

# INTRODUCTION

In recent years, there has been a significant increase in research interest in the integration of functionalized nanoscale materials in diverse applications. The application of nanotechnology in functionalized and modified processes is promising for use in the delivery of drugs, bio imaging, diagnosis and therapy, genetic material sequencing, biosensors, active packaging, agriculture, and the environment (**Sharma et al., 2021**). *The prodigious application of nanotechnology inspired me to carry out research in this field.*

## 1.1 Importance of Nanoparticles

It is important to understand that nanoparticles (NPs) are not just simple molecules, but rather, they are complex, multi-layered structures. Their first layer, the surface layer, is especially significant as it can be tailored to suit various applications. It can be functionalized with small molecules, metal ions, surfactants, and polymers, making NPs an incredibly versatile tool for a range of industries and scientific fields. In chemical terms, the shell layer (third layer) is distinct from the core, and the core refers to the NP's center section (second layer) (**Khan et al., 2019**). Among the various types of nanoparticles (NPs), carbon-based NPs and metallic NPs are of great interest due to their applicability, compatibility, ease of synthesis and their size dependent behaviour.

In recent years, NPs have become increasingly interdependent in terms of their optical and electrical properties. Nanoparticles of noble metals, for instance, possess size-dependent optical characteristics and are characterized by an extinction band in the UV-visible region that is not found in bulk metals. Localized Surface Plasmon Resonance (LSPR) is a phenomenon that occurs when the input photon frequency is constant and the conduction electrons are collectively excited (**Eustis and El-Sayed, 2006**). Magnetic nanoparticles have emerged as a fascinating area of research, with applications across a wide range of fields such as catalysis, biomedicine, magnetic fluids, MRI, and environmental remediation. Due to their unique mechanical properties, NPs have the potential to revolutionize surface engineering, nanofabrication, and manufacturing. Researchers are exploring the various mechanical characteristics of NPs, including elasticity, hardness, stress, strain, adhesion, and friction, to determine their exact mechanical behavior. Surface coating, coagulation, and lubrication also

play a vital role in the mechanical properties of NPs. With magnetic nanoparticles, researchers can design innovative solutions for water purification and MRI technology, making them an essential tool for scientific inquiry and technological advancement (Guo *et al.*, 2013).

*Considering the importance of nanoparticles in emerging fields, this research study focuses on delving the synthesis, characterization and applications of the nanoparticles in detail.*

### 1.2 Metallic and Non-metallic nanoparticles

Metallic nanoparticles were employed to embellish church windows throughout the mediaeval era. Noble metal nanoparticles have a distinct niche in the world of nanotechnology due to their unique features. The most essential property of nanoparticles is their high surface area to volume ratio, which allows them to easily interact with other particles. The increased surface area to volume ratio of nanoparticles allows for quicker diffusion at lower temperatures. This topic has become increasingly exciting as we can directly treat diseased cells and tissues without perturbing or damaging healthy cells (Li *et al.*, 2012).

Gold nanoparticles (GNPs) are widely used in medicine because of their remarkable stability, unparalleled compatibility with the human body, and unique ability to effortlessly integrate with organic molecules or active atoms (Pissuwan *et al.*, 2019). The versatility of GNPs in interacting with a diverse array of molecules on their surface is truly remarkable. These tiny particles have the potential to make a significant impact in the fields of medicine and biology by enabling interactions with proteins, antibodies, nucleic acids (DNA or RNA), enzymes, medicines, and fluorescent dyes. Harnessing the power of GNPs can lead to innovative solutions and breakthroughs in the development of new medical treatments and diagnostic tools (Slocik *et al.*, 2005; Ramalingam *et al.*, 2019).

Silver nanoparticles (SNPs) are one of the most researched and promising zero-dimensional nanomaterials in the modern world, with impressive results reported in pharmaceutical sciences (Amarnath Praphakar *et al.*, 2018; Yan *et al.*, 2020; Ma *et al.*, 2019), cosmetic products (Kraeling *et al.*, 2018; Odeniyi *et al.*, 2020), anti-infective coatings and wound dressings, antimicrobial textiles (Zhou and Tang, 2018; Fajar *et al.*, 2019; Narasaiah *et al.*, 2018), and food packages (Amini and Azadfallah, 2018; Kumar *et al.*, 2018; Lazić *et al.*, 2020). SNPs' specific interest in biomedical applications are primarily

from their beneficial characteristics, broad antibacterial activities, minimal anti-pathogenic resistance, and exceptional efficacy against multidrug-resistant pathogens (**Mishra and Padhy, 2018; Liao *et al.*, 2019; Samoilova *et al.*, 2018**).

