Raman, X-ray photoelectron spectroscopy ultraviolet–visible spectroscopy UV–vis DR, photoluminescence PL and N2 adsorption–desorption isotherm.	Photolytic activity	Hua et al, 2021
56	zinc acetate dihydrate was used (CH3COO)2 Zn2H2O)		Leave	30	a hexagonal-type structural	ultraviolet–visible spectroscopy UV–vis DRS,	Enzymatic activity	Jing et al, 2021
57	Silver nitrate	Thymus vulgaris (T. vulgaris)	Leaf extract	5	Metallic structure	XRD, FTIR, UV-Visible, TEM, EDX, and SAED techniques	Antimicrobial Activity	Abolghasemi1 et al 2019
58	zinc nitrate	Cordia myxa	Leave	9-11	Hexagonal and trigonal	UV–Visible spectral analysis, FT-IR,CFE-SEM,EDX	Antibacterial activity	Saif et.al 2019

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59	zinc acetate dihydrate Zn (CH3COO)2 ·2H2O	Pseudomonas aeruginosa	Biomass	6-21	Spherical shape	FT-IR, TEM, and XRD	Antibacterial activity	Abdo et.al 2021
60	zinc nitrate	Parthenium hysterophorus	Leaf extract	10	hexagonal phase structures	UV–vis and FT-IR	Antimicrobial activity	Райгель et al, 2021
61	Copper oxide	Sambucus nigra L. extract	Fresh shoots	20-130	crystal	X-ray diffraction, field emission gun- scanning electron microscope, transmission electron microscope, SAED	Anti- cancer activity.	Umamaheswari et.al 2021
62	Zn (OH)2	Platenium hysterophorus	Leaves	10	spherical	FT-IR, UV-vis, SEM, TEM	Anti-microbial activity	Verbič et al 2021
63	Zinc acetate dihydrate	M.fragrans plants	Fruit	66, -22.1mv	Spherical, eliptical	XRD, FTIR, UV, SEM, TEM, DLS TGA	Anti-bacterial activity	Vidya et al, 2013
64	Zinc acetate dihydrate	Pomegranate and wood ash	Peel	37.6-96.7	crystals	XRD, FTIR, UV, AFM, SEM, ICP-MS	Photocatalytic activity	Ashwini e.t al ,2021
65	Zinc nitrate	Calotropis Gigantean	Leaves	30-35	Spherical, and hexagonal	SEM, X-ray diffraction	Photocatalytic activity	Jiménez-Rosado et al, 2022
66	Zinc nitrate hexahydrate	Cayratia pedata	Leaf, roots and flower	52.24	crystalline	XRD, UV, FTIR, EDX, FESEM	Anti-microbial, anti-bacterial,	Thi et al, 2020
67	Zinc chloride	Capsicum annuum	Pepper	11	crystalline	SEM, XRD	Antioxidant activity	Dogan et al, 2020
68	Zinc acetate dihydrate	Orange	Peel	Depends upon physiochemical parameters	Crystal	X-Ray, FTIR, TEM	Anti-bacterial activty	sAwwad et al, 2022
69	Zinc acetate	V. Multifida	Aqueous plant	10-100	Hexagonal and quasi spherical	XRD, UV Vis, FTIR, SEM, TEM	Anti-biofilm activity	Vidya et al, 2013
70	Zinc nitrate hexahydrate	Ailanthus altissima	Fruit extracts	5-18	spherical	XRD, FTIR, SEM, TEM	Anti-bacterial activity	Thi et al, 2020
71	Zinc nitrate	Calotropis Gigantean	Leaves	30-35	Spherical, and hexagonal	SEM, X-ray diffraction	Photocatalytic activity	Soto-Robles et al 2019
72	Zinc nitrate	Orange fruit peel	Aqueous extract	Depend on parameters	Deepened on parameter	Uv Light	Antibacterial activity	Cao et al, 2021
73	Zinc nitrate	Hibiscus Sabariffa	Flower extracts	30 to 8	Semi circular	XRD, FTIR	Photocatalytic activity	Álvarez-Chimal et al, 2021

