2

REVIEW OF LITERATURE

The initial step for research on the title starts with a systematic literature search. The following pages provide the important reported prior art on the materials utilized for the study, nanoparticle-based switches for the detection of toxic materials and selected applications of the nanoparticles. The systematic review of literature is conducted for a period of 15 years (2008-2023). Some relevant supporting information beyond 15 years is also included to substantiate complete search.

The following pages compile the review pertaining to

- ➢ Metallic nanoparticles
- ✓ Gold nanoparticles
- ✓ Silver nanoparticles
- ✓ Zinc oxide nanoparticles
- ➢ Non-metallic nanoparticles
- ✓ Reduced graphene oxide and its applications
- ➢ Literature review on bioreductants
- ✓ Review of literature pertaining to work on *Terminalia bellerica*
- ✓ Review of literature pertaining to work on *Garcinia combogia*
- ✓ Review on Rice Washed Water (RWW) and its conventional and scientific applications
- ✓ Review on free edges of *Corpus unigus*
- ➢ Review on anti-bacterial activity of nanoparticles
- ➢ Review on skin cancer activity of nanoparticles
- ➢ Review on nanoparticle-DNA binding studies
- ➢ Review on *Allium cepa* root tip toxicity assay
- ➢ Review on sun screen lotions and its importance
- ➢ Review on Carbon Paste Electrodes
- ➢ Review on nano switches
- ✓ Review on methods to detect ammonia
- ✓ Review on methods to detect cyanide
- ✓ Review on methods to detect melamine

2.1 Metallic nanoparticles

Metallic nanoparticles have fascinated scientists for over a century and are now heavily utilized in biomedical sciences and engineering. They are a focus of interest because of their huge potential in nanotechnology. Today these materials can be synthesized and modified with various chemical functional groups which allow them to be conjugated with antibodies, ligands, and drugs of interest and thus opening a wide range of potential applications in biotechnology, magnetic separation, and preconcentration of target analytes, targeted drug delivery, and vehicles for gene and drug delivery and more importantly diagnostic imaging. Moreover, various imaging modalities have been developed over the period of time such as MRI, CT, PET, ultrasound, SERS, and optical imaging as an aid to image various disease states. These imaging modalities differ in both techniques and instrumentation and more importantly require a contrast agent with unique physico-chemical properties. This led to the invention of various nanoparticulated contrast agents such as magnetic nanoparticles (Fe_3O_4), gold, and silver nanoparticles for their application in these imaging modalities. In addition, to use various imaging techniques in tandem newer multifunctional nanoshells and nanocages have been developed (**Mody *et al.*, 2010**). Nanoparticles have successfully come to aid various disease states, but the advances in biomedical imaging depend largely on the shape, size, and selectivity of the nanoparticle to the target (**Evanoff *et al.*, 2005**). Moreover, the type of the particle synthesized also governs the imaging modality to be used and thus the cost of diagnosis. Even though current investigations have demonstrated that multivalent composite materials can provide significant advantages, the ambiguity in developing them for a particular target with high specificity is still challenging. Fortunately, the field of nanotechnology continues to grow interest within the chemical research community with major discoveries as well as new scientific challenges (**Giljohann *et al.*, 2010**). ***Plant-mediated synthesis gained importance as it is biocompatible, low-cost, environmentally acceptable, and simple and can be easily scaled up for commercial production of NPs.***

2.1.1 Gold nanoparticles

Colloidal gold, also known as gold nanoparticles, is a suspension (or colloid) of nanometer-sized particles of gold. The history of these colloidal solutions dates back to Roman times when they were used to stain glass for decorative purposes (**Giljohann *et al.*, 2010)**. However, the modern scientific evaluation of colloidal gold did not begin until Michael Faraday’s work of the 1850s, when he observed that colloidal gold solutions have properties that differ from bulk gold (**Edwards and Thomas, 2007**). Hence the colloidal solution is either an intense red color (for particles less than 100 nm) or a dirty yellowish color (for larger particles) (**Murphy *et al.*, 2008; Tong *et al.*, 2009**). The interesting optical properties of these gold nanoparticles are due to their unique interaction with light **(Jain *et al.*, 2008)**. In the presence of the oscillating electromagnetic field of the light, the free electrons of the metal nanoparticles undergo an oscillation with respect to the metal lattice (**Jain *et al.*, 2006; Kelly *et al.*, 2002; Крейбиг and Vollmer, 2013**). This process is resonant at a particular frequency of the light and is termed the Localized Surface Plasmon Resonance (LSPR). After absorption, the surface plasmon decays radiatively resulting in light scattering or nonradiatively by converting the absorbed light into heat. Thus for gold nanospheres with particle size around 10 nm in diameter have a strong absorption maximum of around 520 nm in aqueous solution due to their LSPR.

As the applications of GNPs are increasing day –by day, the demand for their synthesis also increases simultaneously. It has aroused interest among researchers worldwide to develop novel interdisciplinary routes for synthesizing highly stable, monodisperse, and safe GNPs for various applications. An alternative approach to synthesize biocompatible NPs, termed "green synthesis" has evolved to overcome the challenges in the conventional chemical synthesis method. It is an emerging branch of nanotechnology and has attracted huge attention among researchers, industries and people concerned about environmental pollution and health hazards. Green synthesis techniques are important as they are an eco-friendly approach that involves using natural bioresources and avoids toxic chemicals to synthesize different types of NPs (**Soltys *et al.*, 2021**). For instance, cobalt ferrite nanoparticles are synthesized using extracts of grape peel, pulp, and cobalt-zinc ferrite NPs using honey (**Tatarchuk *et al*., 2021a; Tatarchuk *et al*., 2021b**).

Various plants, microorganisms, and biomolecules derived from them are excellent sources for synthesizing various types of NPs. Extracts from different parts of the plant, such as leaves, roots, seeds, flowers, fruits, bark, etc., and microbes, including bacteria, fungi, and algae, are widely used to synthesize NPs with varying sizes and shapes using interdisciplinary routes (**Lee *et al*., 2020; Rattan *et al*., 2021**). The precursor gold salt solution is treated with microbial culture or plant extracts, which are then bioreduced to form GNPs. Different metabolites and biomolecules such as sugars, fatty acids, proteins, enzymes, and phenols play a crucial role in the synthesis of the GNPs (**Can *et al*., 2020; Teimuri-mofrad *et al.*, 2017; Batool *et al.*, 2022; Abed *et al.*, 2023**).

2.1.2 Silver nanoparticles

SNPs are particles of silver, with particle sizes between 1 and 100 nm in size. While frequently described as being "silver", some are composed of a large percentage of silver oxide due to their large ratio of surface to bulk silver atoms. Like GNPs, ionic silver has a long history and was initially used to stain the glass for yellow. There is also an effort to incorporate silver nanoparticles into a wide range of medical devices, including bone cement, surgical instruments, surgical masks, etc. Moreover, it has also been shown that in the right quantities, ionic silver is suitable for treating wounds (**Qin 2005**; **Atiyeh *et al*., 2007; Landsdown 2006**). In fact, silver nanoparticles are now replacing silver sulfadiazine as an effective agent in treating wounds.

Additionally, “Samsung” has created and marketed a material called Silver Nano, which includes SNP on the surfaces of household appliances. Moreover these nanomaterials have received considerable attention in biomedical imaging using SERS, due to their attractive physiochemical properties. In fact, the SPR and large effective scattering cross-section of individual silver nanoparticles make them ideal candidates for molecular labeling (**Schultz, 2000**). Thus, many targeted silver oxide nanoprobes are currently being developed.

Plant-mediated synthesis of SNPs is a widely adopted technique due to the availability of various plants and their easy and safe utilization. Different parts of the plant including fruits, roots, flowers, leaves, peels, etc., have been successfully utilized for the green synthesis of bioactive SNPs. Plant extracts contain numerous bioactive compounds such as alkaloids, flavonoids, terpenoids, tannins, saccharides, phenols and Vitamins, as well as various enzymes, amino acids, and proteins (**Du *et al.*, 2016; Singh *et al.*, 2016; Sukweenadh *et al*., 2021)**. Due to the presence of these active biomolecules in plant extracts, synthesis of bioactive SNPs using plants is more stable and more effortless. In the last few years, many studies have been conducted for the green synthesis of bioactive SNPs using different parts of plants such as fruits, seeds, roots, flowers, stems, leaves, peels, etc. For instance, the leaf extract of *Clerodendrum viscosum* was used for facile, rapid, and eco-friendly synthesis of the bioactive SNPs (**Nahar *et al.*, 2020**). They also investigated the antimicrobial efficacy of biosynthesized SNPs against various pathogenic bacteria. **Pawar and Patil, 2019** synthesized SNPs using tuber extract of *Eulophia herbacea*. Fruit extract of *Amomum villosum* was used by **Soshnikova *et al*., 2017** for the facile synthesis of SNPs. The seeds and roots of *Durio zibethinus* and *Rheum palmatum*, respectively, were used for the green synthesis of SNPs (**Sumitha *et al*., 2018; Arokiyaraj *et al*., 2017**). Peel extracts of different vegetables such as *Lagenaria siceraria*, *Luffa cylindrica*, *Solanum lycopersicum*, *Solanum melongena* and *Cucumis sativus* were investigated for synthesis of bioactive SNPs (**Sharma *et al.*, 2016**). Synthesis time, size and shape of synthesized SNPs and their bioactivity vary greatly depending on the plant or part of the plant which was used for synthesis. For example, SNPs of 10 to 30 nm in size were synthesized using root extract of *Panax ginseng* by two hours’ reaction (**Singh *et al.*, 2015**). According to **Adeyemi *et al.*, 2020** the leaf extract of *Spondias mombin* produced rod- or triangular-shaped SNPs. The plant extracts of *Prunus Africana*, and *Camellia sinensis* produced spherical-shaped SNPs **Ssekatawa *et al.*, 2021**. Various parameters such as the extract - salt ratio, incubation time, incubation temperature, pH, etc. also greatly affected the easy, rapid, high, and stable synthesis of SNPs using plant extracts (**Hamauda *et al.*, 2019; Huq, 2020; Singala *et al.*, 2022; Nguyen *et***

***al.*, 2023**). The probable mechanism of plant-mediated synthesis of SNPs is the chemistry of reduction and oxidation.

2.1.3 Zinc oxide nanoparticles

Metal oxide nanoparticles, such as ZnO, have been researched extensively for applications in biotechnology, photovoltaic, photocatalysis, sensors, cosmetics, and pharmaceuticals due to their unique properties at the nanoscale level. ZnONPs have been fabricated using conventional physical and chemical processes. Still these techniques are limited due to the use of hazardous chemicals that are bad for the environment and high energy consumption. Plant-mediated synthesis of ZnONPs has piqued the interest of researchers owing to secondary metabolites found in plants that can reduce Zn precursors and stabilize ZnONPs. Thus, plant-mediated synthesis of ZnONPs has become one of the alternative green synthesis routes for the fabrication of ZnONPs. This is attributable to its environmental friendliness, simplicity, and the potential for industrial-scale expansion (**Mutukwa *et al*., 2022**).

