

GREEN SYNTHESIS, CHARACTERIZATION AND APPLICATION OF ZINC OXIDE-IRON OXIDE NANOCOMPOSITES

Submitted in partial fulfillment of the requirements for the award of
Master of Science Degree in Physics

By

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC

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This is to certify that this Project report is the bonafide work of **DIVYA.D** (Reg. No: 41590004) who carried out the project entitled "**GREEN SYNTHESIS, CHARACTERIZATION AND APPLICATION OF ZINC OXIDE-IRON OXIDE NANOCOMPOSITIES**" under our supervision from **NOVEMBER 2022** to **MAY 2023**.


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ABSTRACT

Green nanotechnology has recently had a significant influence on advances in biological applications. Plant based phytochemicals are employed for the synthesis of nanoparticles as green methods due to their reducing properties for metal compounds into nanometals. In recent decades, the composite material has been known as an excellent material in many potential applications. Therefore, the choice of nanocomposite synthesis method becomes a significant thing especially in controlling material properties. Semiconductor metal oxides have been used widely in many fields of applications in electronics such as photocatalysis processes, adsorption of heavy metals, solar cells and gas sensors. Zinc oxide nanoparticles (ZnO NPs) are an example of semiconductors widely used in many industrial and consumer products. Modification of ZnO NPs by various metal and metal oxide NPs not only can improve the properties of ZnO NPs but also add brand-new properties, creating multifunctional products. Iron oxide NPs are vital metal oxide nanoparticles that can be used in several therapeutic applications and surface manipulation is necessary to make iron oxide NPs biocompatible. The low reactivity, agglomeration, and oxidation of iron oxide NPs can be avoided by coating with another metallic oxide NPs, such as zinc oxide NPs. The surface coating of iron oxide NPs not only decreases the cytotoxicity of iron oxide NPs but also increases the stability and efficiency of antimicrobial potential of Iron oxide NPs. In the present study, zinc oxide-iron oxide nanocomposites was prepared using *Turbinaria ornata* seaweed as reducing as well as stabilizing agent through a facile one-pot co-precipitation method, green route which is environment benign and low cost. The structural characterization was done using X-ray diffraction (XRD) and Fourier transform Infrared (FTIR) analysis.

LIST OF ABBREVIATIONS

NCs	-	Nanocomposites
ZnO	-	Zinc oxide
XRD	-	X-ray Diffraction
FT-IR	-	Fourier Transform Infrared Spectroscopy
TEM	-	Transmission Electron Microscope
Nps	-	Nanoparticles
nm	-	Nano Meter
hrs	-	Hours
cm	-	Centi meter
mg	-	Milli gram
kg	-	Kilo gram
MeV	-	Mega electron Volt

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CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION TO NANOCOMPOSITES

Nanocomposites are composite materials in which at least one component has a dimension of around 10^{-9} m or less. It refers to tiny particles embedded in various matrix materials, such as ceramics, glass and polymers, such as metals, semiconductors and dielectric materials. The composite material has a reputation for being a superior material for applications (Ulya *et al* 2019). Nanomaterials have drawn a lot of interest in the last 10 years due to their positive effects on a variety of industries, including consumer goods, pharmaceuticals, cosmetics, energy and medical (Roco *et al* 2003). One of the phases of the multiphase solid material has 1, 2, or 3 dimensions that are less than 100 nm, or it has a structure with nanoscale repeat distances between the many phases that make up the molecule. It is also known as materials made up of two or more components with diameters in the range of one to one hundred nanometers (nm). In order to combine the unique qualities of its constituent parts, nanocomposites are heterogeneous (multiphase) materials made up of at least one nanoscale phase (also known as a nanofiller) that is disseminated in a second phase (also known as a matrix) (Masoud Safdari *et al* 2018).

To strengthen (fiber, particle, annular film, and filler) in the matrix (polymer, metal, and ceramics), a nanocomposite material is conceptually a mixture of nanomaterials made of two or more separate nanocomposite materials (Hasanpour *et al* 2013). Generally speaking, top-down and bottom-up techniques are used to synthesize nanoparticles. When using the second method, nanoparticles are created that are specific in size, shape and structure as opposed to the first method's nonuniform macroparticle reduction to nanosized particles (Amara Dar *et al* 2021). Green chemistry is the use of a predetermined principle to lessen or completely stop the use or production of hazardous substances in the development, production, and use of chemical goods. The method to get rid of them is called green synthesis. The goal of the ecologically friendly process known as "green synthesis" is to minimize energy use, remove hazardous waste and utilize environmentally friendly solvents. In order

to save the environment, green synthesis describes how to make nanoparticles with fewer and generally safer chemicals (Vogler *et al* 1999; Vázquez *et al* 1996). Green synthesis of nanoparticles uses reagents that are safe, non-toxic and beneficial to the environment. Metal particle size reduction during nanocomposite synthesis is a very appealing subject for researchers as it gives up a variety of chances to create unique products (Moghaddam *et al* 2009).

Magnetic nanoparticles, in particular Fe_3O_4 , are one of the nanomaterials that have become increasingly important in recent years, notably in the field of medicine. In general, magnetic nanoparticles offer a number of advantages, including their distinct magnetic characteristics and biocompatibility. (Petcharoen *et al* 2012). Nanoparticles are atomic or molecular aggregates that are smaller than 100 nm in at least one dimension and exhibit altered physical and chemical properties relative to bulk materials (Nel *et al* 2006). Compared to microcomposites, nanocomposites have attracted a lot of scientific and commercial attention for the following reasons: Low threshold for percolation (between 0.1 and 2% volume). At low volume fractions, particle-particle correlation (orientation and position) emerges (10^6 - 10^8 particles/ m^3). High particle density (numbers) per volume of particles extensive interfacial area (10^3 - 10^4 m^2/mL) per volume of particles. Particle separation is minimal (10-50 nm at 1-8% vol%). The stiff nanoparticle inclusion, the separation between particles, and the relaxation volume of polymer chains all have comparable sizes.

1.2 ZINC OXIDE NANOPARTICLES

Calamine or Zinc White, an inorganic substance having the formula ZnO , is another name for zinc oxide. It comes in the form of an insoluble white powder. The two major crystal forms of zinc oxide are hexagonal wurtzite and cubic Zinc blende. Under normal circumstances, wurtzite is the most prevalent and stable structure. An atmospheric oxide called Zinc oxide is insoluble in water. In both acids and alkalis, it dissolves. It serves as a thickening agent, colourant, sunscreen since it lessens and prevents sunburn, and treatment for diaper rash. Additionally, it is utilised in nail products, over-the-counter medicine items and to prevent premature skin ageing. The most promising material is zinc oxide due to its special qualities,

which include thermal and mechanical stability at room temperature, good physical and chemical stability, abundance, availability and inexpensive cost. Additionally, Zinc oxide NPs enhance polymers' thermal behaviour.

It has been observed in several investigations that adding ZnO NPs to dental adhesive solutions considerably increased the anti-microbial characteristics without negatively compromising the bond strength (Saffarpour *et al* 2016; Jowkar *et al* 2018; Gutiérrez *et al* 2019). Zinc is a potent reducing agent with a modest level of reactivity (Rai *et al* 2008). ZnO nanoparticles show great promise as an antibacterial substance. It was found that even after composite synthesis, ZnO still has an antibacterial potential. Zinc oxide nanoparticle also has a hard and rigid structure making it useful in the ceramic industry. One of the advantages of using zinc oxide nanoparticle in the biomedical field is because they act as a good surface material (Amara Dar *et al* 2021). Nano fertilizers made of ZnO composites have also been used (Chithra *et al* 1998). The second most prevalent metal oxide after iron, zinc oxide nanoparticle is also the cheapest, safest and most straightforward to produce (Kalpana *et al* 2018). By altering the morphology of zinc oxide nanoparticles produced using various synthesis methods, precursors or materials, it is simple to change their physical and chemical behaviours (Bala *et al* 2015).

1.3 IRON OXIDE NANOPARTICLES

Iron oxide nanocomposites have an easy-to-synthesize natural component. It contains particles with sizes between 1 and 100 nm. Opportunities exist for developing applications based on iron oxide nanoparticles. One sort of magnetic substance with intriguing properties is magnetite, which has the chemical formula Fe_3O_4 . Oxygen and iron combine to form the chemical molecule known as iron oxide. There are known to be several iron oxides. They are frequently non-stoichiometric. Rust is probably the best-known example of the related class of substances known as oxyhydroxides. Oxyhydroxides and iron oxides are common in nature and are crucial to numerous geological and biological processes. They are found in haemoglobin and are employed as iron ores, pigments, catalysts and thermite. An essential biological component utilized as iron supplements, iron oxide plays a significant part in medical procedures. The primary ingredient in goods produced by the pharmaceutical, paint, plastic, ink and cosmetic industries, as well

as in copperplate and dye stamping inks. It is also employed in gene therapy, pharmaceuticals, drug delivery systems, contrast agents for magnetic resonance imaging (MRI) and other applications.

1.3 ZINC OXIDE-IRON OXIDE NANOCOMPOSITES

As a zinc coordination entity and an iron coordination entity, ZnO/Iron Oxide is a mixed metal. Additionally, coated and dispersion forms as well as ultrahigh and high purity are offered. They are also offered as dispersion by the company that makes nanofluids. Its applications include serving as an anti-microbial, anti-biotic and anti-fungal agent when added to coatings, bandages, nanofiber, and alloys, among other things and more study is being done to determine whether they have any possible electrical, dielectric, magnetic, optical, imaging, catalytic, biological or bioscience capabilities. When necessary, American Elements produces a variety of standard grades, such as Mil Spec, ACS, Reagent and technical grade, food, agricultural and pharmaceutical grade, and optical grade. High photocatalytic activity and magnetic characteristics are present in the ZnO/Fe₂O₃ NP-based material (Wang *et al* 2016). Growing interest is being shown in the manufacture of nano-ZnO through biological systems, primarily because it uses fewer potentially dangerous chemicals and produces nanomaterials that are less cytotoxic. It is possible to produce zinc oxide by biosynthesis using a variety of biological components, such as bacterial, fungal and plant extracts (Ogunyemi *et al* 2019; Kalpana *et al* 2018; Król *et al* 2019).

1.5 SYNTHESIS OF ZINC OXIDE-IRON OXIDE NANOCOMPOSITES

In order to create nanocomposites, two or more components must be combined at nanoscaled dimensions various synthetic methods can be used to create composite materials and various research have been conducted to provide information on their structure and morphology. (Rizal *et al* 2016; Bansal *et al* 2016). Nanoscience and technology have shown promise in the fields of agriculture, biomedicine, water disinfection, hazardous waste cleanup and air purification (Korake *et al* 2014; Deepa *et al* 2015). Numerous techniques, including the coprecipitation approach have been reported for the manufacture of zinc oxide and

iron oxide nanoparticles (Gupta *et al* 2005). This work describes a plant-mediated method for the manufacture of zinc oxide nanoparticles. The zinc nitrate derivative and the native medicinal plant extract were used to successfully create the nanoparticles (Ashwini Jayachandran *et al* 2021). Create $\text{Fe}_2\text{O}_3/\text{ZnO}$ nanocomposites using the co-precipitation technique. FeO and ZnO are determined to be 11 and 40 nm in size in XRD measurements. The functional group of FeO and ZnO was found in each wave number (Syamsul Bahtiar *et al* 2019).