Zinc oxide nanoparticles (ZnONPs) have captured the interest of many in recent years due to their versatile applications in electronics, optics, and biological systems (**Anubuvannan *et al.*, 2015; Sundrarajan *et al.*, 2015; Vanathi *et al.*, 2014; Jamdagni *et al.*, 2018; Prasad and Jha, 2009; Patil and Taranath, 2016; Gunalan *et al.*, 2012**). Compared to other metal oxides, such as TiO<sub>2</sub> and CuO, ZnONPs are the most intriguing as they are cost-effective, safe, and easy to synthesize. Notably, the US Food and Drug Administration has recognized ZnO as a generally recognized as safe (GRAS) metal oxide (**Pulit-prociak *et al.*, 2016**). ZnONPs boast exceptional catalytic activity, optical and UV filtering properties, and anti-inflammatory and wound healing properties (**Mirzaei *et al.*, 2017; Patel *et al.*, 2015; Stan *et al.*, 2015; Sherly *et al.*, 2014; Gunalan *et al.*, 2011; Elumalai and Sivasubramanian, 2015; Sheikhloo *et al.*, 2011**). With its outstanding UV filtering characteristics, ZnO has become a popular ingredient in cosmetics, especially in sunscreen lotions (**Wodka *et al.*, 2010**).

Graphene is a 2D material and considered as a wonder material by the research community due to its exemplary properties. Graphene oxide (GO) and reduced graphene oxide (RGO) have the potential to revolutionize the field of materials science. To fully utilize their capabilities, it is recommended to primarily use RGO in binary, ternary, or quaternary composites. This approach offers two main advantages. Firstly, RGO-based composites have a hierarchical structure that exhibits a wide range of novel or improved structure-related properties. Secondly, they can be easily synthesized from a variety of precursor structures, such as sheets, rods, ribbons, wires, needles, particles, spheres, prisms, etc., through a range of synthetic and/or physical methods, such as chemical/thermal reactions, pyrolysis, functionalization, polymerization, doping, and hybridization. The benefits of multi-component composites in applications such as sensors, mechanics, rheology, and anti-corrosion are numerous. By combining RGO with other materials, a greater number of beneficial synergistic effects can be achieved (**Tarcan *et al.*, 2020**).

*The intriguing applications of GNP, SNP, ZnONP and RGOs prompted me to explore on these materials.*

---

**1.3 Nanoparticle Synthesis-Reported methods and materials**

Two distinct basic principles of synthesis (i.e., top down and bottom up techniques) have been examined in the available literature to prepare nanomaterials of desired sizes, shapes, and functions. In modern materials science and technology research, a new era of 'green synthesis' approaches/methods is gaining attraction. Green synthesis of materials/nanomaterials developed by control, cleansing, and remediation will essentially help to increase their environmental friendliness. Some key characteristics of "green synthesis" can thus be represented by a number of components, including waste prevention/minimization, derivative/pollution reduction, and the use of safer (or non-toxic) solvents/auxiliaries, as well as renewable materials. Green synthesis is required to avoid the generation of undesired or hazardous by-products by the development of sustainable, and environmentally friendly synthesis procedures (Singh *et al.*, 2018).

*Considering the aforesaid advantages of green methods of synthesis, the present study involves use of plant parts and ecofriendly raw materials as reductants for synthesis of metallic and non-metallic nanoparticles.*

**1.4 Pharmacological activities of nanoparticles**

The green synthesized nanoparticles' organometallic composition and biocompatibility suggest that they might be suitable candidates for the development of phyto-nanomedicines. Despite the use of medicinal plants in green synthesis, the majority of studies failed to test the nanoparticles for their attributed pharmacological properties or bioactivity, which will ensure the correlation between the medicinal plants used in the process and the nanoparticle. As a result, studying the pharmacological effects of plant extracts in green synthesized nanoparticles would be extremely beneficial in advancing this subject of nanomedicine. As green synthesis gives unique pharmacological characteristics to the resultant nanoparticles, a thorough knowledge of exactly what compounds are involved in the reduction and capping processes will enhance this field of study. Extensive toxicity studies must be conducted for the green synthesized nanoparticles before they are screened for their medicinal activities (Selvakesavan and Franklin, 2021).

