# SYNTHESIS OF COPPER OXIDE NANOPARTICLES USING CHEMICAL METHOD AND ITS CHARACTERIZATION AND CYTOTOXICITY STUDIES AND ANTI-MICROBIAL STUDIES

**Abstract**

Nanotechnology is being studied in almost all technological domains, but the public is ignorant of its extensive uses in medical, engineering, environmental, electronics, military, and security. Recent technological advancement shows that nanotechnology and nanoscience must evolve. Nanomaterials (NMs) are used in technological developments due to their adjustable physical, chemical, and biological characteristics and better performance over bulk equivalents. NMs are divided by size, chemical composition, capping agents, form, and country of origin. Metal nanoparticles are used in one method of the chemical production of anti-cancer NPs. Due to their excellent biocompatibility, stability, and distinctive surface features, gold nanoparticles (AuNPs), for example, have been thoroughly investigated for their potential as anti-cancer agents. Several techniques, such as chemical reduction, photo-reduction, and electrochemical reduction, can be used to create AuNPs chemically. The publication reviews NM classifications, history, and several nanoparticle and nanostructured material sources, both manmade and natural. Nanoparticles (NPs) and nanostructured materials are versatile.

**Keywords:** Nanomaterials (NM), Nanoparticles (NPs), Copper oxide (CuO), Bimetallic (BM), Monometallic (MM)

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## I. INTRODUCTION

Nanomaterials have emerged as a fascinating new class of materials that are in great demand for a wide range of applications in a number of fields. One way of imagining the length of a nanometer is to imagine lining up five atoms of silicon or ten atoms of hydrogen, with each atom being exactly one nanometer in length. A material is considered to be of the nanomaterial category if its size or one of its dimensions is between 1 and 100 nanometers (nm). It is difficult to establish the exact beginning of human usage of nanoscale things because of their small size. However, the use of nanomaterials has a long history, and people have unintentionally used them for a wide range of purposes for a very long time. Around 4500 years ago, mankind began adding asbestos nanofibers to ceramic mixtures in order to make them more durable (1,2). Nanomaterials may be categorised according to their dimensionality and occur in a wide range of morphologies, including nanorods, nanoparticles, and nanosheets, for example. Nanorods or nanotubes are examples of one-dimensional nanomaterials, whereas films and layers are examples of two-dimensional nanomaterials. Nanoparticles are a sort of nanomaterial with zero dimensions, while nanorods and nanotubes have one dimension each. The majority of them fall under the category of solitary, individual nanomaterials. The interaction of two or more particles will result in a change in the properties of both of the interacting particles. These particles may be classified as either bulk or three- dimensional nanomaterials, depending on their specific composition (3,4).

The field of nanotechnology has made enormous strides in recent years, both in terms of the research conducted into it and the applications that it has found. The interesting and extraordinary features demonstrated by nanoparticles, such as their durability, high diffusivity, various chemical and biological activities, and also their diversified uses when compared to their bulk materials, are the cause of the exponential expansion in nanotechnology. These properties are responsible for the exponential growth of the nanotechnology industry. The enormous potential of nanotechnology is finding widespread application in the field of medicine. It has led to the elimination of infectious illnesses via the use of nanoscience in conjunction with biological research. In particular, there has been a significant uptick in interest all around the globe in the production of nanoparticles via the use of environmentally benign green nanotechnology-based technologies. The typical production of nanoparticles via the use of physical and chemical processes has had a significant detrimental effect on the surrounding environment. As a result, there is a need for the production of biogenic nanoparticles using methods that are safe for the environment, with a particular emphasis on the integration of bio and nano-techniques (5).

Nanoparticles are particulate dispersions or solid particles that have a size in the range of 10-1000 nm, according to the definition given in (6). The term "nanotechnology" refers to a burgeoning subfield of the physical sciences that involves the production and study of a wide variety of nanomaterials. Copper, zinc, titanium, magnesium, gold, alginate, and silver are some of the metals that are now being used in the production of a variety of metallic nanostructures. Nanoparticles are being incorporated into a broad variety of materials, including those used in the cosmetics and clothing industries, as well as those used in energy storage devices like solar and oxide fuel batteries (7). Nanoparticles are also being employed in a variety of medicinal treatments, as well as in the manufacturing of many types of industrial goods, such as solar and oxide fuel batteries. Due to the fact that they possess both physicochemical and physical properties, metal oxide nanoparticles, namely CuO, have recently attracted a great deal of interest and scrutiny. It has been determined that amalgamation of CuO nanoparticles is superior than that of other metal oxide nanoparticles owing to the huge potential uses that these nanoparticles have had in the preceding decade (8). Nanoparticles are of great interest because they act as a bridge gap between the atomic/molecular structure4 and the material in bulk. This is because nanoparticles exhibit completely new or improved properties based on specific characteristics such as size, shape, distribution, ionic strength, capping agent, and morphology (9). This is why nanoparticles are of such great interest. Nanotechnology and nanoengineering have the potential to bring major scientific and technical improvements in a variety of sectors, including physiology and medicine (10).

Nanoparticles have been the subject of much research because of the possibility that they may be used in biological applications such as the administration of drugs and imaging (11). These magnetic nanoparticles have been put to use in a variety of biological applications, including the detection and treatment of cancer (12). Nanoparticles of semiconductor material known as quantum dots exhibit distinctive characteristics both optically and electronically. They have been put to use in a wide variety of applications, including bioimaging, display technology, and solar cells (13). These carbon nanoparticles have the structure of a tube, and they have been investigated for the possibility that they may be used in a variety of applications, including the administration of drugs and the operation of electrical equipment (14).

