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Application of nanotechnologies and nanoparticles in the field of health sciences

Aplicación de las nanotecnologías y las nanopartículas en el campo de las ciencias de la salud

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SUMMARY

Introduction: Nanotechnology and the use of nanomaterials and nanoparticles offer enormous possibilities for improving human life.

Objective: Argue the importance of the use and study of nanotechnology and nanoparticles in the field of health sciences.

Methods: Narrative bibliographic review on nanotechnologies and the use of nanoparticles in health sciences. A search was carried out in databases such as Scopus, Scielo, university repositories and books on the Internet through Google Scholar. Initially, 45 references were obtained from articles, theses and printed texts, 26 were taken into account for their relevance, timeliness and solid scientific results.

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Development: Nanotechnology is currently seeking to position itself as the new technological revolution. It is based on the research and use of nanomaterials, which have attracted much interest due to their reduced size and the new structures that can be formed with them and which exhibit significantly improved biological, physical and chemical properties compared to their molecular precursors. In consistency, nanoscience and nanotechnology have linked engineering with biology, chemistry and physics, enhancing their possible applications in a wide variety of fields such as electronics, ceramics, catalysis, magnetic data storage, structural components, food, cosmetics, biological and medical.

Conclusions: The emergence and development of nanotechnology and nanomedicine allows the design of systems that help improve the biological properties of different substances.

Keywords: nanotechnology; nanoparticles; nanomedicine; technological innovation.

RESUMEN

Introducción: La nanotecnología y la utilización de nanomateriales y nanopartículas ofrecen enormes posibilidades para mejorar la vida humana.

Objetivo: Argumentar la importancia del uso y estudio de la nanotecnología y las nanopartículas en el campo de las ciencias de la salud.

Métodos: Revisión bibliográfica narrativa sobre las nanotecnologías y el uso de las nanopartículas en las ciencias de la salud. Se realizó una búsqueda en bases de datos como: Scopus, Scielo, en repositorios de universidades y libros en Internet a través de Google Scholar. Se obtuvieron de inicio 45 referencias a partir de artículos, tesis y textos impresos, fueron tomados en cuenta 26 por su pertinencia, actualidad y resultados científicos sólidos.

Desarrollo: En la actualidad la nanotecnología, busca posicionarse como la nueva revolución tecnológica. Se basa en la

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investigación y el uso de nanomateriales los cuales han atraído mucho interés debido a su tamaño reducido y a las nuevas estructuras que pueden formarse con ellas y que exhiben propiedades biológicas, físicas, químicas, significativamente mejoradas y en comparación con sus precursores moleculares. En consistencia, la nanociencia y la nanotecnología ha vinculado la ingeniería con la biología, la química y la física, potencializando a sus posibles aplicaciones en una amplia variedad de campos como la electrónica, la cerámica, la catálisis, almacenamiento de datos magnéticos, componentes estructurales, alimentos, cosméticos, biológicos y médicos. **Conclusiones**: El surgimiento y desarrollo de la nanotecnología y la nanomedicina permite diseñar sistemas que ayuden a mejorar las propiedades biológicas de diferentes sustancias.

Palabras clave: nanotecnología; nanopartículas; nanomedicina; innovación tecnológica.

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INTRODUCTION

Nanotechnology is a relatively new science that consists of the study, analysis, structuring, formation, design and operation of materials at molecular scales, which we call nanomaterials; [1, 2] It is defined as the discipline in charge of the study, design, synthesis, manipulation and application of materials, devices and functional systems, through the control of matter at the nanoscale and the exploitation of phenomena and properties of matter also at the nanoscale. [2, 3] Nanotechnology is the study, design, creation, synthesis, manipulation and application of

materials, devices and functional systems through the control of matter at the nanoscale by exploiting phenomena and their properties. [4, 5]

Nowadays, nanotechnology seeks to position itself as the new technological revolution. It is based on the research and use of nanomaterials which have attracted much interest due to their reduced size (1-100 nm) and the new structures that can be formed with them and which exhibit significantly improved biological, physical and chemical properties compared to their molecular precursors. [6]