ZnONPs can be prepared using aqueous plant extracts from leaves, flowers, roots, stems, and barks. This is due to the presence of phytochemicals in plants that are capable of functioning as reducing agents as well as stabilizing or capping agents during the fabrication of NPs. These phytochemicals include terpenoids, flavonoids, phenolic compounds, saponins, alkaloids, tannins, carbohydrates etc. They have been reported responsible for reducing Zn salt precursors and stabilizing ZnONPs during synthesis (**Akintelu *et al*., 2020; Drummer *et al.*, 2021; Naiel *et al.*, 2022; Sachin *et al.*, 2023**).

Upadhyay *et al.*, 2020 conducted a comparison study of structural, morphological, and optical properties of ZnONPs synthesized using conventional chemical methods and leaf extracts of *Ocimum tenuiflorum*. The study reported that green synthesis using plant extracts resulted in better properties of ZnONPs than chemical methods. In another study, **Gunalan *et al.*, 2012** synthesized ZnONPs using *Aloe vera* extract and had higher antibacterial activity than the bulk ZnO and ZnONPs prepared using the chemical route. These studies demonstrate safer, simpler, and cost-effective preparation of ZnONPs. Additionally, plant-mediated synthesis of ZnONPs has gained attention in the biomedical field over the years, and this is mainly due to the plant-mediated ZnONPs exhibiting greater biological activity than plant extracts, bulk ZnO and ZnONPs prepared via chemical means.

The literature review on the metallic nanoparticle reveals that there is no reported work on the chosen bioreductants for this research work. This research gap helps in framing one of the objectives of this research work.

2.2 Non-metallic nanoparticles

Nanotechnology emerged in the 1980s due to the convergence of experimental advances such as the invention of the scanning tunneling microscope in 1981 and the discovery of fullerenes in 1985, with the elucidation. The popularization of a conceptual framework for nanotechnology goals began with the publication of the book Engines of Creation in 1986 (**Bayda *et al.*, 2019**). Carbon nanotubes have been discovered in pottery from Keeladi, India, dating from around 600–300 BC (**Bayda *et al.*, 2019; Kokarneswaran *et al.*, 2020**). Cementite nanowires have been discovered in Damascus steel, a material that dates back to around 900 AD; nevertheless, its origin and creation methods are unclear. However, it is unknown how they developed or whether the material containing them was used on purpose. Silica and Boron-based nano materials has also gained importance due to their exemplary properties (**Tahmasbi *et al.*, 2023; Chen *et al*., 2023**).

2.2.1 Reduced graphene oxide and its applications

Reduced graphene oxide has mechanical, optoelectronic or conductive properties similar to pristine graphene because it possesses a heterogeneous structure comprised of a graphene-like basal plane that is additionally decorated with structural defects and populated with areas containing oxidized chemical groups. The graphene-like properties make reduced graphene oxide a highly desirable material to be used in a plethora of sensorial, biological, environmental or catalytic applications as well as optoelectronic and storage devices. To further advance the development of the existent technologies and to design novel and better applications based on reduced graphene oxide, it is first necessary to understand which synthetic routes and processing strategies are suitable to significantly boost specific properties of this material alone or as a component in various composites (**Tarcan *et al.*, 2020**).

The high surface area, mechanical strength, and electrical and thermal conductivities, of graphene and its derivatives have found promising applications in various fields of material science and engineering, including energy storage, catalysis, drug delivery, sensing and biosensing, and water treatment (**Novoselov *et al.*, 2005; Liu *et al.*, 2010; Zhu *et al.*, 2010; Ciesielski *et al.*, 2014; Gonzalez-Dominguez *et al.*, 2018; Wang *et al.*, 2011; Gao *et al.*, 2020; Joshi *et al.*, 2020; Poudel *et al.*, 2021**). As a result, graphene and its derivatives have become one of the most fascinating and hottest research topics in the realm of carbon nanomaterials. RGO, a derivative of graphene, has been produced using various methods. Chemical reduction of exfoliated GO is particularly efficient and advantageous in large-scale RGO production, as it can produce high-quality RGO with a comparatively reduced oxygen content at a low cost and in a short time (**Feng *et al.*, 2013; De Silva *et al.*, 2017**)

Alternative solutions that are ecologically beneficial and simple are in high demand to address the limitations of traditional methods. One pioneering strategy for effective, green, and simple procedures is the use of safe and plentiful natural sources as reducing agents in aqueous-phase GO reduction (**Liu *et al.*, 2010; Zhu *et al.*, 2010; Wang *et al.*, 2012; De Silva *et al.*, 2018**). Plants, among other natural sources, enable scalable, safe, and cost-effective procedures. Green tea (**Wang *et al.*, 2011**), mango leaves and potato (**Sadhukhan *et al.*, 2016**), Aloe vera (**Bhattacharya *et al.*, 2017**), eucalyptus bark (**Manchala *et al.*, 2019**), sugarcane bagasse (**Gan *et al.*, 2018**), kaffir lime peel (**Wijaya *et al.*, 2020**), *Terminalia chebula* seed (**Maddinedi *et al.*, 2015**), and rose water (**Haghighi *et al.*, 2013**) have all been reported as reducing agents for the conversion of GO to RGO. These green-synthesized RGOs were studied for applications such as sensing, photocatalysis, electrochemical charge storage, and so on. Furthermore, some of these green-synthesized RGOs exhibit a high affinity for organic dyes (**Bhattacharya *et al.*, 2017; Gan *et al.*, 2018; Wijaya *et al.*, 2020; Arias *et al.*, 2020**). Although a lot of plants have been investigated, plant sources accessible regardless of the region are still attractive for practical uses.

There are no previous reports on the synthesis of RGO using cereals and pulses washed water. This research gap was filled by this current study and possible applications were carried out.

2.3 Literature review on bioreductants

2.3.1 Review of literature pertaining to work on *Terminalia bellerica*

T*erminalia bellirica* (Gaertn.) Roxb. widely grows in the Indian subcontinent, including Pakistan, Nepal, Bangladesh, Sri Lanka, as well as South-East Asia. In India, it is popularly known as “Bahera” in Hindi, while in English and Sanskrit it is known as “Beleric Myrobalan” and “Bibhitaki”, respectively. It is a large deciduous tree with a buttressed trunk and thick brownish-gray bark with shallow longitudinal fissures, attaining a height of 20–30 m at maturity. The leaves grow at the tip of the branches and have features such as alternative arrangement, entire margins, rounded tip or sub-acute, elliptic-obovate, prominent midrib, pubescent when young and become glabrous with maturity. The flowers are pale greenish-yellow with an offensive odour, borne in axillary spikes longer than the petioles, but smaller than the leaves. Each fruit has an ellipsoid seed; bark is gray or pale brown with longitudinal fissures and shallow cracks.

Traditional uses of *T.bellirica* are correlated to the wide-ranging pharmacological activities of the numerous bioactive secondary metabolites, *viz.* alkaloids, flavones, lignans, tannins, phenols, coumarin, terpenoids, glycosides and saponins present in it (**Abraham *et al.,* 2014**). *T.bellirica* as a whole or its specific components possess ethnomedicinal attributes and are used in various herbal formulations. It is used as astringent, laxative, antipyretic, and anthelmintic agent (**Kumar and Khurana, 2018**). Fruits are useful in the treatment of asthma, bronchitis, hepatitis, diarrhea, piles, dyspepsia, eye diseases, hoarseness of voice, and scorpion-sting and used as hair tonic (**Rastogi and Mehrotra, 2004; Singh, 2011**). Decoction of the green fruit is useful in the treatment of cough (**Deb *et al.,* 2016**). Fruit pulp is used in dysenteric-diarrhea, leprosy, piles, and dropsy (**Singh *et al.,* 2018**). Partially ripe fruit acts as purgative and fruit kernel is narcotic. *T. bellirica* fruit is used in the treatment of menstrual disorder in Bangladesh (**Mallik *et al.,* 2012**). Appreciable antimicrobial activity has been associated with the triterpenoid compounds present in the fruits (**Deb *et al.,* 2016**). Bark gum and kernel oil show purgative actions, while seed oil exhibits anti-rheumatic activity (**Ghani, 2003**). The leaves enhance appetite, relieve piles, lower cholesterol and blood pressure, boost immunity and prevent aging and also improve the body's ability to resist against pathogens (**Kumar and Khurana, 2018).**

“Triphala”, a well-established natural formulation in ayurvedic medicine consists of dried fruits of the three plant species, namely *Phyllanthus emblica* L. (also known as *Emblica officinalis* Gaertn.), *T. chebula* Retz., *and T. bellirica,* which are native to the Indian subcontinent. It is defined as a “tridoshic rasayana” in ayurveda as it maintains the harmony of three fundamental bodily bio-elements or “doshas”, such as “Vata” (properties of dry, cold, light, minute, and movement), “Pitta” (metabolism), and “Kapha” (watery element). “Triphala” stimulates longevity and rejuvenation in individuals of all ages (**Peterson *et al.,* 2017**). “Triphala” also has restorative and revitalizing potential as its ingredients act on the immune system and exert positive response to the body against several infectious conditions (**Belapurkar *et al.,* 2014**).

The previous reports show the evidence of TB as a good pharmacological agent and its formulations as effective medication for various ailments. However there is no reports on the TB fruit part aided metallic nanoparticle synthesis and its pharmacological activity. This inspired me to use TB fruit parts as a source of bioreductants for the synthesis of GNPs and to

explore its bactericidal (our team successfully published an article) and nanoswitching property (presented in an international web conference).

2.3.2 Review of literature pertaining to work on *Garcinia combogia*

The fruit rind of *Garcinia gummi-gutta,* commonly known as *Garcinia cambogia (syn.),* is traditionally used as flavouring in fish curries due to its sharp, sour taste. Additional ethnobotanical uses include its use as a digestive and a traditional remedy to treat bowel complaints, intestinal parasites and rheumatism. This small fruit, is most popularly used and widely advertised as a weight-loss supplement. Studies have shown that the extracts as well as (-) HCA, a main organic acid component of the fruit rind, exhibited anti-obesity activity including reduced food intake and body fat gain by regulating the serotonin levels related to satiety, increased fat oxidation and decreased de novo lipogenesis. HCA is a potent inhibitor of adenosine triphosphate-citrate lyase, a catalyst for converting citrate to acetyl-coenzyme A, which plays a key role in fatty acid, cholesterol and triglyceride synthesis. The crude extract or constituents from the plant also exerted hypolipidaemic, antidiabetic, anti-inflammatory, anticancer, anthelmintic, anticholinesterase and hepatoprotective activities in *in vitro* and *in vivo* models. Phytochemical studies of various plant parts revealed the presence of mainly xanthones (e.g. carbogiol) and benzophenones (e.g. garcinol) together with organic acids (e.g. HCA) and amino acids (e.g. gamma aminobutyric acid). Currently, a large number of GC/HCA dietary supplements for weight management are being sold although the possible toxicity associated with the regular use of these supplements has raised concerns. In most cases, complaints have been related to multicomponent formulations and at this stage GC has not been confirmed as the potentially toxic (**Semwal *et al*., 2015**). GC is used for the synthesis of ZnONP (**Sivakamavalli *et al.*, 2022**) and GNP (**Nithya and Jayachitra, 2016**).