Liposomes are nanoparticles with a spherical form that are comprised of lipids. They have been used for the administration of drugs as well as gene therapy (15). These are but a few examples of the many kinds of nanoparticles and the possible uses for each of them. There are a great number of additional kinds of nanoparticles, and the continuing research that is being done in this area keeps revealing fascinating new applications for these materials. The nanoparticles have several applications, the most of which are in the medical profession; as a result, the topic has garnered a lot of interest in recent years due to developments in areas like as Drug delivery: It is possible to build nanoparticles to convey medications to particular sites inside the body, which may increase the effectiveness of the treatment while simultaneously lowering its adverse effects (16). It is possible to utilize nanoparticles to deliver medications or radiation directly to cancer cells, which increases the treatment's effectiveness while decreasing the collateral harm to healthy tissue (17). It has been shown that the performance of energy storage devices like batteries and supercapacitors may be enhanced by the addition of nanoparticles. It is possible to purify water by removing contaminants using nanoparticles. These pollutants may include heavy metals, organic compounds, and microorganisms.

In a prior work, it was revealed that CuO nanoparticles (NPs) display favourable physical and chemical features, such as high surface areas, appropriate redox potential, great electrochemical activity, superthermal conductivity, and good stability (18). These qualities were found in CuO nanoparticles. CuO nanoparticles have found use in a wide variety of areas, including the sensing of the environment. It is possible to employ Cu and CuO NPs as therapeutic agents for wound healing as well as antibacterial agents, antifungal agents, anticancer agents, and anti-inflammatory agents. Antibacterial Research has shown that nanoparticles composed of copper and copper oxide suppress the development of both Gram-negative and Gram-positive bacteria (19). According to the findings of the research, copper oxide nanoparticles shown substantial antibacterial activity against a variety of bacterial strains, including drug-resistant strains, and showed promise for use in the creation of antibacterial coatings for medical devices and wound dressings. In addition, the research proved the lethal effects of copper oxide nanoparticles on cancer cells, as well as the possible application of these particles in the treatment of cancer. The production of ROS by the nanoparticles caused cancer cells to undergo apoptosis, which ultimately resulted in DNA damage and the death of the cells. According to the findings of the research, there is also the possibility of specifically targeting cancer cells by functionalizing copper oxide nanoparticles with particular ligands or antibodies.

The biocompatibility and cytotoxicity of copper oxide nanoparticles were examined by Biointerfaces when applied to human skin cells. According to the findings of the research, copper oxide nanoparticles displayed only a negligible amount of toxicity towards the cells when present in lower concentrations. However, the level of toxicity rose when the nanoparticles were present in higher concentrations. According to the findings of these investigations, copper oxide nanoparticles have the potential to be used in a variety of biomedical applications, including antibacterial coatings, cancer treatment, and drug delivery. However, further study is required to optimise their characteristics and biocompatibility in order to guarantee that they may be used in clinical applications without risk and in an effective manner.

Applications of nanotechnology may be found in many different areas, including but not limited to the domains of electronics, materials science, medical, energy, and environmental science. It has opened the door for the creation of new materials and gadgets that possess unique features and functionalities. For instance, the use of nanotechnology has resulted in the creation of computer processors that are both quicker and more efficient, as well as sophisticated medication delivery systems for the treatment of cancer that are targeted, high- performance energy storage devices, and water purification systems. The discipline of nanotechnology is still in its early phases of growth, and there are many obstacles that need to be addressed, such as the safety and ethical concerns that are related with the usage of nanoparticles. Additionally, the field of nanotechnology is still in its early stages of development. However, the possible applications of nanotechnology are quite broad, and its continuous growth is anticipated to have a significant influence on a variety of facets of our lives in the not-too- distant future. The design, synthesis, and manipulation of materials and devices on the nanoscale scale are the topics that are explored in the discipline of nanotechnology, which is a subfield of both science and technology.

Because of their one-of-a-kind electrical, optical, and catalytic capabilities, some metals, including gold, silver, copper, platinum, and iron, are often used in the process of nanoparticle creation. Titanium dioxide, zinc oxide, iron oxide, and copper oxide are just a few examples of the types of metal oxides that are often used in the production of nanoparticles owing to their high stability and wide range of potential uses. Due to the distinctive electrical and optical characteristics that semiconductors possess, such materials as silicon, cadmium selenide, and cadmium sulphide are often used in the process of nanoparticle creation. Because of their capacity to stop nanoparticles from aggregating into larger clusters, polymers including polystyrene, polyethylene, and polyvinylpyrrolidone are often utilised as stabilising agents in the manufacture of nanoparticles. Because of their capacity to regulate the size, shape, and surface characteristics of nanoparticles, surfactants like cetyltrimethylammonium bromide (CTAB) and sodium dodecyl sulphate (SDS) are often utilised as stabilising agents in the production of nanoparticles (20).