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74	NaOCl	Sanbuscus nigra L. extrarct	Fresh shoots	500	Crystal structure	XRD, field emission electron scopy, TEM	exhibited low toxicity on A549 cancer cells	Sadiq et al,2021
75	Zinc nitrate hexahidrated	Dysphonia ambrosioides	Dry leaves	5-30 Commercial size range 15-35	Quasi-sperical (cricles), irregular shape	X ray diffraction (XRD). Feild emission electroicroscopy. TEM, FTIR and TG.	Structural characterization	Shashanka et al, 2022
76	Zinc acetate	Syzygium cumini	Leaves	10-12.55	Crystal structure	XRD, SEM, FTIR, UV-vis spectrophotometer	Photocatalytic activity	Sadiq e.t al, 2021
77	Zinc nitrate hexahydrate	Tilia Tomentosa	Leave	22	single-phase hexagonal structure	XRD, SEM,	Photochemical activity	Anand et al 2019
78	Zinc acetate dihydrated	Eriobutria japonica	Seed	50	Hexagonal wurtzite	XRD, EDX, FTIR.	Photocatalytic activity	Jejenija et al, 2019
79	Zinc nitrate	Prunus Dulcis	Almond gum	30	Hexagonal shape	x-ray diffraction	Antimicrobial activity	Thema e.t al ,2015
80	Zinc chloride, sodium hydroxide	Brassica oleracea L. var. italica	Broccoli leaves	17	Hexagonal	XRD, EDX, TEM, FTIR.	Photolytic activity	Vidya e.t al, 2013
81	Zinc acetate dihydrate	Melia azadrech and Cassiafistula	Leaf	3 to 68	Spherical	XRD, FTIR, STEM, UV-VIS, DLS	Antimicrobial	Thi et.al, 2020.
82	Zinc Nitrate	Myristica fragrans	Fruit	43.3	Spherical	XRD, FTIR, STEM, TEM, TGA, DLS	Larvicidal	Xu et. al, 2021.
83	Zinc acetate	Coriandrium sativum	Leaf	100	Rod and spherical	XRD, SEM, TEM	Synergistic	Soto-Robles et.al, 2019.
84	Zinc nitrate	Citrus sinensis	Fruit	11-95	Spherical		Antibacterial	Cao et.al, 2021.
85	Zinc chloride and sodium hydroxide	Brassica oleracea L.var.italica	Vegetable	14-17	Hexagonal	XRD, TEM, FTIR, EDX, UV, P	Photocatalytic	Chimal et al,2021
86	Zinc nitrate hexahydrate salt	Eucalyptus globulus labill	Leaf	27-35	Spherical	XRD, FE-SEM, EDX, BET, DSC, FTIR	Physiochemical and Antimicrobial	Verbič et. al, 2021.
87	Zinc acetate dihydrate	Hibiscus subdariffa	Leaf	12-46	Elongated, spherical	XRD, FTIR, UV-VIS	Antibacterial and antioxidant	Umavathi et .al, 2021.
88	Zinc acetate dihydrate	Peganum hamla	Leaf	39.94	Spherical	XRD, SEM, EDX	Antibacterial	Sadiq et. Al, 2021.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/2G8JN

