

Nanoscale Diagnosis and Therapy: Nanotheranostics as an Advance in Nanotechnology

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Abstract

The term "nanotechnology," introduced in 1986, refers to the emergence of a novel technology poised to transform existing protocols at the nanoscale. For many years, publications regarding nanotechnology have generated significant expectations related to discoveries and solutions. In 1990, with the inception of green chemistry, the scientific community began to reassess its approach, inspired by adaptations of protocols established by various eco-friendly institutions. Consequently, researchers specializing in nanotechnology embarked on a new quest to develop innovative protocols centered on the biosynthesis of nanostructures. Green nanotechnology emerged on the global stage as a result of the collective endeavors of the scientific community, culminating in a noteworthy scientific contribution, particularly from the year 2010 onward. However, from this point forward, the evolution of nanotechnology has increasingly integrated therapeutic and diagnostic functions within nanostructures. Theranostics itself represents a significant advancement in science. Furthermore, when green nanotechnology is coupled with theranostics, the benefits derived from this combination are profound. This review article will examine the evolutionary trajectory of nanotechnology, culminating in theranostic green nanotechnology, which, on an evolutionary scale, exemplifies the most desirable developments in contemporary science while highlighting successful applications associated with this innovative technology.

Keywords: Metallic nanoparticles, Green synthesis, Green nanotechnology, Nanoscience evolution, Diagnosis, Therapy, Cancer

Introduction

Nanotechnology emerges amidst global science established by stable and repetitive protocols, seeking to present, firstly, to the scientific community a new perspective on possible technological advances associated with a nanometric scale. With the article "Engines of creation: The coming era of nanotechnology," Drexler inserted the term nanotechnology for the first time in a scientific publication in 1986, and a new era emerged, as its title suggests, in the search for understanding and application of the new science being presented [1]. The first articles published between 1980 and 1999 were theoretical and pointed to hope towards nanoscience [1-6]. Since the 2000s, scientific production has primarily focused on the synthesis and characterization of nanostructures, unveiling to the scientific community a vast potential associated with nanostructures and their advantages when compared to bulk. This potential has sparked optimism about the future of the field as science continues its mission

to compare nanotechnologies with established technologies and to demonstrate, primarily, the advantages associated with the nanoscale [7-9].

Data extracted from the Google Scholar platform show that between 1986 and 1990, approximately 1,900 articles were published worldwide mentioning the term nanotechnology, according to an analysis on Google Scholar. This seemingly modest number, however, was a significant starting point in the search for understanding the nanoscale for technological innovations and proposals for work with future perspectives. It marked the beginning of a journey where scientists sought to contextualize discoveries and new scientific possibilities through a minimum of theory.

The scenario was even more impressive between 2001 and 2024. Around 1,020,000 articles were published mentioning nanotechnology. However, during this period, an important watershed needs to be highlighted. In 1990, the term "green chemistry" emerged, establishing 12 principles that must be

respected so that new products emerge in an environmentally responsible manner [10-14]. Furthermore, in 2015, the United Nations launched the Sustainable Development Goals, encouraging the scientific community to think more harmoniously with the environment [15]. A new search has begun to integrate technologies into the environment responsibly. In this context, the profile associated with new scientific productions with nanotechnology has changed.

The new analysis searches for terms disseminated in the scientific literature that introduce so-called “green” methodologies, which introduce eco-friendly concepts into the synthesis routes of nanostructures [16-21]. Making the same assessment, in the same periods, no article from 1986

to 1990 found the term “green synthesis” associated with nanotechnology. From 1991 to 2000, the search for the terms eco-friendly, green synthesis and biosynthesis associated with nanotechnology began to emerge, and much of this emergence is related to the understanding of the nanoscale behavior of nanosystems. Because they present characteristics of colloidal systems, scientists worldwide are beginning to understand the powerful dispersive and stabilizing potential of the dispersive medium from plant extracts [22-26]. Then, the biosynthesis of nanostructures begins to emerge. As **Figure 2** suggests, and in comparison with **Figure 1**, the evolution associated with green nanotechnology is an essential factor in the aggregation of new technologies based on eco-friendly concepts.

