Recent advances in the use of nanomaterials with antimicrobial capacity

Avances recientes en el uso de nanomateriales con capacidad antimicrobiana

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Abstract

The present study was carried out to analyze the importance of biofilms and nanoparticles in-depth due to the development of new practices where nanotechnology is reflected. It includes the production and application of Materials such as atoms or individual molecules, up to materials with dimensions of 100 nm (nanoparticles) in biological, physical, and chemical systems. A search for original and review articles in English and Spanish in the last ten years was carried out in the following databases: MedLine, Library Plus, ProQuest, NCBI, and ScienceDirect. The study of biofilms and nanoparticles remains in continuous evolution; due to the essential changes for humanity and the implications that these associations present in the various fields from medicine to industry.

Keywords: Nanoparticles, biofilms, microbial.

Resumen

El presente estudio se llevó a cabo para analizar en profundidad la importancia de biopelículas y nanopartículas, debido al desarrollo actual de nuevas prácticas en las que se refleja la nanotecnología, que incluye la producción y aplicación de materiales como átomos o moléculas individuales, hasta materiales con dimensiones de 100 nm (nanopartículas) en sistemas biológicos, físicos y químicos. Se llevó a cabo una búsqueda de artículos originales y de revisión en inglés y español en los últimos diez años: MedLine, Library Plus, ProQuest, NCBI y ScienceDirect. El estudio de biopelículas y nanopartículas permanece en continua evolución; debido a los cambios importantes para la humanidad y las implicaciones que estas asociaciones presentan en los diversos campos de la medicina y la industria.

Palabras clave: Nanopartículas, biopelículas, antimicrobiano.

Introduction

Through this work, you can see the importance that has acquired biofilms and nanoparticles. An analysis was conducted with 50 scientific articles, explaining in each of them the application that is given to these nanomaterials, such as the cleaning of a Residual water using nanoparticles, the prevention of various infections, among others, the lifestyle of biofilms, is present in all microorganisms and confers unique properties. The study of biofilms is essential to understand and thus carry out various processes related to microorganisms. On the other hand, the nanoparticles revolve around the improvement of existing materials and the innovation of new materials, they allow the creation of stronger, lighter, cleaner, and smarter surfaces and systems. Nanoparticles can be classified according to their origin in nanoparticles of natural origin (or ultrafine particles), incidental nanoparticles and artificial or fabricated nanoparticles. In nature they play a vital role, for example, the green synthesis of metallic nanoparticles has attracted many researchers, as it is a simple ecological approach that aims to reduce the use of substances dangerous to human health and the medium Environment.

Methods

An exhaustive search was carried out in PubMed, Scopus, Google scholar, and Scielo databases to find an article that related the recent advances in the use of nanomaterials with antimicrobial capacity. The search was conducted until January 2018. A text-mining step was carried out to detect citation-associated relationships between nanomaterials and antimicrobial capacity. It was considering the dates of publication and the country of origin.

These keywords were recognized through literature reviews using a wide variety of academic databases and search engines available online, such as GoPubmed (http://gopubmed.org/web/gopubmed/), pubGraph (http://datamining.cs.ucla.edu/cgi-bin/pubgraph.cgi), and helioblast (http://helioblast.heliotext.com/) and the analysis of associations among these terms was done in the PubMed/MEDLINE literature database was carried out using the Jaccard co-occurrence score, as a measure of the degree to which the two queries coincide among all publications.

Results

Also, are supported with recently published literature (Table 1).

