Journal of Medicinal and chemical Sciences

Journal homepage: www.jmchemsci.com

Review Article

Biomedical Scope of Gold Nanoparticles in Medical Sciences; an Advancement in Cancer Therapy

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ARTICLE INFORMATION

Received: 30 August 2020
Received in revised: 27 October 2020
Accepted: 28 October 2020

DOI: 10.26655/JMCHEMSCI.2020.3.9

KEYWORDS

Gold nanoparticles
Cancer therapy
Cancer cells
Thermal ablation

ABSTRACT

Nanotechnology is a vast and fast emerging area of scientific research studies resolving several complications related to conservative medication therapies, including underprivileged water solubility, absence of capability to target the problematic cancerous cells in individual bodies, common spreading, universal poisonousness as well as weak therapeutic capabilities. Nanoparticles are developing attractive vital tool of recent investigative studies in all scientific areas of research, particularly in nano scale sciences. Biomedical scope of nanoparticles, specifically of gold nanoparticles (GNPs), especially in cancer therapy is remarkably encouraging through results of modern scientific research studies from all over the world. As per as their biocompatibility and nontoxicity, Surface Plasmon Resonance improved their light absorption and scattering properties. Surface Plasmon Resonance also has improved their capability for conversion of absorbed light in localized heat to make the GNPs extra appropriate, for example, as locating agents for photo-thermal cancer therapy and drug delivery sites. Because they target the cancerous cells as well as infected cells for either actively or passively which cause the thermal ablation of these cells. Furthermore, advanced surface-volume ratio of GNPs assists in activation of their open surface with ligands to target cancerous and infected cells precisely as well as with compatible polymers which makes the GNPs additional appropriate in internal body applications. In this review, we have mainly focused on prospective uses of the GNPs in cancer therapy, concluding that the GNPs are the best drug carrier for cancer treatment and play a most significant role.

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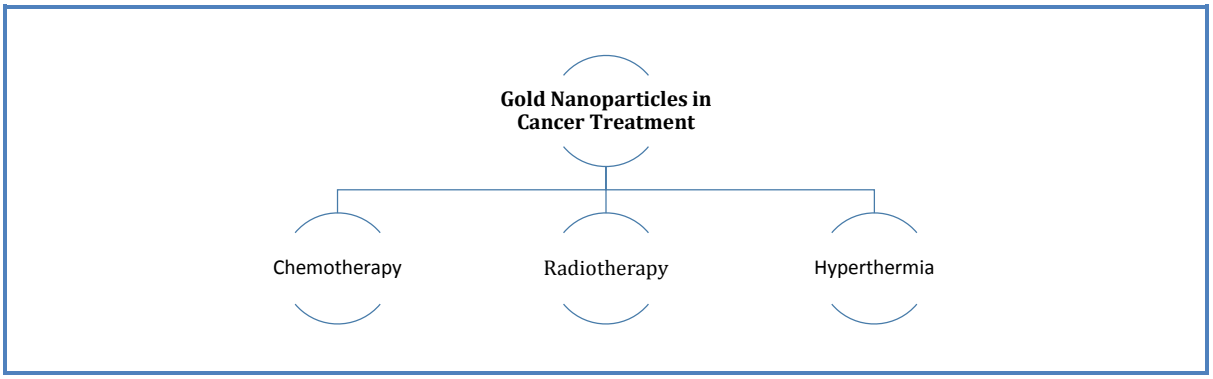
Graphical Abstract



Introduction

Nanotechnology is a vast and fast emerging area of scientific research studies resolving several complications related to the conservative medication therapies, including underprivileged water solubility, absence of capability to target the problematic cancerous cells in individual bodies, common spreading, universal poisonousness as well as weak therapeutic capabilities [1]. Nanoparticles (NPs) are developing attractive vital tool of recent investigative studies in all scientific areas of research, particularly in nano scale sciences. The progresses in functionalization of chemistry with innovative NPs and their differentiated uses in cure of several human infections have focused worldwide [1].