There are reported work on GC aided metallic nanoparticles and their pharmacological properties, but there is a research gap on the nanoswitching properties of GC mediated GNP. This was taken as one of the objective.

2.3.3 Review of literature pertaining to Rice washed water (RWW)

Some of the important aspects of RWW, used for a variety of purposes around the world but still require more scientific validation has been highlighted in the following pages.

RWW is a white milky liquid obtained after washing rice. According to traditional knowledge, RWW is used in various skin care, hair care, and other adjuvant for various ailments.

Inspired by the traditional uses of RWW for skin and hair care, several skin care products and hair shampoos are now commercially available in the market. RWW soaps and bathing gels are widely available in the market. Pantene, a well-known hair shampoo manufacturer, claims that fermented RWW as one of the ingredients in their most recent hair shampoo formulation (**https://www.pantene.in/en-in/browse-by-collection/hair-fall-shampoo-and-conditioner/**). Despite the lack of proper scientific validation, numerous beauty blogs, report on the direct use of RWW for skin care, hair care, and plant growth.

India ranks among the top countries in the world in terms of rice cultivation and production. Rice, also known as *Oryza sativa L*. Rice is a food crop consumed by half of the world's population because it provides all the calories required for daily activities. Rice is one of the agricultural commodities produced around the world. Rice contains all of the essential nutrients and minerals, as well as being a good source of carbohydrates. There are numerous rice varieties because of biotechnology advancement. Their cultivation method can also be modified based on the geographical and tropical conditions of the cultivation site. However, the growth process is the same regardless of the requirements. It is well known that rice and rice products such as rice bran and rice bran oil have equal benefits in health and skin care applications. RWW is one such rice-aided product.

It is customary to wash the rice before cooking and to discard the washed rice water. The ethnic Yao ladies of Huangluo, China, are proof of the RWW usage tradition. Female rice farmers in China, Japan, and other Southeast Asian countries used RWW for bathing and washing. With an average hair length of 6 feet, the women became the "longest hair village in the world" according to the Guinness Book of World Records. The Yao ladies believe the fermented RWW they use, to purify their hair keeps it long, black, and smooth. RWW can decongest and manage these ladies' long hair (**Khadge and Bajpai, 2018**). In times of scarcity, rural women in Kothein village, Myanmar, are said to use RWW to clean their dishes. **Aye, 2018** praised and highlighted the village women's wise and useful water management. Due to significant nutrients, RWW is used for punnac preparation and to wash potteries during the drought season (**Hettiarachchi and Jayasooriya, 2016**). RWW is used as feed instead of water for cattle and goats in many parts of the world (**Rifky *et al.*, 2018; Sikder *et al.*, 2015**). To clean oil pots, the face, and the hair, RWW has been used in China since ancient times, and Chinese households have learned this from personal experience. On the other hand, a comprehensive scientific theory still needs to be discovered (**Chen *et al.*, 2019**).

Recently, two Indian patents have been filed by our research team on the synthesis of metallic and non-metallic nanoparticles using RWW from different rice varieties (Patent application number 202141004547 Dt 12/2/2021 and 202041009199 Dt 5/2/2021).

- **Reports on nutrients and fungi identified from RWW**

Rice and millet wash water possess nutrients such as Vitamins, starch, Fe, Mg, K and Ca. (**Qiao *et al.*, 2013**). RWW contains crude protein, crude ash, sugar, starch, crude fat, minerals (Fe, Cu, Zn, Mn, Mg, K, Na, Ca, Cl, P, Se), and Vitamins (VB_{12}, V-E). The RWW had five efficacies, according to the results of the component analysis: decontamination, hairdressing, fertilizer, medication, and deodorant (**Peng and Du, 2013**).

Several lots of California brown rice of the short-grain variety were found to have a wide range of thiamine levels (208 to 298 per 100 g, raw weight basis). There was no significant loss of thiamine when brown rice was thoroughly washed with five changes of water. Partially polished rice was found to have nearly 70% more thiamine than untreated brown rice. Due to washing, partially polished rice lost more thiamine than brown rice (about 20 percent). This higher loss was caused by the washing away of clinging rice polish that adheres to partially polished grains (**Miller *et al.*, 1945**). During cold water washing, raw milled rice loses approximately 60% of its nicotinic acid (I), whereas parboiled milled rice, which has nearly twice as much nicotinic acid (3.2 mg per 100 g.), loses approximately 12%. (**Swaminathan, 1941**). Thiamin losses in polished rice were 42 percent and 13 percent during washing with tap water and distilled water (free of Cl^-), respectively, while Vitamin losses were 63 percent and 23 percent during washing and cooking with tap water and distilled water, respectively (**Motooka *et al.*, 1981**). The treatment of RWW with varying pH and chitosan concentrations revealed no improvement in turbidity reduction with variation in chitosan concentration at pH 4 and 5, but significantly improved turbidity reduction at pH >6 compared to control experiments (**No *et al.*, 1994**). It was reported that a membrane method was used to recover useful components such as protein from RWW produced during the processing of washed rice (**Chung and Park, 2002**).

The most common fungi found in fermented RWW were *Proteobacteria* (62%), *Firmicutes* (28%), *Cyanobacteria* (10%), and *Bacteroidetes* (0.5%). The bacteria found in the core RWW include *Trabulsiella, Pseudomonas, Serratia, Lactobacillus, Erwinia, Enterobacter, Clostridium, and Acinetobacter* (**Chen *et al.*, 2021**). RWW is also used to cultivate Entomo pathogenic fungi such as *Verticillium lecanii, Metarhizium anisopliae, Beauveria bassiana (Bals.) and Vuil. Paecilomyces fumosoroseus (Wize)* (**Jitendra *et al.*, 2012**). Rice and wheat washing water also aided in the growth and sporulation of all three fungi studied. RWW produced the highest spore count in *M. anisepliae* (**Patel *et al.*, 1990; Sahayaraj and Namasivayam, 2008**). The pattern of lactic acid bacteria development in rice washed water investigated using a completely randomized design and a factorial design revealed the highest number of bacteria in 1:3 RWW. Thus RWW is recommended as a probiotic drink for animals. The results show that rice water can be used as a probiotic drink within 12 to 42 h of fermentation (**Gil *et al.*, 2015; Gong *et al.*, 2017**). Lactic acid bacteria are made using RWW (**Buang, 2019**). Cattle / buffaloes in Sundarbans delta are fed with paddy straw along with rice gruel, RWW, rice bran and kitchen waste (**Das and Hema Tripathi, 2008**).

- **Review of literature pertaining to applications of RWW**

The effects of RWW on broiler chicken growth and lipid peroxidation levels were investigated. RWW has been shown to be a potential high-energy feed resource, and RWW dried at high temperatures has been shown to alter lipid peroxidation in broiler chickens via increased antioxidant activity (**Ijiri *et al.*, 2013**). Bacterial cellulose (BC) is a biopolymer with numerous applications ranging from medicine to electronics. To generate BC, *Komagataibacter xylinus* was fed two types of liquid waste: tofu liquid waste and RWW. It was found that both tofu liquid waste and RWW are equally efficient (**Apriyana *et al.*, 2020)**. The treatment of kenaf fibres with RWW improved their mechanical and interfacial properties (**Park *et al.*, 2015**).

- **RWW as probiotics**

RWW are used in the preparation of soidon starters (fermented bamboo shoots). It has been reported that the addition of RWW (high in starch) during soidon starter preparation may have favoured *Bacillus* population, enhancing the probiotic nature of the soidon (**Jeyaram *et al.*, 2010**). The pungent smell, bitterness, and fishy taste of *Gastrodia elata* blume were reported to be reduced when treated with RWW and rice-bran solution fermented with *Lactobacillus brevis* and *Lactobacillus plantarum*. The treatment in fermented RWW also changed the biobenificial contents of the species (**Chang and Ahn, 2011**). 'Insects tea' is not only a traditional drink for the ethnic minority of southwestern China, but it is also one of China's traditional exports, according to Li Shizhen's "Materia Medicas Compendium." Insect tea is made from the excrement of insects that feed on plants. To protect the tea leaves from insects, RWW is sprayed on them (**Xu *et al.*, 2013**). A ready-to-drink bitter gourd beverage was developed. As a debittering step, the sliced bitter gourd was soaked in rice washed water (**Chern *et al.*, 2018**).

- **RWW in Ayurveda and Chinese medicine**

In several Chinese medicinal combinations RWW has a prominent role. In most of the combination cerebrovascular and cardiovascular diseases RWW is used (**Li *et al.*, 2007**).

Dushivishari gulika along with RWW as adjuvant is advised to patients with *Visphota kushta* (blistering skin disease) is characterized by transparent blisters with thin skin covering according to Ayurveda (**Ashtanga Hridaya Vagbhata , 2010).** In traditional Chinese medicine, Jin-Changzhu must be treated with RWW before it is used therapeutically for the removal or reduction of poisonous and dehydrating chemicals atractylodin and acetyl atractylodinol (**Ding *et al.*, 2000**).

Tandulodaka is the ayurvedic term for RWW. According to Bhaishajya Ratnavali 8/32, it is considered derivative dosage in the form of cold infusions. In ayurvedic terms, it is used as anupana (co-drink). People in extremely cold weather, as well as those with asthma or a severe cough, should avoid taking tandulodaka formulations **(https://www.easyayurveda.com/2017/10/11/rice-water-tandulodaka/**). RWW are thought to enhance the pharmacological activities of medicinal plants (**Juárez-Vázquez *et al.*, 2013**). This results in a variety of formulations that use RWW. Mehavajra Rasa is one of the Ayurvedic compounds used to treat Diabetes Mellitus Type -2. Shilajatu, Rasasindoor, Kantlauha, Swarnmakshik, Manahashila Trikatu, Triphala, Bilva, Jeerak, Kapith, Haridra are the compounds' ingredients. This medication must be taken with 500mg of Nimbachurna, Ghrita, and RWW (**Richa and Kamal, 2017**).

A composite of *Scorzonera albicaulis Turcz*, brown sugar, and rice-washed water for the treatment of lithiasis such as hepatolithiasis, cholecystolithiasis, bile duct calculus, renal calculus, and urethral calculus was developed (**Yin, 2007**). It is customary that at the end of 6 days of menstruation, the woman is required to wash her hair with CHENGHI, rice-washed-water boiled with specific herbs, as practiced by the Meitei community of Manipur (**Singh, 2004**).