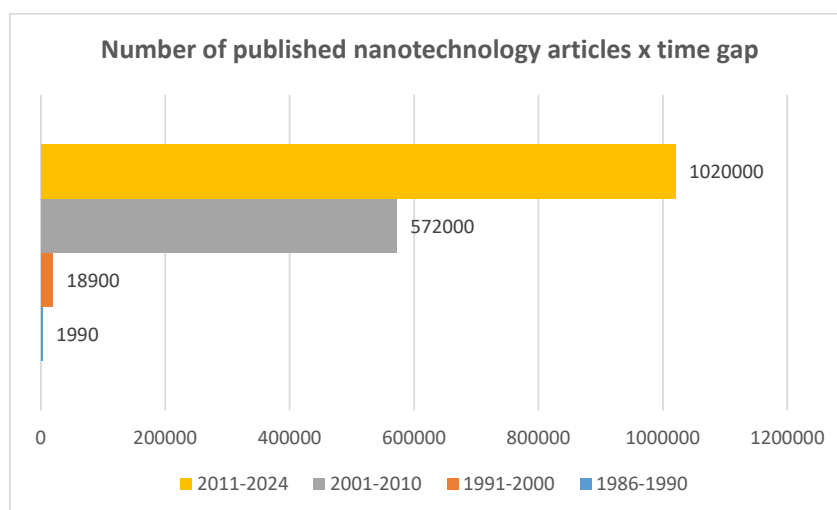


Figure 1. Analysis of the evolution of the number of published articles related to nanotechnology from the first publication to the present year.

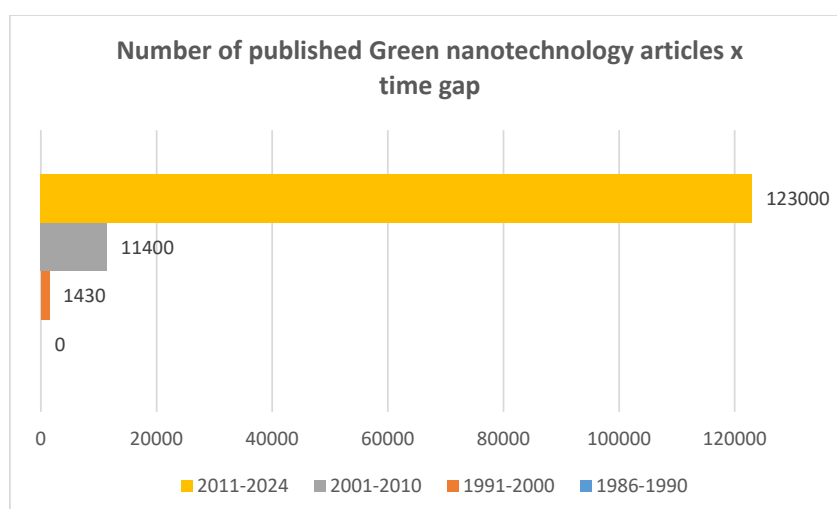


Figure 2. Analysis of the evolution of the number of published articles related to green nanotechnology from the first publication to the present year.

In general, terms, green nanotechnology represents a significant evolution when it aligns protocols and the environment and generates as a final product a nanomaterial with insignificant cytotoxicity and high efficiency for a wide range of applications. Safe and environmentally friendly protocols and sustainable technologies aligned with the current planetary demand have represented a significant innovation over the years. These protocols present stability, repeatability, and efficiency, in addition to presenting final products with very low or no cytotoxicity, very low energy and water consumption, and low cost. This allows for a wide range of application possibilities that resonate with various applications, and in the health area, they have shown increasing use [27-31].

Theranostics justifies its name because its main objective is the conjunction of diagnosis and therapy. The growing search for the development of this technology led to the so-called Theranostic Nanotechnology or Nanotheranostics. Thus, from the 2000s onwards, the scientific community used therapy and diagnosis on a nanoscale [32-42]. The studies, although in increasing production, are still in their early stages but represent a new configuration for scientific productions on the world stage every year (**Figure 3**). The proposal encompasses a series of serious diseases, such as cancer, which can be diagnosed and treated efficiently and quickly without side effects and insignificant cytotoxicity, especially when compared to conventional therapies. Therefore, searching for methodologies that detect and treat malignant tumors as soon as they are discovered becomes urgent and increasingly closer.

The combination of nanotechnology, the environment, and the ability of nanosystems to diagnose and treat diseases is seen as a new hope for the near future. The development of Nano devices based on green technologies, capable of

diagnosing and synergistically treating a disease, is the most advanced therapeutic approach expected, as they are less invasive and more specific, generating diagnostic efficiency and incredibly advantageous treatment by minimizing side effects. Thus, green nanotheranostics is a promising approach that will result in assertive diagnoses and more conservative treatments [43-48]. The graph analysis in **Figure 4** demonstrates that discoveries associated with green nanotheranostics are increasing and represent a significant technological advance in the treatment and diagnosis based on green nanotechnologies with an ecologically responsible approach.

Suppose an evolutionary scale associated with nanotechnology is established. It is the most innovative thing in contemporary science since it is associated with green nanotheranostics. These potentialities are beginning to align with the most urgent needs of medicine and those equally urgent associated with the environment. Therefore, approaching green nanotheranostics in the evolutionary chain of the history of nanotechnology, expressed in (**Figure 5**), can be a good way to welcome discoveries and understand the gains and advances in this new approach.

