Chapter-1
Introduction and review of literature

1.1 Introduction

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1.1 Introduction

1.1.1. Concept and significance of Nanotechnology

Nanotechnology literally means any technology at a nano-scale and it includes the fabrication and application of physical, chemical, and biological systems at nano-scales, as well as the incorporation of the produced nanostructures into larger systems (Chen et al., 2004). A generally accepted definition of nanotechnology is given by The National Nanotechnology Initiative in the United States as the understanding and control of matter at nanoscale dimensions which is accepted to be approximately from 1 to 100 nanometers, where unique phenomena enable novel applications (NNI, 2007). Nanotechnology is gaining tremendous impacts in our economy and society in the early 21st century, comparable to that of semiconductor technology, information technology, or cellular and molecular biology. It promises breakthrough in areas such as materials and manufacturing, nanoelectronics, energy, biotechnology, information technology since many decades. Nanotechnology has generated prospective impact in a number of biomedical fields including oncology cardiology, immunology, endocrinology, ophthalmology etc. as well as greatly applied in specialized areas like tumour targeting, brain targeting and gene delivery.

1.1.2. Nanomedicine

In recent years, nanotechnology has created considerable attention in field of medicine due to the facility with which nanostructures interact with the body at the molecular scale. was According to the definition of 'Nanomedicine' by European Science Foundation is 'the science and technology of diagnosing, treating and preventing disease and traumatic injury, of relieving pain, and of preserving and improving human health, using molecular tools and molecular knowledge of the human body' (Martin, 2006). US NIH revised this definition as: 'Nanomedicine refers to highly specific medical intervention at the molecular scale for curing

diseases or repairing damaged tissues, such as bone, muscle, or nerve'. New therapies in cancer research using nanomedicine are being developed to improve the specificity and efficacy of drug delivery, thus reaching maximal effectiveness with minimum side effects (Sahoo et al., 2007). The size and the surface charge of nanoparticles can directly affect cellular uptake (He et al., 2010) and nanoparticles can be tailored to a particular application. Despite the small size, nanoparticles can be loaded for instance, with DNA or molecules such as therapeutic and diagnostic agents (de Barros et al., 2012).

1.1.3. Metal nanoparticles

Among different nanomaterials, metal nanoparticles have been proved to be the most convenient and suitable as these possess unique optical, electronic, chemical and magnetic properties those are different from their individual atoms as well as bulk counterparts. It is known that the intrinsic properties of metal NPs are mainly directed by their size, shape, composition, crystallinity and structure. In principle, one could control any one of these parameters to fine-tune the properties of these NPs (Gentile et al., 2016; Pileni et al., 2017).

Presently these nanoparticles are evolving as potent delivery carrier for drug and biosensor. Among different metal nanoparticles, silver and gold nanoparticles are of major importance for biomedical use. Surface functionalization on these nanonarticles can effortlessly been performed and various ligands such as peptide, protein, sugars and DNA can be decorated on their surface. Due to surface functionalization capability, metal nanoparticles have been used for active delivery of bioactive substances, drug discovery, bioassays, imaging, detection and several other applications.

1.1.3.1. Gold Nanoparticles

Gold (Au) is exceptional compared to other metals owing to its resistance to ruining. Usage of Au are found in the Chinese civilization in 2500 BC for medical purposes. Afterwards, a number of ancient cultures have made use of Au-based materials for the treatment of several diseases like smallpox, measles, syphilis and skin ulcers (Daniel and Astruc,2004). In today's epoch of nanotechnology, substantial research is presently going on for revealing potential antimicrobial, anticancer and biodiagnostic applications of gold nanoparticles (AuNPs)-based materials for clinical applications (Soppimath et al., 2008).

A main challenge for molecular and macromolecular therapeutics is delivery and programmed release of therapeutic subtances to definite physiological targets. A number of drug delivery nanocarriers such as polymer micelles and vesicles, liposomes, dendrimers, nanocapsules and metal nanoparticles have been utilized as excellent delivery vehicles. In recent times, gold nanoparticles (AuNPs) have developed as an encouraging delivery system for effective transport and release of pharmaceuticals into various cell types. Due to its incomparable physico-chemical properties, it has several other applications in the fields of biomedical imaging and diagnostic for identification of many diseases (Sharma et al., 2015).