Table 1. Recent advances in the use of nanomaterials

Application	Nanoparticle	Methodology	Results	Reference
Biofilms based on Chitosan.	Lanthanum lanthanum hexaboride (LaB_6).	The ethylene glycol dispersion was evenly coated on the surface of a standard glass slide (76 mm x 26 mm) using an airbrush. The slides were sintered in a tubular oven using a nitrogen atmosphere for 15 minutes at 260 °C.	The absorption spectrum characteristics were consistent with the absorption of the nanoparticles of LaB_6, which indicates that they could be used as material for the transmission of light efficient for the production of hydrogen by cells PSB CQK 01 and conversion of the Residual light in heat energy.	(1)
Removal of nanomaterials in wastewater	Copper oxide (CuO)	Wastewater biofilms used for CuO NP exposure experiments were previously cultivated in a simulated rotational biological contactor (RBC) for two months. The RBC reactors received flocculant sludge (5 g mixed liquor) and volatile solids/L). In this research, three concentrations of CuO were tested: 1, 10, and 50 mg/L	These results revealed that the nano-CuO aggregates' particle size increased with their mass concentrations ranging from 1 to 50 mg/L in these waters. Through the analysis of time resolved DLS (dynamic light scattering) and SEM (scanning electron microscopy), the aggregation of CuO NPS was observed in the wastewater samples	(2)
Biofilms of Staphylococcus	Nanoparticles laden with rifampicin	The formulations of the SLN (solid lipid nanoparticles) and rifampicin-sln were prepared by homogenization, high-shear ultrasound, and high pressure. Homogenization methods for the lipid phase were (HPH). GMS, Preciro, and stearic acid, were used Tween 80 and Poloxamer 188 as surfactants. The aqueous phase was prepared by dissolving Tween 80 or Poloxamer 188 in double distilled water at 10 mL	The data revealed maximal bacterial reduction with sln loaded rifampin, and in turn, differences between sln formulations and free rifampin ($P < 0.05$). The results imply that the biofilm cells were eradicated depending on the time ($P < 0.05$). Biofilms were more susceptible to higher formulation concentrations ($P < 0.05$)	(3)
Ecological water paint	Zinc oxide (ZnO)	The nanoparticles were produced by the pyrolysis process (FSP) through a spraying flame in a reactor prototype, which implies a production capacity of 100 g of pure nanopowder per hour. This process is quite attractive because it can use various precursors to synthesize a large spectrum of functional nanoparticles.	The ZnO-Ag nanoparticles possess significant antimicrobial properties against bacteria (*Pseudomonas aeruginosa, L. monocytogenes, Salmonella spp., S. aureus, and B. subtilis*). Besides, the antifungal activity of NPs was demonstrated using Aspergillus Niger.	(4)
Carbon biofilms	Titanium dioxide nanoparticles (TiO_2)	Using 304 stainless steel discs (diameter 6 mm and 1 mm thick). The films DLC and TiO_2 DLC (0.1 and 0.3 g/L) were produced using chemical plasma, enhanced vapor deposition. The pH of the solution was adjusted to 6.10 using HCl (0.1% v/v) and changing in the medium every three days.	Hydroxyapatite (HAP) was obtained in DLC films with and without incorporating the nanoparticles of TiO2. The presence of nanoparticles of TiO2 increased the graphite and decreased the disorder of the DLC.	(5)
Antibiopelícula of Green	Nanoparticles of (CuNPs)	Two chemical reduction methods synthesized the CuNPs: copper salt was used as an essential precursor, the gum Kondagogu extract as stabilizer, HH (hydrazine hydrate) as a reducing agent and L-ascorbic acid as an antioxidant. NaOH was used as a catalyst and adjusted pH.	The green CuNPs synthesis stabilized by gum Kondagogu extract has been successfully demonstrated at room temperature without using any inert gas atmosphere. The prepared CuNPs are stable due to the thin layer of rubber of the Kondagogu extract surrounded by nanoparticles.	(6)