In the current work, Rectorite-based magnetic ZnO photocatalysts (RFC/ $\text{Fe}_3\text{O}_4/\text{ZnO}$) are synthesized and characterized. The created photocatalysts had a high specific surface area and capacity for absorption, proving the significant potential of magnetic composites as a powerful, reliable, and simple to recover catalyst (Wang *et al* 2018). $\text{Fe}_3\text{O}_4/\text{ZnO}$ nanocomposites are made using the sol-gel method, and they are evaluated using XRD and FE-SEM methods. The size and form of nanocomposites affect their interface properties. The XRD test results were connected to the Fe_3O_4 and ZnO phases, which had crystallite sizes of 7.5 nm and 2.5 nm, respectively. (Ali Bahari *et al* 2016; Habibatum Nurul Ulya *et al* 2019). Fe_2O_3 and ZnO nanocomposites were successfully synthesized using the coprecipitation method, and the resulting structure was trigonal and hexagonal. Fe_2O_3 has a fabrication size of 84.9 nm, ZnO of 33.4 nm, and $\text{Fe}_2\text{O}_3/\text{ZnO}$ of 44.9 nm. ZnO, Fe_2O_3 , and $\text{Fe}_2\text{O}_3/\text{ZnO}$ have micrometer thicknesses of 22.56, 22.44, and 44.99, respectively (Yudyanto *et al* 2020).

1.6 APPLICATION OF ZINC OXIDE-IRON OXIDE NANOCOMPOSITES

Industrial use for photocatalytic oxidation materials made of zinc oxide and iron oxide nanocomposite (Awwad *et al* 2012; Meng *et al* 2008). ZnO NPs are efficient at lowering anxiety-related behaviour. Iron oxide nanoparticles have a slight anti-anxiety effect (1 mg/kg), which diminishes at higher doses (5 mg/kg). (Kesmati *et al* 2014). Nanomaterials with low costs and toxicities include ZnO NPs. Iron oxide and zinc are also beneficial for lowering anxiety. (Fahimeh Ardeshiri *et al* 2020). In order to remove COD more effectively, iron oxide and zinc oxide nanoparticles may both be utilized (Sorna Prema Rajendran *et al* 2017). The industrial production of rubber and tyres, ceramics and glass, pharmaceuticals and cosmetics, agricultural,

paints and coatings and more specifically used more than 1.4×10^6 tones of zinc oxide in 2021 (Alam *et al* 2019; Nasser *et al* 2021). Another n-type semiconducting oxide is ZnO, which has a high melting point of 1975°C , a direct band gap of 3.02-3.30 eV, and a high binding energy of 60 MeV (Darezereshki *et al* 2011). Because of their uses in a variety of industries, including cosmetics, biosensors, antibacterial cream and biomedical applications Zinc Oxide nanoparticles (ZnO NPs) are the most commonly utilized types of metal oxide-based nanoparticles. In one study, applying Fe_2O_3 nanoparticles intraperitoneally at a concentration greater than 7 mg/kg exhibited synergistic effects on anxious behaviour, but applying the same dose of 5 mg/kg had no discernible effects. On the other hand, a different study found that Fe_2O_3 dosages of 2 and 5 mg/kg produced anti-anxiety benefits (Fahimeh Ardeshiri-Lordejani *et al* 2020).

CHAPTER-2

LITERATURE SURVEY

In 2019, Syamsul Bahtiar *et al* synthesize FeO/ZnO nanocomposites by co-precipitation method. In XRD data shows that FeO & ZnO has size of 11 & 40 nm. The functional group of FeO & ZnO were detected in their respective wave number.

In 2020, Abbas *et al* focused on phytochemical of Creeper BM water extract for synthesizing iron oxide/zinc oxide NPs. UV spectrum analysis shows wavelength of FeO/ZnO nanocomposite and it is irregular shape. It is used in medical purpose.

In 2021, Addul Rahman Mohammad *et al* use simple & convenient method of electrospinning to develop flexible PENGs from polyvinylidene Fluoride (PVDF) with piezoelectric and dielectric properties. This PENG is promising mechanical energy harvester and its good dielectric properties reveals ability to use material as good as power sources for wearable & flexible electric device.

In 2018, Wang *et al* synthesize and characterize Rectorite-based magnetic ZnO photocatalysts (RFC/Fe₃O₄/ZnO) in present work. The fabricated photocatalysts possessed high specific surface area and capacity of absorption and it also demonstrates that magnetic composites has great potential as an effective, stable and easily recovered catalyst.

In 2014, M. Farrokhi *et al* shows ZnO was immobilized on magnetite nanoparticles by chemical method and its was used as an absorbent. The prepared sample was characterized by FTIR, XRD, SEM and EDX. Psuedo second order model better described the adsorption kinetics of RB5 into adsorbent than the pseudo-first-order model.

In 2016, Ali Bahari *et al* synthesize Fe₃O₄/ZnO nanocomposites by sol-gel method and evaluates using XRD, FE-SEM techniques. The interface properties of nanocomposites depend on their size and shape.

In 2019, Habibatum Nurul Ulya *et al* synthesis ZnO/Fe₃O₄ nanocomposites using sonochemical and sol-gel method. The results of XRD test related to the form of

Fe_3O_4 & ZnO phases that had crystallite size of 7.5 nm & 2.5 nm.

In 2021, O. Dlugosz *et al* used two step process to obtain $\text{Fe}_3\text{O}_4/\text{ZnO}$ nanoparticles. XRD analysis and magnetic hysteresis studies have confirmed that depending on mass share of $\text{Fe}_2\text{O}_3:\text{FeO}:\text{ZnO}$ material with variable magnetic and photocatalytic properties were synthesized. It was used in photodegradation study on group of dye solution differing in molar mass, dye charge and solvent.

In 2021, Reda M. El-Shishtawy *et al* demonstrate that the results of immobilizing catalase on $\text{CS}/\text{ZnO}/\text{Fe}_2\text{O}_3$ at pH 8.0 is a very effective procedure because the biocatalyst was much more stable than immobilization on CS/ZnO . This biocatalyst exhibited low activation energy, deactivation energy contrast value and high affinity to the substrate.

In 2020, Yudyuanto *et al* successfully synthesis the Fe_2O_3 and ZnO nanocomposites by coprecipitation method with an obtained structure as trigonal and hexagonal. Fabricated size of Fe_2O_3 is 84.9 nm, ZnO is 33.4 nm and $\text{Fe}_2\text{O}_3/\text{ZnO}$ is 44.9 nm. The thickness of ZnO, Fe_2O_3 and $\text{Fe}_2\text{O}_3/\text{ZnO}$ is 22.56, 22.44 and 44.99 (micro meter).

In 2014, Kian Mun Lee *et al* successfully prepared $\text{ZnO}/\gamma\text{-Fe}_2\text{O}_3$ nanocomposites were via precipitation method. TEM analysis showed that nearly spherical morphology was obtained and average particle size of ZnO and $\text{ZnO}/\text{Fe}_2\text{O}_3$ exhibit better photodegradation ability than that of our ZnO.

In 2019, Ying Zhang *et al* develops a method to synthesis nanocomposites in triethylene glycol using a thermal decomposition method under the protection of Nz gas. The prepared nanocomposites are characterized and their adsorption performance on RhB is investigated. The synthesized nanocomposites can be easily separate from aqueous solution.

In 2014, Juan Xia *et al* Bifunctional magnetic $\text{Fe}_3\text{O}_4/\text{ZnO}$ nanocomposites with different molar ratio were successfully synthesized by a facile two-step strategy. A series of the characterizations manifested that the combination of Fe_3O_4 with ZnO nanoparticle was successfully. The result show the degradation percentage. $\text{Fe}_3\text{O}_4/\text{ZnO}$ nanocomposites could be also served as convenient recyclable photocatalysts because of their magnetic particles.

In 2013, Ahmad Hasanpour *et al* prepare Fe_3O_4 nanoparticles from ferric nitrate ($\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$) and ethylene glycol ($\text{C}_2\text{H}_6\text{O}_2$) & composite nanopowder of Fe_3O_4 -ZnO were obtained from zinc acetate and diethanolamine using sol-gel method. XRD results confirm the formation of Fe_3O_4 -ZnO nanocomposites. TEM shows that prepared powders are made of the spherical shape particles.

In 2016, Ali Bahri *et al* synthesize $\text{Fe}_3\text{O}_4/\text{ZnO}$ nanocomposites by sol-gel method & its properties were studied by XRD, leakage current-voltage and FTIR spectroscopy. The results show that with increasing the aspect ratio and reducing the size of the nanocomposite, the electrical characterization improved.

In 2017, M. Roeinfard *et al* synthesis $\text{Fe}_3\text{O}_4/\text{ZnO}$ nanocomposite by sol-gel method using iron nitrate, ethylene glycol, zinc acetate dehydrate & $(\text{NH}_4)_2\text{CO}_3$ and were characterized by XRD, FTIR, XPS, AFM, TEM. These nanocomposites due to their small size, colloidal stability, magnetic properties and nontoxicity can be good candidate as option in medicine application.

In 2008, R. Y. Hong *et al* synthesize Fe_3O_4 magnetic nanoparticles (MNPs) by co-precipitation method. The phase purity was confirmed by XRD analysis. The crystal size was found to be 10 nm from TEM.

In 2016, D. S. Winatapura *et al* successfully synthesize $\text{Fe}_3\text{O}_4/\text{ZnO}$ nanocomposites (NC) by a wet milling method using a HEM machine. $\text{Fe}_3\text{O}_4/\text{ZnO}$ was characterized by XRD, FTIR, SEM, TEM, VSM. Its applications are purification process, catalysts, separation and photodegradation.

In 2015, L. E. Bykova *et al* shows structural & magnetic properties of ZnO- Fe_3O_4 nanocomposites were produced by the solid-state reaction. Ferrimagnetic Fe_3O_4 clusters with an average grain size of 40 nm and a magnetization of $\sim 430 \text{ emu/cm}^{-1}$ at room temperature, which are surrounded by a ZnO layer with a large contact surface, have been synthesized.

In 2018, Shashi B. Atla *et al* prepare Magnetite ZnO catalysts, then characterize and tested for their photocatalysis in the degradation methylene blue dye under sunlight irradiation. Photocatalytic reactivity was related to the defects present in the sample under the synthesized conditions. ZnO nanoparticles show superior photocatalytic activity. The significant enhancement in photoactivity could be

attributed to the synergistic effect of adsorption by silica and ZnO catalysis. The recycle experiments using external magnetic showed the remained activity which demonstrated the stable and efficient magnetic separable catalysts.

In 2018, Wang *et al* synthesizes Rectorite/Fe₃O₄/ZnO composites and characterizes it. Rectorite/Fe₃O₄/ZnO exhibited the highest photoactivity for the removal OH methylene blue dye at pH 6.0. The primary degradation mechanism swas also proposed based on the detected intermediates. Our study demonstrated that Rectorite/Fe₃O₄/ZnO composite shave great potential a catalysts for the treatment of dye pollutants in aqueous solutions.