Given all the above, the article aims to disseminate the advances in nanotechnology, since the synthesis of nanostructures was a determining milestone in the visibility of nanoscience in the global scientific scenario. With the first articles associating the nanoscale with possible advances in science, scientists from all over the world began screening in search of problems addressed conventionally, intending to implement nanotechnologies as new therapies for old global problems, such as new environmentally friendly and efficient materials to improve and preserve life on the planet and economic, the search for storage and production of clean energy, development of nanotechnologies capable of

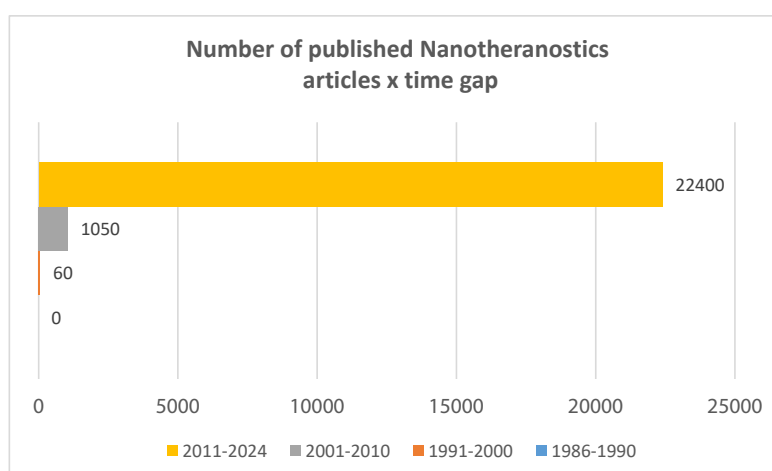


Figure 3. Analysis of the evolution of the number of published articles related to nanotechnology from the first publication to the present year.

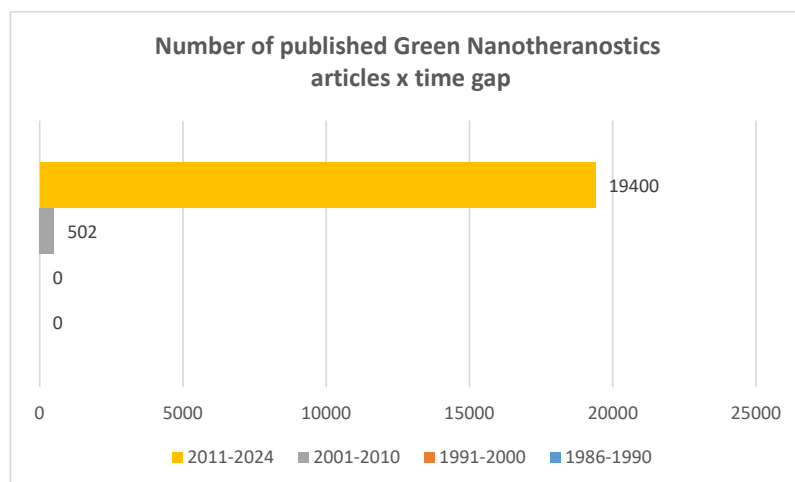


Figure 4. Analysis of the evolution of the number of published articles related to Green nanotheranostics from the first publication to the present year.

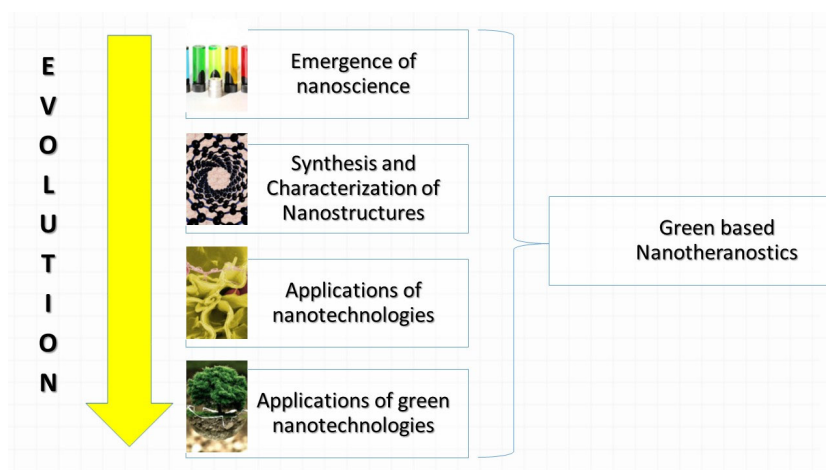


Figure 5. The nanotechnology evolution overview.

promoting environmental recovery, based on sustainability and regeneration, Nano sensors capable of detecting pollutant or disease indices with excellent detection limits, with simple, economical and efficient synthesis routes. In addition to pharmaceutical, medical and cosmetic health applications based on green nanotechnologies, which are efficient and environmentally friendly.