Film of hybrid nanocomposites of chitosan oxide and graphene.	AgNP Silver Nanoparticles	The preparation of silver nanoparticles (AgNP) was made using an $AgNO_3$ precursor and starch reduction as a capping agent. The stirring solution was added and $AgNO_3$ to the starch solution to achieve a final concentration of 1 mm. Then NaOH was added to the mixture, stirring until the solution's color becomes dark yellow, confirming the formation of silver nanoparticles (AgNP).	The surface's nature plays a vital role in the inhibition of bacterial attachment on this, during the formation of biofilms, the study of wettability of these confirmed that the film of Nanocomposites GOns-CH-AgNP It has greater hydrophobia of the surface between all.	(7)
Prevention and treatment of orthopedic infections	Nanoparticles of Chitosan and Yodopovidona	The prepared nanoparticles were characterized By its size and potential zeta to obtain optimized polymers and concentration of TPP (sodium Tri-polyphosphate). For the preparation of CNPs-laden vancomycin. This was prepared by a similar protocol, dissolved in a chitosan solution. This using 0.1% of the solution for vancomycin encapsulation.	The diameter of CNPs was 276.4 ± 16.48 nm with 0.145 PDI for the combination of 0.1% chitosan and 0.5% TPP. The nanoparticles' size increased by increasing the concentration of Chitosan (0.15% and 0.2%). Hydrogel was formed by the crosslinking of alginate with divalent Ca_2 + ions.	(8)
Methylene Blue	Chitosan Nanoparticles	Chitosan (CSNPs) nanoparticles were produced based on the Ioni-gelling method, which consists of positively charged amino groups with electrostatic of Chitosan (CS) and opposite-loaded tripolyphosphate ions (TPP)	The results showed that the formation of nanoparticles was noted at very high or very low concentrations of CS and TPP. The biofilm quantification test using Violet crystal showed that all strains were strong biofilm producers under experimental conditions.	(9)
Fresh water biofilm	Titanium oxide nanoparticles (TNPs)	In this study, a stock suspension (100 mg-L) of TNPs, it was prepared by adding 0.1 g of the TNPs to 1 L of natural lake water (filtered through a membrane of 0.22 mm), at room temperature, the concentration of TiO ions dissolved in the dispersion m Edia incubated for 12 h under UV	The average particle diameters of fresh TNPs (50 mg L1) in Milli-Q water and fresh water were in the range of 87e226 nm and 198e372 nm, respectively. Differences in colloidal stability can be attributed to the influence of ions present in the medium of exposure.	(10)
Candida biofilms	Silver nanoparticles (Ag NPs)	Most of the nanoparticles were spherical in shape, the size oscillated between 3 and 80 nm. During the synthesis of the nanoparticles, the reaction mixture's color was changed from light yellow to dark brown, which indicated superficial excitation Plasma of AgNPs.	The metabolic activity was affected by about 20-73% in 24 h in different Candida species when treated with 100 ppm of AgNPs. Comparatively, a non-significant difference was observed in the enzymatic activities of different Candida spp. Against 100 ppm AgNPs	(11)
Biofilms in modern glass	Silver nanoparticles (Ag) and titanium dioxide (TiO_2)	Four random samples were taken from the panels using soft sterilized sponge pieces (1 cm^2), moistened in sterile deionized water, and squeezed into a syringe barrel to remove excess water. Stainless steel molds were used with cutting areas of 16 cm^2 for sampling a defined glass area.	Examination in the digital microscope showed that the primary colonization organisms on the glass surfaces were filamentous fungi, according to Drewello et al. (2000). They stated that the main groups of microorganisms that colonize modern glass surfaces are fungi.	(12)
Biofilm Bacterial	Zinc Oxide NPs	The bacterial activity of biofilms at different maturity stages was determined by an adenosine triphosphate assay (ATP). The content was quantified eight times to The first 24 h, with an interval of 3 H, and eight times between 24 and 72 h, with an interval of 6 H.	Substantial ZnO-NPs toxicity was observed (10, 50, 100 mg L1) for young biofilms that cause higher ATP reduction at 99% when biofilms with higher maturation levels were exposed to ZnO NPs, biomass ATP was lower than that of control.	(13)