In 2008, Ruipeng Fu *et al* prepares γ -Fe₂O₃/ZnO composite particles by simple solution method. The phase and purity of the composite particles were characterized by XRD analysis and morphology was studied by SEM, with diameters in the range of 300-400 nm. The composites exhibit magnetic response to an external magnetic field.

In 2016, Jian Wang *et al* synthesizes Fe₃O₄/ZnO binary nanoparticles by two-step chemical method and characterized using various analytical instruments. The magnetization saturation value of the core/shell nanoparticles is sufficient high for magnetic separation when applied as reusable catalyst in waste water treatment. Fe₃O₄/ZnO exhibit enhanced photocatalytic activites than those of the pure ZnO nanoparticles.

In 2014, Xiaohui Feng *et al* synthesize Fe₃O₄-ZnO hybrid nanoparticles through the dehydration of Zn(AC)₂.H₂O in the process of DEG and Fe₃O₄ nanoparticle. The size will increase with decrease in the amounts of Fe₃O₄ added for reaction. Phenol degradation upon UV radiation in presence of these nanoparticles was investigated. The degradation rate was dependent on the type, size and composition of produced.

In 2015, Jilla Saffari *et al* synthesis Fe₃O₄/ZnO nanocomposites by surfactant-free sonochemical method in aqueous solution. The prepared product was characterized by XRD, SEM, EDS & FTIR. The photocatalytic behaviour of Fe₃O₄/ZnO nanocomposites was evaluated using the degradation of eight organic dyes under UV light radiation. The results show that Fe₃O₄/ZnO nanocomposites have applicable magnetic and photocatalytic performance.

CHAPTER-3

AIM AND SCOPE

3.1 AIM OF THE PRESENT INVESTIGATION

- To synthesis Zinc Oxide/iron oxide nanocomposites using *Turbinaria ornata* seaweed extract.
- To characterize the synthesized Zinc Oxide/Iron Oxide nanocomposites by various structural and microscopy analysis such as X-Ray diffraction (XRD), Fourier Transform-Infrared (FT-IR) and Transmission Electron Microscopy (TEM)/High Resolution TEM (HRTEM) with Energy Dispersive X-ray analysis (EDAX).

3.2 SCOPE OF THE PRESENT INVESTIGATION

- Zinc Oxide/Iron Oxide Nanocomposites is synthesized via coprecipitation method, a green route which is environment benign and low cost.
- In this method, sea weed (*Turbinaria ornata*) extract was used as reducing as well as stabilizing agent for the preparation of Zinc Oxide/Iron Oxide nanocomposites for the first time.
- The prepared Zinc Oxide/Iron Oxide nanocomposites will be used as insecticides in agricultural fields.

CHAPTER-4

EXPERIMENTAL AND CHARACTERIZATION TECHNIQUES

4.1 MATERIALS AND METHODS

4.1.1 Materials

Materials used for synthesis of zinc oxide-iron oxide nanocomposites are zinc acetate dihydrate, ferric chloride anhydrous, sodium hydroxide pellets and extract from sea weed (*Turbinaria ornata*) powder.

4.1.2 Preparation of Zinc oxide-Iron oxide nanocomposites

To prepare zinc oxide-iron oxide nanocomposites firstly, ZnO and Fe₃O₄ were separately synthesized and then composited. Sea weed powder (2 gm) soaked in 200 ml of deionized water for 24 hrs and filter it. The filtered solution is used as sea weed extract. For synthesis of ZnO Nps, Zinc acetate solution and sodium hydroxide solution were prepared separately and mixed under stirring for 30 min. Add 40 ml of sea weed extract to zinc acetate solution drop by drop and stir for 30 min. Then sodium hydroxide solution was added to zinc acetate solution drop by drop and stirred at room temperature for 2-3 hrs. After stirring, the final solution has been kept for ageing for 24 hrs. Then the solution was filtered, washed and dried at 70 C/24 h. Finally, it was calcinated at 600 C/6 h. ZnO NPs was finally obtained. Similarly for synthesis of Fe₃O₄ NPs Ferric chloride solution was prepared followed by sodium hydroxide solution and it undergoes same process as the preparation of ZnO NPs. Finally after preparing the solution and kept for ageing it was filtered, washed and dried at 70 C/24 hrs and calcinated at 600 C / 6 hrs. Fe₃O₄ was finally obtained. In order to prepare zinc oxide-iron oxide nanocomposites both ZnO and Ferric chloride was taken to be dissolved and prepared as one solution and the above mentioned process have followed.