Nanotechnology: A Great Discovery!

A material is classified as nanoscale with at least one dimension between 1 and 100 nanometres (nm) [49]. This dimension leads to a series of properties associated with the nanoscale since a larger contact surface significantly increases reactivity, so nanostructures tend to be more reactive when compared to bulk. High reactivity depends on several factors, such as

the chemical composition of the nanomaterial, precursor concentration, and the state of aggregation in the synthesized nanosystem, as well as the nanoparticles' size, morphology, and coating. As a main advantage, nanotechnology presents optimized properties due to the larger contact surface, use of little reagent, and efficiency of action at the intended end due to greater availability. However, there are disadvantages such as the increase in the vibrational energy of the nanostructures; aggregation and inactivity of the method, since exceeding the range established in the standard, the nanotechnology is lost; and in the case of metallic nanostructures, there may be the possibility of oxidation of the fundamental element, due to the high reactivity and loss of chemical properties [50-53].

Due to its highly differentiated characteristics, nanotechnology has invaded all industrial sectors. It is

increasingly gaining ground in sectors that significantly impact industrial production and the planet's economy, ranging from computing to food, engineering to medicine, agriculture to pharmaceuticals. In the field of computing, transistors that are more efficient and as small as possible are increasingly being studied, so the nanoscale will allow for a greater quantity in a smaller space, which is increasingly desirable. The biggest issue associated with computing is predicting and scaling the production of nanotechnology-based transistors on an industrial scale. The study on carbon nanotube field effect transistors (CNFETs) defined a promising nanotechnology for innovation in computing that is expected to go beyond the limits of the laboratory and can be scaled to an industrial scale [54-55]. Nanotechnology is used in preservatives, biosensors, and packaging in the food sector. With food shortages becoming increasingly exacerbated, increasing the shelf life of food is becoming increasingly urgent. Packaging based on nanotechnology allows for the control of the growth of pathogenic microorganisms, which promotes an increase in the shelf life of food. Furthermore, nanosensors allow for the detection of whether the product has already expired due to the presence of detected microorganisms [56-59]. In the field of engineering, there are benefits of nanotechnology in many of them, mainly in biomedical engineering, through the efficiency of nanostructures in combating pathogenic microorganisms, in addition to intelligent coatings based on nanotechnology that creates an efficient protective layer in combating hospital contamination [60], in addition to the development of intelligent fabrics and dressings based on nanotechnology that effectively favors recovery [61-63]. In agriculture, the replacement of fertilizers and pesticides with products based on nanotechnology is increasingly prevalent.

However, considering the large proportions used, there is still a lack of legislation to safely regulate their use. In addition, the development of sensors that diagnose soil health is currently being targeted [64,65].

Green Nanotechnology

Technological advances aligned with the environment sustainable development goals seek to balance the planet's demands with the new urgent challenges that living beings are already facing. The climate emergency, the scarcity of water resources, poverty, and health are increasingly present demands, and the search for solutions must come quickly. The word sustainability comes from the Latin "sustain," which means to conserve. In many ways, sustaining the planet's conditions is already becoming a risk. Aquatic environments with a level of pollution outside the average are suitable for treatment, invasive health treatments with significant side effects due to above-average cytotoxicity, and exacerbated industrial production, among many current scenarios, and they require much more than sustaining a reality. Therefore, the sustainable bias must sometimes be replaced by environmental regeneration. Studies confirm the efficiency of green syntheses of nanostructures in all urgent contexts compared to traditional methodologies, which use toxic precursors, high water and energy consumption, and high industrial value [66,67].

Based on this growing need for developing new protocols that generate new sustainable materials, nanotechnology aligns scientific development based on efficient and advantageous green protocols, as expressed in **Figure 6**.