Colloidal gold nanoparticles (AuNPs) are mainly attention-grabbing and have noteworthy utilisations in biomedical field because of (i) their high chemical stability and less harmful nature, (ii) its easy synthesis and fabrication process and (iii) good biocompatibility, chemical inertness and non-interfering property with other biomaterials (Wang et al., 2009). However, the size, shape, surface chemistry and optical properties of AuNPs are quite well-regulatory and have opened up several very exceptional and exciting possibilities of applications.

1.1.3.1.1. Different methods for synthesis of gold nanoparticles:

Various methods have been developed for the synthesis of gold nanoparticles and general methods for the synthesis of gold nanoparticles include chemical, physical, and biological methods.

In chemical methods AuNPs generally produced by reduction of hydrochloroauric acid ($HAuCl_4$). This causes Au^{3+} ions to be reduced to neutral gold ions. Turkevich method was pioneered by Turkevich et al., 1951. Generally, it is used for producing modestly monodisperse spherical AuNPs suspended in water having 10–20 nm in diameter. Brust method discovered by Brust et al., in 1994s and can be used to produce AuNPs in organic liquids that are normally not miscible with water (like toluene). It encompasses the reduction of $HAuCl_4$ solution with tetraoctylammonium bromide (TOAB) solution in toluene and sodium borohydride ($NaBH_4$) as an anti-coagulant and a reducing agent, respectively.

In physical method, γ- Irradiation method was proved to be best for the synthesis of AuNPs with manageable size and high purity. The γ- irradiation method is implemented to synthesize AuNPS with size of 2 - 40 nm. In this method natural polysaccharide alginate solution was considered as stabilizer (Anh et al., 2010).

The development of eco-friendly technologies in AuNPs synthesis is of great importance to expand their biological applications. Nowadays, AuNPs with well-known size, shape, chemical composition and morphology have been synthesized by using various plant products, bioactive phytochemicals, microorganisms and their applications in many medical and technological areas have been reconnoitred. The biosynthesis of gold nanoparticles by microbes or plant products are designated as “green chemistry” procedures and assumed to be safe, clean, nontoxic and environmentally acceptable.

1.1.4. Plant based natural products or Phyto-compounds

Plants are important sources of medicines and the world is now moving towards the herbal medicine or phytomedicines that repair and strengthening bodily systems and help to destroy offending pathogens without toxic side effects (Pandey et al., 2011). According to current estimate, 80% of total world population is still dependent on plant based drugs (Pandey et al., 2011). In last few decades, medicinal plants have become an important source for the discovery of novel pharmaceuticals. It was found that out of all new chemical entities launched in the market between the periods of 1981-2002, 54% are either directly derived natural products or their derivatives (Newman et al., 2000). Some of this plant derived compounds, such as atropine, colchicine, digoxin, vinblastine, taxol, morphine, reserpine are directly used as drugs (Fabricant and Fransworth, 2001). Lastly, instead of the utilization of plants harvested in the wild, the tendency in the domestication, manufacture biotechnological studies and genetic development of medicinal plants, will provide pronounced advantages, since it will be possible to get consistent and great quality raw materials which are fundamental to the effectiveness and safety of herbal drugs (Calixto and Calixto, 2000).

1.1.4.1. Indole-3-carbinol:

Indole-3-carbinol (I3C) is a naturally occurring compound present in cruciferous vegetables that is identified to excite detoxifying enzymes in the gut and liver. Many studies designate its potential value as a chemo preventive agent for breast cancer through its estrogen receptor (ER) modifying effect (Wong et al., 1997). Down-regulation of the expression of the estrogen-responsive genes pS2 and cathepsin-D and up-regulatation of BRAC1 are also occurred by I3C. Other *in vitro* studies illustrate that I3C hinders the expression of cyclin-dependent kinase-6 and induces a G1 cell cycle arrest independent of ER signaling (Cover et

Figure 1.1: Sources of indole-3-carbinol

al., 1998). I3C persuades cytochrome P450 1 family that may resuls in potential drug interactions.

1.1.5. Cancer:

Cancer occurs from a series of molecular events that mainly alter the normal properties of cells. In cancer cells, normal systems that check cell overgrowth and the invasion of other tissues. These malformed cells divide and grow in the presence of signals that usually inhibit cell growth. Therefore, they need no special signals to influence cell growth and division. As these cells grow, they develop new characteristics, including alterations in cell structure, reduced cell adhesion. These genetic changes allow the changed cell to divide and grow, even in the presence of normal cells that typically inhibit the growth of nearby cells.

