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The Nanotechnology (Preparation, Applications, and Cancer Treatment): Review

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Abstract:

The medical, engineering, and technological fields witnessed a great leap in the development and improvement of the properties of various materials to use them in the best applications and benefit from them, especially in the medical fields. Materials have evolved through the introduction and development of various production methods to improve the quality of materials, and one of these methods is the method of producing nanomaterial's that gave a quantum leap in the properties of materials compared to ordinary materials because of their distinctive effect on (engineering, medical and technological applications). Among the most important applications of nanotechnology in cancer treatment, the effect of this technology has been observed to treat and reduce cancer. There are multiple ways to manufacture nanomaterials, but one of the most important methods is the Sol-Gel method, So we will address the fundamentals of this process, its most important applications because This method has proven its economic and efficient to manufacture various nanomaterials in different shapes and is considered simple compared to other methods. This review deals with methods of manufacturing nanoparticles in general and the treatment of cancer.

Introduction:

Cancer was and still is the most dangerous disease to human life, so scientists have strived to treat or reduce the risk of this disease through the use of different treatments and techniques. Nanotechnology is one of the most important methods for cancer treatment [1].

Nanoparticles have been used to treat cancer and tumors. Targeted therapies are best among the common cancer therapies because they are more efficient and cause fewer unwanted side-effects than other (regular) chemotherapies, including weaker viability, reduced dosage requirement, decreased adverse side effects, low therapeutic indicators, multiple medications resistance, and nonspecific objectives. [2,3]. Recent studies have shown that NPS have many advantages in diagnosing and treating tumors apart from medicines, imaging agents, and genes (with diagnostic capacity) [4,5]. In the last two decades, NPs have provided a number of treatment methods based on NPs for clinical experiments [6]. In this study, NPs have assessed the role of different methods of cancer treatment in cancer treatment [7].

Nanotechnology is considered one of the most important technologies that have been developed and improved because it is of great importance in medical, engineering, and industrial terms because of the materials that are produced with this technology because it has unique properties compared to regular materials that helped support and develop various applications, where scientists and researchers have reached many methods for producing nanopowders, including mechanical methods (such as milling), chemical (chemical precipitation), and physical methods (such as condensation). Several researchers have developed and improved various methods for producing nanomaterials[8,9].

One of the most important processes for producing nanoparticles and thin films is the Sol-Gel method because it produces materials of high purity in addition to the ability to control the type of the resulting material [10].

2. Sol gel method

The sol-gel methods involve two different phases: solution and gelation. As the name implies, A sol is an interlinked network of a solid-phase part that forms a continuous entity in a secondary, usually liquid, phase a colloidal particle suspension [9]. These phases are preserved throughout sol-gel technology through the chemistry that occurs during the gel evolutions and can be manipulated in many different ways; for instance the modification of the initial precursors, the time allowed for the gelling, catalysts, solvency, Conditions of gel or the physical treatment of the gel itself. Sol-gel processes can be utilized by gelating solutions in developing solid materials and producing many useful morphologies (Fig1) [11]

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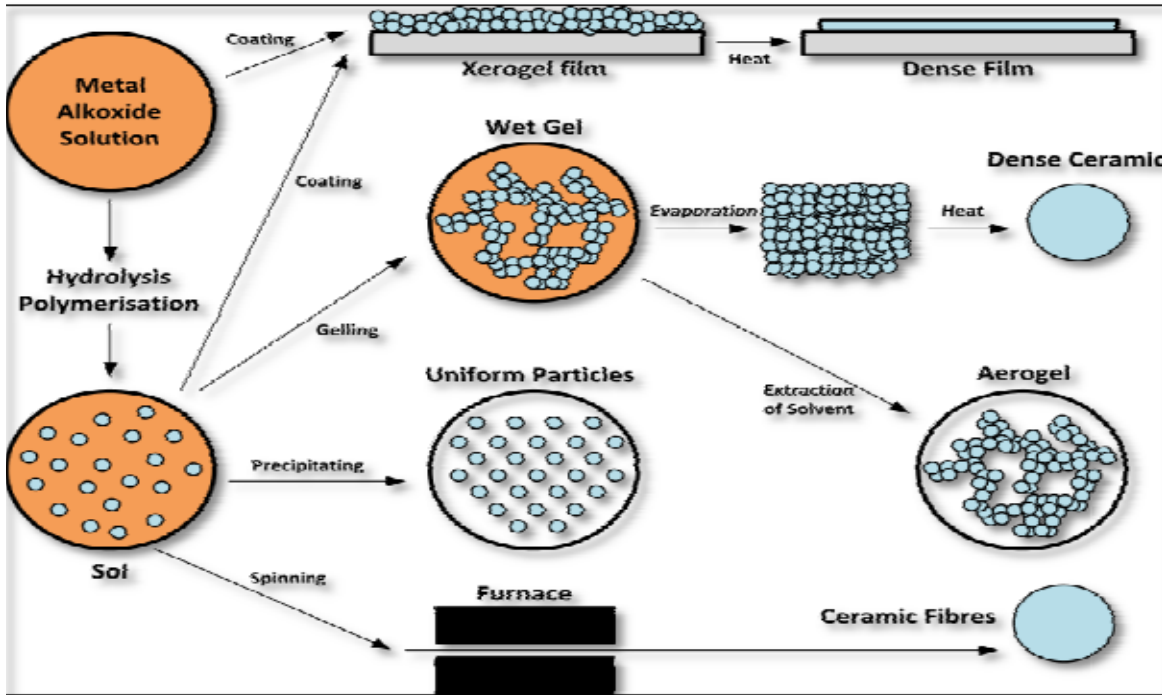