**1.4.1 Anti-microbial studies of nanoparticles**

Researchers face important challenges in developing broad-spectrum medicines that are multi-microbe resistant and have fewer health complications since bacteria can

develop resistance to the medications (**Abusaiba and Thualfakar, 2020**). Plant extracts, which block quorum sensing, operate as anti-pathogens (**Kalia et al., 2019**). This is where plant-mediated natural medicinal compounds come in. Natural therapies are always embraced by humans because they are safe, one such is ayurveda, which is rooted in Indian heritage. Medicinal plants and the chemicals generated from them are used to treat a variety of infections (**Kumar and Khurana, 2018**). This prompted us to investigate the therapeutic fruit *Terminalia bellerica* (TB). Additionally, nano-based materials have important biological applications, such as antibacterial properties (**Patel et al., 2019**). Multidrug resistant bacteria's (MDRB) are considered to be a threat to the public health and considered to be a source for hospital acquired infections (**van Duin and Paterson, 2016**). Antibiotics which tackle the MDRB are need of an hour. Metallic silver is well known for its anti-microbial property. There are reports on the antimicrobial properties on nano sized silver (**Firdhouse and Lalitha, 2016**).

SNP synthesized using plant extracts of *Tabernaemontana divaricate*, *Basella alba*, and *Allium fistulosum* had effective anti-bacterial activity against both gram negative and gram positive bacteria (**Vinodhini et al., 2022**). It was reported that SNP synthesized using Panchakavya, an ecofriendly fertilizer shows good antimicrobial activity when coated on a kid's napkin (**Govarthanan et al., 2014**). Similarly SNP synthesized using *Passiflora foetida* fruit extract coated on indoor walls inhibits the growth of indoor fungus *Fusarium sp* (**Elangovan et al., 2022**). GNPs offer effective antimicrobial coatings for medical equipment and aid in the treatment of antibiotic-resistant urinary tract infections. Notably, independent of the reported mechanism of drug resistance, the GNPs were effective against all *E. coli* strains. The interaction of nanoparticles with bacteria's surface is entirely physical. The non-specific method of gold nanoparticle action would be advantageous for drug resistance, assuming that the traditional antibiotics interact with particular targets in the bacterial cell and that bacteria might evolve resistance through modification. (**Piktel et al., 2021; Parmar and Sanyal, 2024**).

*The potential antimicrobial activity of GNP and SNP against clinically isolated gram-positive and gram-negative microbes was tested in this study.*

### 1.4.2 Skin cancer studies of nanoparticles

Skin cancer is one of the most common carcinomas worldwide, and it is classified into two types: melanoma and non-melanoma. Skin cancer is a worldwide problem with a growing tendency; thus, innovative therapeutics is required. Skin cancer therapy relies heavily on local therapeutic techniques. NPs have enormous potential uses in medicine and the capacity to overcome frequent chemotherapeutic issues. The skin serves as a barrier between the body and environmental allergies, toxins, and toxic substances. The epidermis, dermis, hypodermis, and many appendages such as hair follicles, sweat glands, and sebaceous glands make up this unique barrier. The capacity of metallic NPs to permeate the deep layers of the skin and overcome the skin barrier is debatable. The interaction of NPs with the skin is still being studied, since it has been demonstrated that certain NPs may penetrate the stratum corneum (outer layer of epidermis), while others can penetrate deeper into the skin layer and reach the systemic circulation (**Filon *et al.*, 2015**). Shape, charge, size, formation, and surface modification are all variables that influence metallic NP's skin adsorption.