In consistency, nanoscience and nanotechnology have linked engineering with biology, chemistry and physics, enhancing their possible applications in a wide variety of fields such as electronics, ceramics, catalysis, magnetic data storage, structural components, food, cosmetics, biological and medical. [7]

An increasing use of nanomaterials has been reported in biological applications related to medicine such as: sensors, medical devices, cosmetics and preservative agents, due to greater safety and stability compared to bulk precursors or their organic counterparts. [7] Nanotechnology is today one of the branches of science with the greatest capacity to revolutionize life in all its aspects, its impact would trigger a second industrial revolution. [6]

In recent years, nanotechnology has attempted to position itself as a new technological revolution, reaching the industrial level by being conceived as the field of applied sciences concerning the manipulation of matter on a scale smaller than a micrometer. [8] The synthesis of nanomaterials, according to their origin, is classified as natural, incidental (when they arise during combustion) and artificial; on the other hand, the manufacturing processes of nanomaterials are classified as descending/ascending. [9, 10]

Top-down techniques consist of dividing macroscopic material or group of solid materials until reaching nanometric size, using physical methods such as grinding or attrition, chemical methods and volatilization of a solid followed by condensation of the volatilized components, until obtaining a series of assemblies that are controlled with precision until reaching the desired size; on the other hand, bottom-up techniques consist of the manufacture of nanoparticles with the capacity to self-assemble or self-organize through the condensation of atoms or molecular entities in a gaseous phase or in solution. [9, 10]

The emergence and development of nanotechnology and nanomedicine allows for the design of systems that help improve the biological properties of different substances. Thus, "nanomedicine uses nanometric-sized tools for the diagnosis, prevention and treatment of diseases and to gain a greater understanding of the complex underlying pathophysiology of the disease." [11]

For this reason, various studies have focused on nanomaterials, since they can exhibit significantly improved biological, physical, and chemical properties compared to their molecular precursors. [8] Therefore, it is feasible that their incorporation into the study of new materials with potential biological properties will have a benefit, not only in medicine, but also in materials science. Nanoparticles (NPs) are of particular interest, since they have the capacity to potentially improve drug delivery, being able to encapsulate drugs and direct them to the target tissue in a controlled and precise manner. [12]

Based on the elements raised, the present research established as its objective: to argue the importance of the use and study of nanotechnology and nanoparticles in the field of health sciences.

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METHODS

Narrative bibliographic review on nanotechnologies and the use of nanoparticles in health sciences. A search was carried out in databases such as Scopus, Scielo, Pubmed, in university repositories and books on the Internet through Google Scholar. Initially, 45 references were obtained from articles, theses and printed texts, 26 were taken into account for their relevance, timeliness and scientific results.

DEVELOPMENT

Nanoparticles (NPs) and their applications in medicine

Nanoparticles (NPs) are structures with sizes less than 100 nanometers (i.e. 1 X10-7m), which can be synthesized from different materials, including metals. [10] They are produced from different types of metals such as gold, iron, platinum or metal oxides. In the clinical field, NPs are used as a vehicle to transport drugs that improve the selectivity of the treatment, this means that they allow the site of action where the drug must be released to be better located, with an efficacy of just seconds, compared to drugs that can have the effect after 10 or 15 minutes. [10, 13]

NPs are structures with dimensions similar in size to many biological molecules and their use led to the emergence and development of nanomedicine, a branch of nanotechnology that allows diagnosing, treating and preventing diseases and trauma, relieving pain, preserving and improving human health, using tools and molecular knowledge of the human body. [14] In addition, thanks to their small size and shape, they can incorporate substances that facilitate the recognition of cells and tissues, acting as biosensors to detect if there is any abnormality in the body. They are systems made of natural polymers that contain an active substance, they are used in the transport of medicines. [10, 13]