Fluvial biofilm	ZnO + Zn^{+2} NPS	Several structural and functional parameters of algae, such as community structure, photosynthesis, and biomass, were used to estimate the conditions of biofilms affected by toxicity. The chlorophyll-a (CHL-a) concentration and the quantum yield of algae photosynthesis were analyzed with a Fito-PAM.	Zn^{+2} toxicity was found to be stronger and faster than ZnO nanoparticles due to the accumulation of these and the protective effects of EPS (extracellular polymeric substances) in the biofilm's particular structure. In turn, increased concentration in Ros production was observed about the level of control in biofilms due to ZnO and Zn^{+2} nanoparticles.	(14)
Candida albicans biofilm	Chitosan nanoparticles	Nanoparticles of chitosan-encapsulated ferulic acid, 10 mL each, were prepared. The concentrated FA variation was added to 1 mL of chitosan solution (1% w/v) with intermittent Vortex to obtain different nanoparticles' formulations. This mixture of 0.25 ml TPP (1 mg/ml) was added to the drop Wise to render the encapsulated Chitosan nanoparticles.	The particle size and the prevailing Zeta potential, governs the formation of a stable nanosuspension, since it influences large electrostatic repulsion between particles. The nanoparticles were synthesized and investigated by their size and dynamic light scattering techniques and FESEM analysis.	(15)
PVC fiber	Silver nanoparticles (Ag NPs)	Silver/silicon nanoparticles were synthesized by dispersing 1 g of Ag NPS in 200 mL ethanol. The suspension was treated with 7.7 mL of ammonium hydroxide while stirring gently. Then, 10 ml of Teos were added at 25 °C. The final mixture was vigorously stirred during 24 h. and diluted with acetone, centrifuged and decanted at 12,000 rpm for 15 min.	We determined the antibacterial properties of the membranes prepared qualitatively using the inhibition zone. The clean PVC had no antibacterial activity around the membranes without bacterial growth by the growth of bacteria on the surface in the PVC membrane.	(16)
Staphylococcus aureus biofilm	Gold nanoparticles (Au NPS)	The microorganism used in this study was MRSA (UTMC 1442). This strain was a clinical isolate recovered from a chronic wound and showed resistance to antibiotics: amoxicillin clavulanate, Oxacillin, Cefoxitin, ciprofloxacin, Gentamicin and Amikacin (30 mg). The strain was kept on a nutritious agar plate with regular transfers in a fresh medium.	The chemical with the reduction method synthesized the negatively charged gold nanoparticles. The results showed that MRSA was a strong strain of biofilm formation. Between different conjugates, MB/GNPs in the molar ratio of 20/1 (at a concentration of 33 mm and 185 ppm for MB and GNPs, respectively).	(17)
Biofilms of Salmonella	Nanoparticles of Chitosan	Chitosan nanoparticles were prepared by the Ionic crosslinking method using TPPas cross-linker. 1 mg of Ciprofloxacin was added to 10 ml of chitosan solution prepared in 1% acetic acid (v/v) and stirred at 500 rpm for 20 min at room temperature.	The MBC for ciprofloxacin, CCNPs was 10,400 and 600 g/mL, respectively. Also, intracellular antimicrobial efficacy of ciprofloxacin, cCNPs against Salmonella was determined using 264.7 raw macrophage cells.	(18)
Biofilms of Staphylococcus epidermidis	Polymeric nanoparticles	The biofilm formed on a 24-well plate was washed twice with purified water. It was treated with two types of NP suspensions (CS-PLGA NPS and CS-Sol NPS) at a concentration of 1.0 mg/ml in medium tryptone soy broth (TSB) supplemented with 0.25% glucose. The plaque was incubated for 4 H at 37 °C under 0.5% CO_2. The NP suspension was eliminated by aspiration and the buffered saline phosphate (PBS) (2 mL) was added to the plaque.	Through two novel techniques developed for Biological images It was possible to understand the intracellular behavior of NPs polymers, such as CS-PLGA NPs and CS-Sol NPS within biofilms. Using these measurement techniques without damage to biological materials, it was possible to avoid the long times of measurement thanks to the omission of the staining procedure.	(19)
Biofilms bacterial	Nanoparticles of Chitosan	Chitosan 6g were dispersed in 130 mL isopropanol and 4.8 g of NaOH (40%). Submechanical agitation (600 rpm) was added at room temperature for 20 min. Then, monochloroacetic acid (MCA) dissolved in 28.8 GOF Isopropanol was added under continuous agitation, and the reaction mixture was removed at room temperature by 24 h.	The results suggest that the subinhibitory concentrations of compounds were effective against the formation of biofilm. Action on virulence mechanisms is a promising target for new antimicrobial therapeutic approaches.	(20)