The creation of copper oxide nanoparticles has been accomplished by a variety of different methods, including chemical, biological, and physical processes. Sonochemical, precipitation, sol-91 gel, chemical reduction, chemical bath deposition, hydrothermal approach, non-vacuum and spin-92 coating sol–gel is a wet-chemical process that involves the formation of an inorganic colloidal suspension (sol) and gelation of the sol in a continuous liquid phase (gel) to form a three-dimensional network technique, electrothermal, and green chemistry pathway are some of the processes that fall under this category. The use of highly toxic chemicals that are released into the environment or absorb on the surface of materials that may cause unfavourable effects in the medical applications, high cost, low product efficiency, and high energy consumptions are some of the limitations that are associated with the synthesis of copper oxide nanoparticles via chemical or physical methods (21). Copper oxide nanoparticles that are produced by environmentally friendly methods are beneficial to the environment, economical, safe, durable, stable, and have a longer shelf life. The creation of copper oxide nanoparticles has included the utilisation of a wide variety of biotic resources.

The synthesis of copper oxide nanoparticles attributed to the presence of plants in the process. Producing copper oxide nanoparticles by making use of plant extracts has seen a substantial amount of study done in the area (22). In spite of the fact that bacteria, algae, and fungus all provide their own unique set of advantages to the manufacturing process of copper oxide nanoparticles, there are a number of obstacles that must be overcome in order to make use of these species. The most major obstacles are the bacteria's inherent toxicity, the method of isolating the germs, and the incubation process (23). As a consequence of this, the utilisation of plant extracts as a source of raw material in the production of metal and metal oxide nanoparticles is something that is highly recommended. The production of plant-based nanoparticles is an easy and uncomplicated process that is also risk-free, consumes only a little amount of energy, and results in particles that are more stable than other types. This technique involves combining the metal salt with a number of additional components. Fungi were used as a catalyst in a procedure that resulted in the formation of copper oxide nanoparticles. In the course of the past several years, a wide variety of fungal species have been used in the manufacturing of copper oxide and other metal nanoparticles. Fungi are more resistant to the agitation, flow pressure, and other conditions that are present in a bioreactor or any other growth chamber than bacteria are. Extracts of microorganisms that have had their cells removed may be used as reducing, catalysis, or capping agents in the biogenic manufacture of nanoparticles (24).

Fungus that is well-known by many people inspite of the fact that Trichoderma species are responsible for the creation of a broad range of bioactive metabolites such as pyrones, polyketides, terpenes, diketopiperazine, glycolipids, and enzymes, these metabolites do not play a role in the synthesis of copper oxide nanoparticles (25). Fungi have the potential to create nanoparticles through two principal routes: the intracellular route, and the extracellular way. When compared to the extracellular technique, the size of the nanoparticles that are synthesised inside the fungal species may be smaller; nonetheless, they will still have appropriate dispersity and well-defined dimensions. This is in contrast to the extracellular approach. The generation of nanoparticles through the extracellular pathway is connected with a significant number of positive outcomes and outcomes. There is a possibility that the synthesised nanoparticles do not include any cellular components. For the most part, the production of nanoparticles has been accomplished by the fungus through its extracellular pathway. This is owing to the fact that fungi release a range of metabolites, which during the process of creating nanoparticles may function both as reducing agents and as agents that stabilise the particles (26). As part of the process of synthesising nanoparticles, several strains of fungi have been used in the manufacture of metal oxide nanoparticles, which include included copper oxide nanoparticles.

## II. EXPERIMENTAL METHODS

Any heterogeneous reaction that takes place in the presence of aqueous solvents or mineralizers at high pressure and temperature in order to dissolve and recrystallize (recover) materials that are normally intractable in their natural form is referred to as "hydrothermal processing" (27). Dissolving 100 mM of copper (II) sulphate pentahydrate (CuSO45H2O) in 75 mL of distilled water with continuous stirring on a magnetic stirrer at room temperature for thirty minutes was a typical method for performing research. The procedure was carried out for a period of thirty minutes. Following a thorough mixing of the water and NaOH, the resulting liquid was allowed to rest at room temperature for thirty minutes. It was 75 millilitres of distilled water that was utilised for the experiment. Drop by drop, the NaOH solution is added to the CuSO4 solution that is being kept at room temperature in the magnetic stirrer. This process continues until the very last drop has been added. This procedure will continue until both solutions have been completely incorporated into one another. A distinct hue shift manifested itself after an unspecified amount of time had passed during which the solution had been stirred while being kept at room temperature. After that, it is kept for a period of 24 hours in a hydrothermal autoclave that is placed within a hot air oven at a temperature of $190^0$F. The steps are repeated a certain number of times till the desired total has been reached. After producing the precipitate, it was subjected to centrifugation at 10,000 rpm for ten minutes in order to remove any contaminants. This process was done many times, and in between each iteration, the precipitate was washed with deionized water. For the purpose of collecting the sludge-like material that was formed, a Petri plate is utilised. The completed item was baked in an oven with hot air at a temperature of $190^0$F for twenty-four hours to complete the drying process.

## III. SULTS

The specified technique was followed in order to generate the nanoparticle, and the nanoparticles that were produced conformed to copper oxide and had mechanical characteristics such as UV, XRD, FTIR, and TEM. Studies on the cytotoxicity of the newly produced rod-shaped copper oxide nanoparticles were performed after the nanoparticles were synthesised and analysed subsequently.