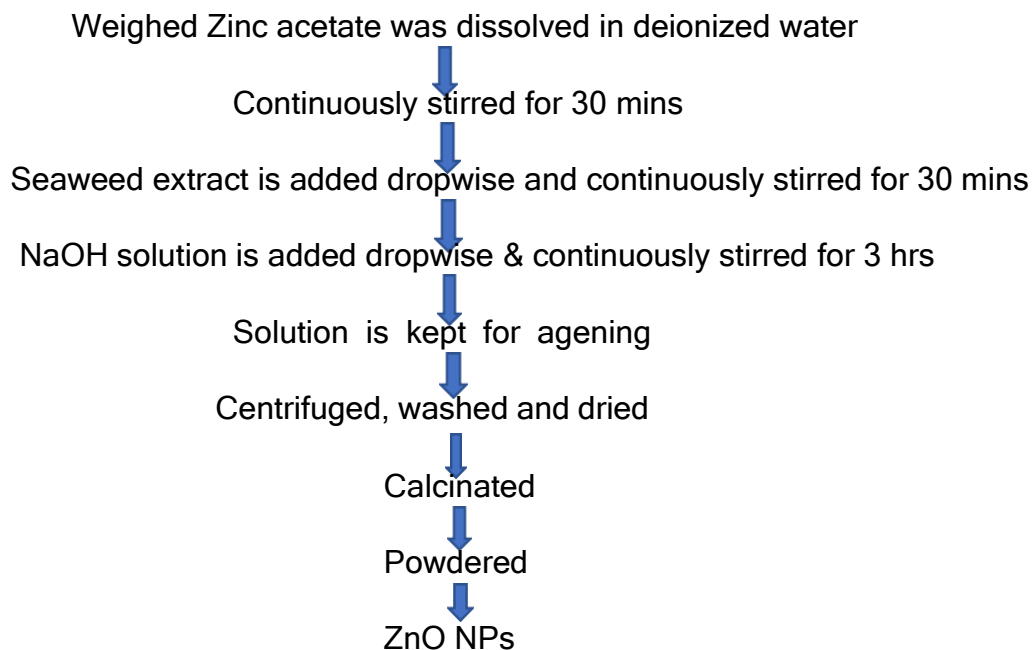


Fig 4.1 Flowchart for the preparation of ZnO nanoparticles

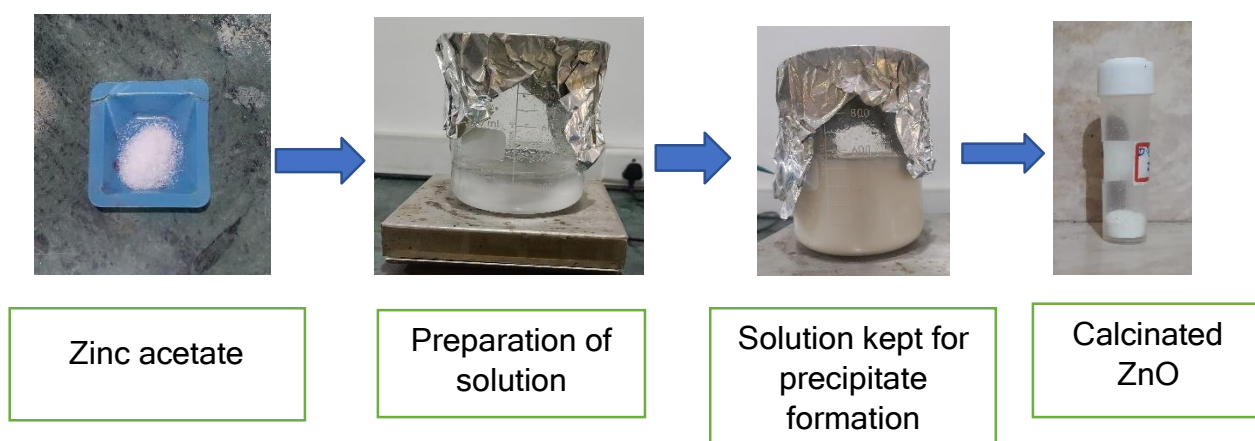


Fig 4.2 Schematic diagram of the preparation of ZnO nanoparticles

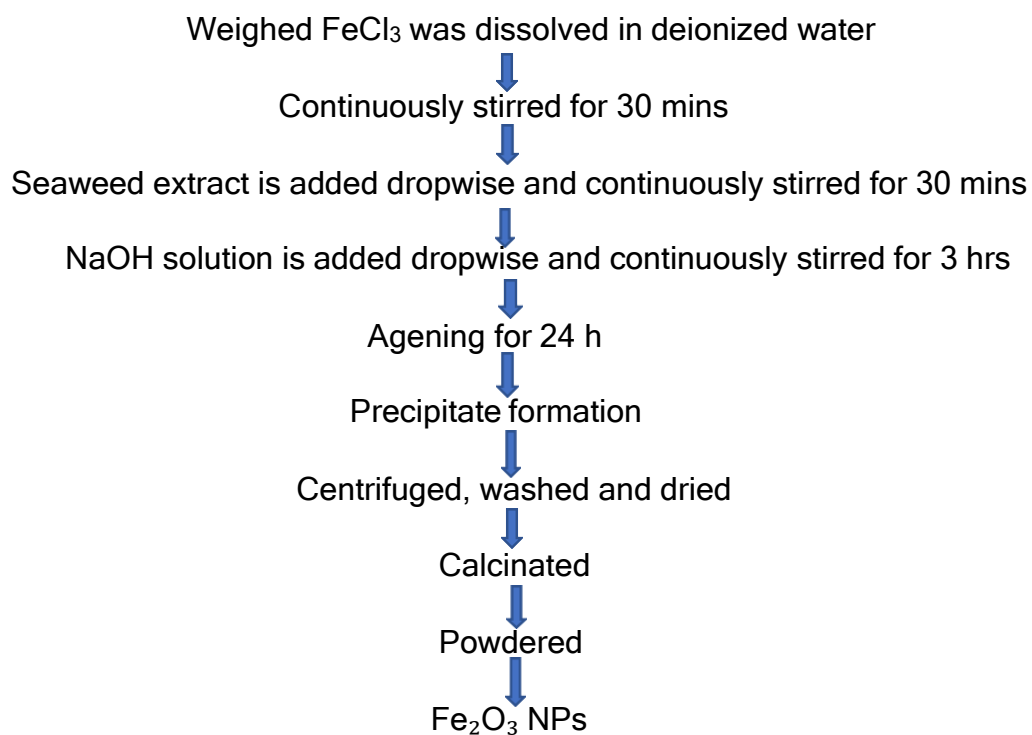


Fig 4.3 Flowchart for the preparation of Fe_2O_3 nanoparticles

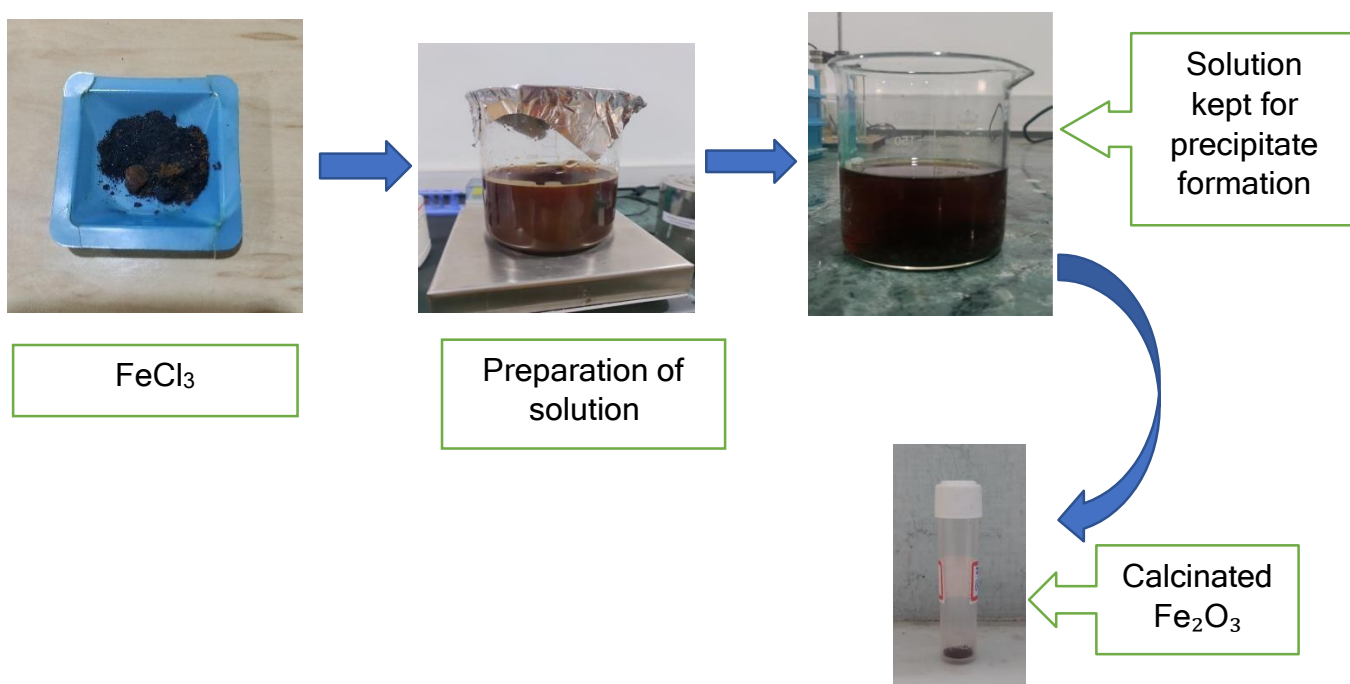


Fig 4.4 Schematic diagram of the preparation of Fe_2O_3 nanoparticles

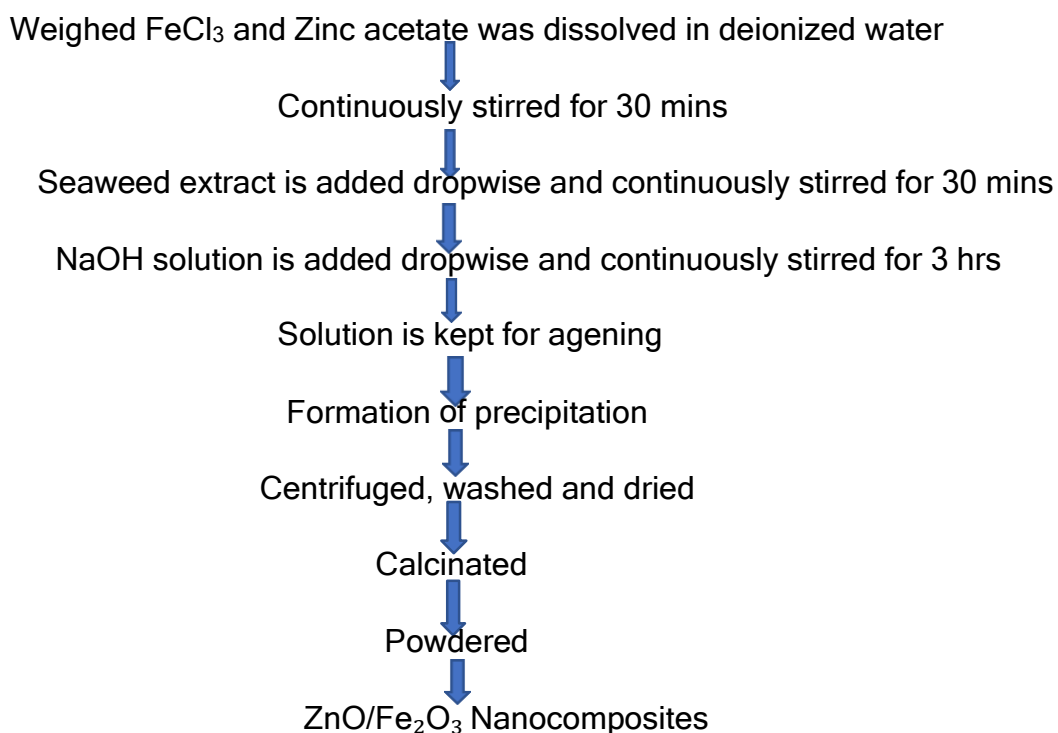


Fig 4.5 Flowchart for the preparation of $\text{ZnO/Fe}_2\text{O}_3$ nanocomposites

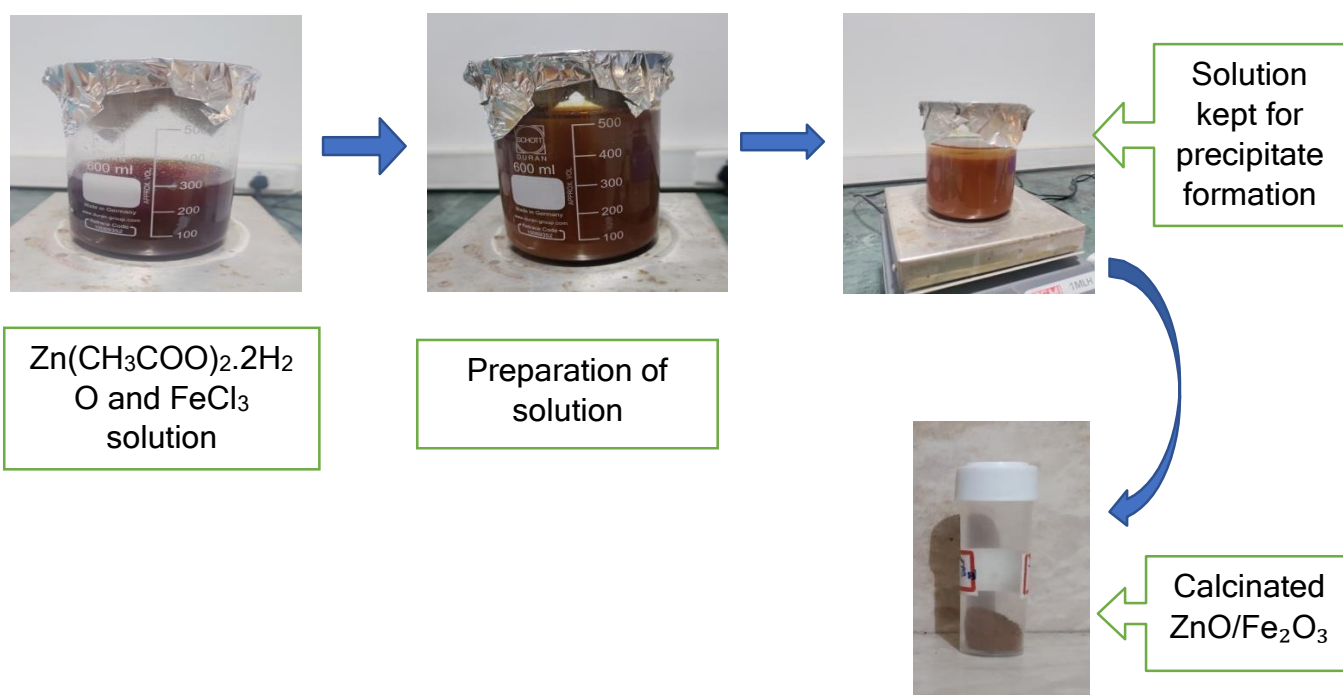


Fig 4.6 Schematic diagram of the preparation of $\text{ZnO/Fe}_2\text{O}_3$ nanocomposites

4.1.3 CHARACTERIZATION TECHNIQUE:

XRD characterization studies of Shimadzu Powder X-ray diffractometer (PXRD) with Cu K (1.541 Å) radiation and nickel filter in the 2θ range 20-80° at a scan rate of 2 / min provided excellent characterization of the final products. FTIR studies of the nanocomposites were performed by Perkin Elmer FTIR spectrometer in the range of 4000 cm⁻¹ to 400 cm⁻¹. TEM characterization studies were performed and EDAX value is obtained.

4.2 CHARACTERIZATION TECHNIQUES:

4.2.1 X-Ray diffraction (XRD)

A flexible and non-destructive method known as X-ray diffraction (XRD) provides extensive details regarding the crystalline structure of both natural and artificial materials. X-ray diffractometer was used to conduct the study on X-ray diffraction. An effective analytical tool for locating and describing unidentified crystalline minerals is X-ray powder diffraction (Cullity *et al* 2001). Monochromatic X-rays are used to determine the interplanar spacing of the unknown materials. Samples are analyzed as powders with grains in random orientations to ensure that all crystallographic directions are sampled by the beam. When the Bragg conditions for constructive interference are obtained, a reflection is produced and the relative peak height is generally proportional to the number of grains in a preferred orientation.

The X-ray spectra generated by this technique will provide a structural fingerprint of the unknown material. Mixtures of crystalline materials can also be analyzed and relative peak heights of multiple materials may be used to obtain semi-quantitative estimates of abundances. A glancing X-ray beam may also be used to obtain structural information of thin films on surfaces. In addition, changes in peak position that represent either compositional variation (solid solution) or structure-state information (e.g: order-disorder transitions, resolution, etc.) are readily detectable. Peak positions occur where the X-ray beam has been diffracted by the crystal lattice. The unique set of d-spacing derived from this pattern can be used to fingerprint the material. For typical powder patterns, data is collected at 2θ from 10° to 80°, angles that are preset in the X-ray scan. In the present investigation, XRD pattern of the

prepared powder samples were recorded using Siemens D-5005 X-ray powder diffractometer at a scanning rate of 1°/min in the range of 20° to 80° using CuK α radiation ($\lambda = 1.5418 \text{ \AA}$).