Biofilm of clinical Bacterial	Nickel oxide Nanoparticles	E. globulus sheets were thoroughly washed several times with tap water followed by DDW to remove particulate matter and other contaminants from the surface. They were cut into small pieces, and 20 g of chopped foliage was suspended in 100 mL of DDW. The extract in water was prepared by autoclaving for 15 minutes by pressure at 15 lbs.	All isolates of *E. coli* and *P. Aeruginosa* used in this study were potent BLEE producers. The NIO-NPS were evaluated simultaneously for their potential antimicrobial method. Through the antibacterial activity of the nanoparticles against a range of bacteria, the species varied considerably.	(21)
Antibiopelícula Clinical Bacterial	Silver nanoparticles (Ag NPS)	For preparation, bacterial isolates cultivated in nutrient broth were incubated in a rotating stirrer overnight at 37 ° C. After 24 h, the culture centrifuged at 10,000 rpm for 10 min. The supernatant was collected for the synthesis of silver nanoparticles. The antibacterial activity of biosynthesized AG-NPS proved favorable against some pathogenic resistant bacteria (*E. coli, S. aureus, P. aeruginosa, and K. pneumoniae*).	It was demonstrated that the silver nanoparticles biosynthesized by E. coli culture with the supernatant, which was spherical and an average size of 33.6 Nm. There were antibacterial and antibiopelícula effects of AG-NPS against *E. coli, P. aeruginosa, K. Pneumoniae,* and *S. aureus.* Biofilm components after exposure to AG-NPs reveal a low level of proteins, polysaccharides, lipids and nucleic acids compared with controls.	(22)
Nitrogen removal	Cerium dioxide nanoparticles	In this study, SBBR was employed with a working volume of 3l and 2,5L of wastewater treatment. During the cultivation period, each cycle comprised a 2-minute filling phase, 5 H of Aeration recirculation, 3 H of anaerobic reaction and 5 min draining. The combined packing acted as a carrier for the microorganism's attachment, which was suspended in the reactors.	This study reveals that long-term exposure to 10 mg/L of CeO_2 NPs significantly inhibited the elimination of TN and observed a lower inhibition in the SBBR that was punctured with the progressive concentration of CeO_2 NPs from 0.1 to 10 mg/L. Highly diminished microbial and enzymatic activities related to the impact of the gradient, PH level and ORP profiles and inhibition effects of CeO_2 NPs	(23)
Biofilm against *Pseudomonas aeruginosa*	Silver Nanoparticles Ag NPs	The silver nanoparticles of L. speciosa extract leaves were biosynthesized based on the easy process and its medicinal value. Approximately 20 g of dried leaves were cut into pieces and 0.10 g of silver nitrate were added to the extract slowly and continuous agitation for one hour at 75 °c. The reaction was maintained for incubation by one hour in the dark chamber to reduce the photographic activation of silver nitrate at room temperature.	It was observed during the qualitative analysis; That major secondary metabolites such as tannins, phytosterols, carbohydrates, alkaloids, terpenoids, among others, were found to be predominant, while gums and mucilage were found to be absent. L. speciosa leaves extract glucoside is responsible for an anti-inflammatory agent.	(24)
Using the Ed STÖBER method	Bioactive Glass Nanoparticles	Bioactive glass nanoparticles; They were prepared through the Sol-gel process, according to the method described by Xia et al. Teos (21.6 mL) was used as a precursor of silicon dioxide (SiO_2), distilled water (13.9 mL) and 2 M nitric acid (2.8 mL) (as a catalyst for hydrolysis), were mixed in ethanol of 50 mL. The mixture reacted by 60 min at ambient temperature in continuous stirring magnetically employing Teos acid hydrolysis.	The SEM micrographs of sun-gel derived crystals after incubation for 3, 7 and 14 days in SBF showed the formation of the typical morphology of the "cauliflower" formed on the surface from day 3. The SEM micrographs of BG without drugs, ag-doped and sun-gel-derived BGSG and AG-BGSG, showed that the sun-gel-derived BG, either doped or with AG, forms highly porous, very rough and irregular particles of the size of one micron.	(25)