1. **Ultraviolet Visible Analysis:** UV spectroscopy is the most important technique for determining whether or not copper oxide nanoparticles have been formed (28-30). The generation of copper oxide from copper ions was tracked by detecting UV vis spectra of the reaction mixture. These spectra were acquired on a uv visible spectrometer between 200 and 800 nm. The spectrum exhibits a distinctive absorption at a certain wave length, and when it was subjected to UV-vis light, the peak that appeared between 200 and 500

was the one that was relevant.

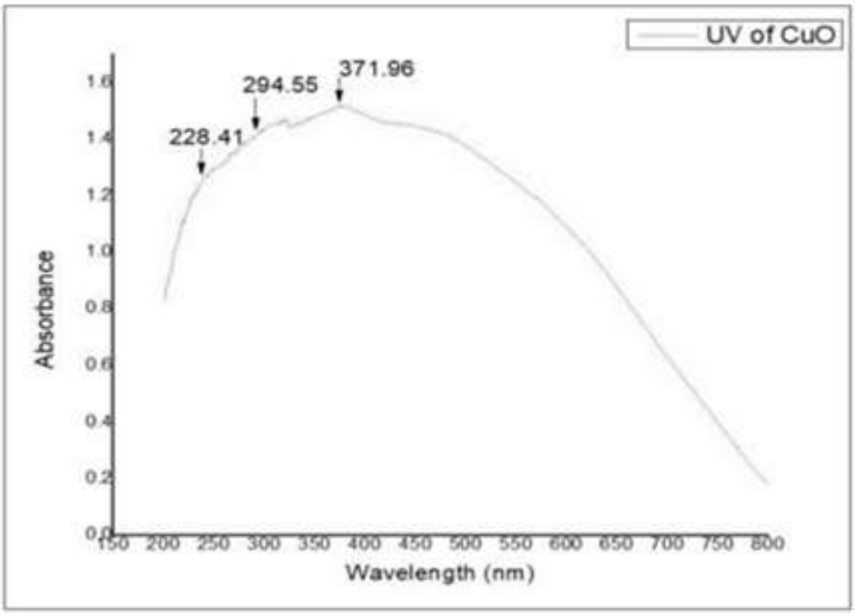
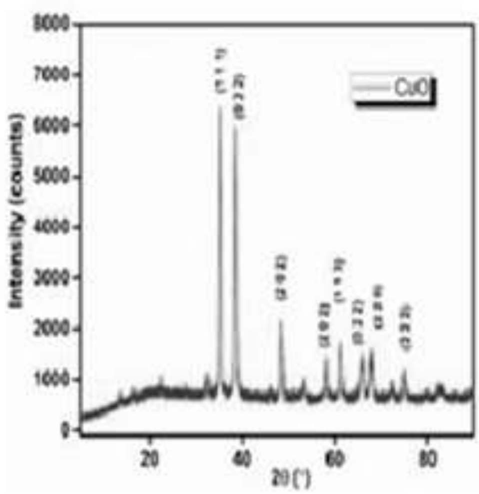



**Figure 1:** Ultraviolet visible Spectrum of CuO

2. **X-Ray Diffraction Analysis:** An X-ray diffraction study is carried out in order to investigate the crystal phases and crystallinity of the CuO-NPs that were formed. It was noticed that the XRD pattern was present in the peak at 32.29(2), 35.301(4), 36.35(3), and 38.497(4). The presence of peaks corresponding to Miller indices (31-35) (111), (022), (202),(202), (113), (022),(220), and (222) lends credence to the hypothesis that CuO-NPs have a monoclinic structure.



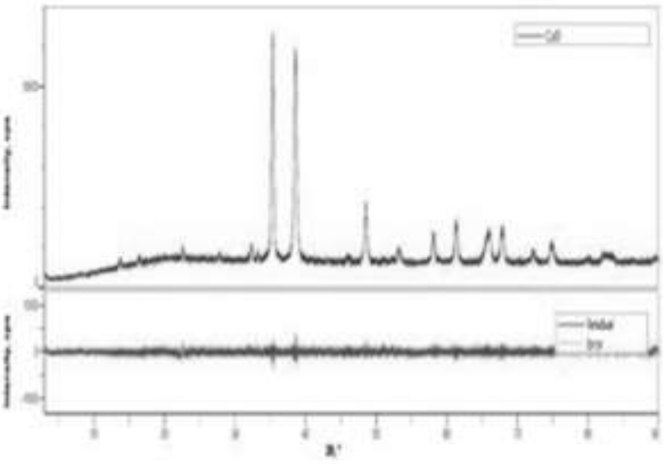



**Figure 2a:** *X-ray Diffraction of CuO* **Figure 2b:** *Peak Profile of CuO*

3. **Fourier Transform Infrared Analysis:** The FTIR spectrum of copper oxide nanoparticles that were synthesised and studied was compared to the infrared spectrum of nanoparticles of copper oxide. This was done as part of the comparative studies of FTIR. The peaks in the IR spectra that are located exactly at 3563.41 $cm^{-1}$ might be created by N–H stretching, or they could be caused by hydroxyl groups that are adsorbed on CuO nanoparticles. Both of these possibilities are possible. The stretching of the C–H bond is responsible for 3386.44 $cm^{-1}$,whereas the deformation of the OH group is responsible for 1121.18 $cm^{-1}$ (36-37). Some of the peaks show reflections in the range of 777.24 $cm^{-1}$ to 985.64 $cm^{-1}$, and it is possible that the bending mode of the vibrations is to blame for these reflections.