Nanotechnology is vital for delivery of drug materials, with numerous dormant uses in medical prescription and investigation. The extensive usage of NPs in the areas of nanomedicine is including, cancer therapy, investigative methods, and medicinal resolutions [2]. Nanoparticles (NPs) are developing, attractive, and vital tool of investigative studies in all scientific areas of research, particularly in nano scale sciences. The selection of NPs for cancer therapy is extremely preferred by their distinctive physiochemical features that grip for future improvement of cure of infections in cancer therapy with negligible reverse influences. NPs are units having size ranges between 1nm to 100 nm, and possess the innovative properties because of their higher size to volume ratio [3].

Metal NPs are the focus of investigation determinations as new platforms for cancer therapy to specified target site. Nano carriers are innovative tools for cancer therapy specific target sites. Over the centuries, numerous distribution resources were intended built on diverse NPs, such as Nanopolymers, NPs liposomes, Nao dendrimers, nano rods, and nano-tubes. Innovations in nanotechnology assure to renovate synthesis of drugs, drug delivery, and clinical trials. By knowing how the materials work perversely at particular cell or component, investigators are exposing the huge therapeutic potential of nanoscale approaches [4]. Though plentiful study is quiet in its initial periods, researchers and investigators are producing innovative tools and evolving novel approaches for fundamental study areas for synthesis of drug, drug carriers, target indications, reduction in toxicity, and tools optimization [5]. Biomedical scope of nanoparticles, specifically of gold nanoparticles (GNPs), especially in cancer therapy is remarkably encouraging through results of modern scientific research studies from all over the world. As per as their biocompatibility and

nontoxicity, Surface Plasmon Resonance improved their light absorption and scattering properties, and their capability for conversion of absorbed light in localized heat to make the GNPs extra appropriate, for example, as locating agents for photo-thermal Cancer Therapy and drug delivery sites. Because they target the cancerous cells as well as infected cells for either actively or passively which cause the thermal ablation of these cells.

It has been accounted for likewise that GNPs have special synthetic and somatic features for carrying and releasing of therapeutic agents [6, 7]. The primary favorable position of GNPs as a medication transporter is that the gold center is latent and non-dangerous, additionally the selection of GNPs is supported with blending ease and their position of functionalization, largely complete thiol links. Most prominently, from their photograph, somatic features can activate medication discharge [8] at remote spot. Furthermore, the advanced surface-volume ratio of GNPs assists in activation of their open surface with ligands to target cancerous and infected cells precisely as well as with compatible polymers which makes the GNPs additional appropriate in internal body applications.

Gold Nanoparticles (GNPs)

Gold is one of the first metals that have been exposed. The account of investigation and scope of Gold periods however some thousand years. Early evidence on colloidal gold may initiate in treatises by Arabic scientists, Chinese researchers, as well as Indian investigators, who worked to achieve the colloidal gold as timely as in fifth-fourth eras. The scientists used colloidal gold for therapeutic and further purposes. In Middle times of Europe, colloidal gold was investigated and applied in all chemistry research centers.

Metal NPs are the focus of investigation determinations as new platforms for cancer therapy to specified target site. Nano carriers are innovative tools for cancer therapy specific target sites. Over the centuries, numerous distribution resources were intended built on diverse NPs, such as Nanopolymers, NPs liposomes, Nao dendrimers, Nanorods, and nano-tubes. Innovations in nanotechnology assure to renovate synthesis of drugs, drug delivery, and clinical trials.

Functionalized GNPs with organized optical as well as geometrical characteristics are focus of focused research works and medical uses, including biosensors, different immune systems, experimental clinical sciences, genomics, laser therapy of tumors and cancer cells, drug delivery, antigens and DNA, scanning, imaging and control of cancer cells and cancer tissues with usage of state-of-art indication methods [9].