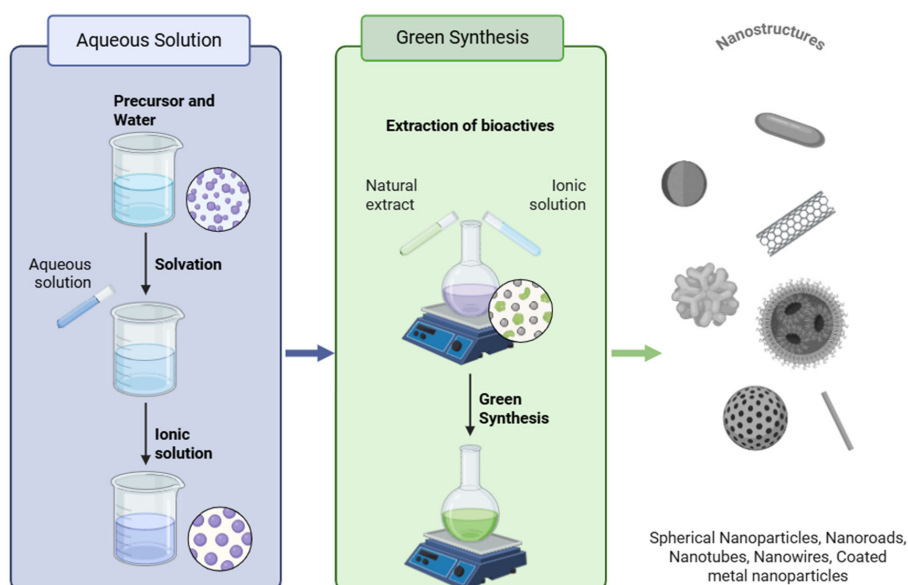


Figure 6. Nanostructures based on Green synthesis.

Table 1 lists the main metallic nanostructures synthesized in a green way, based on plant extracts, which are silver nanoparticles (AgNPs), zinc oxide nanoparticles (ZnONPs), magnesium oxide nanoparticles (MgONPs), and gold nanoparticles (AuNPs). It is possible to certify a wide variety of applications with high efficiency and very low or no environmental impact based on cytotoxicity studies and the useful life cycle of the nanomaterial, which makes it, in fact, biodegradable and integrated with the principles associated with sustainability and regeneration. Applications range from agriculture, where silver nanoparticles (AgNPs) are synthesized based on plant extracts such as *Serratia* sp, *Brassica rapa* L, and *Capparis spinosa* L, and are intended for agriculture as nano fungicides, Antifungal activity wood-rotting pathogens and seed priming [68-70]. They also act in water treatment, degrading toxic substances when treated with ZnONPs based

Table 1. Highlight of studies based on nanostructures synthesized in natural extracts and their applications.

Nanostructure	Natural Extract	Performance	Reference
AgNPs	<i>Serratia</i> sp	Nanofungicide/Agriculture	[68]
AgNPs	<i>Brassica rapa</i> L.	Antifungal activity wood-rotting pathogens/Agriculture	[69]
AgNPs	<i>Capparis spinosa</i> L.	Seed priming/Agriculture	[70]
AgNPs	<i>Salvia Sclarea</i>	Antibacterial action	[74]
AgNPs	<i>Clematis gouriana</i> leaf extract	Bloodstream infections	[75]
AgNPs	<i>Malvastrum coromandelianum</i>	Anti-dengue and mosquitocidal	[76]
AgNPs	<i>Ocimum</i> species	Anticancer potential	[77]
AgNPs	<i>Camellia Cinensis</i>	Ovalbumin-induced allergic conjunctivitis	[78]
AgNPs	<i>Chenopodium album</i> extract	Antifungal potential on patogenic fungi	[79]
AgNPs	<i>Calotropis procera</i> leaf extract	Removal of Cr ³⁺ from petroleum waste water	[80]
ZnONPs	<i>Pontederia crassipes</i> leaf extract	Anticancer property	[81]
ZnONPs	<i>Dysoxylum binectariferum</i> Fruit Extract	Antimicrobial potential	[82]
ZnONPs	<i>Epipremnum aureum</i> leaves	Photocatalytic degradation of Congo red	[83]
ZnONPs	<i>Shilajit</i> aqueous extract	Anticancer activity against HeLa cells	[84]
ZnONPs	<i>Azadirachta indica</i>	Removal of carbamazepine in water and soil systems	[85]
ZnONPs	<i>Mariposa Christia vespertilionis</i>	Potential as anode materials in sodium-ion batteries	[86]
ZnONPs	<i>Vitex negundo</i>	Degradation of methylene blue dye	[87]
ZnONPs	<i>Syngonium podophyllum</i>	Efficient Cr(VI) removal	[88]
ZnONPs	<i>Allium sativum</i>	Efficacy against murine cryptosporidiosis	[89]
ZnONPS	<i>Solanum tuberosum</i>	Antibacterial agent in the active packaging	[90]
MgONPS	Lemon juice	Degradation of organic pollutants	[91]
MgONPS	Pumpkin seed extract	Against breast cancer cells	[92]
MgONPs	<i>Datura metel</i> leaves	Antimicrobial activity	[93]
MgONPs	<i>Terminalia catappa</i>	EBT Dye Removal	[94]
MgONPS	<i>Eichhornia Crassipes</i> leaf extract	Antibacterial activity	[95]
MgONPs	<i>Tagetes erecta</i>	Antioxidant potential	[96]
AuNPs	<i>Panicum Maximum</i>	Hepatocellular carcinoma	[97]
AuNPs	<i>Sphagneticola trilobata</i>	Anti-breast cancer	[98]
AuNPs	<i>Acorus calamus</i>	Anti-Alzheimer potential	[99]
AuNPs	<i>Moringa oleifera</i>	Lung cancer	[100]
AuNPs	<i>Crocus sativus</i>	Effect of antidepressant in adolescence	[101]

on *Lepidagathis ananthapuramensis* leaves and rubber leaf extract [71,72]. Even treating diseases such as cancer with silver and gold nanoparticles based on *Butea monosperma* leaf extract [73], and iron and silver nanoparticles synthesized using alcoholic *Blumea eriantha* DC plant extract.