Cancer has a major economic impact on society across the world. In 2016, an estimated 1,685,210 new cases of cancer will be diagnosed in the world and 595,690 people will die from the disease. In 2016, the most common cancers were breast cancer, lung and bronchus cancer, prostate cancer, colon and rectum cancer, bladder cancer, melanoma of the skin, non-Hodgkin lymphoma, kidney and renal pelvis cancer, thyroid cancer, leukemia, pancreatic and endometrial cancer (Siegel et al., 2017). Tobacco, asbestos, aflatoxins and ultraviolet light are the most common and important human carcinogens. Almost 20% of cancers are connected with chronic infections, the most significant causative organisms are hepatitis viruses (HBV, HCV), papilloma viruses (HPV) and *Helicobacter pylori*. There is growing recognition of the causative role of lifestyle factors, comprising diet, physical activity, food additives, hormonal factors and alcohol consumption. Genetic susceptibility may significantly modify the risk from environmental exposures (Doll and Peto, 1981).

1.1.5.1 Types of Cancer:

It can be classified by the type of cell from where cancer originating, such as an epithelial cell or a squamous cell.

1.1.5.1.1 Carcinoma:

Carcinoma is the most common type of cancer among different types of cancer. The epithelial cells cover the inside and outside surfaces of the body belong to this category. Adenocarcinoma is a cancer that forms in fluid and mucus producing cells and these types of cell containing tissues are called glandular tissue. The very common breast carcinoma also falls into adenocarcinoma.

1.1.5.1.2 Leukaemia

Leukaemia is that type of cancer which spreads in the blood cell producing tissue of bone marrow. But the difference from other cancer is that no solid tumor formation occurs, instead huge numbers of abnormal white blood cells starts to accumulate in the bone marrow and blood. Thus abnormality of normal blood composition makes it tougher for the body to perfuse tissues with oxygen or fight infections.

1.1.5.1.3 Lymphoma

Lymphoma starts in lymphocytes (T and B Cells) and in lymphoma, there is formation of abnormal lymphocytes in lymph mode, lymph vessels and some organs of the body which are the part of immune system and helps in fighting infections or diseases.

There are two main types of lymphoma.

a) Hodgkin Lymphoma–This lymphoma arises from abnormal lymphocytes which are forming usually from B lymphocytes.

b) Non Hodgkin Lymphoma (NHL) – Different types of NHL develop from different types of white blood cells (B-Cell, T-Cell, NK Cells). Among them NHL from B-Cells are most common. In adults the most common NHL are aggressive large B-Cell lymphoma and indolent follicular lymphoma. Lymphoma can occurs in skin also. Primary CNS lymphoma, a unusual variant of NHL, is seen in white blood cells in brain, spinal cord or eye. Treatment and the outcome depend on the staging and type of lymphoma.

1.1.6. Cancer therapy

The three main approaches in cancer treatment are (a) Surgical excision, (b) radiation therapy and (c) chemotherapy. These approaches depend on tumour type and development stage of cancer. Major therapeutic approach for the treatment of localized and metastasized cancer is chemotherapy, which are used alone or in combination with other forms of therapy. However, conventional chemotherapy has some limitations (a) Inadequate water solubility: Most chemotherapeutics from plant or synthetic origin show hydrophobicity and have need of solvents to formulate the dosage form which sometimes produce severe toxicity, (b) Dearth of selectivity: Most chemotherapeutics have less selectivity for cancerous cells and cause substantial impairment to fast growing normal cells and (c) Multidrug resistance (MDR) (Seigel et al., 2017).

Treatment preferences and effectiveness has considerably developed and upgraded over the years but the incidence of adverse effects among cancer treatments is a common theme. Even after elimination of tumours by surgery or tumour regression after chemotherapy, the patients are affected by nausea, hair loss, infection, anaemia, nerve problems, urinary problems, and many others. Furthermore, many prospective cancer treatments having curative implications, do not even obtain FDA approval because of their severe side effects compared to their effective role on the tumour (Arrowsmith, 2011).