*Pondering on the need for a solution for anti-skin cancer agents, the present study focuses on determining the efficiency of GNP, SNP and washed waters of cereals and pulses against skin cancer cell lines.*

### 1.4.3 DNA binding of nanoparticles

Many prescribed drugs now in clinical use or advanced clinical studies have DNA as their pharmacological target. Targeting DNA to govern cell processes via transcription (gene expression and protein synthesis) or replication (a critical stage in cell growth and division) appears rational, intuitively attractive, and conceptually simple. Small ligand molecules attach to DNA, causing it to be altered and/or inhibited. Altering or inhibiting DNA activity is essential to cure or control a disease (**Kennard, 1993**).

The research of drug-DNA interaction is particularly intriguing and important not only for understanding the mechanism of contact, but also for the creation of novel medications. However, the mechanism of interactions between drug molecules and DNA is still unknown. More basic ways for exploring the mechanism of interaction must be introduced. Understanding the mechanism of contact will allow for the development of novel DNA-targeted medicines and their *in vitro* testing (**Hajian *et al.*, 2009**).

---

*Considering the importance of DNA binding studies, the interaction of synthesized GNP and SNP with ct-DNA (calf thymus DNA) was studied by a facile UV-visible spectrophotometric method.*

#### **1.4.4 Allium cepa toxicity assay**

The increasing usage of nanotechnology in high-tech sectors is expected to expose humans to nanoparticles. Nanotechnology is also being employed in medical sciences to achieve individualized treatment. However, the same characteristics that make nanoparticles desirable in medicine (small size, chemical composition, structure, large surface area, and shape) may contribute to nanoparticle toxicology in biological systems. Indeed, the smaller the particles, the larger the surface area per unit mass; this property renders nanoparticles highly reactive in the cellular milieu. As a result, the particle surface's inherent toxicity will be amplified (Donaldson *et al.*, 2006).

The *Allium cepa* toxicity assay is a popular and very sensitive technique for investigating chromosomal abnormalities induced by numerous chemical toxic substances. *A. cepa* has a small number of chromosomes ( $2n = 16$ ), it is easy to examine the genetic alterations at the chromosomal level that occur after plants are exposed to harmful substances. This test has been used to look into the impact of toxins on the regularity of cellular division. The test is an easy way to gain a thorough understanding of how harmful compounds, alone or in combination, cause chromosomal changes (Sabeen *et al.*, 2020)

*The importance of determining toxicity cannot be overstated. Therefore the synthesized best nanoparticles which have shown good pharmacological activity have chosen for Allium cepa root tip toxicity assay.*

### **1.5 Cosmetic application of nanoparticles**

Cosmetics are defined as “articles intended to be rubbed, poured, sprinkled, or sprayed on, introduced into, or otherwise applied to the human body or any part thereof for cleansing, beautifying, promoting attractiveness, or altering the appearance” (<https://www.fda.gov/cosmetics/cosmetics-laws-regulations/cosmetics-us-law>).

#### **1.5.1 Sun screen lotions**

Repeated sun exposure has the ability to create both short-term and long-term alterations in the skin's structure. In the short term, frequent exposure causes erythema

(reddening) of the skin, which is generally known as sunburn (Moore, 2013). The erythema is followed by the activation of melanocytes, which increases their rate of melanin synthesis (increased melanization), darkening the skin tone, often known as tanning. Repeated exposure causes irreversible loss of skin elasticity and may result in the development of skin malignancies, including melanomas (Harrison and Bergfeld, 2009). The severity of skin damage is determined by the duration of exposure, seasonal variations in incident sunray intensity, geographical location, and host-dependent factors such as age, skin colour, behavioral factors, and immune status (Jou and Tomecki, 2014; Rigel, 2008; Harrison and Bergfeld, 2009).

The use of sunscreens (also known as sun protectants) to protect against the harmful effects of the sun's rays has increased during the last several decades. This could be attributed to increased awareness of the potentially harmful effects of prolonged sun exposure (Albert and Ostheimer, 2003). Sunscreen can be classified into either topical or systemic types based on their delivery mechanism. For topical sunscreens, they are further divided into organic and inorganic types depending on how they protect the skin (Rigel, 2014). It is reported that ZnONP due to their excellent UV blocking properties are utilized in sun screen lotions.