- **RWW in cosmetics and anti-ageing**

Everyone wishes to be beautiful. This is why, since the Vedic period, humans have used cosmetic preparations. Numerous cosmetic concoctions are mentioned later in the post vedic era, Kavya, Natya, and Ayurvedic treatises. Haramekhala is a humanity treatise that explains various cosmetic preparations that make use of basic herbal medicines. Haramekhala discusses various preparations for improving physical appearance and remaining youthful and charming. RWW, along with Nasya and Strotonjana, was used for breast enlargement and shape (**Archana, 2012**).

With the help of some herbals and fermented products, a non-stimulating anti-aging soap was created. This soap's main ingredient and base was fermented RWW. Others included herbal medicines, glycerin, essential oils, propolis, and so on (**Park and Park, 2013**). RWW is thought to be an anti-aging product. According to ***Marto et al*., 2018** a hydrogel formulation made from

RWW has anti-aging properties and is compatible with the pH of human skin. It has also been reported that fermented RWW contains traces of kojic acid, which is an anti-aging agent.

Pitera is a fungi with the highest natural moisturising factor (*Saccharomycopsis febuligera* yeast). Pitera was isolated from fermented RWW (**Khadge and Bajpai, 2018**). This was used to remove makeup in two phases. The researchers attempted to use two naturally-derived components derived from Japanese traditional knowledge as hair-treatment compounds. Yu-Su-Ru (rice washing drainage water) and sericin are two of these components (produced from cocoon thread). Both have been inextricably linked with Japanese life science since ancient times. They both have one thing in common: they have been largely squandered, both in terms of effective natural resource exploitation and elsewhere. Every day, the Heian court women were said to comb their hair with Yu-Su-Ru. The remarkable efficacy of Yu-Su-Ru and sericin as hair-treatment ingredients, both of which are part of Japanese traditional medicine but are rarely used (**Inamasu, 2009**).

These insights on RWW gave a wide knowledge about its composition, industrial applicability and traditional usage of RWW. Our research team could successfully draft a review article on RWW with these above mentioned earlier reported scientific data and it was published in March, 2023 (Chithambharan et al., 2023). This literature also shows that RWW is not taken up for nanoparticle synthesis as bioreductants. To best of our knowledge, till date there is no research work on the synthesis of nanoparticles with other cereals/pulses washed water.

2.3.4 Review on Free edges of *Corpus unigus*

The human nail (*Corpus unguis*) is one of the challenging membranes for the scientists to target and to improve the clinical efficacy of ungual formulations. The understanding of nail physiology, impact of hydration on its properties and presence of trace elements in nails as biomarkers has been explored by various researchers in clinical studies. Despite the importance of biophysical techniques for the assessment of structure and physiology of nail, minimum literature analyses such as biophysical, biochemical and bioanalytical approaches. However, nowadays scientists in bioengineering field are keen in developing non-invasive, reliable and reproducible techniques for the assessment of different anatomical and functional parameters of nails for testing of ungual products and drug delivery (**Thatai and Sapra, 2016**).

Fingernails and toenails can provide valuable insight into metabolic changes in the body, as they come into contact with the periosteum of the phalangeal bone. Fingernail plates grow at a consistent rate of 3.5 mm per month, and they can collect various components such as medicines, toxins, and biomarkers (**Brzozka and Kolodziejski, 2017**). This makes it easy to collect, transport, and preserve nail samples (**Yesil *et al.*, 2012**). In fact, nail clippings have been used to detect toxic components, heavy metal exposure (**Mehra *et al.*, 2003**), nutritional imbalances like iron deficiency (**Djaldetti *et al.*, 1987**), and to study the relationship between fingernail microelement concentrations and coronary heart disease and hypertension (**Tang *et al.*, 2003**). Mineral levels in toenails, such as zinc (Zn) (**Martin-Moreno *et al.*, 2003**) and selenium (Se) (**Kardinaal *et al.*, 1997; Gomez-Aracena *et al.*, 2002**), have also been studied in relation to the risk of myocardial infarction. Human nail plates consist of a three-layered protein structure including alpha keratin, keratin microfibrils in the globular matrix, and keratin related protein (**De Berker, 2013**). Keratin is the primary protein found in nails, while collagen is the primary protein found in bones. Non-enzymatic and post-translational changes to keratin and collagen can be discovered utilizing techniques such as Raman spectroscopy. Post-translational alterations that occur in nail diseases may be linked to bone collagen problems (**Beattie *et al.*, 2010; Buckley *et al.*, 2012**). Therefore, analyzing the mineral and protein content of nails could be a valuable complementary or alternative approach for screening and detecting bone metabolism diseases.

Human fingernails are modifications of the skin. The nail plate, which is produced by the nail matrix, comprises three layers of keratins (**Garson *et al.*, 2000**). Primary components are -keratins, tough insoluble fibrous proteins with three right-handed -helical peptide chains that are twisted into a left-handed coil strengthened by disulfide crosslinks (**Dittmar *et al.*, 2008**). The keratohyalin granules in the nail matrix are composed of amino acids, sulphur, lipids, water, and the balance is made up of calcium phosphates and carbohydrates. Sulphur and nitrogen occur most exclusively in amino acids, and sulphur is mainly found in cysteine. The molecular ratio of cysteine to histidine is 25:1 in keratins (**Block, 1939**). While the content of the neutral amino acid cysteine is variable, the basic amino acids histidine, lysine, and arginine occur in constant molecular ratios of approximately 1:4:12.

Human nail is considered as a keratinous waste. The disposal of keratinous waste is considered to be a tedious task. There are ongoing researches on the disposal of keratinous waste. By developing alternative management strategies that support a circular bio economy, keratinous waste buildup in the environment may be stopped. Valorization of keratin-based wastes offers resources, feedstock, and raw materials for the industries to make keratin-based byproducts for value-added applications while addressing the large amount of biomass produced in the environment. Valorization might improve environmental health, decrease and limit the discharge of keratinous waste in the waste stream, and raise the sustainability and circular economy of business operations (**Chukwunonso Ossai *et al.*, 2022**). ***Synthesizing GNP and utilization the same for development of a new product also contributes to minimize the keratinous waste.***

In 2020, August 13th the popular nation daily of India, "The Times of India" reported use of human hairs in several processed foods. Human hair is made of amino acids and a compound found in human hair L-Cysteine is an amino acid, which is used as an additive to increase the shelf life of buns and breads. In fact, the compound is used by many renowned brands across the world to add this additive to their burgers, sandwiches, pizzas and chocolates (**https://timesofindia.indiatimes.com/life-style/food-news/shocking-additives-present-in-common-foods-will-leave-you-surprised/photostory/77529943.cms**).

Like human hair, human nails are also dead cells. As human hair finds use in edibles; we attempt to incorporate free edges of human nails dispersed water aided GNP in topical skin care lotion formulation. There are no reports on human nails in skin care formulations. A patent filed by our research team for this innovation has been published (Patent application number: 202341013468 Date: 17/3/2023).

2.4 Review on Anti-bacterial activity of nanoparticles

Antimicrobial coating technology is rapidly advancing and has the potential to revolutionize the elimination of biofilms across various industries, including food, medicine, and agriculture. Biofilm-associated infections have grave public health consequences and substantial economic costs (**Hage *et al.*, 2021**). Pathogenic infectious agents that produce biofilms can survive on surfaces for extended periods, and multi-drug-resistant bacterial strains can linger for weeks on hospital surfaces (**Vitelaru *et al.*, 2022**). A staggering 80% of all microbial infections in humans, including meningitis, cystic fibrosis, kidney infections, endocarditis, rhinosinusitis, periodontitis, non-healing chronic wounds, osteomyelitis, as well as prosthetic and implantable medical device and infections, are caused by biofilms, according to the National Institute of Health (**Sonawane *et al.*, 2022; Khatoon *et al.*, 2018**).

Nanotechnology-based techniques have shown promise in reducing bacterial adherence and increasing osseo integration on nanoscale surfaces without the use of biomolecules or antibiotics. Additionally, biomaterials and medical devices hold potential in preventing drug-resistant biofilm infections. The antibacterial activity of most metal-based coatings is related to their oligodynamic effect, which depends on their ionic or nanoform features rather than bulk features. Since ancient times, metals such as gold, zinc, silver, and copper have been utilized for their antimicrobial properties, capable of killing various microorganisms such as gram-negative and gram-positive bacteria, viruses, protozoa, and fungi. Consequently, these compounds have been widely used in antimicrobial-based products in the medical field (**Rai *et al.*, 2009; Siva *et al.*, 2022**).

SNPs have a wide range of applications in various industries, including cosmetics, healthcare, textiles, and coatings, as well as in medical practices, such as treating chronic ulcers, antibiotic-resistant diabetic wounds, and burns. One significant advantage of using SNPs in wound therapy is their ability to promote collagen deposition, which can speed up the healing process and exhibit anti-inflammatory effects (**Ezhilarasu *et al.*, 2020**). However, silver nanomaterials, especially those with dimensions ≤ 10 nm, can be toxic to human cell lines and cause cytotoxicity depending on factors such as size, time, and dose. To overcome this issue, researchers have explored immobilizing these structures on various support materials, such as polymers, activated carbon, metal oxides, and GO, which can enhance the properties of SNPs, such as antibacterial, catalytic, and photocatalytic activity, by increasing their stability, size, oxidation state, and shape (**Díez-Pascual, 2020**).

Nanomaterials are playing a crucial role in combating AMR (Anti-Microbial Resistance) in various applications, including as antimicrobial coatings. This is an emerging field of study that shows promising results. Wound infections can result from bacterial strains that are resistant to one or more treatments. Therefore, NPs with antibacterial properties, which are found in medical dressings and plasters, are an excellent alternative to betadine, alcohol, and antibiotics. The use of silver as an antibacterial agent is growing, and SNPs have been used in many ways to heal wounds with exceptional anti-inflammatory effects (**Sirotkin *et al.*, 2021**). SNP and ZnONP containing cotton bandages, as well as combined SNP/ZnONP bandages, exhibit antibacterial activity against *Acinetobacter baumannii* and *Pseudomonas aeruginosa* (**Khatami *et al.*, 2018**).