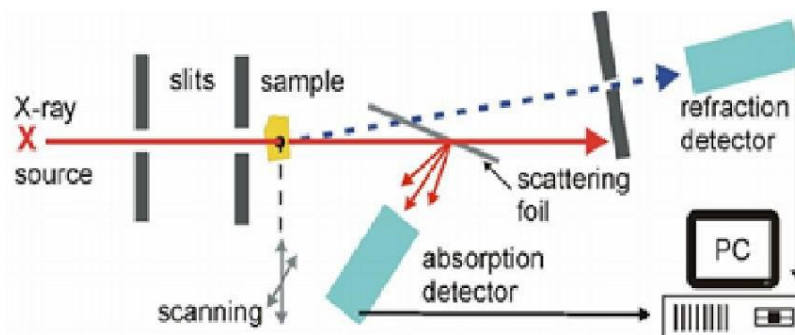


Fig 4.2.1 X-Ray Diffraction

4.2.2 Fourier Transform Infrared (FTIR) Spectroscopy

FTIR used to investigate the functional groups of the nanocomposites. FTIR is plotted in the range of wave number between 4000-400 cm⁻¹. FTIR spectrum has 5 or more than 5 absorption bands, the sample can be complex molecule. Fourier Transform Infrared (FTIR) spectroscopy is a powerful tool for identifying the types of chemical bonds present in a molecule by producing an infrared absorption spectrum that is like a molecular fingerprint. It can be utilized to quantitate the components of an unknown mixture. It can be applied to the analysis of solids, liquids, and gases (Willard *et al* 1986). The wavelength of light absorbed is the characteristic of the chemical bond that can be seen from the spectrum. By interpreting the infrared absorption spectrum, the chemical bonds in a molecule can be determined. FTIR spectroscopy does not require a vacuum, since neither oxygen nor nitrogen absorbs infrared rays. Molecular bonds vibrate at various frequencies depending on the elements and the type of bonds. For any given bond, there are several specific frequencies at which it can vibrate. According to quantum mechanics, these frequencies correspond to the ground state (lowest frequency) and several excited states (higher frequencies). One way to cause the frequency of a molecular vibration to increase is to excite the bond by having its absorbed light energy. For any given transition between two states, the light energy (determined

by the wavelength) must exactly equal to the difference in the energy between the two states [usually ground state (E_0) and the first excited state (E_1)].

FTIR spectroscopy was developed in order to overcome the limitations encountered with dispersive instruments. The main difficulty was the slow scanning process. A method for measuring all of the infrared frequencies simultaneously, rather than individually was needed. A solution was developed which employed a very simple optical device called an interferometer. The interferometer produces a unique type of signal which has all of the infrared frequencies encoded into it. The signal can be measured very quickly, usually on the order of one second or so. Thus, the time element per sample is reduced to a matter of a few seconds rather than several minutes. Most interferometers employ a beam splitter which takes the incoming infrared beam and divides it into two optical beams. One beam reflects off of a flat mirror, which is fixed in place. The other beam reflects off of a flat mirror based on a mechanism, which allows this mirror to move a very short distance away from the beam splitter. The two beams reflect off of their respective mirrors and are recombined when they meet back at the beam splitter. Because the path that one beam travels is a fixed length and the other is constantly changing as its mirror moves, the signal which exits the interferometer is the result of these two beams interfering with each other. The resulting signal is called an interferogram, which has the unique property that every data point (a function of the moving mirror position) which makes up the signal has information about every infrared frequency from the source. This means that as the interferogram is measured, so that all frequencies are being measured simultaneously. Thus, the use of the interferometer results in extremely fast measurements. In the present investigation, the FTIR spectra of the prepared sample were examined using Perkin Elmer FTIR spectrometer in the range of 4000 cm^{-1} to 400 cm^{-1} .

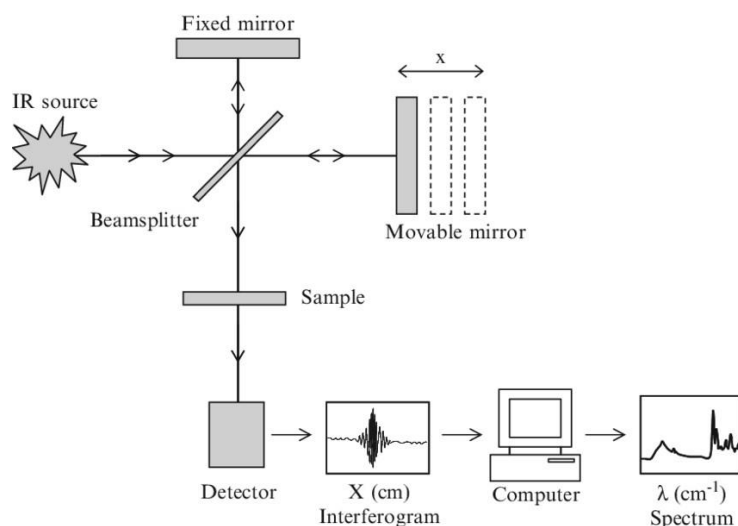


Fig 4.2.2 Fourier Transform Infrared (FTIR) Spectroscopy

4.2.3 Transmission Electron Microscope (TEM)

A TEM investigation of the prepared sample revealed the existence of various NP kinds. The distribution of the fibres and the morphology of the nanomaterials were examined using a transmission electron microscope. The obtained catalysts underwent additional TEM characterization. The catalysts that are produced have a spherical form. The particle size distribution histogram was used to calculate the catalysts' typical particle size. The particle size distribution histogram from TEM, which showed that increasing particle size corresponded to lesser specific surface area, validated this observation. The number of active sites on a catalyst's surface has been found to grow with increased surface area, which in turn makes it easier to produce hydroxyl and superoxide radicals. (Dodd *et al* 2006; Wang *et al* 2007). However, when the α -Fe₂O₃/ZnO nanocomposite was synthesized, the outcomes were different. The shape was rod before and after coating, and the average size was five times larger than α -Fe₂O₃ nanoparticles. (Abbas *et al* 2020). TEM images shows it is spherical shape structures.

Better spatial resolution and the added capability of analytical measurements are TEM's advantages over SEM. This method has a few restrictions, including the need for a high vacuum, thin sample sections, and time-consuming sample preparation. For sample information to be represented by a high-quality image, sample preparation is crucial (Hall *et al* 2007). Compared to scanning electron microscopy, TEM has two advantages: it can offer higher spatial resolution and more analytical

results (Zhu *et al* 2012). Phase-contrast imaging, in which transmitted and scattered electrons are combined to create the image, is used in the imaging mode of TEM called HR-TEM. The most popular technique for figuring out a nanoparticle's interior structure is HR-TEM. To find the scattered electrons, a bigger objective aperture is necessary. This technique aids in the identification of atom arrays found in crystalline formations. Energy dispersive spectroscopy (EDS) is used to identify the chemical composition of synthesized nanoparticles (Su *et al* 2017). Different electron energies can be used with the TEM (typically 100 keV for traditional TEM and 1 MeV for high-resolution imaging).

The contrast of TEM images depends on a number of variables, chiefly on the difference in electron densities of the structures in the sample (difference between organic matrix and mineral electron densities), the thickness and density of the sample, the diameter of the objective aperture, and the energy of the electrons. Other important variables include the sample's density and thickness (Misof *et al* 2011). The diffraction pattern of a sample of mineralized tissue can also be observed using the TEM apparatus. When examining nanoparticles, HRTEM uses a higher resolution to observe how the sample interferes with the electron beam. The absorbance of the beam is measured by standard TEM. HRTEM relies on phase contrast for image creation, however because the image is affected by aberrations in the microscope's imaging lenses, it cannot be interpreted (Thundiparambil Azeez Sonia *et al* 2014).

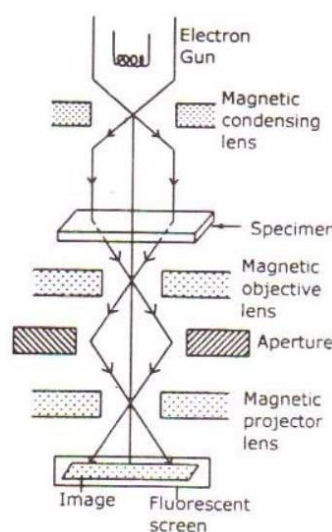
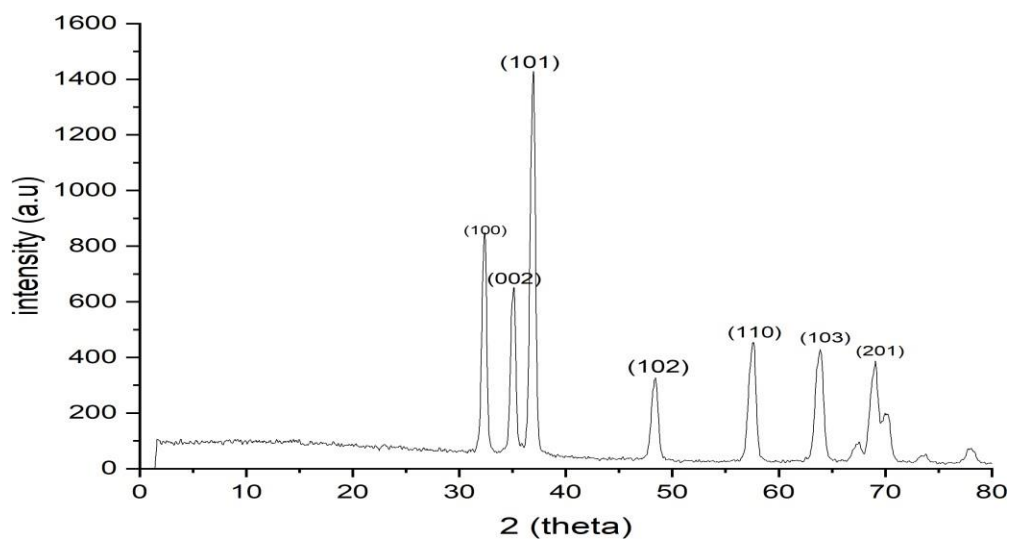


Fig 4.2.3 Transmission Electron Microscope (TEM)