*This study also utilizes the synthesized ZnONP in the sunscreen lotions and aimed at evaluating the sun protection factor by spectrophotometric methods.*

### 1.6 Sensing/ Nano switching application of Non-metallic nanoparticles

Nowadays, the identification of certain compounds, molecules, or atoms at low concentrations is critically important, not only for our everyday comfort and safety but also for our increasingly contaminated environment. Sensors are technical equipment that enables us to detect particular undesired and/or dangerous gases in our residences or environments, as well as numerous life-harming biological chemicals in our food and bodies, as well as hazardous compounds in soil, water, or air. The increase in the complexity of dangerous compounds day by day and need for recognition of more and more traces of biological substances warrants development of devices for extremely sensitive sensors with improved performance (Wei *et al.*, 2024).

Till date, various research groups have developed numerous electrochemical techniques for analytical applications in biology, food, and pharmaceuticals (Cheraghi *et al.*,

**2017; Chandra *et al.*, 2017; Saifeldin, 2020; Meng *et al.*, 2024**). Many analytical techniques, such as chromatography and spectrophotometers, have been developed in these sectors (**Gupte and Luthra, 2017; Shi *et al.*, 2020**), but electrochemical approaches are utilized to detect electroactive analytes at low cost and with high sensitivity. It has many applications since it is a simple method. Electrochemical technology's distinguishing characteristics, such as cheap equipment, rapid reaction times, high sensitivity, and ease of miniaturization, have prompted to do substantial study in this field (**Deepa *et al.*, 2016; David *et al.*, 2017; Purushothama *et al.*, 2018**).

Carbon paste, an age-old carbon-based electrode, has proven to be a reliable and versatile component in electrochemical applications for several years now. Numerous research articles have been published utilizing Carbon Paste Electrodes (CPEs) to detect various analytes including biomolecules, medicines, food additives, pesticides, and more (**Parham and Rahbar 2010; Cheraghi *et al.*, 2017; Hosseini *et al.*, 2018; De Fatima Ulbrich *et al.*, 2020**). The CPE's exceptional ability to renew its working surface with ease makes it the undisputed material of choice in the field of electrochemical sensing applications. With its proven track record, CPEs are an excellent option for researchers and industries looking to enhance their electroanalytical detection capabilities (**Fallah *et al.*, 2020**).

Among the potential chemicals, ammonia, melamine and cyanide are illegally added in food as adulterants. It is essential to detect their presence in food. The environmental contamination is also relatively high. Recently, approximately 80% ammonia is produced for fertilizers while the rest is used in pharmaceuticals, cleaning products, explosives, and refrigeration. Ammonia is commonly found in dairy and ice cream operations, wineries and breweries, petrochemical industry, fruit/vegetable juice processing plants, and soft drink manufacturing facilities (**Kwak *et al.*, 2019**).

Free cyanide and hydrogen cyanide (HCN) are both more dangerous forms of cyanide. Traditional cyanide testing procedures such as titration, distillation, chromatography, or potentiometry are costly, time consuming and tedious. As a result, there is still a need to create more rigorous, low-cost, and labor-intensive cyanide testing procedures. A number of colorimetric detection techniques were developed in an effort to make anion quantitative detection and monitoring economical, simple, and easy to follow (**Gunnlaugsson *et al.*, 2006**).

Melamine, a white solid organic chemical that has been commercially synthesized, is one of the most recent fretting poisonous chemical to be added to the list of known toxic components. Melamine is added to milk in order to increase its protein content. Melamine adulteration is caused in part by its cheap, accessibility and obtainability. Melamine molecules are not easily processed by the human body, leading to the formation of insoluble crystals that can cause kidney damage and abnormalities. Unfortunately, this has been demonstrated in the past when six infants died and 300,000 people fell ill in China back in 2008 due to the consumption of melamine-contaminated milk products. It is crucial to ensure that food products are free of harmful contaminants to prevent such tragedies from occurring again in the future (**Xiang *et al.*, 2011**). Following the melamine disaster in China, India has partially prohibited the import of Chinese milk and dairy products. Following this incident, all nations with advanced economies, including the United States, the United Kingdom, and Europe, imposed a total ban on melamine goods to ensure safe health.