89	Zinc nitrate	Parathenium hysterophorus	Leaf	10	Spherical	XRD, SEM, TEM	Antimicrobial	Kumari et al ,2022
90	Zinc nitrate	Anoectochiles elatus	Leaf	60-85	Spherical	XRD, SEM, UV	Antimicrobial, anti-inflammatory, antioxidant	Shabaani et al ,2020
91	Zinc nitrate	Prosphis fracta	Seed	16-26	Spherical	UV-visible, XRD	Antimicrobial activity	Faisal et al, 2021.
92	Zinc acetate dihydrate	Solanum rantonnetii	Leaf	12	uniform spherical	FTIR, XRD, SPR	Antifungal	Sadiq et al, 2021.
93	Zinc acetate	Syzgium cumini	Leaf	10-12.55	crystal structure	FTIR. XRD, SEM	Photocatalytic	Khatami et al, 2018.
94	Zinc nitrate hexahydrated	Dysphonia ambrosiodes	dry leaf	5-30	irregular	FTIR, XRD, TEM	structural characterization	Anand et al, 2019.
95	Zinc nitrate	Calorops gigantean	Leaf	30-35	spherical and hexagonal	XRD, SEM	Photocatalytic	Naseer et al, 2020.
96	Zinc nitrate	Prunus duclis	almond gum	30	hexagonal	XRD	Antimicrobial	Shashanka et al, 2020.
97	Zinc nitrate hexahydrate	Ailanthus altissima	Fruits	5-18	crystalline structure	XRD, SEM	Anti-bacteriaL	Awwad et al, 2020.
98	Zinc acetate hydrate	Eriobutria japonica	Seed	50	hexagonal	FTIR, XRD, EDX	Photocatalytic	Jiménez-Rosado et al, 2022.
99	Zinc nitrate hexahydrate	Tilia tomentosa	Leaf	22	single phase hexagonal	XRD, SEM	Photochemical activity	El-Belely et al, 2021.
100	Zinc chloride	Capsicum annum	Pepper	11	crystalline	XRD, SEM	Antioxidant	Hashemi et al, 2021.
101	Zinc nitate	Arthrospira platensis	Platensis part	e ≈30.0 to 55.0	spherical, crystallographic	UV–V is spectroscopy, FT-IR, TEM, EDX,XRD, and XPS	Antimicrobial activity	Ramya et al, 2021
102	Zinc nirtate	Olea europapea	Leave	41	spherical	FTIR, TEM, XRD and DLS	antiradical scavenging activity	Rathnasamy et al, 2017
103	zinc (II) nitrate hexahydrate (Zn $(NO_3)_2·6H_2O$)	Psidium guajava	Leaf extract	27	wurtzite hexagonal structure	EDAX analysis	photoluminesce	Raunak et al, 2018
104	zinc acetate dihydrate	Carica papaya	Leaf	~50	hexagonal wurtzite	UV–Visible spectroscopy	photocatalytic	Naseer et al,2020

Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/2G8JN

						system. FESEM and TEM analysis	and phot ovoltaic	
105	Methyl orange	Calotropis procera	leaf extract	15 to 25	Spherical shape	XRD, DRS, TEM and FT-IR	photocat alytic applicati on	Souri et al, 2018
106	M zinc acetate dihydrate	Cassia fstula and Melia azadarach	Leaf extract	3.62	airly well-defned	XR, FTIR spectroscopy, SEM, UV-Vis and dynamic light scatteringDLS	antibacte rial potential	Sathappan et al, 2021
108	zinc nitrate	Cissus quadrangulari s	Stem part	23-64	hexagonal wurtzite phase	UV, FTIR, XRD and SEM	antihelmi ntic, antibacte rial, antiarthrit ic and antioxida nt activities	Naraian et al, 2016
109	Zinc acetate (Zn (CH3COO) 2	FICUS HISPIDA L	Leaf extract	11	Wurtzite structure	UV-Visible,UV-Vis, XRD	Antioxida nt activity	Alayande et al,2019
110	Zinc sulphate	Musa ornate flower sheath	Aqueous extract	36	Spherical	UV– visible spectrophotomete r,XRD, FTIR,SEM,TEM	Antimicro bial activities	Sultana, et.al,2017
111	ZnNO3 Zinc nitrate	Amaranthus spinosus	Leaf extract	8-14	rod shaped with hexagonal phase structure	X-ray analysis TEM-EDAX, XRD	antioxida nt, photocat alytic and antibacte rial activities	Mehndi et al,2017
112	Zinc acetate dihydrate	Polygonum chinense	Leaf extract	16.64	crystalline phase formation	UV-visible spectroscopy UV-vis, FTIR and XRD.	Antibacte rial activity	Vijayakumar et al,2016
113	Zinc acetate	Peganumharm ala	Seeds	37	Crystalline	UV–vis spectrophotomete r	Antibacte rial activity	Ansari et al, 2020
114	(Zinc acetate and zinc nitrate	Laurus nobilis L	Leave extract	(21.49, 25.26)	Spherical shape	UV–Vis,FT-IR, XRD, EDX and SEM	Toxicity	Nadeem et al, 2018
115	Zinc acetyle	Cinnamomum verum	Bark part	~45	Crystalline	X-ray diffraction and microscopic techniques such as scanning electron microscopy and transmission electron microscopy.	Antibacte rial activity	Santhosh et al,2017
116	Zinc nitrate (Zn	Silybum marianum L	Seed part	22-23	Spherical	FT-IR spectra,BET and BJH	antidiabe tic and antibacte	Farid et al,2019