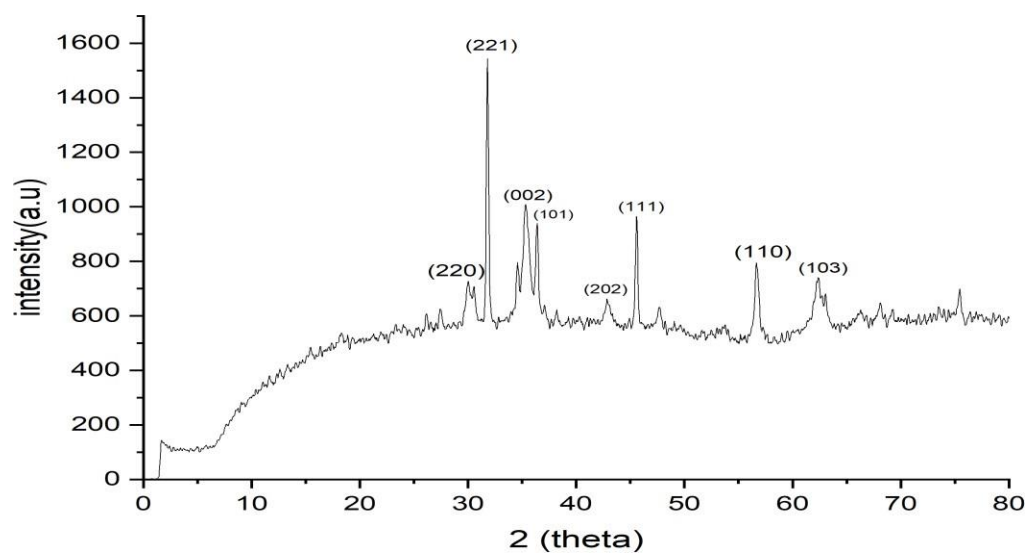
CHAPTER-5

RESULTS AND DISCUSION

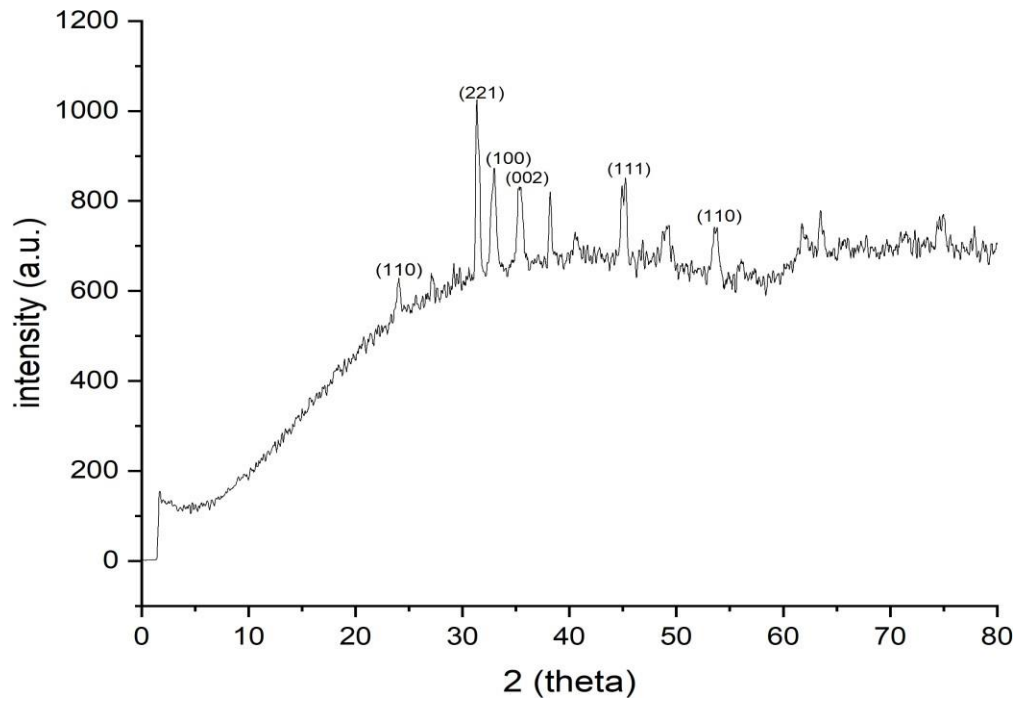
5.1 XRD ANALYSIS



(a)



(b)

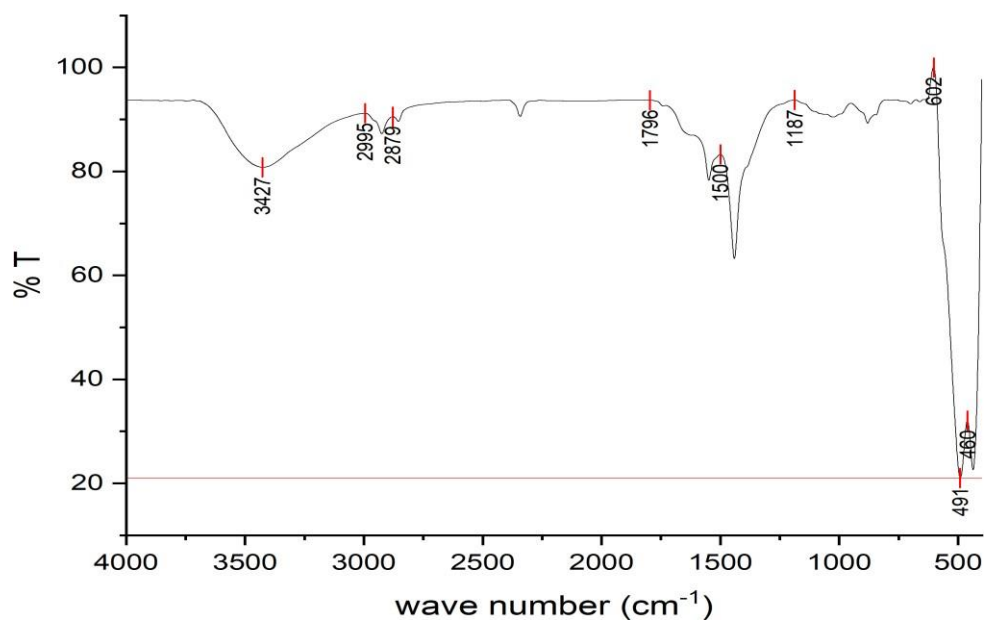


(c)

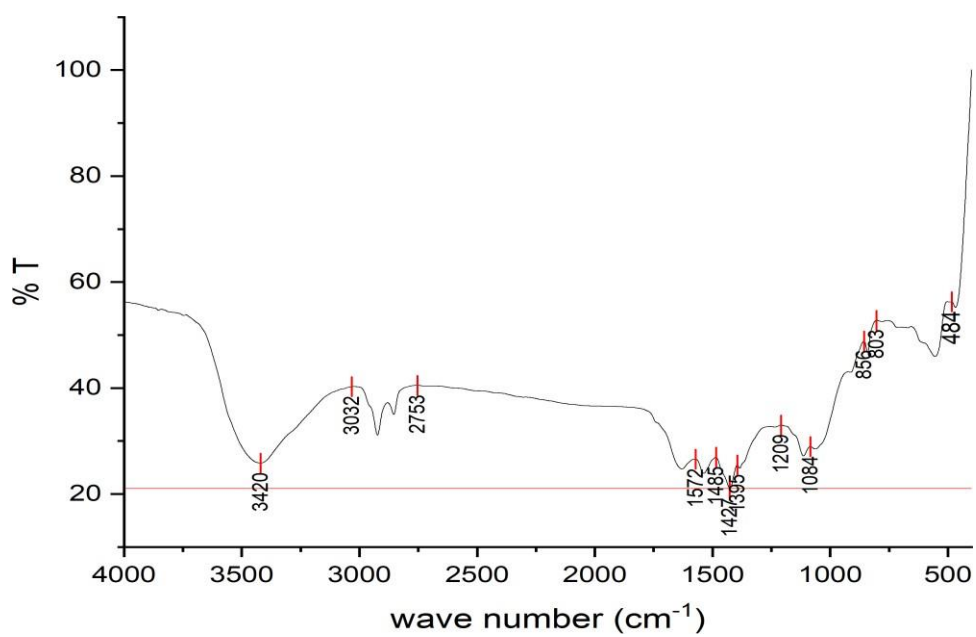
**Fig 5.1 X-ray diffraction pattern (XRD) of (a) pure ZnO nanoparticles
(b) ZnO/Fe₂O₃ nanocomposites and (c) pure Fe₂O₃ nanoparticles**

Figure 5.1(a) shows the peak of ZnO detected at the angle of 2θ is 32.20° , 35.13° , 36.93° , 48.38° , 57.63° , 63.89° & 69.11° coincides with the Miller section of hkl planes of (100), (002), (101), (102), (110), (103) & (201). (Abbas *et al* 2020; Farrokhi *et al* 2014). The sharp peaks appear at the range of 30-40. We will look the nature of Bragg's peaks appearing in XRD pattern to get results. Figure 5.1(b) shows the peak of ZnO/Fe₂O₃ detected at the angle of 2θ is 30.07° , 31.81° , 35.31° , 36.34° , 42.85° , 45.50° , 56.63° & 62.37° coincides with the Miller section of hkl planes of (220), (221), (002), (101), (202), (111), (110) & (103). (Ulya *et al* 2019; Syamsul Bahtierz, *et al* 2019). Figure 5.1(b) is the Fe₂O₃ doped ZnO compound. Figure 5.1(c) shows the result peak of Fe₂O₃ detected at the angle of 2θ is 24.01° , 31.45° , 32.99° , 35.64° , 45.14° & 53.80° coincides with the Miller section of hkl planes of (110), (221), (100), (002), (111) & (110). (Farrokhi *et al* 2014; Ulya *et al* 2019).

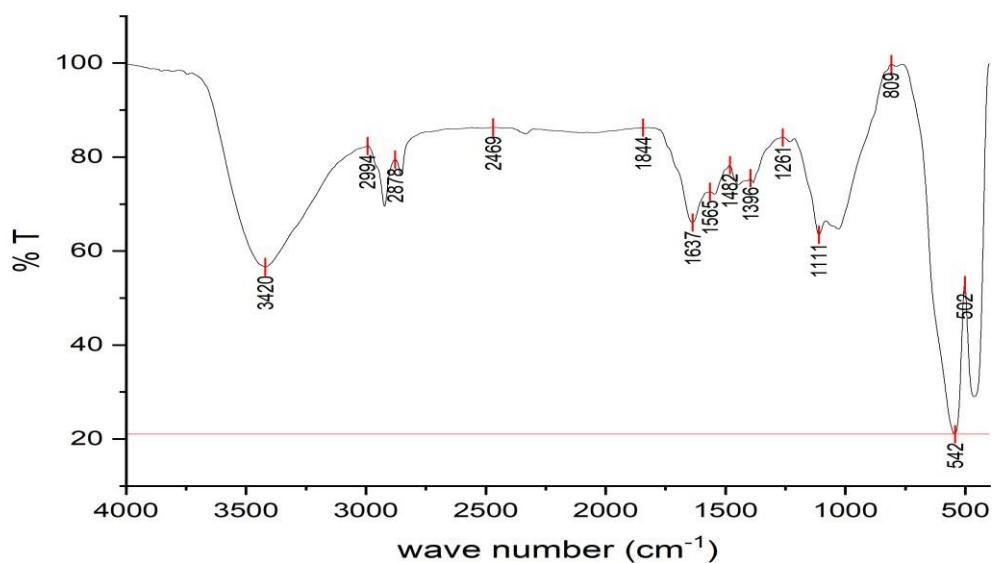
5.2 FTIR ANALYSIS



(a)



(b)