However, GNPs have been acknowledged as an attractive candidate for delivery of drug particle to detected target cells (Figure 1). The receiving of GNPs as an outstanding candidate for delivery of therapeutic agents was due to its exceptional possessions particularly in transportation and release of drug to its target cells. Therapeutic particles delivered must be significantly smaller in size embedded in drug particle or in large biomolecules, for example, amino acids, nucleic acids, RNA, or DNA and efficiency of their discharge at site is an essential for effective treatment [10].

GNPs, usually have extraordinarily higher surface-to-volume ratio, due to the biocompatibility and inertness, and can be certainly functionalized with numerous other functional groups. so, they can also play a key role in the medical field as adjuvants, reducing the toxic effects, increasing the immunogenic effects, and offering the storage stability of medicines and other drugs related to

vaccinations, and also possess the excessive potential [11].

The GNPs have been become of greatest popularity due to their effectiveness in cancer therapy and drug delivery. GNPs had established the many of current day's drugs which possess the basis of functional moieties and their proficiencies in distribution of amino acids, protein, nucleic acid, and gene therapy in vivo cure [11]. For biomedical usage, outer functionalization of GNPs is essential so as for making the GNPs to explicit sickness zones, enabling to specifically interface with other cell or biomolecule. The subsequent GNPs possess the interesting characteristics [3], for example, measure and figure-subordinate visual and electronic attributes, a high surface zone to sum proportion, and surfaces that can be quickly changed with the ligands holding valuable assemblies, for example, amines, phosphines, and thiols, which display preference for gold faces [12]. From the methods of their accumulation to attach the ligands, extra moieties like antibodies, amino acids, proteins, and dinucleotides are utilized to report the prevalent advantages [4]. The wide scope of use for GNPs depends on exceptional somatic as well as synthetic characteristics. Specifically, optical features of GNPs are controlled with their surface plasmon resonance [2], that relates with joined excited conductive electrons and confined within wide region, from noticeable to infrared (IR) area, contingent upon size, shape and structure of molecule. It has been accounted for likewise that GNPs have special synthetic and somatic features for carrying and releasing of therapeutic agents [6, 7]. The primary favorable position of GNPs as a medication transporter is that the gold center is basically latent and non-dangerous, additionally the selection of GNPs is supported with blending ease and their position of functionalisation, by and large complete thiol links. Most prominently, from their photograph, somatic features can activate medication discharge [8] at remote spot. As per as their biocompatibility and nontoxicity, Surface Plasmon Resonance improved their light absorption and scattering properties, and their capability for conversion of absorbed light in localized heat to make the GNPs extra appropriate. For example, as locating agents for photo-thermal Cancer Therapy and drug delivery sites because they target the cancerous cells as well as infected cells for either actively or passively which cause the thermal ablation of these cells.