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/2G8JN

	(NO3)2·6H2O)						rial activities	
117	Zinc acetate [Zn(O2CCH3)2(H2O)2	Passiflora caerulea f	Leaf	70	Spherical shped	UV–vis,XRD,FT-IR, SEM	Antibacterial activity	Chimal, et al, 2021
118	zinc acetate dihydrate Zn (Ac)2·2H2O	Pichia kudriavzevii	Fruit	~10–61	hexagonal wurtzite structure	XRD and TEM technique	Antimicrobial and Antioxidant Activities	Hossain et al, 2019
119	Zinc nitrat	Astragalus membranaceus (AM	Leaf extract	38.54 to 11.68	spherical in shape	X-ray diffraction analysis	Antioxidant	Ropa et al, 2019
120	Zinc oxide	Xanthomonas oryzae pv. Oryzae	Flower	40.5 to 124.0	Crystalline shape	FTIR,XRD,TEM and SEM	antibacterial activity	Abdelbaky et al, 2022
121	Ethylene glycol	Lemon	Fruit	100	Cylindrical	FTIR, XRS, TEM, XRD, SEM	antibacterial activities against Dickeya dadantii	Abdelbaky et al, 2022
122	Zinc nitrate hexahydrate	Sea buckthorn	Fruit	17.15	Hexagonal	FE-TEM; JEM-2100 F, JEOL, USA	Degradation of industrial dyes and treatment of waste water	Irfan et al, 2021
123	sodium tripolyphosphate	Tomato	Aqueous extract	31.3 to 88.9	Spherical and hexagonal	SEM, TEM, XRD, FTIR	Anti-bacterial activity against rice pathogen	Zaki et al, 2020
124	Zinc acetate dihydrate	Pelargonium odoratissimum	Leaf	34.12	hexagonal pure Wurtzite structure	UVS, DLS, FTIR, XRD, HRTEM	Anti-oxidant, anti-bacterial, anti-inflamatory	Elsayed et al, 2022
125	Zinc nitrate hexa-hydrate	Pomegranate	Leaves and flower	56.75	Un-even round	XRD, TEM, SEM,	Anti-bacterial activity	Elshayb et al, 2021
126	Zinc chloride	Guava	Plant	41,34	Hexa-gonal	SEM, XRD,	Self-cleaning and anti-microbial activity	Hashemi et al, 2016
127	Zinc acetate dihydrate	Cotton	Plant	8-23	Crystalline	XRD, SEM, TEM, EDX, FTIR	Controlling soil born pathogen	Ogunyemi et al, 2019
128	Zinc nitrate	Dates	Palm, pits extract	46,2	Crystal	XRD, TEM, EDX, FTIR	Adsorption and	pooja et al, 2022

Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/2G8JN

							photocat alytic degardio n	
129	Zinc sulfate hexa-hydrated	Rice	Grain	31.4	Crystalline	XRD, TEM, SAED	Enhance grain yeild	Ukidave et al, 2022
130	Zinc nitrate	Olive	leave	41	Spherical	FTIR, TEM, XRD, DLS	Anti-radial scavengi ng activity	Abdo et al, 2021
131	Zinc nitrate	Chamomile	Flower	48.2	Crystalline	UV-VS, FTIR, XRD, TEM	Antibacte rial activity	Jamdagni et al, 2018
132	Zinc acetate dihydrate	Eucalyptus lanceolatus	Leaf	100	Hexa-gonal	FTIR, XRD, TEM, UVS	Anti-fungal activity,	Modi et al, 2022
133	Zinc acetate	Coriandrum sativum	Leaves	78 to 84	Crystalline	XRD, TEM, SEM, PTC	Use as fertilizer	Haque et al, 2022
134	Zinc acetate dihydrate	Pseudomonas aeruginosa	Biomass filtrate	21	Crystalline	UV-VS, FTIR, SEM. TEM	Activity against pathogen ic microbes	Alaghemand et al, 2018
135	Zinc acetate	Nyctanthes arbor-tristis	Flower	12 to 63	Crytalline	XRD, DLS, TEM,	Anti-fungal activity	Sabir et al 2014
136	Zinc chloride	Onion	Peel waste	100	Spherical	FTIR, DLS, FESEM	Activatio n of enzymes	Jamdagni et al, 2017
137	Zinc acetate dihydrate	Azadirachta Indica	Leaf	25.97	wurtzite hexagonal	XRD,	Anti-bacterial analysis, photo catalytic analysis	Mehar et al, 2019
138	Zinc nitrate	Nigella Sativa L.	Seed	20	Hexa-gonal	XRD, SEM	Effect on the Height and Number of Branche s	Umavathi et al, 2021
139	Zinc nitrate	Calotropis gigantean	Leaf	25	Crystalline	XRD, FTIR	photocat alytic degradati on materials of enviroent al pollutant s	Vijayakumar et al, 2022

Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/2G8JN

140	Zinc acetate dihydrate	Nyctanthes arbor-tristis	Flower	12 to 32	hydrodynamic	FTIR, XRD, DLS, TEM, MIC	Anti-fungal activity	Khatami et al, 2018
141	Zinc acetate dihydrate	Peganum hamla	Leaf	39.94	Spherical	XRD, SEM, EDX	Antibacterial	Fazlzadeh et al, 2017
142	Zinc nitrate	Parathenium hysterophorus	Leaf	10	Spherical	XRD, SEM, TEM	Antimicrobial	Sadiq et al, 2021
143	Zinc nitrate	Anoectochiles elatus	Leaf	60-85	Spherical	XRD, SEM, UV	Antimicrobial, anti-inflammatory, antioxidant	Chimala et al, 2022
144	Zinc nitrate	Prosphis fracta	Seed	16-26	Spherical	UV-visible, XRD	Antimicrobial activity	Vidya, et al, 2013.
145	Zinc acetate dihydrate	Solanum rantonnetii	Leaf	12	uniform spherical	FTIR, XRD, SPR	Antifungal	Anand et al, 2019.
146	Zinc acetate	Syzgium cumini	Leaf	10-12.55	crystal structure	FTIR. XRD, SEM	Photocatalytic	Awwad et al, 2020.
147	Zinc nitrate hexahydrated	Dysphonia ambrosiodes	dry leaf	5-30	Irregular	FTIR, XRD, TEM	structural characterization	Ansari et al, 2020.
148	Zinc nitrate	Calorops gigantean	Leaf	30-35	spherical and hexagonal	XRD, SEM	photocatalytic	Umamaheswari et al, 2021
149	Zinc nitrate	Prunus duclis	almond gum	30	Hexagonal	XRD	Antimicrobial	Eissa et al, 2022.
150	Zinc nitrate hexahydrate	Ailanthus altissima	Fruits	5-18	crystalline structure	XRD, SEM	AntibacteriaL	Bala et al,2020
151	Zinc nitrate hexahydrate	Cinnnamomum vernum	Bark	45	Crystal	FTIR, UV, TEM	Antibacterial	Degefa et al,2021
152	Copper oxide	Raphanus sativus var. Longipinnatus	Leaf	Depend on parameters	Depend on parameters	UV–vis, FTIR, SEM, XRD	Anticancer	Sharma et al,2021
153	zinc sulfate and sodium metasilicat	Origanum majorana	Peel	16.77	crystal	ransform infrared spectroscopy, UV–Visible spectroscopy, X-ray difraction, and transmission electron microscopy	Ant-imicrobial	Jayappa et al,2020
154	Zinc acetate dihydrate, tri-sodium citrate	Hibiscus subdariffa	Leaf	16–60	Spherical	UV, , FTIR, XRD	Anti-bacterial	Rahimi et al,2022

Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/2G8JN

155	Zinc acetate dihydrates	Vegetables (onioin, cabbage	Bark	17, 18 , 24 , and 15 .	Hexagona	XRD, UV, , FTIR	Anti-bacterial	Umavathi et al,2021
156	Zinc sulfate	Phanerochaete chrysosporium	Free -extract	5 to 200	Hexagonal	SEM, EDS and thermogravimetric analysis	Anti-microbial , anti-bacterial, anti-fungal	Umavathi et al, 2022
157	Methanol, zinc nitrate hexahydrate	Mussaenda frondosa.	Leaf, stem	5-25	Hexagonal	SEM, FTIR, DLS, EDS, UV	Antioxidant, Antidiabetic, Antimicrobial, Anticancer, Photocatalytic activity	Cao et al, 2021
158	zinc acetate	H. officinalis	Free- extract	10–100	Spherical	FTIR, XRD, TEM and FESEM	anti-inflammatory, anti-angiogenesis and cytotoxicity	Faisal et al,2021
159	Zinc nitrate	Parthenium hysterophous	Fresh leaves	10	Spherical	XRD, FT-IR, TEM, SEM	Anti-microbial activity	Rosado et al,2022
160	Zinc acetate	Coriandrium sativum	Leaf	100	Rod and spherical	XRD, SEM, TEM	Synergistic	Doğan et al 2020
161	Copper oxide	Sambucus nigra L. extract	Fresh shoots	20-130	Crystal	X-ray diffraction, field emission gun- scanning electron microscope, transmission electron microscope, SAED	Anti-cancer activity.	Cao et al, 2021
162	Zinc acetate dihydrate	M.fragrans plants	Fruit	66, -22.1mv	Spherical, eliptical	XRD, FTIR, UV, SEM, TEM, DLS TGA	Anti-bacterial activity	Umvathi et al,2021
163	Zinc chloride	Capsicum annuum	Pepper	11	Crystalline	SEM, XRD	Antioxidant activity	Jayachandran et al, 2021
164	Zinc acetate	V. Multifida	Aqueous plant	10-100	Hexagonal and quasi spherical	XRD, UV Vis, FTIR, SEM, TEM	Anti-biofilm activity	Reddy et al, 2021
165	Zinc nitrate hexahydrate	Ailanthus altissima	Fruit extracts	5-18	spherical	XRD, FTIR, SEM, TEM	Anti-bacterial activity	Shabaani et al, 2021
166	Zinc nitrate	Calotropis Gigantean	Leaves	30-35	Spherical, and hexagonal	SEM, X-ray diffraction	Photocatalytic activity	Abdelmigid et al, 2022

Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/2G8JN

167	Zn (OH)2	Platenium hysterophorus	Leaves	10	Spherical	FT-IR, UV-vis, SEM, TEM	Anti-microbial activity	Kalaba et at, 2021
168	Zinc nitrate hexahydrate	Cayratia pedata	Leaf, roots and flower	52.24	Crystalline	XRD, UV, FTIR, EDX, FESEM	Anti-microbial, anti-bacterial,	Naseer et al,2020
169	Zinc nitrate hexahydrate	Tilia Tomentosa	Leave	22	single-phase hexagonal structure	XRD, SEM,	Photochemical activity	Ukidave et al, 2022
170	Zinc acetate dihydrated	Eriobutria japonica	Seed	50	Hexagonal wurtzite	XRD, EDX, FTIR.	Photocatalytic activity	Iqbal et al, 2021
171	Zinc oxide	Punica granatum	Peel	300	hexagonal	UV-VIS,XRD,SEM,TEM, and FTIR spectroscopy	Antibacterial	Abdelbaky et al, 2022.
172	Zinc oxide	Streptomyces plicatus MK-104	Seed	21.72 to 22.4	Spherical	TEM. XRD and DLS	Antimicrobial and Nematicidal	Rakgotho et al, 2022
173	Zinc oxide	Cassia fistula	leaf	320 and 324	Spherical	XRD,FTIR,SEM,UV-Vis and DLS	antibacterial	Rakgotho et al, 2022
174	Zinc oxide	Coriandrum sativum	Pulses	100	Spherical	XRD, SEM, and TEM	antioxidant	Cao et al, 2021
175	Zinc oxide	Elaeagnus angustifolia	leaf	399	crystalline	UV, XRD, FT-IR, EDX, SEM, TEM, DLS	antimicrobial	Chimal et al, 2021
176	Zinc oxide	Pelargonium odoratissimum	leaf	Depend on parameter	Hexagonal	XRD,FESEM and EDX, HRTEM and SAED	Antibacterial and Anti-inflammatory	Robles et al, 2019
177	Sodium Chloride	Agathosma betulina	Shoot	27.5	Hexagonal	FTIR spectra	Antioxidant	Jayachandran et al, 2021
178	Zinc nitrate	Hibiscus Sabariffa	Flower extracts	30 to 8	Semi circular	XRD, FTIR	Photocatalytic activity	Robles et al, 2019
179	NaOCl	Sanbuscus nigra L. extrarct	Fresh shoots	500	Crystal structure	XRD, field emission electron scopy, TEM	exhibited low toxicity on A549 cancer cells	Keihan et al, 2022
180	Zinc nitrate hexahidrated	Dysphonia ambrosioides	Dry leaves	5-30 Commercial size	Quasi-sperical (cricles), irregular shape	XRD, feild emission electroicroscopy. TEM, FTIR TG.	Structural characterization	Hendi et al, 2022

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 66 Issue 05 | 2023
DOI 10.17605/OSF.IO/2G8JN

				range 15-35				
181	Zinc nitrate	Hibiscus sabdariffa	Leaf	30 to 8	hexagonal crystalline, semicircular	XRD, XPS	photocatalytic activity	Robles et al, 2019
182	Zinc nitrate	Cayratia pedata	Leaves	52.24	Crystalline	FESEM, XRD, EDX,FT-IR UV–visible spectroscopy	Enzyme immobilization	Jayachandran, et al, 2021
183	Zinic salt	Polygala tenuifolia	Roots	100	Crystalline	UV-visible spectroscopy	Antibacterial agent	Wang et al, 2022
184	zinc nitrate	Calotropis Gigantea	Leaves	30-35	Crystallites, spherical, hexagonal	SEM and XRD	Antipathogenic	Abdo et al, 2021
185	sodium nitrate	Camellia sinensis	Dried leaves	18 to 33	Spherical	MTT assay, FT-IR spectroscopy, XRD Analysis, TGA, EDX Analysis, FE-SEM, FT-IR analysis	anti-biofilm	Saif et al,2019
186	Zinc acetate	Nigella sativa	Seed	372	hexagonal wurtzite	UV-Vis, X-Ray diffraction	antiviral, antiinflammatory	Jing et al, 2021
187		Wild plant	flower	0.32	Crystal	X-ray diffraction, electron microscopies, photoluminescence spectroscopy, SEM. TEM.	antibacterial activity	Moghaddam et al, 2017
188	Zinc nitate	Parthenium hysterophorus	Leaf	10	Spherical	UV-vis, FT-IR, X-ray diffraction, SEM, TEM	Antimicrobial	Sharma et al, 2020
190	Zinc nitrate	Euphorbia abyssinica	Bark	350–380	Crystal	XRD, ultraviolet–visible spectroscopy, and Fourier transform infrared spectroscopy.	antimicrobial activity	Chen et al, 2019

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