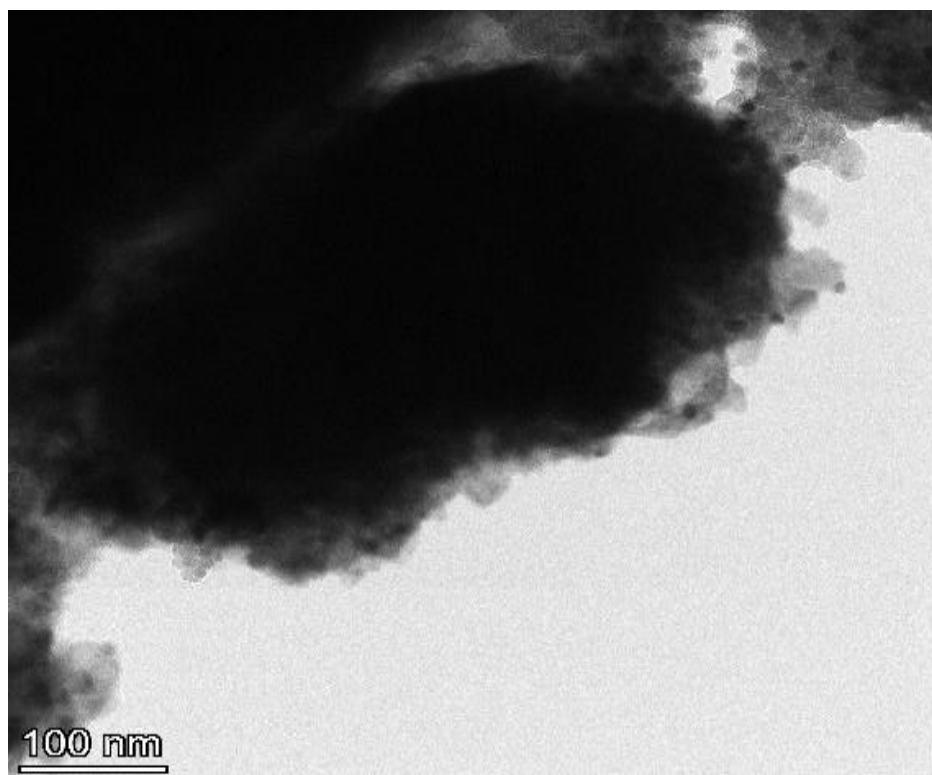


(c)

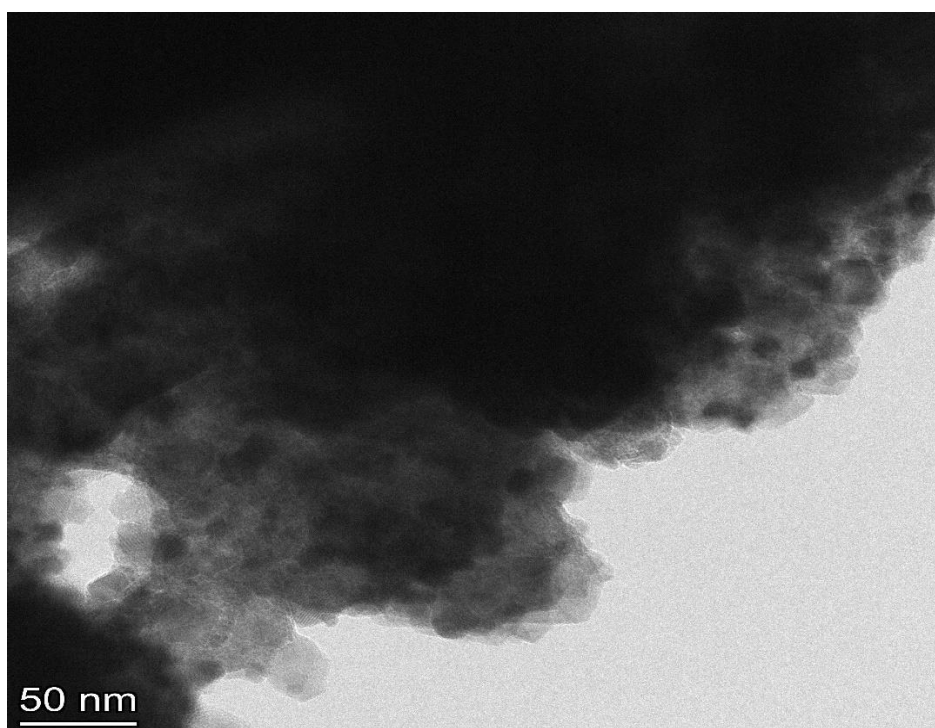
Fig 5.2 FTIR Spectrum of (a) pure ZnO nanoparticles, (b) ZnO/Fe₂O₃ nanocomposites and (c) pure Fe₂O₃ nanoparticles

FTIR is mainly used to investigate the functional groups of the nanocomposites. FTIR is plotted in the range of wave number between 4000-400 cm⁻¹. FTIR spectrum has 5 or more than 5 absorption bands, the sample can be complex molecule. Figure 5.2(a) has sharp peaks appearing at 400-500 cm⁻¹ which are the representations of stretching vibrations of ZnO. (Farrokhi *et al* 2014; Wang *et al* 2018). The weak band near 1500 cm⁻¹ is referred to H-O-H vibration mode, 1024 cm⁻¹ is referred to O-C-O vibration group, 3426cm⁻¹ corresponds to O-H group. From figure 5.2(b) the band near 1500 cm⁻¹ are H-O-H vibration band, 1063 cm⁻¹, 1113 cm⁻¹ O-C-O band, 1425 cm⁻¹ corresponds to C-C vibration band, 1628 cm⁻¹ referred to -C=C- (of alkene) band, 3420 cm⁻¹ corresponds to OH hydroxyl group. (El-Shishtawy *et al* 2021; Abbas *et al* 2020). Figure 5.2(c) is similar to figure 5.2(a) indicating the hybridization of ZnO nanocomposites with Fe₂O₃. (Ulya *et al* 2019). In Figure 5.2(c), 1300-1500 cm⁻¹ is due to the carboxyl bond stretch of symmetric and asymmetric C=O group. (Syamsul Bahtiar *et al* 2019). The O-C-O group comes between 1000-1500 cm⁻¹. The band at 3420 cm⁻¹ corresponds to hydroxyl group.

5.3 TEM ANALYSIS



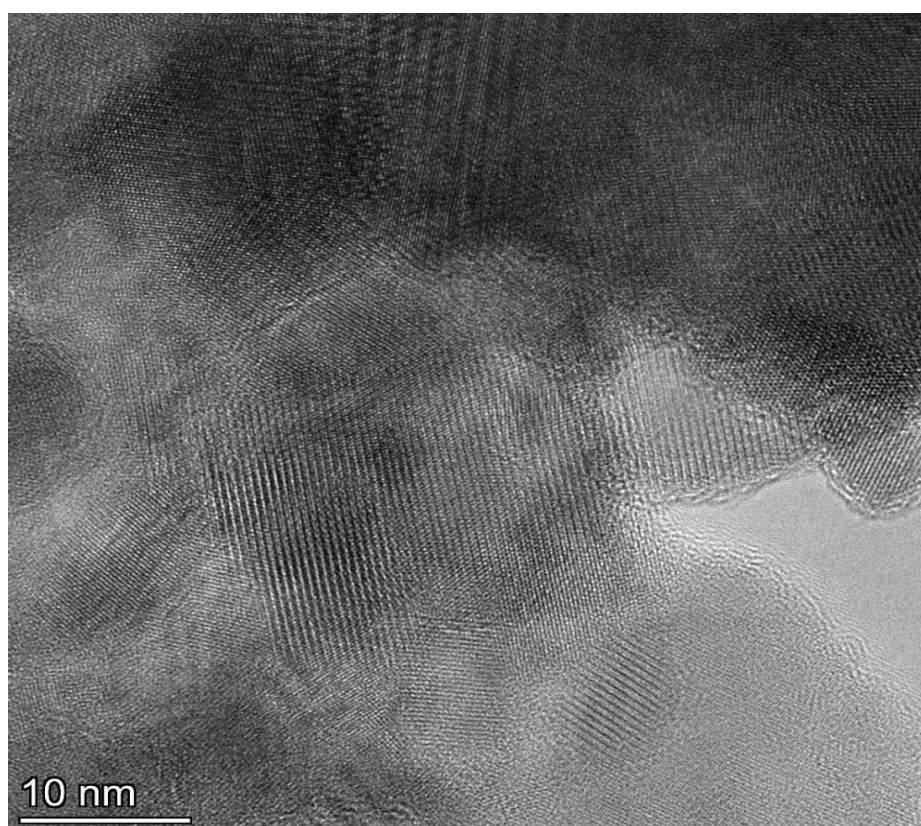
(a)



(b)

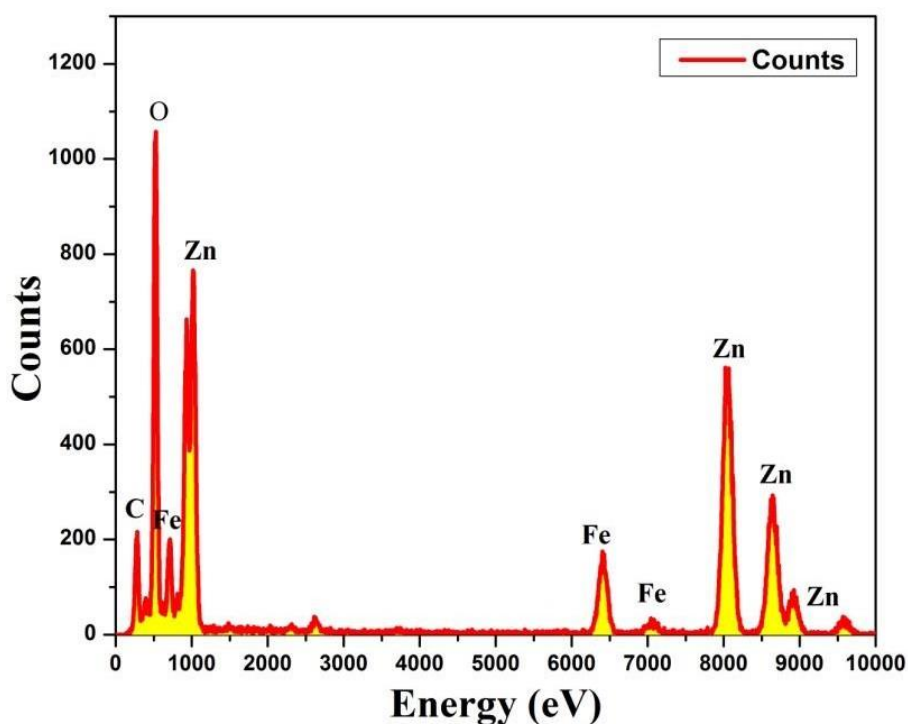


(c)



(d)

The morphology of the nanomaterials was examined using a transmission electron microscope (Abdulrahman Mohammad Alahzm *et al* 2021). The prepared nanocomposites underwent additional TEM characterization. The nanocomposites that are prepared have a spherical morphology. Fig 5.3 (a,b) depicts the TEM images of ZnO-Fe₂O₃ nanocomposites. Fig 5.3 (c,d) depicts the HRTEM images of ZnO-Fe₂O₃ nanocomposites. The information regarding the elements included in the synthesised particles can be found in the EDAX spectra presented in fig. 5.3 (e). The presence of Zn and Fe in the ZnO and FeO samples, respectively, is obvious, whereas both elements are shown in the hybrid. The samples' purity is confirmed by the lack of any other components (Abdulrahman Mohammad Alahzm *et al* 2021).