In current years, there has been an unparalleled progess in the field of nanomedicine with the development of new nanoparticles for the treatment and diagnosis of cancer. Nanoparticles due to their small size and large surface area-to-volume ratio, exhibit distinctive biological properties, which permits them to bind, absorb, and carry small molecule drugs, proteins, RNA, DNA and probes with high efficiency. Their high stability, high carrier capacity, the ability to incorporate both hydrophobic and hydrophilic substances and different administration routes compatibility make them very attractive in the field of oncology.

1.1.7. Drug Delivery

The goal of drug delivery, an important axis of biotechnology research is to delivery of a specific agent to an exact site of action to produce pharmacological effect (Wang et al., 2005). When developing a drug delivery strategy, the target as well as the nature of the carrier and the route of administration must be considered (Ranade and Hollinger, 2003). The concept of drug targeting was developed over a century ago by Paul Ehrlich, who emphasized a strategy to selectively attack pathogens which is known as magic bullet (Strebhardt and Ullrich, 2008). However, with advances in nanotechnology, the non-covalent link of drugs with particulate carriers has come to the light. The challenge of developing drug delivery devices is dependent on the biocompatibility of the system. Furthermore, for the design of an effective drug delivery system - dispersibility, stability, permeability and good interaction with the cell membrane are considered as the decisive factors (Bader and Putnam, 2014).

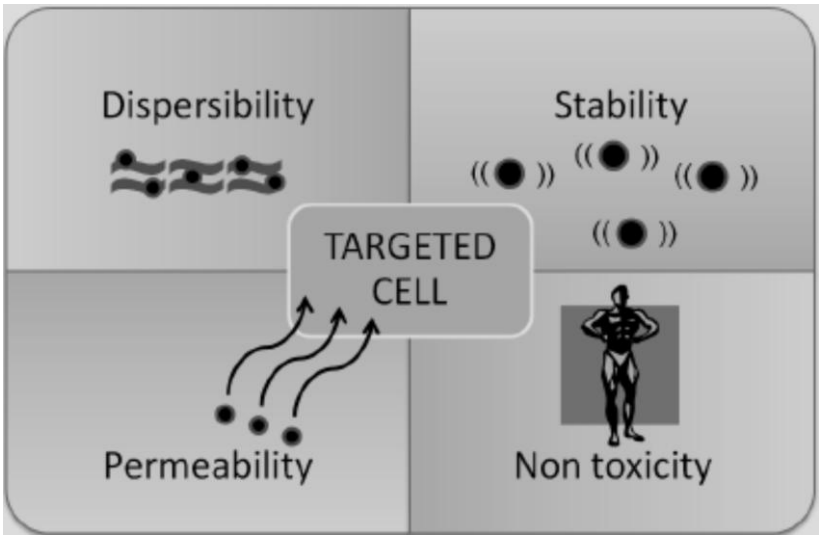

Figure 1.2: Main factors contributing to the biocompatibility of a drug deliver carrier.

1.1.8. Drug targeting to tumours

For the treatment of cancer, the matter of drug targeting is particularly important. Conventional chemotherapy delivers a cytotoxic agent indiscriminately to neoplastic and normal cells. Drug targeting in cancer treatment is considered to avoid damage to the healthy organs and tissues and still increasing the uptake in tumour cells. Nanotechnology-based chemotherapeutics can be tailored to deliver increased amounts of drug to the target tumour tissues by modifying their distribution.