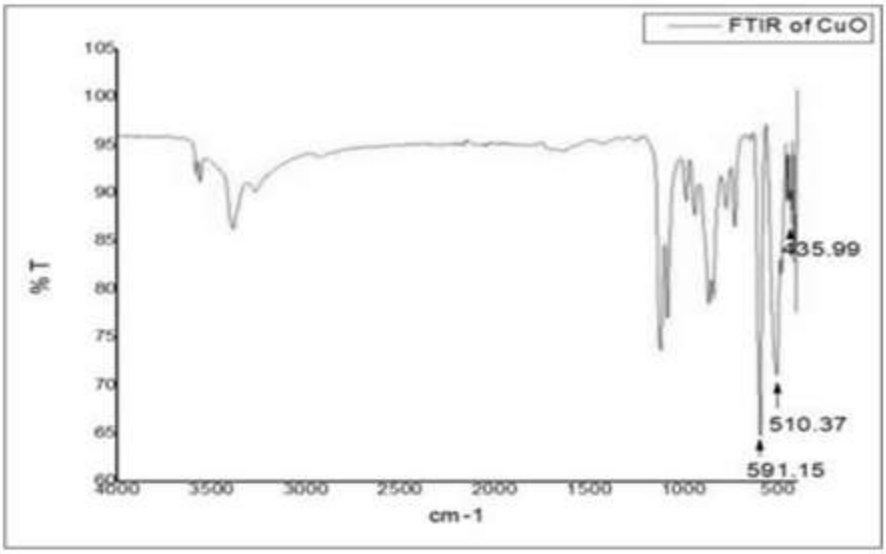



**Figure 3:** Fourier transform infraredof CuO

4. **Dynamic Light Scattering-Zeta Potential:** Zeta potential is a physical property which is exhibited by any particle in suspension, macromolecule, or material surface. It can be used to optimize the formulations of suspensions, emulsions and protein solutions, predict interactions with surfaces, and optimise the formation offilms and coatings (38). The zeta potential and particle size distribution of Chemical (10 ml) CuO-NPs are investigated by dynamic light scattering (DLS) technique uses to form hydrodynamic radius considering each particle as a separate sphere in Brownian movement Zeta potential (ZP) values expose details regarding the surface area charge and the stability of samples. CuO-NPs are 5.4. Since, ZP valuesabove +30 eV or below −30 eV is high charge which makes repulsion between particles to preventcoalescence and aggregation of the nanoparticles.

**Table 1: Zeta Potential Mean Data Set(CuO)**

| Peak No. | Zeta Potential | Electrophoretic Mobility |
|---|---|---|
| 1 | 5.4mV | 0.000042 $cm^2/Vs$ |

**Table 1a: Zeta Potential Average Data Set (Cuo)**

| Peak No. | S.P.Area Ratio | Mean(nm) | S.D (nm) | Mode (nm) |
|---|---|---|---|---|
| 1. | 0.28 | 1.7 | 1.0 | 1.8 |
| 2. | 0.52 | 1007.4 | 666.6 | 616.6 |
| 3. | 0.20 | 4748.6 | 1364.2 | 6273.1 |
| 4. | 1.00 | 1453.8 | 1848.4 | 616.6 |