It has been suggested by studies that exposure to melamine is possible only through food products that have been adulterated with it. Nevertheless, it has been recently uncovered through research that melamine and its derivatives can also be traced in indoor dust originating from household products that contain melamine (**Zhu and Kannan, 2018**). Extensive research has unequivocally demonstrated that melamine-formaldehyde resin plates absorb melamine when exposed to acidic meals at specific temperatures. Despite their durability and visually appealing nature with lively hues, melamine products have a notorious history of being a major food and animal feed adulterant dating back a decade. The eggs of laying hens that were fed a diet contaminated with melamine were found to contain melamine residues (**Yang *et al.*, 2011**). Apart from acute renal failures (**Yang *et al.*, 2008**), it causes sperm DNA damage and abnormalities in the male reproductive system (**Quan-Xin *et al.*, 2011**).

Melamine is eliminated through the urine, also long-term exposure causes urinary tract cancer. Melamine-contaminated milk causes immunological issues in newborns (**Zhou *et al.*, 2010**). It has been discovered that melamine is present in breast milk (**Yurdakok *et al.*, 2014**) and causes serious problems in obstetrics (**Wiwanitkit, 2009**). It is important to note that the transmission of the virus to the embryo can occur through the placenta, which can result in kidney issues for newborns (**Partanen *et al.*, 2012**). Melamine products should not be used in the microwave and cannot be recycled. Unfortunately, some people may be

unaware of this and still attempt to use them in the microwave. It's worth noting that acidic substances like apple juice and lemon juice discolour melamine cups (**Bradley et al., 2005**).

Additionally, the tolerated daily intake (TDI) of melamine in humans is 0.2 mg/kg body weight (<https://www.who.int/mediacentre/news/release/2008/pr48/en/>). The fact remains that daily exposure to melamine through food contact articles is a highly significant source of the substance in the human body. This issue is particularly pressing in India, and it is concerning that limited research has been conducted on it so far.

*In lieu of the aforesaid problems, this research work focuses on the detection of melamine, ammonia and cyanide by colorimetric and electrochemical methods by fabricating reduced graphene oxide, GNP/carbon paste electrodes.*

### **1.7 Research Gap**

It is important to identify the research gap and accordingly design a research plan as a solution to the research problem. With the through literature survey, identification of the research gap was possible and the potential reductants for the synthesis of metallic and non-metallic nanoparticles were identified. In view of adopting the green synthetic route, the present study involves use of extracts of *TB* dry fruit parts and commercially available *Garcinia cambogia* (GC) capsules, washed waters of cereals and pulses, and *Corpus unguis* (Human nails (HN)) free edges for the synthesis of nanoparticles.

*Terminalia bellerica Roxb.* is a highly beneficial medicinal tree that thrives in the wet Indian sub valleys. Its fruit and other parts have been long known for their powerful therapeutic properties. In fact, the dry fruit and fruit portions of TB are so potent that they are key ingredients in the popular ayurvedic composition Triphala. Triphala is a trusted remedy for fever, cough, skin ailments, and liver disorders that has been used for centuries (**Kumar and Khurana, 2018**).

Fruits are used as medication for various health ailments (**Kumar and Khurana, 2018; Kirthikar and Basu, 1993**). There are reports on the synthesis of GNP from TB whole fruit (**Smina et al., 2021**) but not with the TB fruit parts individually.

Commercially available GC capsules suspended in water are utilized for nanoparticle synthesis. The capsule of GC is administered for weight reduction. GC is also known as *Garcinia gummi-gutta*. It belongs to the family of *Clusiaceae*. It is commonly called as Malabar tamarind. This particular fruit is dried and used to preserve fishes. Also, the fruit

rinds add more flavour to South Indian cuisines. Though this medicine is not administrated as per ayurveda, the ancient folk tribal people used this for several ailments (Majeed *et al.*, 1994; Semwal *et al.*, 2015). The fruit parts are rich in xanthonenes, organic acids and benzophenones (Anju and Rameshkumar, 2017). The fruit is also rich in Hydroxy Citric Acid (HCA) which is well known for hypo-lipidemic activity endorsing its use in weight management.