Fig (1) : Sol gel processing.

The processes are shown in Fig.1. are by no means restrictive or complete. These steps may be extended, modified, or completely removed except for solvation and gelation, depending upon the specific application [12]. The stages of hydrolysis and condensation reactions are constant in the production of sol-gel-derived bioactive materials. This section describes the routes of soil gel synthesis for biomedical ceramic and glass networks that are most frequently used [11].2.1 Enhancing in sol-gel:

Gel drying is a vital process for important social applications. Kistler 13 first studied supercritical drying, resulting in an exceptional volume of a pore of up to 99.8 percent for the production of aerogels [13]. The doping of sols with chemical additives led to the discovery of micellar materials. The recent developments in solgel are due to chemical synthesis in coordination chemistry [14]. One important problem is the production of materials with different surface functions, such as hydrophobic nature. In addition, it is necessary to graft chemically, via chemical compounds such as molecular catalysts, enzymes, or other bio-molecules. An organic molecule able to produce polymer gelations can create inorganic-organic hybrid materials with interesting properties [15].

2.2 Advantages of Sol Gel:

Between substratum and top layer improved adherence. The gel condition allows materials to be modeled into complex geometry. Precursors of ceramic oxides dissolved in a proper solvent for solar gel processing produce a highly pure product. The process is low (200-600°C) at low temperature. It is a simple, economic and effective method for manufacturing high-quality coatings [16].

2.3 Sol Gel's Benefits

Due to certain limitations, sol-gel techniques cannot achieve their full industrial potentials. Some have high permeability, low wear strength, low bondage, and a tough control of porosity. 0.5 µm is the maximum thickness limit for a crack-free property. During the thermal process, thick coatings may result in failure. The thermal mismatch and surface dependence of the technology Sol-gel are currently suffering an inconvenience. Obviously, a lack of knowledge of the complex reaction is one of the main disadvantages of this technique. One of the disadvantages of the Sol-gel method is its costly raw material, drying and sintering, and scheduling. Sixteen to 20 [17].

2.4 Biomedical applications

There are several applications of nanomaterials resulting from the Sol-Gel process [18].

Tissue repair and regeneration matrices and scaffolds.

2- Sol-glasses and hybrids with bio-active effect.

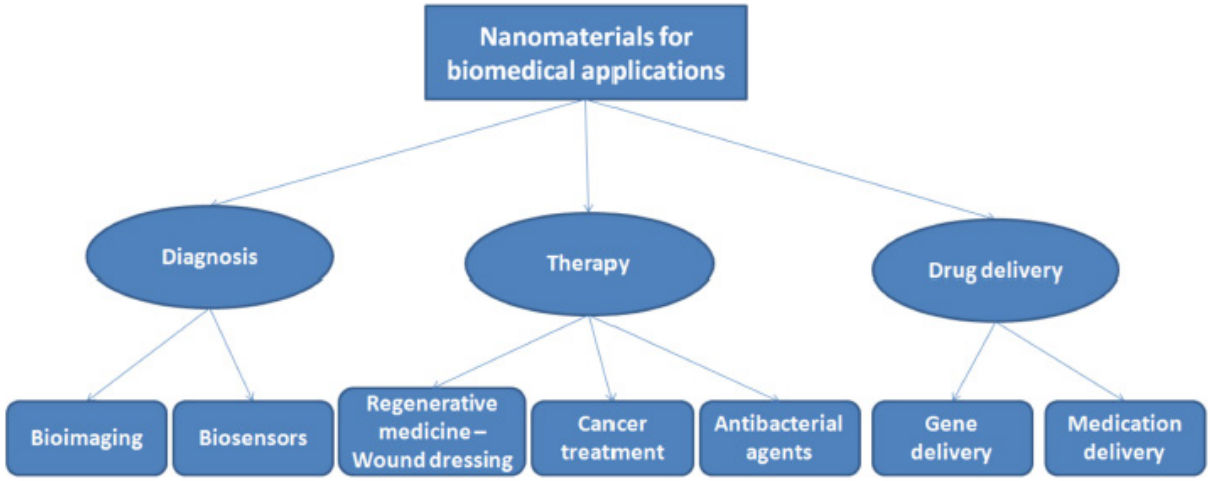
Regenerative Medicine.