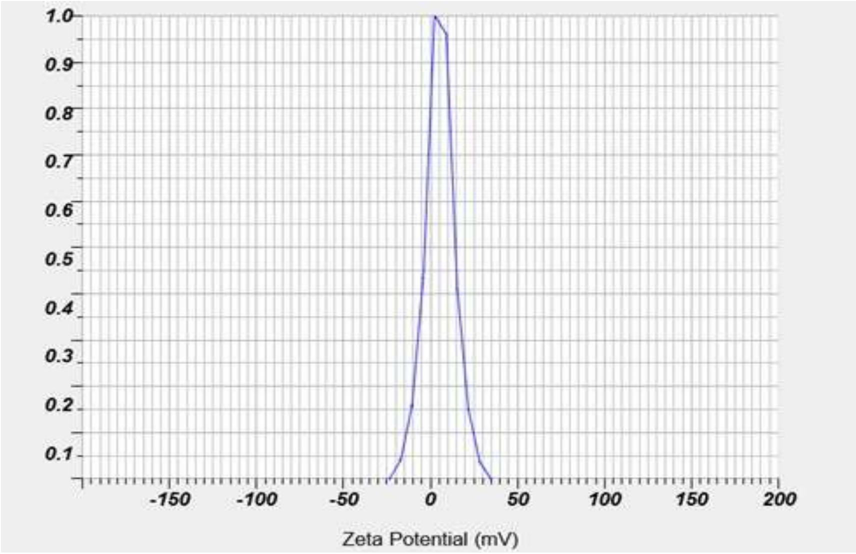



**Figure 4a:** Zeta Potential Mean Result Graph (Cuo**)**

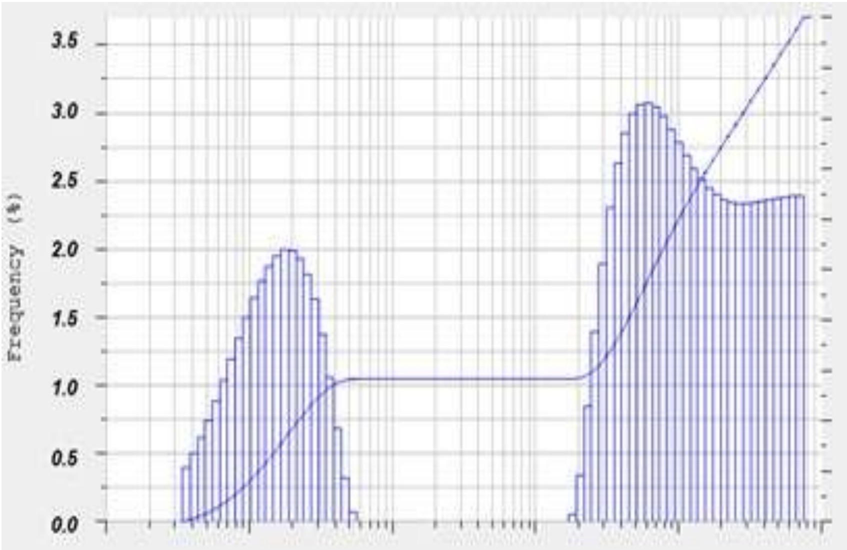



**Figure 4b:** Zeta Potential Average Result Graph (Cuo)

**Table 1c: Zeta Potential Average Data Set (CuSO4)**

| Peak No. | S.P.Area Ratio | Mean(nm) | S.D (nm) | Mode(nm) |
|---|---|---|---|---|
| 1. | 0.99 | 87.3 | 436.7 | 0.8 |
| 2. | 0.01 | 6353.0 | 633.7 | 6722.6 |
| Total | 1.00 | 120.9 | 633.4 | 0.8 |

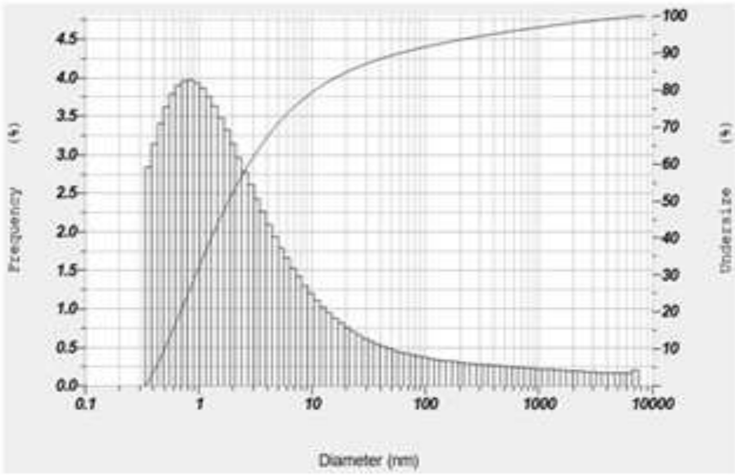



**Figure 4c:** Zeta Potential Average Result Graph (CuSO4)

5. **Transmission Electron Microscopy Analysis:** The form, measurement, and morphology of 10 millilitres of CuO-NPs. CuO-NPs are being analysed by HR-TEM. The morphology of these particles is asymmetrical, and their distribution is not consistent. Under the experimental circumstances that were observed, this is presumably attributable to the fact that the surfactant is only partially soluble in the solvent (39). They take the form of rods and are of a much larger size.

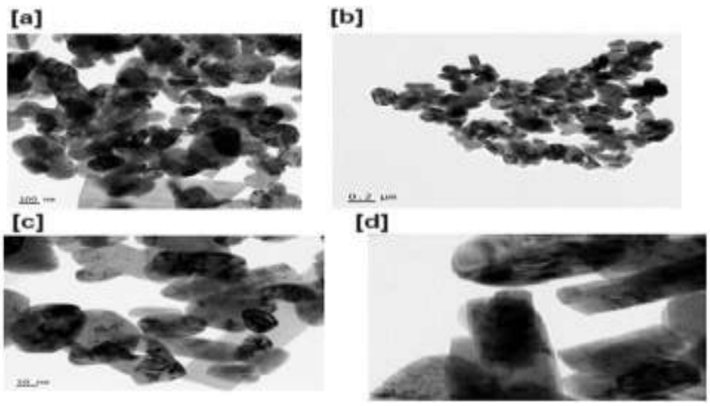



**Figure 5:** Transmission Electron Microscopy Images of[a]100nm,[b] 0.2µm,[c] 50nm and[d] 20nm

6. **Cytotoxicity Studies:** In order to determine the level of cell viability, neutral red (NR) and MTT tests were performed; however, for the 4 T1 cells, only the MTT assay was carried out. The MTT test is based on the conversion of water-soluble MTT into non-soluble purple formazan, which may be measured using spectrophotometry (40-42). The concentration of 1.59 mg/ml was used for the MTT test, and it was performed. Since it was discovered that the cell viability was more than 100%, this indicates that the copper oxide production is not hazardous to the cell.