*There are limited studies on washed waters of cereals and pulses and Corpus unguis free edge. The detailed study of these components is one of the objectives of the present study.*

### 1.8 Objectives of the study

This research work aims to address some of the compelling applications of metallic and non-metallic nanoparticles. The main objective of this study is to synthesize metallic nanoparticles such as Gold, Silver and Zinc oxide nanoparticles and a non-metallic nanoparticle- reduced graphene oxide. Environment-friendly synthetic approaches are adopted by using plant extracts, cereals, pulses washed water, and human nail components as reducing agents in the synthesis. Particular importance is given to the utilization of waste materials such as cereals, pulses washed water, and human nails for the synthesis of nanoparticles. Furthermore, this study explores some of the selected pharmacological, cosmetic, biological, and sensing/nano switching applications of the nanoparticles.

#### Objectives in detailed below:

##### 1.8.1 Primary objectives

- ✚ To synthesize metallic nanoparticles, such as Gold, Silver, and Zinc oxide, as well as non-metallic nanoparticles, such as reduced graphene oxide, using plant extracts (aqueous), cereals, pulses washed water, and human nail washings (aqueous) in a total of twenty-one samples
- ✚ To study the nature of nanoparticles by analytical characterization techniques and classify their applications
- ✚ To explore selected biological, pharmacological, cosmetic, and colorimetric/electrochemical/analytical sensing applications/ nanoswitching behaviour of the synthesized nanoparticles

## 1.8.2 Specific objectives of the study

### 1.8.2.1 Synthesis of metallic and non-metallic nanoparticles

- i. To prepare the extracts (aqueous) of *Terminalia bellirica* dry fruit parts and commercially available *Garcinia cambogia* capsules by steam bath method, preparation of cereals and pulses washed water (conventional washing) and *Corpus unguis* free edge is sonicated in water to obtain the washed solution
- ii. To screen the components of the bioreductants by phytochemical analysis (TB aqueous extracts), nutrient and elemental analysis (cereals and pulses washed water) and elemental analysis (HN)
- iii. To synthesize Gold, Silver and Zinc oxide and reduced graphene oxide nanoparticles using the prepared bioreductants
- iv. To optimize the synthesis condition of metallic nanoparticles by different method of synthesis viz, room temperature, sonication, solar irradiation and microwave heating methods and the effect of bioreductants upon synthesis method and time of formation of nanoparticles

### 1.8.2.2 Analytical characterization of metallic and non-metallic nanoparticles

- v. To determine the Surface Plasmon Resonance band of the biosynthesized nanoparticles by UV-Visible spectroscopy
- vi. To evaluate the functional groups present in the bioreductants and its interaction with the metal ions and the graphene oxide by FTIR spectroscopy
- vii. To reckon the crystalline behaviour of metallic and non-metallic nanoparticles by XRD
- viii. To interpret the surface morphological characteristics of the nanoparticle by FE-SEM and EDX analysis
- ix. To analyze the stability of the non-metallic nanoparticle by TGA and metallic nanoparticles by Zeta potential analysis
- x. To interrogate the bands of reduced graphene oxide by Raman spectral analysis

### 1.8.2.3 Pharmacological, Biological, Cosmetic and Sensing/Nanoswitching applications of metallic nanoparticles and toxicity assay

- xi. To evaluate the antibacterial activity of metallic nanoparticles against common infections causing gram negative and gram positive bacteria
- xii. To fabricate antibacterial earphone buds coated with silver nanoparticles and to evaluate its surface profiling and bactericidal activity against *S.aureus* bacteria which cause ear infection
- xiii. To assess the anti-cancer activity of gold and silver nanoparticles against skin cancer cell lines.
- xiv. To assess the interaction of metallic nanoparticles with ct-DNA- *in vitro*
- xv. To determine the toxicity of bioactive gold nanoparticles
- xvi. To formulate skin care lotions incorporating human nail washings aided gold nanoparticles and zinc oxide nanoparticles (using cereals and pulses washed water) and their Sun Protection Factor determination
- xvii. To peruse the colorimetric and electrochemical sensing action of synthesized gold nanoparticles to sense  $\text{CN}^-$  and  $\text{NH}_3$

xviii. To detect melamine leached from melamine tableware by FT-IR fingerprinting analysis and the toxicity assessment by comet assay