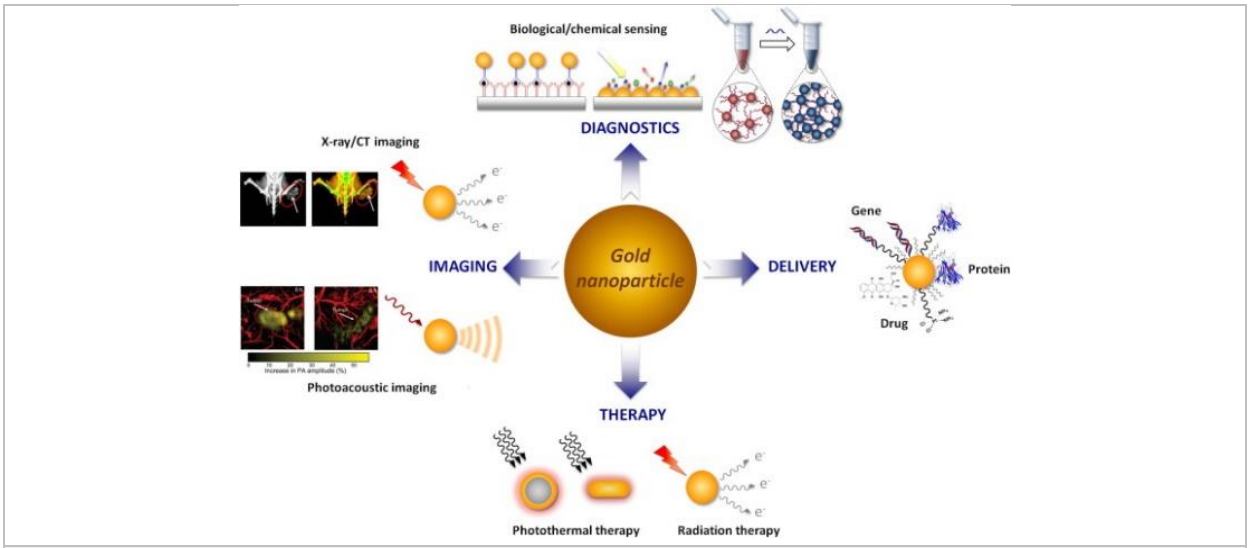


Figure 1. GNPs for diagnostic purposes [1]

Cancer Therapy

Over the last few years, great development have been achieved in the synthesis and applications of GNPs for cancer treatment. GNPs are particularly appropriate to destruct the cancer cells thermally due to their surface activation and heating capability photothermally [1]. Cancer Therapy is an multidisciplinary field with extensive possible uses in treatment of cancer, with cancer cell diagnosis, molecular-imaging, bio-informatics, and target therapy [13]. Conventional approaches for tumor therapy include the chemo-therapy, radiation treatment, and surgical treatment. The development of specialized GNPs for use in finding and cure of cancer is increasing, due to their specific properties [9], like their ability to interact with different drugs, retention in tumor tissues, light absorbance in near-infrared light and their interaction with radiations [14]. GNPs particularly have greatly focused for cancer research in previous years due to their simplistic fabrication as well as surface variations, greatly improved and changeable optical features including outstanding biocompatibility for clinical approaches [15].

As a developing idea which enables instantaneous prediction and cure, execution of therapeutic NPs bears strong potential for enhanced tumor therapy and decreased negative influences [11]. GNPs are used in cancer treatment due to their ability to interact with different drugs, retention in tumor tissues, light absorbance in IR light and their contact with radiations. Having the advantages of their exclusive features, several researches of cancer treatment by GNPs have been applied it photo-thermally to destruct the tumor cell or tissues which may contain potential for clinical usage (Figure 2) [16]. When the cancer cells are bombarded with focused laser light of appropriate wavelength, GNPs can destruct the structure of bacterial cells and tumor tissues [17].