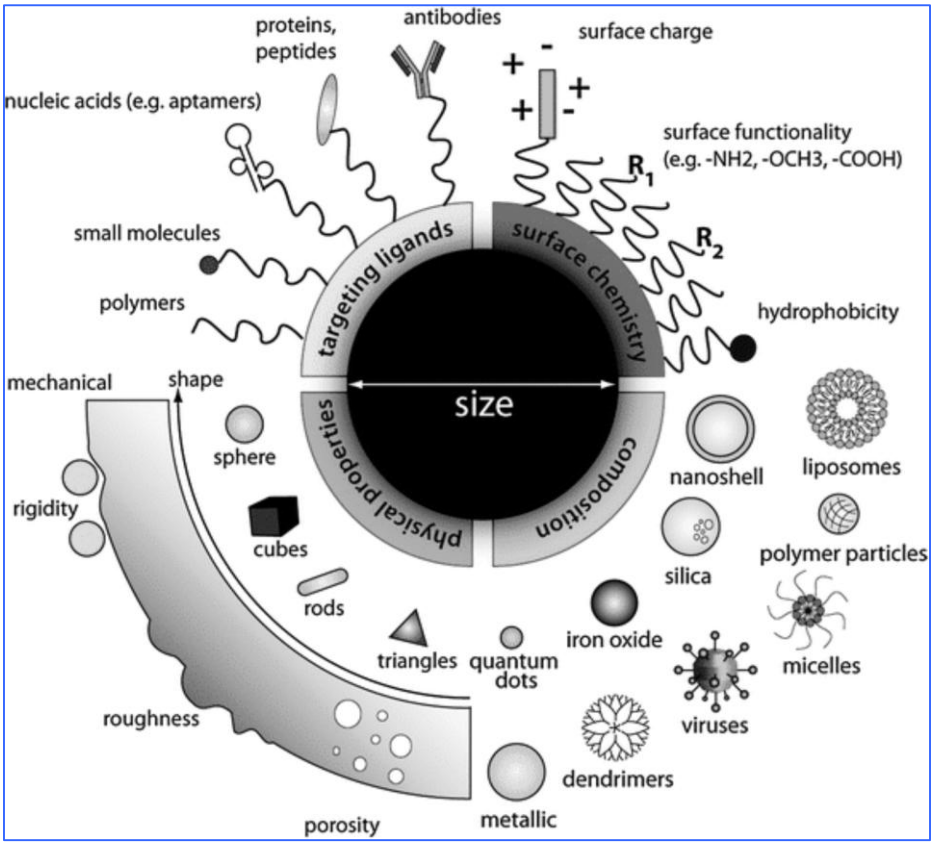

Figure 1.3: Important elements for nanoparticles design.

1.2. Review of literature:

Deaths from cancer around the world are expected to increase upwards with an estimated 12 million deaths by cancer in 2030. The frontiers of cancer research are therefore consistently challenged to advance the most effective means of cancer treatment. Findings accumulated from cancer research would probably benefit mankind and save countless lives. Current therapies working for the treatment of cancer include surgery, chemotherapy and radiation therapy. While these methods have been practiced for decades, they have their many limitations and side effects. Surgical removal of tumours is controlled mainly. Chemotherapeutic drugs target rapidly dividing cells and not only kill cancer cells but also destroy normal cells (Wagstaff and Jans, 2009). Radiation therapy involves the use of high

energy radiation like X-rays and gamma rays to destroy tumor cells, and inevitably causes deleterious effects to healthy tissues along the radiation path (Boisselier and Astruc, 2009).

In light of the inadequacies of current cancer treatment, a critical thrust towards improving cancer therapy is to exactly target therapeutic agents to tumour cells while saving healthy tissues from harmful effects. This is one of the developing interests in nanotechnology research. Among many nanomaterials being developed for nanomedicine applications, gold nanoparticles (AuNPs) and their potentiality has gained more attention as tumour sensors, drug delivery agents for the eradication of cancers.

1.2.1. Indole -3-carbinol as an anticancer agent:

Indole -3- carbinol (I3C) has been revealed to inhibit the ability of human breast cancer cells to invade surrounding tissue (Meng et al., 2000). I3C has been shown *in vitro* to block the estrogenic stimulation of human papilloma virus (HPV) expression (Yuan et al., 1999).

I3C induced apoptosis and cell cycle arrest at the G1 checkpoint in human prostate cancer cell lines (Chinni et al., 2001). I3C appeared to induce expression of the p21 and p27 tumor suppressor genes, and down-regulating gene NF-kappa-B.

I3C has been shown to inhibit cell cycle progression at G1 (Hudson et al., 1998). I3C has been shown to increase p21 and p27 expression in MCF-7 breast cancer cells (Cover et al., 1998).

Other studies indicated that I3C down regulated epidermal growth factor receptor (EGFR) in human breast cancer cell lines and induce cell cycle arrest and apoptosis (Moiseeva et al., 2007).

Mao et al., 2014 revealed that the growth of nasopharyngeal carcinoma cells was reduced by I3C, which induced apoptosis both *in vivo* and *in vitro*. This study suggested that I3C suppressed the phosphatidylinositol 3-kinase/Akt pathway.