In 2003, nanotaxonomy was developed, a classification that groups the advances in nanomedicine

and allows its diverse applications to be demonstrated. [15] Nanoparticles are superior carriers to liposomes due to their greater stability and properties related to the control in the release of active compounds. They have been used in the administration of a large number of drugs such as antibiotics, antivirals, antiparasitics, cytostatics, vitamins, proteins and peptides, including hormones and enzymes. [5]

Pharmaceutical nanotechnology and enhancement of biological properties

Today, nanotechnology is one of the sciences that has been advancing rapidly and that today has a greater influence in all fields of scientific and technological development. Nanopharmacy is defined as the use of nanotechnology for the prevention, diagnosis and treatment of diseases and injuries, as well as to improve the health and functioning of the human body and other living beings. [5]

The field of medicine and pharmacy have not been the exception, since biological systems interact with their environment through molecules and multimolecular structures that operate on the nano scale, it is there where it is easy to understand why nanotechnology has so much potential in the area of health, pharmaceutical products and biotechnology, due to the advantages that they have over other systems among which are: [5]

- Capacity to protect the encapsulated molecule against its eventual degradation from the moment of administration to the patient until it reaches its site of action or absorption.
- Ability to cross biological barriers such as the skin, gastrointestinal or respiratory mucosa, or even the blood-brain barrier.
- Ability to reach the target organ, tissue or cell group where the molecule must exert its action.
- Ability to reach intracellular compartments.
- Ability to control the release of the active molecule at its site of action or absorption.

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Applications of nanopharmacy would include the discovery of new pharmaceutical agents, the development of drug delivery systems with specific localization or targeting. (16)

The future of pharmacy, in the area of nanotechnology, with respect to the development of therapeutic products and drug delivery systems, would be linked or related to: (16)

- The design of structured, multifunctional materials capable of attacking specific diseases.
- The design of materials containing functions that allow transport through biological barriers.
- The design of nanostructured platforms for tissue engineering.
- The design of stimulus-sensitive devices for drug delivery.
- The design of physically oriented treatments for the local administration of therapeutic products (via lung, eye or skin).

Nanosystems for transporting pharmaceutical active ingredients

Aresystemsofsizenanometric that allow theencapsulation,the unioncovalentwaveadsorptionof moleculesactive. Asconsequence ofhissmall size,arestructures present ahigh surface/volume ratio,withvaluesofsurfacespecific older than60 cm2/cm3; anda wayspecialto interactwithcell membranes, which depends so much onits sizeas oftheircharacteristicssuperficial,and that can determine theeffectiveness and toxicity of the material. (17)

These nanosystems include liposomes, polymeric or lipid nanoparticles, polymeric micelles, dendrimers, polymeric conjugates and antibody conjugates, carbon nanotubes and other nanocarriers. (17)

There are various current developments in nanotechnology, however, nanoparticles (NPs) are the best known and most studied. In this sense, nanotechnology has gained relevance in recent years, since the benefits that nanoparticulate materials confer to this area allow developments that have not been achieved using other sciences. (3)

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Nanotechnology and medicinal plants

The use of materials obtained from nature has allowed the use of different biomolecules formed by living organisms, which have been the result of millions of years of evolution. With the constant evolution of industrial medicine, the use of medicinal plants represents an alternative for the therapeutic approach to various ailments. [18]

For the above, various institutions are dedicated to the research of medicinal plants, because scientific studies consider herbal medicine as a viable option for the treatment of health problems, this is because plants contain molecules with multiple beneficial effects to alleviate various ailments, making combined research of medicinal plants and nanotechnology an alternative that allows a synergy between medicinal plants and nanotechnology. [19]

Green synthesis

Traditional production of nanoparticles uses toxic materials such as solvents and surfactants that can affect the environment. Green synthesis is an alternative technique for bioproduction of nanoparticulate material together with metallic material (gold, silver, iron and metal oxides), which seeks to be environmentally friendly. [10]