Green nanomaterial synthesis uses nature as a raw material but returns to nature the advancements of new environmentally friendly materials. Researchers have created $\text{Nd}_2\text{Sn}_2\text{O}_7$ nanostructures using an innovative, easy and environmentally friendly technique that uses grape juice as a sustainable fuel. These nanostructures, produced at 500°C , have proven effective in destroying a contaminant called erythrosine under UV light, destroying about 90% of it. Still using grape extract, Pr_6O_{11} nanostructures were created in an environmentally friendly and simple way using ultrasound and grape juice as a sensing agent. After characterization, an electrode modified with these nanocrystals was developed to detect CHB. The combination of the large surface area and high performance of Pr_6O_{11} improved the accuracy in detecting CHB compared to the electrode without modification. The sensor showed a low detection threshold, high stability, wide measurement range and good reproducibility, proving to be a promising tool for clinical monitoring of CHB simply and effectively [102]. In addition, they created a nanocomposite of $\text{Nd}_2\text{Sn}_2\text{O}_7$ with Nd_2O_3 , which further improved the efficiency in removing the contaminant, reaching 96%. These green materials have the potential to help in water cleaning and environmental remediation, being a sustainable and efficient alternative for water treatment [103]. Still, in the area of environmental remediation, the study developed an innovative method using ultrasound to produce ceramic oxide (CeO_2) nanoparticles with glucose as a coating agent. This approach significantly improved their photocatalytic properties under visible light, achieving an efficiency of 97.2% in the degradation of the Acid Red 14 dye, much higher than the 9.7% of commercial TiO_2 . The nanocrystals also showed high activity against other contaminants, such as Amlodipine and Malachite Green, with degradation rates above 98%. In addition, they maintained their performance after multiple reuses, demonstrating durability and potential for sustainable applications in water purification [104]. The benefits of green syntheses lie in the mild conditions under which the routes are developed. In this work, a PL- $\text{Dy}_2\text{Ce}_2\text{O}_7$ nanostructure was created using an environmentally friendly approach. This nanocomposite was applied to screen electrodes to develop an effective sensor for detecting the MEZ drug. The sensor showed high efficiency due to the catalytic action and the large surface area of the nanoparticles, in addition to being stable and reproducible under room temperature conditions. This indicates that the sensor has potential for practical use in the pharmaceutical and biological fields [105]. In a study based on natural extracts, CL- $\text{Dy}_2\text{Ce}_2\text{O}_7$ nanoparticles were developed using an environmentally friendly and efficient ultrasound approach, using orange juice as part of the process.

With a uniform spherical shape, these nanoparticles were used to modify a liquid ion electrode, creating a high-performance sensor to detect IZN. The sensor presented a low detection threshold (9.0 nM), and a wide measurement range (from 0.02 to $340.0\ \mu\text{M}$), in addition to being stable, reproducible and selective. Tests on real samples showed that the method is promising for analytical applications, being an effective tool to determine IZN simply and reliably [106]. In the following study, peppermint extract was used as an environmentally friendly scavenging agent to quickly and easily fabricate cubic phase CeO_2 nanocrystals using ultrasound. Since the agent used is environmentally friendly and non-toxic, its application helps to reduce waste and environmental problems. Furthermore, CeO_2 nanocarriers showed potential in cancer treatment as they had cytotoxic effects on cancer cell lines (T98 and SHSY5Y) at various concentrations. These results suggest that CeO_2 nanocrystals may be promising as cancer therapeutics, although further studies are needed to confirm their potential [107]. In another cancer study, sponge-like ceramic dioxide nanostructures were produced using a fast and easy method with a natural agent called *Rosa damascena* extract. These nanostructures have high purity, good crystallinity and cubic structure. The nanocrystals showed strong and dose-dependent cytotoxic effects against the cancer cell lines T98 and SHSY5Y. Since a good chemotherapy treatment should attack cancer cells without harming healthy ones, the ability of the nanocrystals to specifically target cancer cells due to pH differences is an important advantage. The positive effects may be related to the secondary metabolites of plants used in green synthesis. Although further studies are needed, the *in vitro* results indicate that these CeO_2 nanocrystals have great potential as chemotherapeutic agents against invasive cancers [108]. In the food industry, this study presented a new fast and simple technique using mango extract as green fuel to synthesize dysprosium cerium oxide ($\text{Dy}_2\text{Ce}_2\text{O}_7$) nanostructures. These spherical nanoparticles with fluorite structure significantly improved the properties of WS/SSG composite films, making them stronger, with better water vapor barrier, UV protection, and thermal resistance. In addition, the films became more hydrophobic, which is ideal for food and pharmaceutical packaging as it reduces water susceptibility. These improvements are due to the unique properties of the nanostructures and the better adhesion between them and the polymer matrix. Future research can explore the addition of sorbitol to increase flexibility and evaluate antibacterial and antioxidant activities, in addition to ensuring the safety and biocompatibility of these films for direct use with food [109]. This study used lactose as an eco-friendly coating agent to quickly and easily fabricate $\text{Dy}_2\text{Ce}_2\text{O}_7$ nanostructures using ultrasound. These nanostructures were incorporated into WS/LPSM-based films, resulting in denser nanocomposites with improved properties. The films gained greater elongation, UV resistance, and lower water vapor permeability. The addition of Na-MMT nanoparticles together with $\text{Dy}_2\text{Ce}_2\text{O}_7$ maintained adequate mechanical strength. One of the films, with a low