Drug and Gene Delivery Systems.

Prosthetic and Orthosis.

Nanoparticles and cancer treatment

There are other applications as shown in the figure (2) [19].



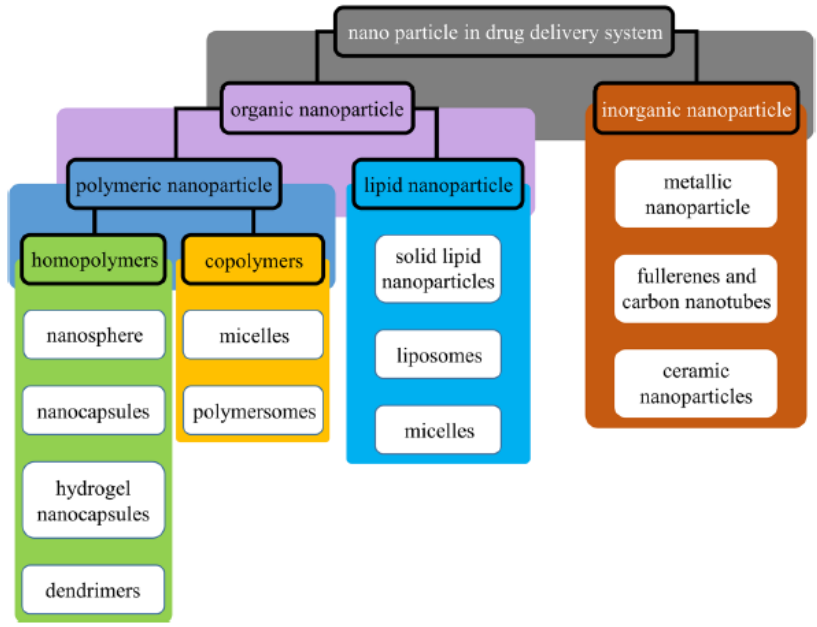
Fig(2). Medical applications of nanoparticles.

2.5 Applications of Sol Gel method in Drug Delivery .

Through study, research, and application, interest in the sol-gel method has increased recently and strongly through its controlled drug delivery. All organic, inorganic, porous, and nanoparticles are studied as pharmaceutical materials [20]. There is a group of applications in this area, we mention one of them [21]:-Nanoparticles used as drug delivery.

1- Porous materials used as drug delivery.
2- drug delivery from gels for orthopedic.
3- Pro- drug delivery.
4- Impurities molecular of drugs.
5- Thin film used as drug delivery.
6- drug delivery for tissue engineering.

There are two major elements of the nanocarriers, organic nanocarriers, and inorganic nanocarriers, as shown in figure (3) below [22].



Fig(3). Classified into of The nanocarriers.