Mohammadi et al., 2017 found that I3C produced anti-leukemic effects through aryl hydrocarbon receptor activation, which is associated with programmed cell death and G1 cell cycle arrest. Administration of I3C to mice in large doses (34-700 mg/kg/day) has been shown to reduce the incidence of spontaneous mammary tumor formation (Bradlow et al., 1991). Large doses of I3C (50-100 mg/day) have also been shown to greatly decrease chemical carcinogenesis in rat mammary tissue (Grubbs et al., 1995).

I3C administration has been shown to prevent cervical cancer in a mouse model (Jin et al., 1999). This study used a human papilloma virus to stimulate cervical cancers. I3C also appeared to protect against skin cancer and estrogen mediated fluid retention in the bladder.

The tumor-promoting activity of I3C has also been observed in an animal colon cancer model (Pence et al., 1986). I3C was found to enhance promotion of tumors of the thyroid and liver induced by administration of multiple carcinogens (Kim et al., 1997).

1.2.2. Green synthesis of gold nanoparticles

AuNPs have wide range of applications in nano-scale devices and technologies due to its chemical inertness and resistance to surface oxidation (Sugunan et al., 2005). AuNPs play a vital role in nanobiotechnology as biomedicine because of convenient surface bioconjugation with biomolecular probes and remarkable plasmon-resonant optical properties (Wu et al., 2011). Many research articles reported the synthesis of AuNPs using plant extracts such as *Ficus religiosa* (Wani et al., 2013), *Memecylon umbellatum* (Arunachalam et al.,2013), *Macrotyloma uniflorum* (Aromal et al., 2012), *Brevibacterium casei* (Mittal et al., 2013),

Citrus limon, *Citrus reticulata* and *Citrus sinensis* (Sujitha and Kannan, 2013), *Piper pedicellatum* (Tamuly et al., 2013), *Terminalia chebula* (Kumar et al., 2012), *Memecylon edule* (Elavazhagan and Arunachalam, 2011), *Nyctanthes arbortristis* (Das et al., 2011), *Murraya Koenigii* (Philip et al., 2011), *Mangifera indica* (Philip, 2010), Banana peel (Bankar et al., 2010), *Cochlospermum gossypium* (Vinod et al., 2011), *Euphorbia hirta* (Annamalai et al., 2013). AuNPs have an important function in the delivery of nucleic acids, proteins, gene therapy and in vivo delivery, targeting, etc (Tiwari et al., 2011). In the recent decade, gold nanoparticles (NPs) (Dykman et al., 2012) have attracted significant interest as a novel platform for various applications such as nanobiotechnology and biomedicine.

1.2.3. Green synthesized gold nanoparticles as an anticancer agent:

Sasa borealis-mediated AuNPs was tested for toxic effect on HEK293 cells and anticancer activity on AGS cells by WST-1 assay (Patil et al., 2018). Anticancer activity of green synthesized gold nanoparticles AuNPs using *Nerium oleander* against MCF-7 breast cancer cell line revealed that the stabilized AuNPs were highly effective for the apoptosis of cancer cells (Barai et al., 2018).

The antiproliferative effects of *Stereospermum suaveolens* capped gold nanoparticles on human lung adenocarcinoma cells A549 were studied using the MTT assay (Francis et al., 2018). An *in vitro* cytotoxic assay of synthesized gold nanoparticles using *Corchorus olitorius* revealed a strong cytotoxic activity in three human cancer cell lines, namely, colon carcinoma HCT-116, hepatocellular carcinoma HepG-2, and breast adenocarcinoma MCF-7.

Gold nanoparticles were biologically synthesized using *Spinaciao leracea* Linn. aqueous leaves extract. These NPs have shown cytotoxicity against C_2C_{12} cells even at very low concentration (5 μg/mL) (Ramachandran et al., 2017). The *in vitro* anticancer efficacy of gold

nanoparticles using leaves extract of *Bauhinia tomentosa* Linn confirmed by MTT assay against lung A-549 cells, HEp-2 cells and MCF-7 cells, respectively (Mukundan et al., 2017).

Eco-friendly gold nanoparticles synthesis was synthesized using marine bacteria *Enterococcus* sp. Synthesized stable gold nanoparticles show more significant anticancer activity against HepG2 and A549 cells at 100 μg concentration of nanoparticles (Rajeshkumar, 2016).