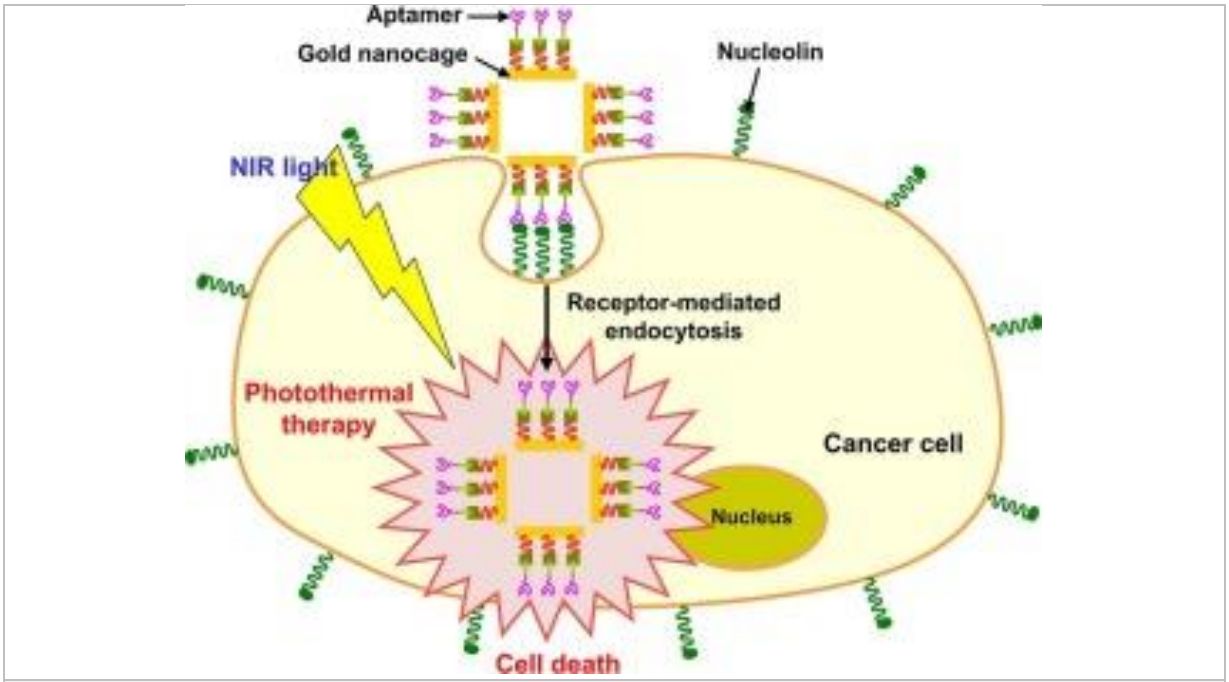


Figure 2. GNPs in photo thermal therapy [16]

For effective application of GNPs in treatment of cancer, gold nanostructure should contains biocompatibility and display superior pointing of tumor cells over healthy cells [18]. For active tumor therapy, gold based NPs can be fabriacted to particularly to distruct the tumor tissues and reduce side effects for healthy cells. Many methods have been applied to improve the cancer cell targeting, cellular intake for effective cancer treatment, as well as methods are usually classified in two classes which are active target method and passive target method.

Passive target method depends on passive growth of GNPs within cancer area because of enhanced permeability retention (EPR) mechanism [19,30]. Several ligand molecules have utilized in trails to enhance cancer cell destruction via particular molecular reactions including proteins, antibodies, nucleic acids, hormones and small molecules. Usually, these approaches depend on contact of GNPs ligand and related part of cancer tissues [18]. The GNPs have been used in combination with magnetic NPs to target specific cell types for efficient imaging of cancer cells. NPscan target tumor cells by an accumulation and entrapment process, known as permeation and retention effect imposed by angiogenic vessels and improper lymphatic flow. Therefore, the NPs can accumulate selectively inside the cancerous cells at higher concentrations than the normal cells. GNPs have the ability to exhibit different surface plasmon resonances [12,25], when placed close to each other; hence they have been shown to differentiate between the normal and the cancerous cells when conjugated to anti-epidermal growth factor receptor antibodies as a biomarker agent.

This is predicted 24.6 millions of individuals are surviving and they achieved a treatment of cancer disease in previous five years. About half of individuals are affected by this disease each year achieve radiotherapy during their cure process. Carrying a therapeutic dosage of radiations to destruct the cancer cells whereas saving the healthy cells is still a strong task in radiotherapy approaches. Idea of applying higher matters to enhnace dosage form to cancer cell while applying radiotherapy was developed over twenty years before as iodine salt utilized for the sansitization of cell cultures.

Chemotherapy

On implementation of chemotherapy, Therapeutic agents, which offer a cytotoxic influence which disrupts the mechanisms supporting fast over growth of cancer cells, are administered [15]. Conservative chemotherapy is actually influensive but also famous due its severe bad impacts due to somewhat random endorsement of chemotherapeutic agents into healthy cells as well as into malignant cells in tissue and organ systems [20,29]. Major enhancement has been established in latest years with beginning of nano size medicines, that provide a significant association with chemotherapy as a novel drug.