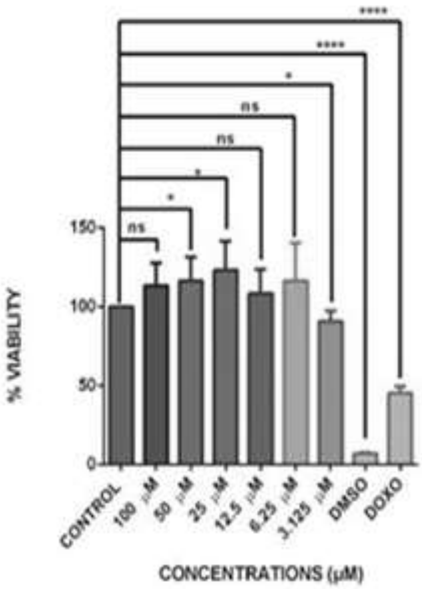



**Figure 6a:** Cell Viability-Concentration Graph

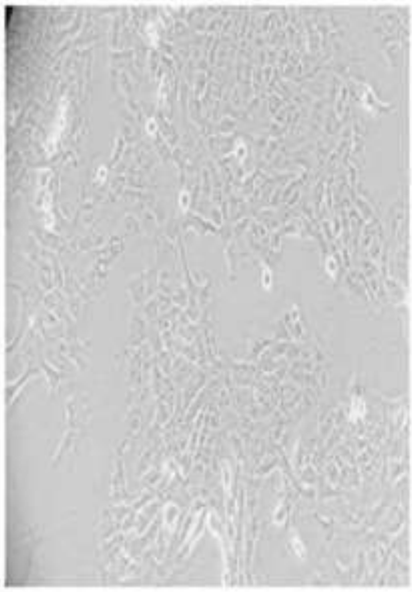


**Figure 6b:** Live Cell Image

**Figure 6c:** 2.5-dphenyl-2H-tetrazolium bromide *assay plate*

7. **Antimicrobialactivity:** The nanoparticle was successfully manufactured, and its antibacterial activity was evaluated. The sample was diluted in water until it had a concentration of 100 mg/ml. Several different concentrations were applied to the culture plate after it had been manufactured (43-45). The plate was made by applying a stripe of microbial culture on the surface of the agar plate.and the well diffusion approach was used for the purpose of conducting the investigation of the nanoparticles' activities. The concentrations that were employed were 25, 50, 75, and 100 microliters. Ampicillin was included as a part of the experiment as a positive control, whereas water served in that capacity. The five different microbial cultures that were used for the task. They consist of staphylococcus aureus (positive), candida, Escherichia coli (negative), bacillus (positive), and pseudomonas aeruginosa (negative). There was no evidence of a zone of inhibition found.

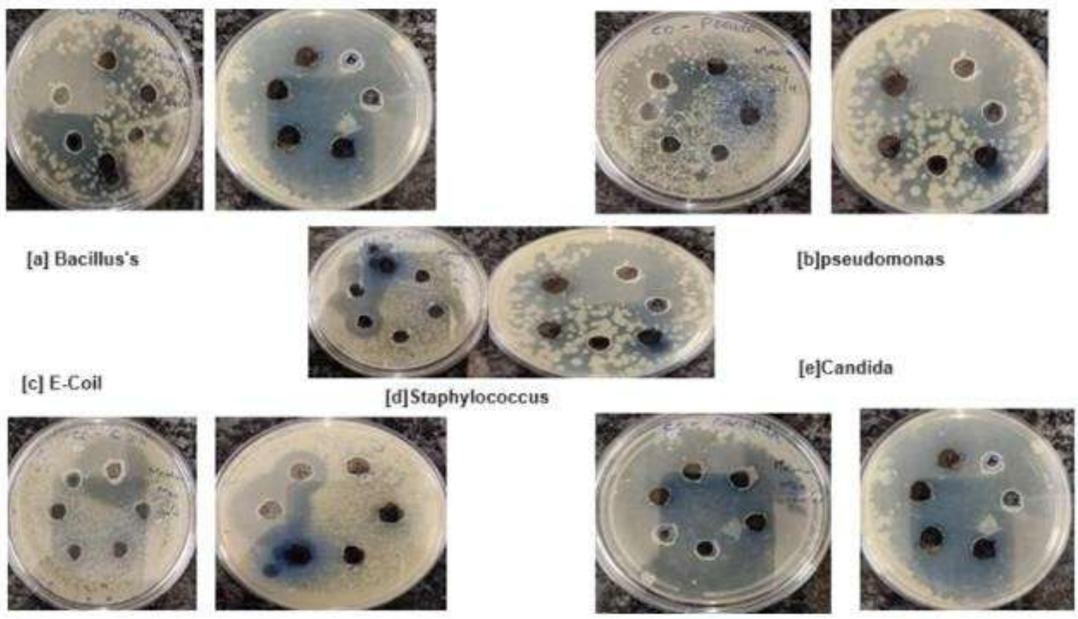



**Figure 7:** Antimicrobial activity of [a]Bacillus's [b]pseudomonas [c]E-coil [d]Staphylococcus and [e]Candida

**Table 4: Zone of inhibition**

| PATHOGEN | 25µL | 50 µL | 75 µL | 100 µL | Positive control | Negative control |
|---|---|---|---|---|---|---|
| Candida | - | - | - | - | +ve | -ve |
| Bacillus | - | - | - | - | +ve | -ve |
| E. coli | - | - | - | - | +ve | -ve |
| Streptococcus | - | - | - | - | +ve | -ve |
| Staphylococcus | - | - | - | - | +ve | -ve |