Using plant extracts to synthesize nanoparticles is the fastest method. On the other hand, one of the goals of green nanotechnology is to use green nanomaterials to replace synthetic products such as plastics. [10, 20]

Nanotechnology has been used to improve the properties of medicinal plants, as in the case of the work evaluating the hypoglycemic and antihyperlipidemic activity of TiO2 nanomatrices with Stevia rebaudiana bertoni extract in alloxan-induced diabetic rats, where nanomatrices were used to enhance the effects of Stevia. [21]

Another study was reported by Rosas et al [22] in 2015, developing nanomatrices of ZnO and plantain extract, with the aim of promoting its healing effects. A study carried out by Letsholathebe et al [23] on the green synthesis of Moringa oleifera leaf extract added with ZnO

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using yellow dye showed good antimicrobial and photocatalytic activity. There are several studies that use nanoparticulate ZnO with multiple applications, some of them in the field of medicine in combination with medicinal plants.

ZnO nanoparticles

Zinc oxide (ZnO) is an adaptable material that has distinctive properties such as high sensitivity, large specific area, non-toxicity, good compatibility and a high isoelectric point, which favors it to be considered with some exceptions, it is within the group of most desirable nanostructures due to its structure and properties, morphological characteristics that make it an eye-catching material that is widely used as a counterpart to a significant scope of energetic and biological applications. [24]

ZnO-based nanostructured materials have proven to be a suitable candidate for binding biological substances; recent research reveals that the goal behind using nanostructures for biosensing applications is to increase the surface-to-volume ratio, which improves their reactivity and allows them to more easily translocate across the cell membrane and efficiently bind analytes. [24]

ZnO, in addition to being useful as a matrix to transport and stabilize the drug during treatment, also has therapeutic properties on irritations and superficial wounds due to its astringent and antibacterial effect in adequate concentrations, protecting the lesion from infections. Zinc oxide is a material that, due to its characteristics, is used in the cosmetic and pharmaceutical industries, as well as in the manufacture of paints and in rubber catalysis. [25]

In the scientific field, its properties as a semiconductor, piezoelectric, pyroelectric and photocatalytic are used for technological applications in optoelectronics, sensors and transducers; while its potential in biological applications has been demonstrated due to its properties: antimicrobial, anti-inflammatory and wound treatment, among others. ZnO has shown advantages as a drug transporter and has a cytotoxic behavior for the treatment of cancer. [25]

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Furthermore, due to its low toxicity, biocompatibility and biodegradability, it is a material of interest for biomedicine and pro-ecological systems such as cosmetics. [25]

ZnO nanoparticles

Given the growing interest in ZnO nanoparticles, different preparation techniques have been developed, such as chemical vapor deposition, hydrothermal method, chemical precipitation, chemical decomposition, Sol-Gel method, pulsed laser, pyrolytic spraying and glycolate, among others. [21]

Sol-Gel technique is the most attractive method for the synthesis of ZnO nanoparticles due to its low production cost, high reliability, repeatability, simplicity, low process temperature, ease of control of the physical characteristics and morphology of the nanoparticles, compositional homogeneity and optical properties. [21]

Nanoparticles used in central nervous system diseases

In the case of Central Nervous System (CNS) diseases, the priority is for the drug to cross the blood-brain barrier (BBB). The most suitable nanostructures for this type of transport are solid NPs. CNS diseases or disorders are a global health problem due to the increasing aging of the population and the lack of effective treatments for them. [24]

In this sense, polymeric nanoparticles containing different encapsulated active agents are able to promote their passage to the target tissue (brain), which opens up the possibility of using them in the treatment of diseases of the nervous system such as anxiety and depression, among others; a possibility that is addressed in this work. [24]

CONCLUSIONS

The emergence and development of nanotechnology and nanomedicine makes it possible to design systems that help improve the biological properties of different substances. Nanoparticles

are of particular interest, as they have the capacity to potentially improve drug delivery, being able to encapsulate drugs and direct them to the target tissue in a controlled and precise manner.

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