Radiotherapy

Radiotherapy is a main therapy and is valuable to cure around 50% of all type of cancer infecteds. The cure depend on deposition of drug dose in cancer cells, usually by bombardment of either gamma radiations (Figure 3) or high energy X-rays or by beam of high energy ions which may enough to irradiate the tumor cells or either their cell membrane and finally cause their death [17,24].

Furthermore, use of NPs in nano size drugs, that have effectively enhanced therapeutic action, is the characteristic of recent chemotherapeutics in current years. The impact of the GNPs in development of chemotherapeutic efficacy is determined by dose enhancement factor (DEF). The DEF of GNPs is well defined as “fraction of

chemotherapeutic drug intake by cancer cells in availibility of GNPs to the fraction of drug intake by the cancer cells in lack of GNPs". It can alter with quantity and effectiveness of GNPs and their site inside infected cells.

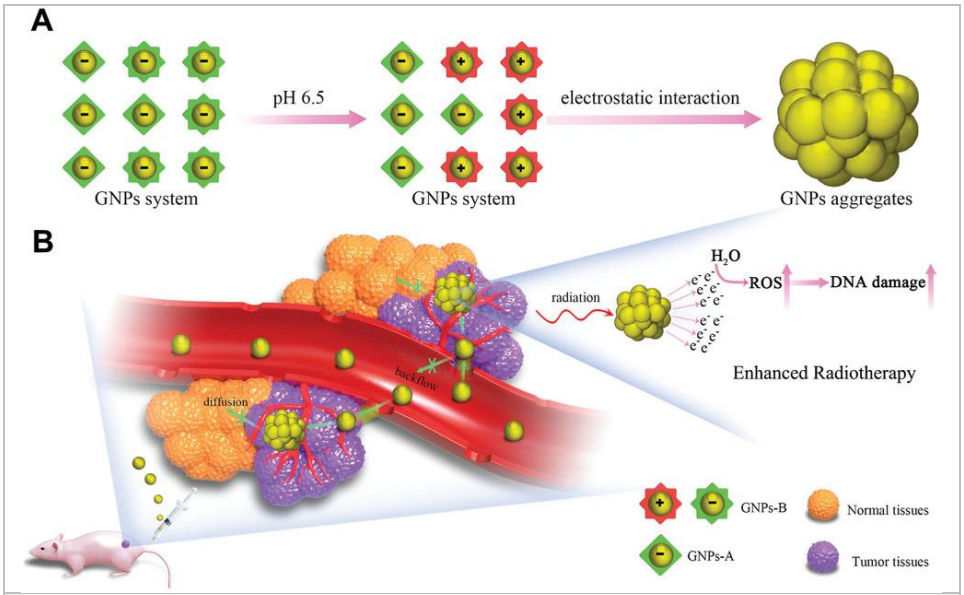


Figure 3. GNPs in radiotherapy [17]

Hyperthermia

Hyperthermia has been newly announced as a modern treatment method for tumor cells and have great potential to fight with this infection. It can be defined as a cure method in which infected cells are exposed to higher temperature which either terminate cancer cells [21,26]. This rise in temperatures of cancer cells alters vascular penetrability, enhances flow of current and ultimately leads to cancer oxygenation [11,28]. Hence, hyperthermia alleviates tissue hypoxia and could be concurrently applied with radioactive drugs or anti-cancer drugs to increase their cytotoxic impacts on cancer. In old hyperthermia, site of individual body having cancer is heated to temperature of 40–45 °C, some degrees beyond physical temperature [19].

Heat is produced outside by means of tools which generates electromagnetic radiations or ultrasound radiations [22,27]. Traditional hyperthermia is applied combined with chemo-therapy as well as radiation treatment mechanism, for the treatment of different kinds of cancers in numerous clinical applications (Figure 4) [11]. The heat produced from gold based NPs can be applied in cancer treatment to destruct tumor tissues.