(e)

Fig 5.3 (a,b) TEM microphotographs of ZnO/Fe₂O₃ nanocomposites.

(c,d) HRTEM microphotographs of ZnO/Fe₂O₃ nanocomposites.

(e) EDAX spectra of ZnO/Fe₂O₃ nanocomposites.

CHAPTER-6

APPLICATION

From a crop protection perspective, agrochemicals are an unavoidable part of agriculture. Agrochemical use is unavoidable since diverse pests cause crop losses of between 30 to 40% every year. However, through drift hazards, run-off, or leaching, about 90% of the applied pesticides are lost into the air or water bodies. (Ghormade *et al* 2011). Research on using nanocomposites to deliver insecticides is in its early stages. Due to its target-specific delivery in the case of controlled release formulations of nutrients and pesticides, wastewater purification, and specificity in sensors for detecting pesticide residues, the use of nanocomposites has attracted interest lately (Subhasis sarker *et al* 2020). An alternative pest management method has been created through the use of nanoparticles (NPs). Under laboratory and green house circumstances, the goal was to assess the insecticidal activity of zinc oxide nanoparticles (ZnO NPs). (Jose A. Gutierrez Ramirez *et al* 2021). Zinc oxide nanoparticles (ZnO NPs) in agriculture have potential in promoting seed germination rate (De la rosa *et al* 2013), plant growth and development (Burman *et al* 2013), as well as fungicide and bactericide properties (Gonzalez-merino *et al* 2021). Using nanoparticles as pesticides is a cutting-edge and promising method that can be beneficial in managing pests where traditional methods have failed owing to resistance issues (Jose A. Gutierrez Ramirez *et al* 2021). In order for plants to grow and develop properly, they require the microelement zinc. Because of its stability and utility in biosafety, ZnO NPs have received a lot of attention over time. (Pandey *et al* 2010).

6.1 Materials and Methods

6.1.1 Maintenance of insect culture

The weevils (*S. oryzae*) have been collected from the Department of Millets, Tamil Nadu Agricultural University and cultured on maize grains. For, mass culturing, hundred grams of disinfected maize seeds [CO MH (8)] were taken and freshly emerged adults of fifty numbers were released. The containers were covered with muslin cloth and maintained at room temperature of $27 \pm 3^{\circ}\text{C}$ and 60% RH with 18 h of light and 6 h of darkness throughout the period of study. Newly emerging

adults after 20 to 25 days of release were used for the maintenance of subcultures. Uniform-aged adults (1 week old) were used for bioassay studies.



Fig 6.1 Light microscopic image of weevils

6.2 Bio-assay procedure

Contact toxicity bioassays were performed to assess the entomotoxicity of nanoparticles in comparison with insecticides and precursor. The maize seeds were treated with different concentrations of biogenic ZnO, Fe₂O₃ and ZnO:Fe₂O₃ nanoparticles (1, 5, 10, 25, 40, 60, 80, 100, 130 and 150 mg/100 g of maize seeds) and the containers were closed muslin cloth and kept in room temperature (27 ± 3°C). A control (without any treatment) was maintained to compare the results. The containers were shaken manually to achieve equal distribution of treatment materials on all maize seeds (Subramanyam and Roesli *et al* 2000). Fifteen pairs of uniformly aged adults were introduced into each container. Three replications were performed for each treatment in a completely randomized block design. For seven days, insect mortality was recorded at 24 h intervals. The Abbotts formula was used to calculate the corrected mortality. The mortality data were subjected for calculating LD₅₀. In addition, bioassays were conducted to confirm the efficacy of lethal, and sub-lethal doses (LD₂₅, LD₅₀, LD₇₅ and LD₉₀) of insecticides causing mortality to the adults of *S. oryzae*. For each treatment, untreated check was maintained.

$$\text{Corrected (\%) mortality} = \frac{X - Y}{100 - Y} \times 100$$

X = Percentage mortality in the nanoparticles treated samples.

Y = Percentage mortality in the untreated check.

6.3 Statistical analysis

The observations were analysed by completely randomized design (CRD) using statistical software SPSS and probit regression analysis was carried out by Finney's method (1971) using excel software. Analysis of variance (ANOVA) was conducted to determine whether a significant effect exists on the various treatments at the 0.05 % level of significance imposed in the *S. oryzae* management and on the agro-morphological characteristics of maize seeds.

6.4 Results and discussion:

6.4.1 Entomotoxic activity of nanomaterials

Probit regression analysis on the toxicity of revealed significant differences in the median lethal doses of nanoparticles, insecticide, and precursor. The LD₅₀ and LD₉₀ doses of ZnO, Fe₂O₃ and ZnO:Fe₂O₃ nanoparticles were calculated χ^2 value was less than the tabular value indicating the goodness of fit (Table 1 & 2). The toxicity of insecticides generally increases with the dose and time of exposure. The pattern of mortality of various insecticides are tabulated. Cent per cent mortality was attained within 6 days for ZnO:Fe₂O₃ nanoparticles whereas seven days for ZnO:Fe₂O₃ nanoparticles at their maximum doses. The efficacy of lethal and sub-lethal doses of various insecticides revealed significant differences in their activity. In all the cases, the LD₉₀ dose was found to be more effective. The results are in accordance with the findings of (Das *et al* 2019) where they reported that ZnO nanoparticles at the dose of 2 g/kg showed 90 % mortality in adults of *S. oryzae*. Similar results were also recorded by (Haroun *et al* 2020). They recorded higher toxicity, reduced enzymes activity (midgut α -amylase, cysteine protease, α -glucosidase, β -glucosidase, glutathione S-transferase (GST) and lipase) and delay in the developmental period of insects (*S. oryzae*, *C. maculatus* and *T. castaneum*), when they were exposed to ZnO nanoparticles.

Table 6.1 Probit regression analysis of mortality data against *S. oryzae*

Particulars	LD ₅₀ mg/100 g of seeds (95 % fiducial limits)	LD ₉₀ mg/100 g of seeds (95 % fiducial limits)	Slope	χ^2 *	Degrees of freedom
ZnO:Fe ₂ O ₃	0.92 (0.58-1.44)	12.13 (2.43-60.71)	1.401	2.024	6
Fe ₂ O ₃	0.44 (0.29-0.69)	6.64 (1.46-30.29)	1.282	2.343	6
ZnO	4.73 (3.95-5.67)	13.92 (8.73-22.20)	3.046	1.776	6

a = In each case χ^2 value from the goodness of fit test was less than the tabular value, ($p = 0.05$), indicating that the data fit the probit model.

Table 6.2 Comparison of effective doses of nanomaterials with the recommended doses of insecticide against *S. oryzae*

Particulars	Dose (mg./100 g of maize seeds)	Cumulative mortality (%)							Total mortality (%)
		1 DAR	2 DAR	3 DAR	4 DAR	5 DAR	6 DAR	7 DAR	
ZnO	19.92	36.67 ^b ± 0.23	76.67 ^b ± 0.68	100 ^a ± 1.20	100 ^a ± 2.33	100 ^a ± 2.33	100 ^a ± 2.33	100 ^a ± 2.33	100
Fe ₂ O ₃	36.39	33.33 ^c ± 0.50	66.67 ^c ± 0.24	96.67 ^b ± 0.70	100 ^a ± 0.05	100 ^a ± 0.05	100 ^a ± 0.05	100 ^a ± 0.05	100
ZnO:Fe ₂ O ₃	1000	60.00 ^a ± 0.22	100.00 ^a ± 0.16	100 ^a ± 1.35	100 ^a ± 0.99	100 ^a ± 0.99	100 ^a ± 0.99	100 ^a ± 0.99	100
Control (Without treatment)		0.00 ^d ± 0.00	0.00 ^d ± 0.00	0.00 ^c ± 0.00	0.00 ^b ± 0.00	0.00 ^b ± 0.00	0.00 ^b ± 0.00	0.00 ^b ± 0.00	0.00
SEd		0.661 2	1.4053	1.746 5	2.104 1	2.104 1	2.104 1	2.104 1	-
CD (0.05)		1.534 7	2.8106	4.035 2	4.852 2	4.852 2	4.852 2	4.852 2	-

CHAPTER-7

SUMMARY AND CONCLUSION

- A environmental benign method for the preparation of ZnO/Fe₂O₃ nanocomposites using co-precipitation method.
- From XRD studies, in order to obtain results, the powdered *Turbinaria ornata* with the combination of nanocomposites displays on topmost sharp peaks and few low sharp peaks with the nature of Bragg's peaks appearing in XRD pattern.
- From FTIR studies, the powdered sample shows the band at 400-500 cm⁻¹ for the main element. It also shows different band at different wavelength.
- This spectrum has an absorption band that consists of an alkene band, a weak band at several vibrational groups, and a hydroxyl group.
- From TEM/HRTEM studies, gives spherical morphological character of the produced nanocomposites in different size and colour.
- This study evaluated the effectiveness of ZnO/Fe₂O₃ nanocomposites for pest control in agriculture. These findings support the use of ZnO/Fe₂O₃ nanoparticles for crop productivity and insect management in agriculture.

ACKNOWLEDGEMENTS

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FACILE ONE POT GREEN SYNTHESIS AND STRUCTURAL CHARACTERIZATION OF ZINC OXIDE-IRON OXIDE NANOCOMPOSITES

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Abstract:

Green nanotechnology has recently had a significant influence on advances in biological applications. Plant based phytochemicals are employed for the synthesis of nanoparticles as green methods due to their reducing properties for metal compounds into nanometals. In recent decades, the composite material has been known as an excellent material in many potential applications. Therefore, the choice of nanocomposite synthesis method becomes a significant thing especially in controlling material properties. Semiconductor metal oxides have been used widely in many fields of applications in electronics such as photocatalysis processes, adsorption of heavy metals, solar cells and gas sensors. Zinc oxide nanoparticles (ZnO NPs) are an example of semiconductors widely used in many industrial and consumer products. Modification of ZnO NPs by various metal and metal oxide NPs not only can improve the properties of ZnO NPs but also add brand-new properties, creating multifunctional products. Iron oxide NPs are vital metal oxide nanoparticles that can be used in several therapeutic applications and surface manipulation is necessary to make iron oxide NPs biocompatible. The low reactivity, agglomeration, and oxidation of iron oxide NPs can be avoided by coating with another metallic oxide NPs, such as zinc oxide NPs. The surface coating of iron oxide NPs not only decreases the cytotoxicity of iron oxide NPs but also increases the stability and efficiency of antimicrobial potential of Iron oxide NPs. In the present study, zinc oxide-iron oxide nanocomposites was prepared using *Turbinaria ornata* seaweed as reducing as well as stabilizing agent through a facile one-pot co-precipitation method, green route which is environment benign and low cost. The structural characterization was done using X-ray diffraction (XRD) and Fourier transform Infrared (FTIR) analysis.

Keywords: Nanocomposites; Green route; XRD; FTIR; Structural characterization

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Paper Title : Facile one pot green synthesis and structural characterization of zinc oxide-iron oxide

..... Nanocomposites

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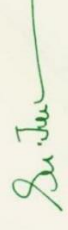
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