The advantages of GNPs as antibacterial agents include the following: (1) Gold nanomaterials can be endowed with high biosafety because gold itself is chemically inert, and the absorption/metabolism of gold nanomaterials can be regulated by the material design. (2) The antibacterial effects of GNPs can be maximized by the chemical manipulation of properties, such as size, shape, and surface, by modifying the surface with different molecules. (3) Gold nanomaterials induce bacterial resistance less frequently than standard antibiotics (**Zhao *et al.*, 2022**). (4) Additionally, GNP can be functionalized by natural antioxidant, biological ligands, various organic molecules, and dendrimer. The functionalized gold nanomaterials have several advantages in surface charge, size, bacterial receptor targeting, biocompatibility, and effective internalization (**Shinde *et al.*, 2021**). Similar to GNP and SNP, titanium and titanium alloys are important in orthopedic implants. Titanium dioxide nanotubes can be formed on the surface of titanium using anodizing treatment. Titanium dioxide nanotubes (TNT) are similar to natural bone matrices because of their nanoscale structure and the use of drugs. Pristine TiO_2 does not possess antibacterial capabilities unless catalyzed by ultraviolet (UV) light, which cannot penetrate tissue to reach implants *in vivo* (**Wang *et al.*, 2017**). Light in the near-infrared region (650–900 nm) has a lower rate of optical adsorption by body components, such as water, and would therefore allow deep tissue penetration without significant damage (**Alenezi *et al.*, 2019**). Infrared light is more efficient than visible light because it has better skin penetration (**Moon *et al.*, 2014**). When TiO_2-NTs are decorated with GNPs, their photothermal effect of GNPs enables them to achieve enhanced photocatalysis. There are also studies showing that without near-infrared laser excitation, titanium dioxide nanotubes modified by GNPs have good antibacterial effects on *Streptococcus gordonii, Porphyromonas gingivalis,* and *Fusobacterium nucleatum*, and the *in vivo* results showed a reduced inflammatory response. Further, research has shown that the surface of GNP-modified TiO_2 nanotubes exhibits a superior antibacterial effect on *E. coli* under NIR laser irradiation (**Xu *et al.*, 2019; Zheng *et al.*, 2020**). Some of the bactericidal activities of the nanoparticles/nano composites are mentioned below.

Nanomaterials	**Bacteria**	**Reference**
$MnFe_2O_4$@SiO_2@Au	*P. aeruginosa*, *Klebsiella pneumoniae* and *Proteus mirabilis* bacteria	**Shirzadi-Ahodashti *et al.*, 2020**
Au@Bi_2S_3	*S. aureus* and *E. coli*	**Wang *et al.*, 2020**
PDMS-ZnO/Au	*E. coli*	**Tang *et al.*, 2020**
AuNPs-COOH/$AgNO_3$	*E. coli* and *S. aureus*	**Panicker *et al.*, 2020**
TNTs/Au/CDs	*S. aureus* and *E. coli*	**Jin *et al.*, 2019**
Ag–Au/CeO_2	*S. aureus* and *E. coli* strains	**Nithya and Sundrarajan, 2020**
Au–Pt	*E. coli*, *P. aeruginosa*, *K. pneumoniae*, and *Salmonella choleraesuis*	**Zhao *et al.*, 2014**
Titania/TiO_2	*E. coli*	**Tang *et al.*, 2019**
Fe_3O_4–Au NCs	Gram-positive and Gram-negative pathogens	**Arockia Jency *et al.*, 2020**
Plant extract@X-NPs, X = Ag, Au	*S. aureus*, *Enterococcus faecalis*, *P. aeruginosa*, *Acinebacter baumannii*, *E. coli*, *K. pneumoniae*	**Shirzadi-Ahodashti *et al.*, 2020**

There are numerous literatures on anti-bacterial activity of nanoparticles. Over usage and contaminated earphone buds cause ear infection among Indians (**https://timesofindia.indiatimes.com/home/science/overuse-of-earphones-for-work-and play-pushes-up-cases-of-infection/articleshow/79360928.cms**).

Critical analysis of literature reveals no work on antibacterial coating of nanoparticles on earphone buds. This is focused as of the objective of the present research work.

2.5 Review on Skin cancer activity of nanoparticles

NPs have a wide range of applications in treating various diseases such as cancers (**Sahoo *et al.*, 2007; Gorantla *et al.*, 2022**). Metallic NPs are important agents, which offer many opportunities for biomedical usages, such as radiotherapy enhancement and diagnostic assays (**Selvan *et al.*, 2010; Baptista *et al.*, 2008**). Metallic NPs have received much attention due to the strong electromagnetic field on the particle surface, simplicity in the synthesis method, and simple surface functionalization (**Jones *et al.*, 2009; Sperling *et al.*, 2008**). Nanoparticle-based drug delivery systems have shown more efficient activities than those of conventional therapies. They outlined desirable pharmacokinetics, accrued targeting of tumor cells, decreased side effects, and drug resistance (**Dadwal *et al.*, 2018**; **Palazzolo *et al.*, 2018**). In order to target different tumor cells, metallic NPs can be used in single forms or in combination with other materials such as polymers, peptides, DNA/RNA, lipids, and antibodies (**Sau *et al.*, 2010**; **Sperling *et al.*, 2010**). Metallic NPs have already gained popularity in targeted drug delivery system through active and passive targeting (by performing tumor imaging).

The skin is an obstacle protecting the body against environmental allergens, chemicals, and harmful substances. This distinctive barrier comprises the epidermis, dermis, hypodermis, and many appendages such as hair follicles, sweat glands, and sebaceous glands. The ability of metallic NPs to overcome this skin barrier and penetrate the deep layers of the skin is controversial. The interaction of NPs with the skin is yet to be fully understood, as it has been shown that some NPs can penetrate the outer layer of the stratum corneum, while others can penetrate deeper into the skin layer and enter the systemic circulation. Numerous factors affect metallic NPs skin adsorption, such as shape, charge, size, formation, and surface modification (**Filon *et al.*, 2015**). Some of the recent reported works on anti-cancer activity of nanoparticles are mentioned below.

Type of nano particles	Cancer cells	Reference
Silver nanoparticles	B16F10 and A431 cell lines	**Shivashankarappa *et al.*, 2019**

Gold nanoparticles	Murine B16 melanoma cells	**Wu *et al.*, 2019**
Magnetic nanoparticle	B16-F10 murine melanoma cells	**Duval *et al.*, 2019**
Silver and gold nanoparticles	Murine melanoma B16F1 and B16F10 cells	**da Silva Cansian *et al.*, 2020**
Iron oxide/salicylic acid nanoparticles	Murine B16 melanoma cells	**Predoi *et al.*, 2020**
Zinc oxide nanoparticles	Murine B16 melanoma cells	**Latif *et al.*, 2021**
Titanium dioxide (TiO_2) nanoparticles	F10 melanoma mouse cell line	**Adibzadeh *et al.*, 2021**
Silver nanoparticles	Human malignant melanoma (A375 cell line, ATCC number CRL-1619)	**Hamdi *et al.*, 2021**
A.calamus-zinc oxide nanoparticle coated cotton fabrics	Human skin melanoma SK-MEL-3 cells	**Vakayil *et al.*, 2021**
Silver nanoparticles	Human and murine skin melanoma cells	**Barbasz *et al.*, 2022**
Cerium oxide nanoparticles	Human melanoma cell line, Me1007	**Amaldoss *et al.*, 2022**
Silver nanoparticles	Human metastatic melanoma cell lines A375 and SK-MEL-28 and the murine melanoma cell line B16-F10	**Kuang *et al.*, 2022**

The previous reports show that the nanoparticles are efficient against skin cancer cell lines. The literature survey helps to identify the research gap; there are still no reports on anti-skin cancer activity of cereals and pulses washed water aided nanoparticles. Thus this gap is taken as one of the objective of this present work.

2.6 Review on nanoparticle-DNA binding studies

A number of novel technologies based on nanoparticle–DNA binding and their interactions have been developed and used in molecular diagnosis, gene therapy and sensing. These approaches offer an opportunity for the development of efficient and low-cost technologies for disease diagnosis and DNA detection with high sensitivity. All these show that nanoparticle–DNA binding based techniques could have a promising implication in medical biotechnology in near future. In addition to the knowledge of chemical and structural properties (biocompatibility, water solubility, and biodegradability), the fundamentals of energetically favorable molecular binding reactions between nanoparticles and DNA is of great importance. It is necessary to understand the interactions within cellular membranes. The DNA–nanoparticle interactions through their molecular bindings and biochemical reactions have drawn an increasing interest (**An and Jin, 2012**).

The selectivity of GNP for ss-DNA binding may arise for several reasons. Many researchers believe that electrostatic forces between the anionic DNA strands and the negatively charged surfaces of citrate-stabilized GNP are less favorable for double-stranded DNA (ds-DNA) binding. The ds-DNA with higher surface charge density exhibits more repulsion than that of ss-DNA (**Gaylord *et al.,* 2002**). Moreover, the study on binding affinity of deoxynucleosides to GNP revealed that the four deoxynucleosides display high affinities, while the thymine interacts much more weakly with the gold surface than other nucleobases (**Storhoff *et al.,* 2002**). The duplex DNA structure prevents the exposure of the bases to gold surfaces and therefore limits the DNA–GNP interactions (**Boon *et al.,* 2000**). The ss-DNA is flexible and favors the wrapping around GNP, while ds-DNA is relatively rigid and not favorable for wrapping around the GNP. The DNA structure may play an important role in DNA–GNP interactions. As hair pin structures are easily formed in a longer ss-DNA at room temperature, the DNA structure can hinder the binding interactions. Binding of longer ss-DNA to 5 nm GNP was not found (**Zanchet *et al.,* 2000**). On the other hand, (**Sandström *et al.,* 2003**) reported non-specific ds-DNA binding to 13 nm GNP by the ion-induced dipole dispersive interactions. It is reported that the polarizability of a conducting sphere is proportional to the cube of the sphere radius. The polarizability was found to be reduced significantly when the particle sizes varied from 13 nm to 5 nm. The size effect of nanoparticle is one of the most important aspects in elucidating the binding mechanism. Particle size of the GNP determines the strength of the DNA-binding to GNP (**Yang *et al.,* 2004**).

Extensive studies have been given to develop simple and ultrasensitive technologies to detect specific DNA sequences using SNPs (**Liu *et al.,* 2006**). **Thompson *et al.,* 2008** reported that oligonucleotide–SNP conjugates offered ultrasensitive DNA detection. **Basu *et al.,* 2008** revealed that the interactions between unmodified SNP and DNA molecules were sequence-dependent, suggesting a close affinity between SNP and nucleobases. Silver staining DNA in polyacrylamide gels has been proved as a highly sensitive method for the detection of nucleic acids in a nanogram range, which revealed that silver has a high affinity to bind DNA or RNA. Circular dichroism and spectroscopic investigations suggested that SNP can significantly change the helicity conformation of DNA and then induce the alteration of non-planar and tilted orientations of DNA bases, resulting in the changes of DNA base stacking, when acting as an intercalator (**Rahban *et al.,* 2010**). AFM topography showed that DNA molecules still remain linear structure (**Yang *et al.,* 2009**). The incorporation of silver particles could stabilize the structure of parallel-motif DNA triple helix (**Ihara *et al.*, 2009**). Self-assembly of G4-DNA–silver nanoparticle structures were obtained by using high concentration of G4-DNA containing phosphorothioate anchor residues at both ends of the DNA molecules, while nonphosphorothioate G4-DNA or diluted phosphorothioate G4-DNA did not yield conjugates (**Lubitz and Kotlyar, 2011**). Apart from nanoparticles, DNA and protein binding studies of anti-covid targets are also reported (**Hashim and Manoj, 2023**).