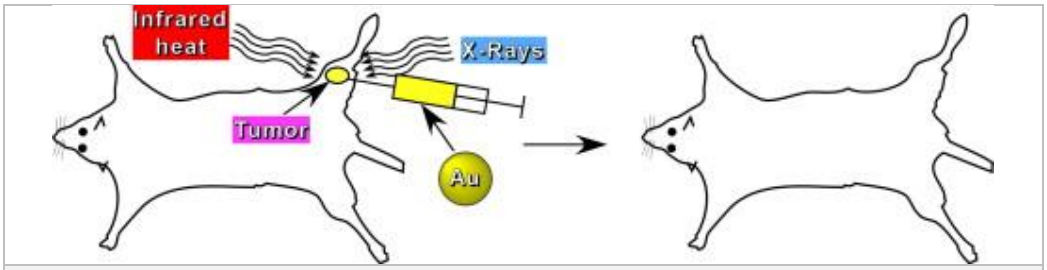


Figure 4. GNPs applied in hyperthermia [19]

The difference between the traditional photo-thermal treatment mechanism [23] and hyperthermia is heat treatment which may happens photo thermally in area about gold based NPs, and cell temperatures can raise upto hundreds of centigrade over body temperatures [15]. It is suggested that the photo-thermal heat treatment can be further effective to cancer cells instead of the healthy cells to overcome the bad impacts of the cancer treatment methods [8].

Traditionally, hyperthermia that is applied in association with the radiotherapy as well as chemotherapy, for extermination of a diversity of cancer categories in numerous experimental tests. Heat produced from GNPs is used in cancer therapy to terminate growth of tumor cells. The difference among traditional [21] and photo-thermal treatment is that the photo-thermal treatment only occurs in zone straight about GNPs, and limited temperature ranges can raise to hundred degrees over physical temperatures [5, 9].

Conclusion

GNPs have higher surface-to-volume ratio due to their biocompatibility and inertness. GNPs can be certainly functionalized with numerous other functional groups. They play a key role in the medical field as adjuvants, reducing the toxic effects, increasing the immunogenic effects, and offering the storage stability of medicines and other drugs related to vaccinations, and also possess the excessive potential. The applications of GNPs in medicals especially for cancer therapy has demonstrated the important developments in modern years. GNPs deal properties for scheming and revealing features which cannot be practicable with predictable therapeutic means.

They display potential in cancer treatment. Except GNPs which have achieved approval for therapeutic applications, currently, numerous further NPs are under several phases of pre-clinical and pharmaceutical improvement and research. By methods for these practical gatherings to attach the ligands, extra moieties like antibodies, amino acids, proteins, and dinucleotides are utilized to report the prevalent usefulness. The wide scope of use for GNPs depends on exceptional somatic as well as synthetic characteristics. Specifically, optical features of GNPs are controlled with their surface plasmon vibrations, that relates with joined excited conductive electrons and confined within wide region, from noticeable to infrared (IR) area, contingent upon size, shape and structure of molecule.

Conflict of Interest

We have no conflicts of interest to disclose.

References

[1]. Abadeer N.S., Murphy, C.J., *J. Phys. Chem. C*, 2016, **120**:4691

[2]. Fazal-ur-Rehman, M. "Novel applications of nanomaterials and nanotechnology in medical sciences-a review." *J. Basic Appl. Sci. Res.* **8.4** (2018): 1.

[3]. Aioub M., Austin L.A., El-Sayed M.A., *Gold nanoparticles for cancer diagnostics, spectroscopic imaging, drug delivery, and plasmonic photothermal therapy*, in *Inorganic Frameworks as Smart Nanomedicines*. William Andrew Publishing**.** 2018

[4]. Fazal-ur-Rehman, M., Iqra Qayyum, and M. S. Ibrahim. "Nanotechnology: An innovation in scientific research and technology." *Current Science* 5.4 (2019): **48-59**.