3. Nanoparticles and their applications in cancer treatment.

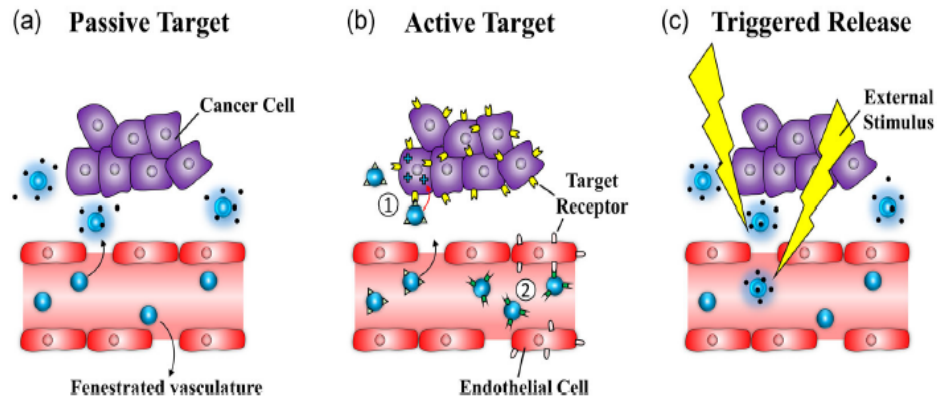
NPS as drug carriers has recently been considered. Nanocarriers change a drug's pharmacokinetic properties to improve effectiveness and to decrease adverse effects [23]. Various types of materials such as polymers, metal parts, lipids, etc. are used in the structure of the NPS used for drug delivery. Different forms and sizes can be produced according to the NPs' structure [24]. The world's pharmaceutical market has been marketed by DDS, a nanocarriers-dependent system. Your DDS application is growing every day. In future research, several NPS functions should be focused on, including drug delivery and simultaneous imaging [25].

In order to improve the medicinal and therapeutic properties of drugs, DDS was developed. They keep the medicine as a repository in themselves [26]. The systems release the medicine at the right time and place. They, therefore, affect pharmacokinetics and the body's pharmaceutical processes [27]. Wide applications in DDS are available for NPS. NPS was at the forefront of DDS recently. Its structure has certain special characteristics that can improve therapeutic drug efficiency [28]; Such properties control the pharmaceutical drug release process in the body, protect pharmaceutical molecules, are smaller than the cells, cross biological barriers for delivery in the target area of the medication, enhance the durability of blood flow medicines, target drug supply, and biocompatibility. Over the last half-century, numerous improvements have affected nanocarriers' variability in the areas of polymers, chemistry, biology, mechanics, and Physics. Therefore, various types of carriers have been brought into the medical sciences with unique properties [29].

4. Targeting the tumors with nanoparticles.

Up to this point, drug nanocarriers were discussed. All efforts in developing different carriers are designed to increase their focus on the delivery of the medicine to the desired location [30]. In this section, we'll take a look at how nanocarriers are used to deliver drugs. Two active and passive medication procedures are generally performed through NPS. Systems are supplied at the target location with passive targeting using physical anatomical conditions. NPS below 100 nm can be easily transported by capillaries of the reticuloendothelial system to hepatic and macrophages [31]. This knowledge can be used to efficiently treat patients with hepatic and spleen diseases. To demonstrate its effectiveness, the medication first penetrates and accumulates in the macrophage. The macrophages then act as a defensive system in the treatment of hepatic and spleen disorders. Another example is the vascular permeability of carcinoid tumors with dysfunctional lymphatic and vascular systems (sarcomas) [32]. As these illnesses are deficient in the lymphatic system, medicines that enter the tumor-infected areas accumulate for a long time after they have left the blood circulatory system to exercise their therapeutic effects. This form of tissue delivery benefits fat, polymer particles, and mycelia [33].

Additionally, this strategy affects the environment of carcinoid tissues. The temperature in carcinoid tissue is higher (over 40°) but has a lower pH (roughly 5.4) than the tissues that seem to be close by these features can be helpful in the development of inactive drugs. pH and heat delivery techniques are used. The active drug delivery method offers better-targeted administration of medication for cells and tissues compared with the passive targeting approach,figure(4) show types of targeting drug delivery [34].