The previous reports highlight the importance of DNA binding studies of nanoparticles which are considered to be drug targets. Thus DNA binding studies are executed for the synthesized nanoparticles in this study.

2.7 Review on *Allium cepa* root tip toxicity assay

Onion (*Allium cepa*) has been considered as apposite material for genotoxicity investigations. It offers many advantages like clarity of mitotic phases, visible, diverse and low chromosome number, stability of karyotype; quick reaction to the toxic materials etc. Therefore, *A. cepa* assay is well documented to determine effects of various genotoxic materials. The effects of metal bioaccumulation in tomato and chili and their subsequent *A. cepa* test were reported. Onion plant is useful in studying genotoxic effects such as chromosomal aberrations (CA), effects on karyokinesis and cytokinesis, nuclear alterations, disorders in the mitotic cycle, and the existence of micronuclei in meristem cells (**Sabeen *et al.*, 2019**). The *Allium* test has been widely used by many investigators to study the biological monitoring, environmental pollution investigation, genotoxicity, and antigenotoxicity potential of many medicinal plants. It was reported that *A.cepa* assay as bioindicator of genotoxicity (**Majewska *et al.*, 2003; Akinboro *et al.*, 2007; Sultan *et al.*, 2009; Frescura *et al.*, 2012; Pastori *et al.*, 2013).**

Leme and Marin-Morales (2009) carried out an extensive review on the *Allium cepa* test and its use in environmental contamination, where they reported that vascular plants are recognized as excellent genetic models for detecting environmental mutagens and are frequently used in monitoring studies. *Allium cepa* is among the plant species used to evaluate DNA damages, chromosomal alterations and disturbances in the mitotic cycle. **Bagatini *et al.*, (2009)** reported *Allium cepa* test was used to evaluate the genotoxicity of a hospital effluent in Santa Maria, Rio Grande do Sul State, Brazil and mentioned the environmental toxicity. **Ragunathan and Paneerselvam (2007)** studied the antimutagenic potential of curcumin on chromosome aberrations in *Allium cepa*. **Lubini *et al.*, (2008)** analyzed the genotoxicity of two species of *Psychotria* (*P. leiocarpa* and *P. myriantha*) through the *Allium cepa* test and the results indicated that both species possess capacity to inhibit cell division and *P. myriantha* possesses genotoxic activity and toxicity determination is also tested by *A.cepa* root tip toxicity assay (**Rajeshwari *et al.*, 2016; Mangalampalli *et al.*, 2018**).

The previous reported articles have substantiated the importance of Allium cepa root tip toxicity assay for the various environmental contaminates, plant extracts and few nanoparticles. Upon reviewing the importance of toxicity assay; this study focus on the A.cepa root tip toxicity assay for the synthesized nanoparticle as they possesses drug like property.

2.8 Review on sun screen lotions and its importance

It has been reported that moderate sun exposure offers a number of beneficial effects, including production of Vitamin D (**Juzeniene *et al.*, 2012**), antimicrobial activity (**Bintsis *et al.*, 2000**), and improved cardiovascular health (**Fleury *et al.*, 2016; Weller, 2016**). However, long-term exposure to UV rays is considered to be a potential risk of skin cancer and acute and chronic eye injuries (**Taylor, 1989**). It has been proved that photoprotectors, especially sunscreen, play a critical role in reducing the incidence of human skin disorders (pigment symptoms and skin aging) induced by UV rays. Sunscreen was first commercialized in the United States in 1928 and has been expanded worldwide as an integral part of the photoprotection strategy (**Sambandan *et al.*, 2011**). It has been found to prevent and minimize the negative effects of UV light based on its ability to absorb, reflect, and scatter solar rays (**Donglikar *et al.*, 2016; Palm and O'Donoghue, 2007**) sunscreens are used. Over the decades of development, sunscreens have been improved step-by-step, accompanying the innovation of photoprotective agents (**Singer *et al.*, 2019**). Certainly, recent sunscreens are found to not only address UV effects, but also protect the skin from other risks (e.g., IR, blue light, and pollution) (**Mistry, 2017**). Indeed, while UV radiation is most commonly implicated in skin disorder development, it is crucial to note the potential role of these considerable harmful factors (**Mistry, 2017; Ham *et al.*, 1976**). It has been suggested that these factors can worsen disorders of dyspigmentation, accelerating aging, and eliciting genetic mutations (**Ham *et al.*, 1976; Schieke *et al.*, 2003**).

Furthermore, the photoprotective efficiency of sunscreen is determined through sun protection factor (SPF) and the protection grade of UVA (PA) values. According to Food and Drug Administration (FDA) regulations, commercial products must be labeled with SPF values that indicate how long they will protect the user from UV radiation and must show the effectiveness of protection. Certainly, the SPF values are generally in the range of 6–10, 15–25, 30–50, and 50+, corresponding to low, medium, high, and very high protection, respectively (**Schalka *et al.*, 2011**). Nevertheless, there are some fundamental misunderstandings of the SPF.

Some of the claims are SPF 15 sunscreen can absorb 93% of the erythemogenic UV radiations, while an SPF 30 product can block 96%, which is just over 3% more (**Osterwalder and Herzog, 2009**). On the other hand, in 1996, the Japan Cosmetic Industry Association (JCIA) developed an *in vivo* persistent pigment darkening (PPD) method to evaluate UVA efficacy of sunscreen. Sunscreens are labeled with PA+, PA++, PA+++, and PA++++, corresponding to the level of protection grade of UVA (PA) obtained from the PPD test (**Moyal, 2010; Wang *et al.*, 2008**). Sunscreens labeled as PA+ express low protection, mainly contributed by between two and four UVA filters. Sunscreens containing four to eight sunscreen agents show moderate levels of UVA blocking and are labeled as PA++. In contrast, the PA+++ and PA++++ symbols represent products that are composed of more than eight UVA filters and provide a high sunscreen efficacy (**Donglikar *et al.*, 2016**; **Moyal, 2010; Wang *et al.*, 2008**).

An emulsion is termed a lotion or cream depending on its viscosity, respectively, below 50,000 and in the range of 150,000–500,000 centipoises, providing almost unlimited versatility (**Klein, 1997**). It is normally produced from two unmixable liquid phases (oil and water), namely “water-in-oil (W/O)” and “oil-in-water (O/W)” emulsions (**Schroder *et al.*, 2008**). Moreover, multiple emulsions (O/W/O and W/O/W), containing both O/W and W/O phases in a stable system, show an effective application in recent sun protection technology (**Smaoui *et al.*, 2007**). Therein, water accounts for the largest proportion, while active ingredients contribute a little amount in an emulsion product. Thus, emulsion sunscreens are cost-effective vehicles (**Klein, 1997**). These formulations possess the ability to spread more easily on the skin and disperse from bottles (**Schroder *et al.*, 2008**). Further, this formula shows great effectiveness in strategies to achieve high SPF, create a uniform, thick and nontransparent sunscreen film when applied on the skin, and minimize undesirable interaction among active sunscreen ingredients (**Klein, 1997; Schroder *et al.*, 2008**). In other words, emulsion sunscreens also provide an elegant medium that can give the skin a smooth and silky feeling without greasy shine (**Schroder *et al.*, 2015**). However, these are extremely difficult to stabilize, especially at high temperatures (**Klein, 1997**).

Organic sun blockers are classified into either UVA (anthranilates, dibenzoylmethanes, and benzophenones) or UVB filters (salicylates, cinnamates, para-aminobenzoic acid (PABA) derivatives, and camphor derivative), which play an important role in absorption activity of sunscreen (**Serpone *et al.*, 2007**). These agents show outstanding safety and aesthetic properties, including stability, nonirritant, nonvolatile, non-photosensitizing, and non-staining to human skin, compared to inorganic UV filters (**Pathak, 1982**). Inorganic blockers have been approved to protect human skin from direct contact with sunlight by reflecting or scattering UV radiation over a broad spectrum (**Sambandan *et al.*, 2011**). The current agents are ZnO, TiO_2, Fe_xO_y, calamine, ichthammol, talc, and red veterinary petrolatum (**Palm *et al.*, 2007**). Although they are generally less toxic, more stable, and safer for human than those of organic ingredients, they are visible due to white pigment residues left on the skin and can stain clothes (**Palm *et al.*, 2007**). According to the literature, hybrid materials are two half-blended materials intended to create desirable functionalities and properties (**Mistry, 2017**). For instance, L'Oréal and Kerastase have introduced the Intra-Cylane™ shampoo, which contains amino functionalized organosilanes hybrid substances that not only protect against hair damage, but also create hair volume expansion, better mechanical properties, and better texture. Merch KgaA and EMD Chemicals Inc. have utilized a number of hybrid compounds, such as silica microcapsules, to control the release of active ingredients that can reduce skin aging and provide high SPF (**Gonzalez, 2002**).

In the presence of antioxidants, the ROS radicals are directly scavenged and prevented from their biological targets. As a consequence, the propagation of oxidants is limited, resulting in preventing aging (**Pouillot *et al.*, 2011**). It is reported that plant metabolites possess antioxidant and UV ray absorption abilities (**Schroeder *et al.*, 2008**).These antioxidant compounds are obtained from Vitamin C, Vitamin E, and plant metabolites (phenolic, carotenoids, and flavonoid compounds) (**Anitha *et al.*, 2016**). **Katarzyna *et al.*, 2020** reported that water: polyethylene glycol (4:1) extract of *Achillea millefolium* (yarrow) provided a maximum SPF value 14.04 ± 0.17, while a 5% hydroglycolic extract of *Achillea biebersteinii* provided a maximum SPF value 11.67. About 1 mg/ml methanol extracts of *Hibiscus furcatus*, *Atalantia ceylanica*, *Mollugo cerviana*, *Leucas zeylanica*, *Ophiorrhiza mungos* and *Olax zeylanica* leaves displayed SPF values ≥ 25 **(Napagoda *et al.*, 2016).**

It is well evident from the previous reports that natural ingredients in the sun screen lotions also enhance the UV protecting property. Thus in this present study, plant extracts and nanoparticles are incorporated in the sun screen formulations and their efficacy is determined.

2.9 Review on Carbon paste electrodes

In the year 2008, it was exactly a half of a century since Ralph Norman Adams, from the University of Kansas in Lawrence, published a short one-page report (**Adams, 1958**), in which he had introduced a new type of electrode, Carbon Paste Electrode (CPE). Over the past five decades, carbon paste, i.e., a mixture of carbon (graphite) powder and a binder (pasting liquid), has become one of the most popular electrode materials used for the laboratory preparation of various electrodes, sensors, and detectors. Such a position is undoubtedly the result of optimal constellation of physicochemical and electrochemical properties of this carbon-like substrate, which soon obtained a high reputation among both theoretical and practical electrochemists, as well as elsewhere, beyond the boundary of electrochemical sciences.