Because of the distinct physical, chemical, and biological properties that they possess, nanoparticles (NPs) are gaining a growing amount of importance in the study and treatment of cancer. In the rapidly expanding area of chemically synthesizing NPs with anti-cancer activity, a wide number of methodologies and approaches are now being researched and examined. In this session, we will discuss some of the most recent advancements that have been made in the chemical synthesis of anti-cancer nanoparticles. In this session, we will discuss some of the most recent advancements that have been made in the chemical synthesis of anti-cancer nanoparticles. Nanoparticles made of metal are put to use in one of the chemical processes that go into the manufacture of anti-cancer NPs. For example, gold nanoparticles (AuNPs), which have good biocompatibility, stability, and unique surface features, have been widely researched for their potential as anti-cancer agents. This is due to the fact that these characteristics make them stand out from other substances. Chemically speaking, the production of AuNPs may be accomplished by the utilization of a variety of methods, including photo-reduction, electrochemical reduction, and chemical reduction. In recent research, AuNPs were created by utilizing an extract from a plant, and the results showed that they effectively suppressed the development of a number of different cancer cell lines.

For example, iron oxide nanoparticles, also known as IONPs, have been the subject of substantial investigation as a possible anti-cancer drug due to the fact that they are biocompatible, possess magnetic properties, and have the ability to target cancer cells by using an external magnetic field. Magnetic nanoparticles are used in this additional technique as the active ingredient. Synthesising IONPs may be accomplished by a variety of processes, some of which include co-precipitation, thermal decomposition, and sol-gel operations. In recent research, IONPs that had been coated with chitosan were developed, and these IONPs shown significant anti-cancer activity against breast cancer cell lines(46). Carbon-based nanoparticles such as graphene oxide (GO), which have different electrical, optical, and mechanical characteristics, have also been investigated for their potential as anti-cancer medicines. This is due to the fact that carbon-based NPs have these features. The production of GO may be accomplished via the use of a variety of processes, including chemical reduction and oxidation-reduction. According to a recent research, GO was recently synthesised by using an environmentally friendly approach that included the utilisation of a plant extract. A great number of cancer cell lines exhibited a substantial level of resistance to the anti-cancer effects of the synthesised GO..

## IV. SUMMARYAND CONCLUSION

Due to the potential uses of copper oxide (CuO) nanoparticles in a variety of domains, including catalysis, sensing, and energy storage, the production of these nanoparticles has been a hot topic of study in recent years. We have examined the synthesis of CuO nanoparticles using a variety of techniques, such as chemical precipitation, hydrothermal synthesis, and the sol-gel method, as part of our thesis study. According to the findings that we have obtained, the technique of synthesis plays a significant influence in defining the size, shape, and characteristics of the CuO nanoparticles that are produced. In contrast, the hydrothermal synthesis approach resulted in the production of smaller particles that were more consistently shaped, whereas the chemical precipitation method resulted in the production of bigger particles with an irregular shape. On the other hand, the sol-gel approach resulted in the production of nanoparticles that had a high degree of crystallinity and purity.

In general, the synthesis of CuO nanoparticles is a difficult process that has to be carefully optimized and characterised in order to attain the characteristics that are sought for a variety of different applications. Our findings provide a contribution to the comprehension of the process of producing CuO nanoparticles and give insights for the conduct of more study in this area. Synthesis of CuO nanoparticles is possible using both chemical and biological approaches. Traditional techniques of chemical synthesis may be replaced with more environmentally friendly and cost-efficient alternatives such as the use of plant extracts and microorganisms. In plant-mediated synthesis, it is possible to make nanoparticles of a wide variety of sizes and shapes, but in microbial-mediated synthesis, one may exert fine-grained control over the size and form of the nanoparticles produced. Additional study is required to improve the effectiveness of these strategies and investigate the ways in which they could be used in a variety of contexts.

Copper ions are commonly reduced to CuO nanoparticles by the application of chemical reducing agents such as sodium borohydride, hydrazine, or sodium citrate during the process of chemically synthesising

CuO nanoparticles. This step is part of the chemical synthesis process. This approach often entails the use of hazardous chemicals, which may be both costly and harmful, and results in the accumulation of undesirable waste. On the other hand, it enables the production of nanoparticles that have a high degree of purity, can have their size regulated, and have a shape that is consistent throughout. In conclusion, the chemical synthesis of CuO nanoparticles allows for exact control over the size and form of the particles, but it also creates hazardous waste, necessitating the employment of dangerous chemicals that are both costly and expensive, and it necessitates their usage. Additional research is required to create more environmentally friendly methods of chemical synthesis and optimise the circumstances of the synthesis.

The prospective uses of polymer films containing CuO nanoparticles in a variety of sectors, such as cancer treatment and antibacterial coatings, have been examined. In the context of cancer treatment, it has been discovered that CuO nanoparticles display anticancer activity via a variety of different mechanisms. These mechanisms include the development of oxidative stress, DNA damage, and apoptosis. Polymer films may have their anticancer efficacy increased as well as their targeted delivery to cancer cells improved if CuO nanoparticles are included into the polymer films. In a similar manner, CuO nanoparticles have shown non-potent antibacterial action against a variety of bacteria, and no zone of inhibition has been discovered for the five different sets of microorganisms. In conclusion, the incorporation of CuO nanoparticles into polymer films might increase the anticancer and antibacterial characteristics of the polymer films, which offers the possibility of applications in cancer treatment and infection control. Additional study is required to improve the synthesis and characterization of these composite materials, as well as to determine whether or not they are safe and effective for the diverse applications being considered.

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