The synthesized *Kedrostis foetidissima* -mediated AuNPs were tested for their antiproliferative activity against bone cancer (MG-63) cell lines (Firdhouse and Lalitha, 2016).

Biofunctionalized gold nanoparticles from *Gymnema sylvestre* revealed that the cytotoxicity of synthesized gold nanoparticles against HT-29 cells (Arunachalam et al., 2014).

Biosynthesized gold nanoparticles from *Couroupita guianensis* flower extract show significant anticancer activity against HL-60 cells. Interestingly, as a result of the application of newly synthesized gold nanoparticles their anticancer potential has been studied using MTT assay, DNA fragmentation, and apoptosis by DAPI staining, and comet assay for DNA damage on HL-60 cells (Geetha et al., 2013).

1.2.4. Green synthesized gold nanoparticles as an antioxidant:

The biocompatible gold nanoparticles synthesized using *Origanum vulgare* showed significant antioxidant effect (Benedec et al., 2018). The antioxidant potential against DPPH revealed that green synthesized gold nanoparticles using *Acer pentapomicum* leaves extract exhibited good antioxidant activity (Khan et al., 2018).

In vitro antioxidant activity studies showed that DPPH (2,2-diphenyl-1-picrylhydrazyl) and ABTS (2, 2'-azino-bis 3-ethylbenzthiazoline-6-sulfonic acid) activities increased in gold

Nanoparticles using *Sumac* aqueous extract in a dose dependent manner (Shabestarian et al., 2017). The biosynthesized gold nanoparticles from edible Basidiomycetes mushroom fungi showed significantly higher antioxidant activity (Madhanraj et al., 2017).

Terminalia bellirica fruit extract-mediated synthesis of gold nanoparticles (AuNPs) showed potent antioxidant activity (Annavaram et al., 2017).

Curcumin coated gold nanoparticles had great antioxidant activity which was better than gold nanoparticles alone (Shaabani et al., 2017). Aqueous phase lavender leaf mediated green synthesis of gold nanoparticles showed higher antioxidant activity against 2,2-diphenyl-1-picrylhydrazyl (Kumar et al., 2016).

The synthesized gold nanoparticles using marine algae *Racilaria corticata* were studied for its antioxidant activity by DPPH free radical scavenging assay and Ferric- ion reducing ability antioxidant power assay (Naveena and Prakash, 2013).

1.2.5. Green synthesized gold nanoparticles as an anti-inflammatory agent:

The *in vitro* anti-inflammatory activity by HRBC membrane stabilization method was studied for the synthesized gold nanoparticle of *Turbinaria conoides*. In HRBC method, nanoparticle at a concentration 200 µg/ml showed maximum percentage of inhibition (73.31 ± 0.89%) (Venkatraman et al., 2018).

Gold nanoparticles from leaf of *Litchi chinensis* shows strong anti-inflammatory activities (Murad et al., 2018). Surprisingly, coated gold nanoparticles generate a significant anti-inflammatory response both *in vitro* and *in vivo* (Moyano et al., 2016).

Gold nanoparticle (AuNP) bioconjugates confirmed their anti-inflammatory affects *in vitro* (Uchiyama et al., 2014)

1.3. Aim and objectives

Though conventional radio- and chemo-therapy have experienced many progresses over years, cancer therapy is still far from optimal. In the present study, the effect of gold nanoparticles (AuNPI3Cs) using indole-3-carbinol on cancer treatment was evaluated.

The following objectives were investigated.

1. Synthesis and characterization of gold nanoparticles (AuNPI3Cs) using indole-3-carbinol.
2. The toxicity of AuNPI3Cs in different animal models.
3. The *in vitro* anti-neoplastic activity of AuNPI3Cs against Jurkat and MCF-7 cells.
4. Targeted *ex-vivo* and *in vivo* molecular therapy using AuNPI3Cs on Ehrlich ascites carcinoma (EAC) cell.
5. The *ex-vivo* and *in vivo* evaluation of anti-proliferative activity of AuNPI3Cs against Dalton ascites lymphoma (DLA) cell.
6. To elucidate the mechanistic basis of anti-neoplastic activity of AuNPI3Cs.
7. To evaluate antioxidant activity and anti-inflammatory activity of AuNPI3Cs.