Although the real boom of carbon paste electrodes and carbon paste -biosensors, arguably representing the most significant movement in the entire history of carbon paste electrodes (**Kalcher, 1990; Kalcher *et al.*, 1995**), has started in the middle eighties; the first successful attempts with modifications appeared yet before. Depending on the criterion taken into account, the priority in appearance can be attributed to the following modified CPEs: i) CPE with solid surfactant as a stabilizer against disintegration of the native CPE in organic solvents. This electrode prepared by **Marcoux *et al*., 1965** had represented the first successful attempt of how to purposely alter some properties of the original carbon paste.

ii) When considering the usual motivation for modifying, an accomplishment of specific interaction with the analyte of interest, the first real representative was proposed by **Cheek and Nelson, 1978** as a CPE made of chemically pretreated graphite (with functional groups immobilized on its particles). In the stripping voltammetric mode, their innovative concept enabled a highly effective accumulation of target ions down to the sub-nanomolar level.

iii) However, if one prefers a simpler configuration of CPE with admixed reagent, then **Ravichandran and Baldwin, 1981** were the first who have reported on this very characteristic procedure for carbon pastes, via the so-called bulk modification (**Kalcher, 1990**).

iv) Finally, should the addition of a third component be the criterion of choice, the first mixture of this kind was reported by **Kuwana and French 1964**, who had studied the behavior of such additional substance(s) directly in the carbon paste bulk.

v) Regarding the first carbon paste-based biosensors, the oldest configurations were developed in Japan (**Yao and Musha, 1964; Ikeda *et al*., 1985)**. Because the carbon paste material in both constructions served solely as one of possible substrates for further modification or coverage with additional membrane, the priority in designing of the first real CP-biosensor which had fully utilized the advantages of the carbon paste matrix for intimate enzyme housing, can be attributed to Polish scientists (**Matuszewski and Trojanowicz, 1988**), who have proposed such a mixture with embedded glucose oxidase for amperometric detection of glucose.

Unmodified CPEs have a low sensitivity and low limits of detection (LODs), which makes them unsuitable for regular analyses but on the other hand, the modified electrode possesses enhanced properties like high selectivity, and electrochemical response of the analyte with increased electrocatalytic activity than the bare electrodes (**Wring and Hart, 1992**). A multitude of techniques like electropolymerization, coating of the electrode with nanoparticles or nanocomposites by drop-casting, self-assembled monolayers, electrodeposition techniques, and molecular imprinting were selected by researchers for the fabrication of various electrochemical sensors (**Madhusudhana *et al.*, 2020; Mandler and Kraus-Ophir, 2011; Rao *et al.*, 2017; Vadivaambigai *et al.*, 2015; Vedhi *et al.*, 2009; Willander *et al.*, 2008**). Also, a wide range of nanomaterials like carbon nanotubes (CNTs), graphene, metal NPs, metal oxide nanomaterials, MXenes, etc. was exploited for developing numerous electrochemical sensors (**Ramakrishnan *et al.*, 2015; Sehit and Altintas, 2020; Szuplewska *et al.*, 2020**). Among these carbon-based nanomaterials, CNTs and graphene possessed several astonishing behaviors such as electrical and optical properties (**Zhu *et al.*, 2012; Martín *et al.*, 2015**). Moreover, the carbon nanomaterials are more suitable for the modification of the electrodes due to their sp^2 hybridization of carbon and the capability to form charge transfer complexes (**Giuliani *et al.*, 2016**).

Considering the ease of fabrication and efficiency of CPE from the previous reports, in this present work modified CPEs are fabricated incorporating GNPs, RGO to determine the nanoswitching ability when exposed to cyanide and melamine by electrochemical methods.

2.10 Review on nano switches

A molecular switch comprises typically a solitary particle that can move controllably between two stable states. The activation for switching between the states can be an electrical flow, an adjustment in temperature or chemical environment, or even light (**https://www.azonano.com/news.aspx?newsID=37373**). Numerous trials on molecular switches are still performed by averaging the particles' appropriate response over multiple and even billions of a similar kind builds the sign-to-clamor proportion and intensifies the signal to be estimated. In those trials, every particle should be non-interacting with the others, so the exchanging capacity depends on one class of atoms. Utilizing numerous rather than one is not just a matter of accommodation. This methodology can accelerate the investigation of new molecular switches by isolating two generally intricate issues: acquiring an exchanging impact and situating one particle on a surface. The effect of acidochromic molecular switches employing plant juices in the solution and impregnated paper forms is well documented **(Szabadvary and Oesper, 1964).**

Various low-dimensional nanomaterials are widely applied in manufacturing electronic device switches and improving switching performance benefits from their characteristics. For advanced electronic devices such as zero-backup power integrated circuits, radio frequency (RF) signal transmission equipment and low-power memory, these circuits always require ideal and reliable low-power switches. Micro-/nanoelectromechanical (M/NEM) switches have many excellent characteristics, for example, the drain current is close to zero, low power consumption and high ON/OFF ratio. Therefore, M/NEM switches have become an ideal device to replace the transistor (**Qian *et al.,* 2017**). However, the practical applications of the M/NEM switches are limited due to the low contact reliability.

Researchers have coated zero-dimensional nanomaterials such as metal NPs include Pt NPs, GNPs and CuNPs on contact electrodes as contact surfaces to improve the performance and lifetime of M/NEM switches by reducing the contact resistance of M/NEM switches (**Patton *et al.,* 2008a**). Among these metal NPs, GNP has been used as a contact material for M/NEM switches (**Patton *et al.,* 2008b**). Besides, 1D CNTs and 2D graphene have drawn much attention owing to their very high Young's modulus (**Kim *et al.,* 2021**), high tensile strength (**Pothnis *et al.,* 2021**), high thermal stability (**Yu *et al.,* 2021**), superior electrical properties and conductivity (**Akbarpour *et al.,* 2020**). Therefore, these carbon-based nanomaterials such as graphite–graphite contact (**Rana *et al.,* 2018**), diamond contact (**Tsunoda *et al.,* 2021**) and graphene–graphene contact (**Van *et al.,* 2018**) have been employed in M/NEM switches.

Unlike conventional solid-state devices, even in harsh environments (high temperature, external electric field or radiation), M/NEM switches can still maintain its performance, making them suitable for applications ranging from automotive to aerospace (**Lee *et al.,* 2010**); advanced molecular-scale electronics are a cornerstone of nanotechnology, and molecular switches are particularly important for nanoelectromechanical systems, random access memories (**Han *et al.,* 2020**) and information technology (**Munoz *et al.,* 2021**). The most widely researched 2D transition metal dichalcogenide (TMDC) is molybdenum disulfide (MoS_2), and the tunnel barrier is observed through its intrinsic nanostructure. Thus, MoS_2 is considered as the ideal material to improve molecular switching performance under the influence of carrier confinement strength (**Pham *et al.,* 2019**). **Pisoni *et al.,* 2018** have been able to confine electrons in MoS_2 and form a one-dimensional transport channel in MoS_2. The molecular switches made of TMDC have the dual function of electrical tunability and high ON/OFF ratio. Furthermore, a resistive switching device based on nanowires (NWs) and nanorods (NRs) has been proposed benefits from the high surface-to-volume ratio of NWs and NRs (**Zhou *et al.,* 2019**). Although the mechanism by which NWs is applied to switches has been studied in depth, the implementation of single-insulated nanostructured devices is still needed (**Milano *et al.*, 2019**). **Table 1** shows the some of the reported chemosensors for the detection of toxic ions/chemicals.

Table 1. Chemosenors for the detection of toxic ions

S.No.	Analyte	Material	Switching mechanism	Reference
1	Cd^{2+}	Rhodamine derivative (RBD4)	Fluorescence switch	**Maniyazagan *et al.*, 2017**
2	S^{2-}	Rhodamine derivative (RBD4)- Cd^{2+} complex	Fluorescence switch	**Maniyazagan *et al.*, 2017**
3	Cu^{2+}	thiol-functionalized rhodamine-based Pt film	Optical switch	**Kim *et al.*, 2008**
4	Pb^{2+}	DNAzyme-based	Fluorescence switch	**Zhang *et al.*, 2011**
5	Al^{3+}	rhodamine-quinoline (REQ)	Colorimetric switch	**García-Gutiérrez *et al.*, 2014**
6	F^{-}	REQ- Al^{3+} complex	Colorimetric switch	**García-Gutiérrez *et al.*, 2014**
7	Hg^{2+}	(S)-binol@ triazol	Fluorescence switch	**Liu *et al.*, 2011**
8	Ca^{2+}	calbindin D9k (Protein)	Fluorescence switch	**Stratton *et al.*, 2008**
9	Al^{3+}	H2L coumarin	Fluorescence switch	**Sarkar *et al.*, 2017**
10	F^{-}	H2L - Al^{3+} complex	Fluorescence switch	**Sarkar *et al.*, 2017**
11	Zn^{2+} & Cu^{2+}	H2L-Coumarin	Fluorescence switch	**Sarkar *et al.*, 2015**
12	Ammonia	Tricyanofuran-hydrozone	Optical switch	**Khattab *et al.*, 2016a**
13	Ca^{2+}	2-(N-acetyl-N arylaminomethylene)benzo[b]thiophene-3(2H)-one (gas phase)	Optical switch	**Bren *et al.*, 2007**
14	Ba^{2+}	2-(N-acetyl-N arylaminomethylene)benzo[b]thiophene-3(2H)-one (in acetonitrile)	Optical switch	**Bren *et al.*, 2007**
15	Amines & ammonia	DCDHF-hydrazone	Colorimetric switch	**Khattab *et al.*, 2016b**
16	Cu^{2+}	SYBR Green I-DNAzyme	Fluorescence switch	**Zhang *et al.*, 2013**
17	As^{3+}	2-amino-5,6,7-trimethyl-1,8-naphthyridine with exonuclease III	Fluorescence switch	**Pan *et al.*, 2018**
18	F/AcO-	4-nitro-2-((pyrimidine-2-ylamino) Me) phenol- Al^{3+}	Colorimetric switch	**Bhattacharyya *et al.*, 2017**

From table 1 it is generalized that most of the chemosensors reported are organic compound based which supports optical, fluorescence switching mechanisms. Considering the

importance of nanoelectromechanical switches, in this present study GNPs and RGO modified CPE are proposed sensing toxic chemicals.