#### 1.8.2.4 Determination of sensing property of non-metallic nanoparticles

xix. To impregnate reduced graphene oxide in carbon paste and electrode fabrication for the detection of melamine by electrochemical analysis

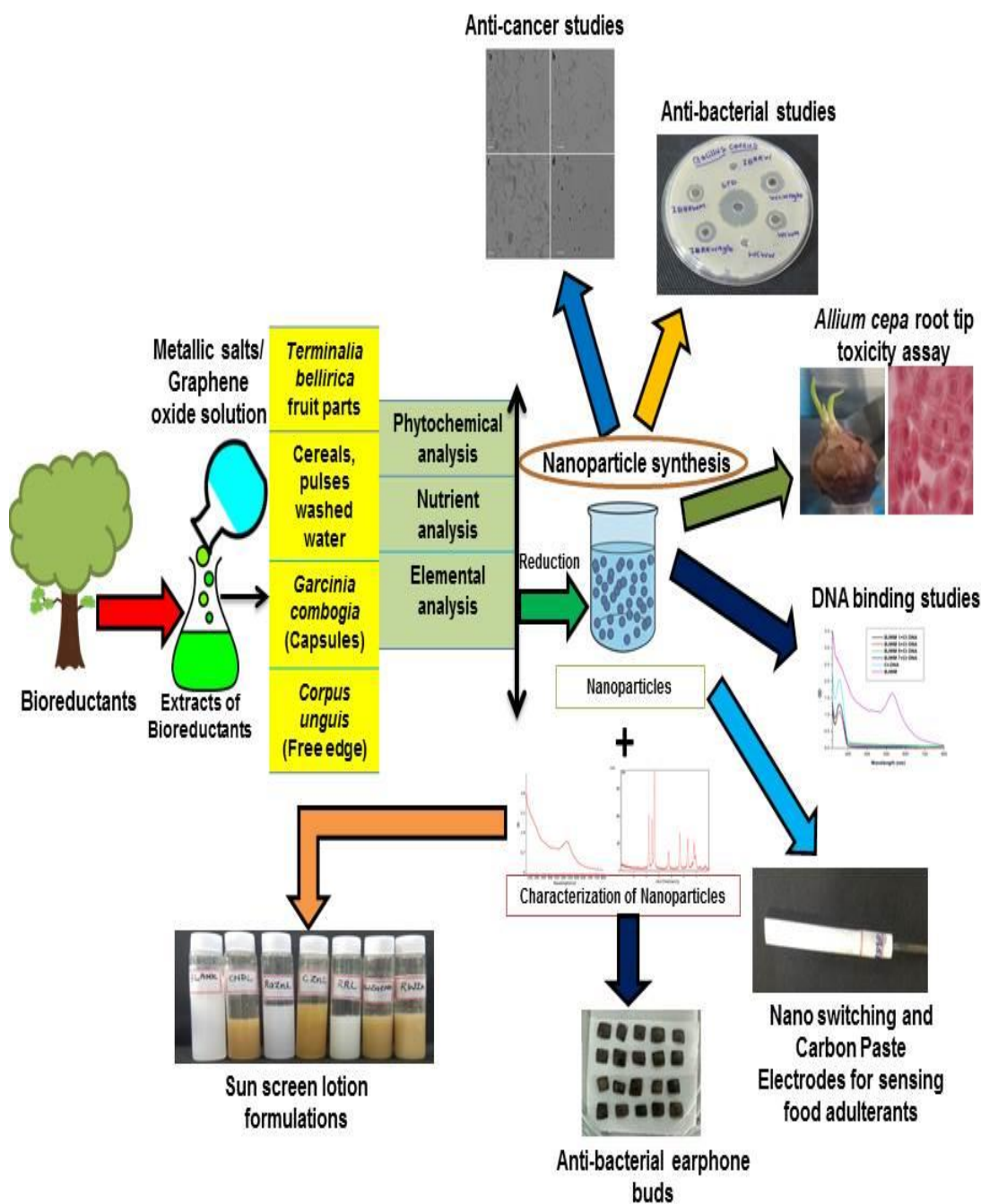


Figure 1. Pictorial representation of the work proposed