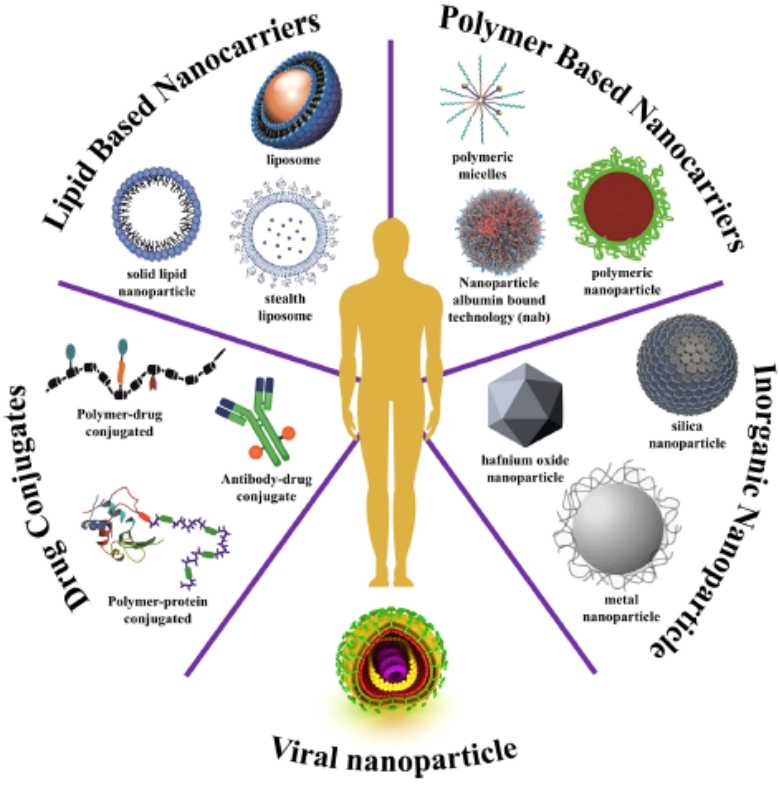


Types of targeted drug delivery. Delivery of carriers to tumor tissue could be done by passive and active targeting. (a) In passive targeting, nanoparticles are designed for transport through leaky vessels and the unique intraorgan pressures of tumors. (b) Inactive targeting of cancer cells (1) or tumor endothelium (2) nanoparticles are designed to adhere to specific biological structures in tumors via the molecular recognition of surface-bound ligands. (c) Triggered release permits nanoparticles to assemble if exposed to an external stimulus such as a magnetic field or light [Color figure can be viewed at wileyonlinelibrary.com]

Fig(4). Types of targeting drug deliver.

4.1 The benefit of nanoparticles in the treatment and imaging of cancer.

Nanocarriers for cancer therapy, including lipid, polymer, inorganic, viral, and drug-conjugated NPs are being investigated as a wide range of NP platforms. (Figure 5) [35] . Moreover, several platforms of the same NP have been approved for clinical use. Nanomedicine is one of the most promising and advanced cancer treatment options today [36]. The majority of research papers say nanomedicine treatment is efficient in in vitro and in vivo cancer treatment. The capacity of NPs as carriers of medications anti-cancer are key advantages: their ability to offer targeted anticancer treatments for tumors, their ability to store thousands of molecules of medicines, and their capacity to address soluble, stable and resilient problems [37]. Furthermore, a number of NP-related diagnostic and therapeutic agents have been licensed for use in clinical tests. Some had previously been authorized by the Food and Drug Administration (FDA) [38]. FDA authorization is granted to NPs such as Daunoxome, Doxil, Depocyt, Abraxane, and Caspar. These drugs work effectively against ovarian, breast, pulmonary, kidney, and other cancers [39,40].



Fig(5).A group of nanopharmaceuticals used to treat cancer

5. Gold and the mechanism of treatment against cancer.

Surgery and chemotherapy are some of the most common treatment options for the treatment of cancer [41]. Most of the gold nanoparticle cancer research studies have used photothermal therapy to destroy cancer cells or tumor tissue that might work in a therapeutic context because of their unique characteristics. Aimed gold nanosphere, nanoshell, and nano came are killed with focused laser pulses in the right wavelength when irradiated. Bacteria and cancer cells can kill It was projected to approach 70-80°C for light absorption by golden nanoparticles, and a two-function PEG link was used to bind up to 150 antibodies to one nanoshell [42].

One fascinating finding is that, due to available monoclonal antibodies, which detect these two proteins, EGFR, and human epidemic growth receptor 2, HER2 has been the focus of most research (which have already been licensed by the Food and Drug Administration [FDA] for cancer therapy) [43]. The assembly on the cell membrane of gold nanoclusters was examined because the absorber wavelength of small gold nanospheres (in the visible range) is not optimally suited for in vivo applications. The creation of nanoclusters led, compared with cells without Nanoclusters, to higher local absorption and red change. Laser-induced cancer cells have significantly improved [44]. A NIR laser was used to observe the killing.

Gold nanoshells are big enough for SPR peaks in NIR (around 100–300 nm in diameter). In an advanced study, human breast cancer cells were exposed to photothermally caused morbidity with the golden nanoshell [45].