- **Review on ammonia sensor**

In the atmosphere, the typical NH_3 level is in low ppb (1–5 ppb) levels (**Mani and Rayappan, 2013**); however, inhaling more than the safe level of NH_3 can trigger life-threatening illnesses due to its highly toxic and corrosive properties to the skin, eyes, and lungs. According to Occupational Safety and Health Administration (OSHA), the exposure limit of NH_3 to human beings is 25 ppm for 8 hours and 35 ppm for 10 minutes (**Mani and Rayappan, 2015; Talwar *et al.*, 2014**). Additionally, NH_3 is considered an environmental pollutant since it is highly reactive and forms aerosols such as ammonium nitrate and ammonium sulphate when it reacts with nitric acid and sulphuric acid in the air, respectively. As a result, these nanosized NH_3 aerosols create smog that exhibit a temperature reducing effect and, consequently, a negative impact on the global greenhouse balance (**Timmer *et al.*, 2013**; **Skjøth and Geels, 2013; Sutton *et al.*, 2008**). Moreover, since exhaled NH_3 in the human breath is one of the critical biomarkers to diagnose lung or renal diseases, monitoring NH_3 by means of breath analyzers is a very important daily routine of clinical practice for people who suffer from those diseases. Therefore, the accurate measurement of NH_3 gas has been in demand to prevent fatal accidents caused by overexposure to NH_3 as well as the environmental problem occurred by increased emissions of NH_3 to the atmosphere, and lethal diseases indicated by high concentrations of exhaled NH_3 in human breath (**Sawicka *et al.*, 2005; Prasad *et al.*, 2003; Gouma *et al.*, 2010**). **Table 2** shows the recently reported ammonia sensors.

Table 2. Previously reported ammonia sensors

S.No.	Analyte	Material	Sensing mechanism	Reference
1	Ammonia	poly(amidoamine) (PAMAM)-coated superparamagnetic iron oxide nanoparticles (SPIONs) decorated with silver nanoparticles	Colorimetric switch	**Abdelaziz *et al.*, 2023**
2	Ammonia	Cu_2O nanoparticles (concave octahedron)	Gas sensing	**Zhao *et al.*, 2023**
3	Ammonia	Silver nanoparticles @ live *Chaetoceros* sp. diatom	Optical switch	**Saadattalab *et al.*, 2023**
4	Ammonia	Layered MXenes/In_2O_3	Chemiresistivity @ RT	**Liu *et al.*, 2022**
5	Ammonia	Ga_2O_3@ Pt NP	Chemiresistivity @	**Tsai *et al.*, 2022**

			RT	
6	Ammonia	Carbon nanofibers @ZnONP	Chemiresistivity @ RT	**Fan and Tang, 2022**
7	Ammonia	TiO_2 NP decorated with black phosphorus	Chemiresistivity @ RT	**Wang *et al.*, 2021**
8	Ammonia	Polypyrrole nanoparticles @ graphene	Chemiresistivity @ RT	**Casanova-Chafer *et al.*, 2021**
9	Ammonia	$AgNbO_3$/Ag composite sensing electrode	Electrochemical sensor	**Li *et al.*, 2021**
10	Ammonia	Electrospun Polyaniline	Chemosensor	**Kumar *et al.*, 2020**
11	Ammonia	Co(tpfpp)ClO_4 treated graphene	Chemiresistivity @ RT	**Mackin *et al.*, 2018**
12	Ammonia	WS_2 nanoflakes	Chemiresistivity @ RT	**Li *et al.*, 2017**
13	Ammonia	fluorographene	Electrochemical switch	**Tadi *et al.*, 2016**
14	Ammonia	Nanostructured ZnO:Co thin film	Chemiresistivity	**Mani and Rayappan, 2015**
15	Ammonia	surface acoustic wave (SAW) resonator with ZnO/SiO_2 (ZS) composite film	Chemiresistivity	**Wang *et al.*, 2015**

The previous report on importance of ammonia detection and the switching mechanism of various materials towards ammonia detection helps to design the protocol for ammonia detection by GNPs and determining their switching mechanism.

- **Review on cyanide sensor**

The extreme toxicity of cyanide and environmental concerns from its continued industrial use continue to generate interest in facile and sensitive methods for cyanide detection. In recent years, there is also additional recognition of HCN toxicity from smoke inhalation and potential use of cyanide as a weapon of terrorism. Cyanides are industrially made in large quantities and used in electroplating, metallurgy, production of organic chemicals, and plastics, photographic developing, fumigation, and mining. Cyanides have been used for unusual and not always admirable activities. Concentrated NaCN solutions have been used to stun colorful fish near the Philippine reefs (they are caught and then (for the most part) revived after release in fresh seawater) to supply fish for aquaria. Despite the fact this practice is illegal in all the relevant countries, an estimated 1 million kilograms of cyanide have been used in waters around Philippines since 1960s (**Mak *et al.*, 2005**), in India CN^- are detected in cooking oils (**Pal and Jain, 2018**). This urges the detection of CN^- in real samples selectively and sensitively. Some of the reported cyanide detection methods are tabulated (**Table 3**).

Table 3. Previously reported cyanide sensors

S.No.	Analyte	Material	Sensing mechanism	Reference
1	CN^-	DNA-CuNPs	Fluorescence switch	**Qing *et al.*, 2016**
2	CN^-	Gold nanoclusters	Fluorescence switch	**Liu *et al.*, 2010**
3	CN^-	Azo phenyl thiourea@ nanostructured Al_2O_3 films	Optical switch	**Gimeno *et al.*, 2008**
4	CN^-	Cysteamine-decorated gold nanoparticles	Colorimetric switch	**Rajamanikandan *et al.*,2023**
5	CN^-	Ni complex with thiourea	Chemosensor	**Chang *et al.*, 2023**
6	CN^-	Fe(III) complex of pyridoxal-beta alanine Schiff base	Fluorescence switch	**Das *et al.*, 2022**
7	CN^-	UiO-66-NH-COCF3 (MOF)	Fluorescence switch	**Rana *et al.*, 2021**
8	CN^-	4,4'-(perfluoropropane-2,2-diyl)bisphenol group with Schiff base sensor	Colorimetric switch	**Pundi *et al.*, 2021**
9	CN^-	Phenothiazine	Fluorescence switch	**Al-Zahrani *et al.*, 2020**
10	CN^-	Azophenol-based chromogenic probe	Colorimetric sensor	**Singh *et al.*,2020**
11	CN^-	Aldoxime based probe	Colorimetric sensor	**Bhaskar and Sarveswari, 2019**
12	CN^-	Ag_2S @ CPE	Electrochemical switch	**Riojas *et al.*, 2019**
13	CN^-	6,7-dihydroxycoumarin @ Cu complex	Fluorescence switch	**Kaushik *et al.*, 2016**
14	CN^-	acylhydrazone	Fluorescence switch	**Hu *et al.*, 2015**
15	CN^-	mesoporous graphitic carbon (iv) nitride and $Cu(NO_3)_2$	Fluorescence switch	**Lee *et al.*, 2012a**

From the previous reports on the cyanide sensors, the research gap was identified that there is no reports on the GC aided cyanide detection. Thus this is chosen as one of the objective of the present work.

- **Review on Melamine sensor**

Melamine developed in the 1830s has widespread uses. It is used in thermoplastics to produce a wide variety of durable and useful products, including dinnerware such as plates and cups. Melamine from these products may migrate to food in trace, nontoxic amounts also it is found in paint and coatings on automobiles, laminates for furniture, and glues for wood and particle board (**Bradley *et al.*, 2005; Ishiwata *et al.*, 1986; Ishwata *et al.*, 1987**). Research of melamine toxicity in animals started as early as 1984 (**Melnick *et al.*, 1984**), however, melamine toxicity did not attract widespread public concern until the outbreak of pet food contamination in the United States in 2007; and in September 2008, it became headlines and center of topic worldwide after the Chinese infant-formula milk scandal. Both the pet food and infant milk were proved to be adulterated with melamine to increase the apparent protein content. The latter event resulted in 51,900 children illness and 6 dead, with symptoms of urinary tract stones and renal failure, according to the World Health Organization (WHO) (**WHO, 2008**).

Recently, various analytic methods have been developed and used to analyze the level of melamine in food samples. Several methods are included such as gas chromatography (GC) (**Yokley *et al.*, 2000**), high performance liquid chromatography (HPLC) (**Ehling *et al.*, 2007**), high performance liquid chromatography/mass spectrum (HPLC/MS) (**Kim *et al.*, 2008**), SERS (**Lin *et al.*, 2008**), capillary zone electrophoresis/mass spectrum (CE/MS) (**Cook *et al.*, 2005**) and micellar liquid chromatography (MLC) (**Beltran-Martinavarro *et al.*, 2014**) are used to detect and quantify melamine. These methods are highly sensitive and specific, but also time-consuming, and they require costly instrumentation, extensive sample preparation and highly skilled personnel. This urges for the development of simple sensors materials for the detection of melamine. **Table 4** shows the previously reported melamine sensors.

Table 4. Previously reported melamine sensors

S.No.	Analyte	Material	Sensing mechanism	Reference
1	Melamine	Polythymidine oligonucleotide @ GNP	Colorimetric switch	**Cao *et al.*, 2023**
2	Melamine	Carbon dots/ionic liquid/SNP/H_2O_2	Fluorescence switch	**Zheng *et al.*, 2023**

3	Melamine	Alginate @ GNP	Colorimetric switch	**Affrald *et al*., 2022**
4	Melamine	DNA hydrogels @ GNP	Colorimetric switch	**Wang *et al*., 2022**
5	Melamine	β-cyclodextrin modified carbon nanoparticles	Fluorescence switch	**Liao et al., 2021**
6	Melamine	GNP (5nm)	Colorimetric switch	**Siddiquee *et al*., 2021**
7	Melamine	DNA@Ag hydrocolloid	Fluorescence switch	**Mu *et al*., 2020**
8	Melamine	Barium sulfate-coated $CsPbBr_3$ perovskite nanocrystals	Fluorescence switch	**Li *et al*., 2020**
9	Melamine	Gold nanoparticles @ Carbon quantum dots nanocomposites	Fluorescence switch	**Hu *et al*., 2019**
10	Melamine	Ordered mesoporous carbon/glassy carbon electrode	Electrochemical switch	**Guo *et al*., 2018**
11	Melamine	Zinc oxide nanospheres modified Pt electrode	Electrochemical switch	**Ezhilan *et al*., 2017**
12	Melamine	ionic liquid/zinc oxide nanoparticles/chitosan/ gold electrode	Electrochemical switch	**Rovina and Siddiquee *et al*., 2016**
13	Melamine	Poly thymine stabilized copper nanoclusters	Fluorescence switch	**Zhu *et al*., 2015**
14	Melamine	citrate-stabilized gold nanoparticles	Colorimetric switch	**Kumar *et al*., 2014**
15	Melamine	polycrystalline gold electrode	Electrochemical switch	**Tsai *et al*., 2010**

From the previous reports it was observed that there are several attempts to detect melamine by nanoparticles including GNPs, SNPs, ZnONPs and carbon-based nanomaterials. But no work on carbon paste electrode surface modified by RGO synthesized using cereals and pulses washed water. This is taken as one of the objective of the present study.