concentration of $\text{Dy}_2\text{Ce}_2\text{O}_7$, stood out for its high elasticity and strength, showing potential for sustainable applications in food and drug packaging. The results indicate that the use of green methods in the synthesis of these nanostructures can lead to films with excellent functional properties, and future research can focus on large-scale production, optimization of nanoparticle proportions, and environmental durability testing [110]. This other study based on biopolymers such as cornstarch and pectin and AgNPs, demonstrated high efficiency in the synthesis of resistant and efficient plastic films against the action of microorganisms, effectively increasing food preservation, as proven in the article [111].

There are so many applications of nanostructures based on the green synthesis process, which are efficient, fast, low cost, eco-friendly, and potentially challenge science towards new paradigms associated with the detection and treatment of diseases.

Nanotheranostics: Nanoscale Diagnostics and Therapy

Theranostic Nanomedicine is based on nanomaterials that can diagnose and identify where the disease is located by implanting nanostructures in the diseased area and diagnosing a tumor by attacking the cancer cells. Nanostructures can highlight the damaged region, aiding in detection and subsequent treatment. Through photothermal therapy, it is possible to identify and treat tumor cells by irradiation and heating using gold nanostructures [112]. Studies indicate that AuNPs demonstrate a promising future in nanotheranostics for cancer therapy, a characteristic attributed to their atomic volume and high biocompatibility [113,114], in addition to demonstrating improvement in cancer detection, as it highlights the cancer cell efficiently and aids in therapy [115]. Another study predicts that AuNPs of around 15 nm are more efficient because their nanoscale can be internalized into the tumor cell, offering greater efficiency in treating Gliosarcoma [116]. Furthermore, the efficient participation of AuNPs in therapies for cancer immunotherapy represents hope for more efficient treatments in metastasis treatment [117]. A Nano flower can be advantageous as it increases the surface area and can, therefore, undergo more significant heating. Thus, the image obtained by photoacoustic spectroscopy, through the absorption of infrared light, generates the diagnosis of the tumor and is converted to treatment with the absorption of light by the nanostructure, combating the tumor cell [118]. Another study uses nanocarriers based on ZnONPs, which can deliver drugs and also be a theranostic platform, in addition to having antimicrobial activity, which makes them efficient structures for combining the usual treatments against chronic and infectious diseases in a single therapeutic platform [119]. Another nanostructure that is the focus of studies, as it efficiently combines detection and therapy, is Platinum nanoparticles. These can efficiently highlight tumor cells and prove to be a powerful platform for drug delivery [120].

Nanomaterials based on carbon also demonstrate effective crescent association with neurodegenerative disorders [121]. Furthermore, titanium dioxide nanotubes have proven efficient in bone regeneration, representing hope for orthopedics [122]. Magnetic nanoparticles have great potential for nanotheranostics since magnetic hyperthermia selectively heats tumors using alternating magnetic fields. Thus, magnetic resonance imaging (MRI) diagnosis occurs with greater sensitivity, and it is possible to vectorize drugs to release drugs directly to the affected site [123]. Nanotheranostics is gradually being introduced to the academic community as a strategy for conducting science more objectively, thinking about protocols capable of detecting and treating the problem. Through nanostructures that, in a combined manner, function as a nanosensor to detect the problem, and through the controlled release of agents that can remedy the problem in question. For example, this study suggests that it will be possible to produce a nanostructure with a shell morphology, capable of functioning as a nanosensor for situations associated with mental disorders. Mental disorders are often accompanied by signs indicating abnormal brain activity that can be detected by electroencephalogram (EEG). Therefore, it will be like brain waves to control the DNA origami nanorobots that promote the release of the drug. This nanostructure is manufactured with a "memory" that allows, upon a certain signal and stimulus, previously detected by electroencephalogram, to open the shell structure and release the drug to control the crisis, even before the patient is aware of the imminent outbreak. Thus, this nanostructure is a powerful sensor that, through the impulse sent by the synapses, allows the shell structure to open and the drug to be released early. This is nanotheranostics in action: detection and remediation in the same nanostructure [124-126].