[5]. Louis C., Pluchery O., *Gold nanoparticles for physics, chemistry and biology*. World Scientific. 2012

[6]. Beik J., Abed Z., Ghoreishi F.S., Hosseini-Nami S., Mehrzadi S., Shakeri-Zadeh A., Kamrava S.K., *J. Control. Release,* 2016, **235**:205

[7]. Brown S.D., Nativo P., Smith J.A., Stirling D., Edwards P.R., Venugopal B., Flint D.J., Plumb J.A.,

Graham D., Wheate N.J., *J. Am. Chem. Soc.,* 2010, **132**:4678

[8]. Yang X., Liu X., Liu Z., Pu F., Ren J., Qu X., *Adv. Mater.,* 2012, **24**:2890

[9]. Jazayeri M.H., Amani H., Pourfatollah A.A., Pazoki-Toroudi H., Sedighimoghaddam B., *Sens. Biosensing Res.,* 2016, **9**:17

[10]. Wust P., Hildebrandt B., Sreenivasa G., Rau B., Gellermann J., Riess H., Felix R., Schlag P.M., *Lancet.,* 2002, **3**:487

[11]. Cabuzu D., Cirja A., Puiu R., Mihai Grumezescu A., *Curr. Top. Med. Chem.,* 2015, **15**:1605

[12]. Cai W., Gao T., Hong H., Sun J., *Nanotechnol. Sci. Appl.,* 2008, **1**:17

[13]. Carabineiro S.J.M., *Molecules,* 2017, **22**:857

[14]. Herizchi R., Abbasi E., Milani M., Akbarzadeh A., *Artif. Cells Nanomed. Biotechnol.,* 2016, **44**:596

[15]. Tatur S., Maccarini M., Barker R., Nelson A., Fragneto G., *Langmuir,* 2013, **29**: 6606

[16]. Tiwari P.M., Eroglu E., Bawage S.S., Vig K., Miller M.E., Pillai S., Dennis V.A., Singh S.R., *Biomaterials,* 2014, **35**:9484

[17]. Gao Z., Zhang L., Sun, Y., *J. Control. Release,* 2012, **162**:45

[18]. Shi P., Qu K., Wang J., Li M., Ren J., Qu X., *ChemComm.,* 2012, **48**:7640

[19]. Shi Y., Goodisman J., Dabrowiak J.C., *Inorg. Chem.,* 2013, **52**:9418

[20]. Rajeshkumar S., *J. Genet. Eng. Biotechnol.,* 2016, **14**: 195

[21]. Paciotti G.F., Myer L., Weinreich D., Goia D., Pavel N., McLaughlin R.E., Tamarkin L., *Drug Deliv.,* 2004, **11**:169

[22]. Fard J.K., Jafari S., Eghbal M.A., *Adv. Pharm. Bull.,* 2015, **5**:447

[23]. Simon, H.B., *N. Engl. J. Med.*, 1993, **329**:483

[24]. Fujii J., Otsu K., Zorzato F., De Leon S., Khanna V.K., Weiler J.E., O'Brien P.J., MacLennan D.H., *Science,* 1991, **253**:448

[25]. Hahn G.M., *Hyperthermia and cancer*. Springer Science & Business Media. 2012

[26]. Abdussalam-Mohammed W., 2019, *J. Chem. Rev.,* **1**:243

[27]. Hameed A., Fatima G. R., Malik K., Muqadas A., Fazal-ur-Rehman M., *J. Med. Chem. Sci.,* 2019, **2**: 9

[28]. Alizadeh S., Nazari Z., *J. Chem. Rev*., 2020, **2**:228

[29]. Yadav S., Sharma M., Ganesh N., Srivastava S., Srivastava M., *Asian J. Green Chem*., 2019, **3**:492

[30]. Abdussalam-Mohammed W., *Adv. J. Chem. A,* 2020, **3**:192

How to cite this manuscript: M. Fazal-ur-Rehman, Iqra Qayyum. Biomedical Scope of Gold Nanoparticles in Medical Sciences; an Advancement in Cancer Therapy. *Journal of Medicinal and Chemical Sciences*, 2020, 3(4), 399-407.
DOI: 10.26655/JMCHEMSCI.2020.3.9