Research in vivo has shown that low NIR light in solid tumors treated with golden nanoshells, capable of leading to irreversible tissues damage, has a significant average temperature increase (not treatment with nanoshells), while controls have a significantly lower average temperature and are not impacted by NIR light exposure [46]. According to a recent study, the destruction of cells required 5,000 gold nanoshells per prostate cell. PEG-coated nanoshells with a peak absorption were intravenously transferred into nude mice with tumors. The NIR lasers have all been ablated in one study, the mouse has appeared to be free of the tumor for several months, and nanoshell-free NIR laser therapy is increasingly common in control cancer [47]. In another study, the high-dose (8.5 L/g) therapy group resulted in 93 percent tumor necrosis and remission [48]. Surprisingly, after 21 days with a lower dose of nanoshell (7 L/g), the tumor has stopped for growth but not for ablation. The reason that the Nanoshell Dose is so small, that it has so greatly changed its therapeutic efficacy requires further research. It's worth emphasizing that none of these in vivo cancer therapy experiments contain targeted molecular targeting, simply passive tumor targeting [49]. The non-specific accumulation of nanoshell in the tumor called 'Enhanced Permeability and Retaining (EPR) Effects causes the aim of passive tumor control, since the tumor vasculature is often more leakage than normal blood vessels and no lymph drainage is present [50]. Photo-induced cell death with gold nanoshells has been used to recruit monocytes towards hypoxic zones within malignancies. Gold nanoparticles in conjunction with photothermal treatments were also studied [51].

Another research on therapy the pigment is a blue-green phthalocyanine (a photosensitizer) the stabilization of gold nanospheres (diameter 2-4 nm) took place. Cultivated tumor cell photodynamic treatment was documented [52]. Gold nanoparticles demonstrated increased anti-proliferation and death of human hepatoma cells caused by the chemo medication Paclitaxel. Radiosensitivity can be enhanced by increasing ionizing radiation absorption by golden nanoparticles, leading to a rupture of single and double-stranded DNA according to a recent study [53]. Although it has been suggested that targeting cancer cells' DNA with gold nanoparticles could provide a novel technique that might be used in a variety of external beam radiation treatments, accomplishing DNA targeting in vivo is extremely challenging [54].

6. The use of nanoparticles in cancer treatment by preserving anti-leukemia release.

Nanoparticles have proven their efficiency in the treatment of leukemia by releasing the reserved or enveloping drug during specific periods of time, thus avoiding taking the drug continuously. The most important nanoparticles used in this field are polymer nanoparticles and include [55]: -

1- poly (D, L-lactic-co-glycolic) acid (PLGA) It is considered one of the important polymers due to compatibility, biosafety, in addition to the ability to degrade safely inside the body.
2- poly (butyl cyanoacrylate), and it is also classified as a biosafe and biodegradable polymer inside the body.
3- (poly (β-aminoester) (PbAE).
4- poly (ε-caprolactone) (PCL).
5- Polyethylene glycol (PEG) modified.

A group of materials was used as drugs that were placed inside the matrix of polymers above, where the drug is released from inside the polymer matrix upon polymer dissolution, and among the therapeutic materials that were placed inside the polymer matrix are [56]: -

A- (all-trans retinoic acid) has been shown to be useful in treating cancer after being placed in PLGA nanoparticles.
B- Etoposide that was loaded in (PLGA) nanoparticles and was released continuously for 72 hours and used to treat lymphocytic leukemia was loaded in (PbAE) and (PCL).
C- Cytarabine that was loaded into (PLGA) nanoparticles, The drug is used to reduce the side effects of traditional leukemia treatment, by reducing the dose, when it has been released for 24 hours. D- Daunorubicin loaded in poly (butyl cyanoacrylate).
E-Arsenic trioxide was loaded in nanoparticles of PEG-PLGA and released for 26 days.
F- Doxorubicin (DOX) loaded in PEG nanoparticles.

7. Conclusions:

Nanomaterials have proven their importance through modern manufacturing methods, especially the Sol-Gel method, which is considered one of the most important methods due to its wide range in producing multiple forms of nanomaterials in addition to the possibility of producing nanomaterials used in various medical fields, and one of the most important forms of nanomaterials produced by this method is Nanoparticles.

On the other hand, various studies have shown that nanoparticles have great potential in treating tumors by special mechanisms that these nanoparticles possess, which have the ability to carry therapeutic materials through them and then control the release of these materials during specific time periods.

NPs have applications in illness detection and therapy, drug administration, and biomedical imaging. As nanotechnology progresses, more potential for the simultaneous targeting and development of appropriate therapeutic technologies in several molecules in tumor samples will become available. The use of NPs to treat in vivo cancers is fast progressing. These advancements may allow malignant antigens to be targeted. Nanotechnology science will revolutionize not only cancer but all medical professions, in the not-too-distant future.

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