Green Nanotheranostics: A Hope

Nanotheranostics represents an evolution in the world of nanoscience, as it presents an innovative bias based on the efficiency of action of nanostructures due to their high reactivity and surface area. In addition, the nanoscale allows for effective interaction between nanoparticles and the target, which makes a difference compared to traditional therapies. Carbon and gold-based nanobiosensors are highly efficient in detecting tumor cells, making excellent diagnosis markers. This efficiency is closely related to the interaction between the nanostructures and the sensor, increasing detection sensitivity [127-129]. Nanobiosensors are already established in the literature, and the diagnosis has proven to be very efficient. Thus, nanobiosensors have begun to be developed, based on green synthesis, as indicated by the evolutionary scale [130]. Many of the existing green chemistry-based sensors are not yet intended for disease diagnosis [131-133], but their syntheses are already well-established. However, the mechanism of action has still not been studied. The same is true when we evaluate studies associated with diseases based

on green nanotechnology. Potential nanostructures based on green syntheses that become allies in diseases such as cancer are already established in the literature [134-138]. Combining diagnosis and therapy based on green nanotechnology is still scarce. Although **Figure 4** shows about 19 thousand articles published on the subject, many refer to the first stage of the study. The process of assimilation of these nanostructures in the treatment is not yet understood, nor is the material's life cycle, even if it is eco-friendly. Gold nanoparticles, synthesized greenly, are the most widely used in green-based nanotheranostics. An easy, low-cost, environmentally friendly green synthesis makes it promising to diagnose and treat cancer [23]. Green AuNPs can be located in the tumor cell and heated by a near-infrared laser, and through biomimicry, they release drugs directly into the tumor cells, sparing healthy tissues. Silver nanoparticles also have the potential for green-based nanotheranostics. The green synthesis of AgNPs is established in the literature, and presents high morphological repeatability, in addition to efficiency and stability. However, there are few reports of their use in nanotheranostics. This scenario is closely associated with the context of mechanisms that link efficiency and toxicity, which minimizes their use as diagnostic and therapeutic platforms [139-141]. Zinc oxide nanoparticles based on green synthesis demonstrate potential in nanotheranostics, as their biocompatibility, stability, and low cytotoxicity have already been established, which are fundamental characteristics for nanotheranostics [142]. Overall, metallic nanoparticles are the most synthesized greenly and demonstrate high potential for the new era of green-based nanotheranostics [143,144].

Conclusion

This article has as its main responsibility the dissemination of a new stage in the area of nanotechnology that seeks to integrate the diagnosis of the problem and therapeutic action into the same nanostructure. The diffusion of nanotheranostics, on an evolutionary scale, is linked to more complete devices capable of integrating potentialities, which until now were carried out on a nanoscale in separate stages. For this, the synthesis routes of these nanoparticles need to present a kind of memory, capable of acting efficiently in the detection of the problem when synthesized, and that in the same nanodevice already present mechanisms that allow the treatment. In this way, a new way of thinking is established at the time of designing the synthesis of the nanostructure, so that it is conditioned to a morphology that allows it to respond to the stimulus and slowly and gradually release the solution to the problem. This new way of thinking is still not widely disseminated, and the paper's main intention is to stimulate research groups around the world with this new scope of production of nanostructures, capable of functioning as nanosensors and also treating the problem concomitantly. A stage associated with a diagnosis is eliminated in the process. And the treatment becomes immediate with that stimulus.

Nanoscience has opened up a promising field in science. The methodologies established in the literature are gradually evolving so that nanotechnology can effectively address urgent problems that, with globalization, are becoming worldwide. The evolutionary scale associated with the nanoscale has become more prominent since the surface area of particles interacts strongly with targets related to microorganisms. In addition, cancer cells, for example, are easily accessed at the nanoscale, which enables the identification and action of specific drugs. This is where nanotheranostics emerged, representing the future in research and solutions for global problems. In the current scenario, combining nanotheranostics with environmentally friendly protocols may become a new challenge for science. Thus, combining diagnosis and therapy based on nanotechnology and associating them with protocols aligned with the environment may represent a significant scientific advance in the coming years. The new era of nanotechnology brings therapy combined with diagnosis and hope. Thus, green nanotheranostics holds great promise for new challenges in the future.

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