Biofilms of wastewater	CeO_2 nanoparticles	Biofilm samples (0.5 g) were harvested at the end of each SBBR system's exposure and immediately stored at 20 º C until their DNA was extracted. This was removed using a E.Z.N.A. soil DNA kit (Omega, D5625-01, USA). The concentration of the DNA extract was determined by 0.8% agarose gel electrophoresis (w/v).	CLSM images demonstrated that the percentage of dead cells gradually increased with an increase in CeO2 NPS concentration. This study clarifies the responses of physicochemical and microbial properties of biofilms exhaustively from wastewater to chronic exposure in different concentrations of CeO2 NPs	(26)
Short-and long-term biosorption	Nanoparticles of FeO	Silica-coated iron oxide nanoparticles were used with a primary particle size of 25 nm. and a silica husk (SiO_2) that prevented the oxidation or release of iron ions. The nucleus and shell were expected to be stable throughout the experiment due to the low water solubility of the $scFe_3O4$-NP used at PH N3 values in aqueous solution at room temperature.	The detailed distribution of $scFe_3O4$-NP operation MBBR is demonstrated by a total equilibrium after 5 h, 18 h and 24 h of injection, according to EQ, from 24 h did not detect any change in the concentration of $scFe_3O4$-NP or the biosorption. This paper provides the first evidence about the fate of $ScFe_3O4$-NP in heterotrophic flow through some systems (flow cells, MBBR).	(27)
Modification of polymethacrylate (PMMA)	ZnO nanoparticles	The suspensions of both types of ZnO-NPs (hydrothermal, type 1 and Solvothermal, type 2) for the coating procedure were prepared in deionized water at a concentration of 0.1 wt% nanoparticles. The method to cover the PMMA samples using the powders of types 1 and 2 were identical. PMMA samples (13x13x2 mm) were immersed in the prepared ZnO-NPs suspension.	The implosion of the cavitation bubbles caused that ZnO-NPS, contained in the aqueous suspension, penetrated the plate's surface, forming a layer. The layers produced by ZnO-NPS type 1 and type 2 were stable and could not be washed due to the procedure made with deionized water. However, the Type 1 layer made up of small and large particles showed a much smaller uniformity, which may be due to a larger particle size.	(28)
Antibacterial biofilm	Ag nanoparticles	The content of AG in colloidal solutions P-AgNP was determined by titration Potentiometric, using the method of standard addition. A combined silver electrode consisting of a plated bar (diameter 8 mm) and a Mercury/mercury sulfate (Hg/Hg_2SO_4, saturated K_2SO_4) were used as reference electrodes (Radiometer analytical Code MC6091Ag-9). The measurements were made with a model Haita 903 and a potentiometer, with accuracy of ± 0.1 mv.	The qualitative mechanism of the synthesis reaction was investigated by FT-IR spectroscopy. The pectin's commercial powder spectrum shows a carbonyl absorption band in 1735 CM1, which is due to both carboxylic acid and ester in pectin groups. A less intense band at 1608 CM1 is attributed to the presence of some carboxylic acid groups. Finally, an excellent absorption in the CM1 of > 3000 due to adsorbed water and AOH stretch.	(29)
Biofilms of wastewater	Nanoparticles cerium	To perform the synthetic exposure experiment, a total of 1.9 L of sewage and 100 mL of suspension of NPs values were introduced into the reactors. The estimated quantities of NPs in wastewater varied from µg/l to mg/l, while their high affinity for microbial aggregates may inducing NPs accumulation.	Organic matter (represented by cod) and nutrients, including nitrogen and phosphorus compounds, dominate pollutants in the decreases in cod, TN and TP from wastewater in various experimental conditions.	(30)
Oleic acid Polymerized	Superparamagnetic nanoparticles	Epoxidized oleic acid, EOA, was obtained by the reaction of fat with formic acid in the presence of hydrogen peroxide, respecting the molar ratio of formic acid: Hydrogen peroxide: oleic acid. The synthesis was made in the presence of toluene to minimize the opening of the ring.	Oleic acid has an unsaturation between carbons 9 and 10. The high reactivity of this unsaturation allows the introduction of functional groups, especially the insertion of oxirane rings through the process of epoxidation.	(31)
Biofilm against clinical isolates	Nanoparticles of FeO	IO NPs were synthesized using the Solvothermal method. FeCl3 by 6h 2o 2.70 G and anhydrous sodium acetate 7.20 g were mixed with 100mL of ethylene glycol under 5h of vigorous agitation. A homogeneous yellow solution was obtained. It has been given to the automatic key of stainless steel lined with Teflon and heated to 200 °c for 8h. After that, the solution was cooled at room temperature and centrifuged at 10,000 RPM for10min.	Biofilms formation in biomaterial implants is a significant threat in the biomedical field. The biofilm secretes sexopoliméricas substances (EPS) comprising polysaccharides, DNA, and extracellular proteins. This layer is impervious to most antibiotics. OA-IONP can penetrate the EPS, break the cell membrane and inhibit the formation of the biofilm.	(32)
Cucumber biofilms	Nanoparticles of Chitosan	GC-MS determined co chemical compositions, and a fused silica capillary tube was used for separation. The temperatures in the injector and the detector were set at 250 and 280 °c, respectively. The initial temperature of the column was 60 °c for 2 min, and rose to 250 °c to 2 °c/min and remained at 250 °c for 5 min. The identification of the component was made based on massive spectral fragmentation.	The results showed that co nanoparticles and gelatin/CO CNPs nanofibers presented a significant eradication effect on E. coli O157: H7 in vitro biofilms. The CO CNPs were obtained when the initial concentration of CO was 2.5 mg/ml. Particle size distribution, PDI, zeta potential, and optimum CNPs Co encapsulation efficiency	(33)
Sulfate-reducing bacteria	TiO_2 nanoparticles	Nanoparticles of anatase TiO_2 (< 25 nm) were obtained from Sigma Aldrich. A stock suspension of NPS TiO_2 (100 µg mL − 1) was prepared in deionized water and sonication at 130 W for 10 min. The working concentrations of NPS TiO2 (0.25, 0.5, and 1 µg mL − 1) were prepared by adding adequate volumes (0.05, 0.1, and 0.2 mL, respectively) of the standard suspension to Baar media.	Nanoparticles of TiO_2 uniformly dispersed and spherical in the size of 30 Nm were observed. Through the stability study of NPs TiO_2 (0.25, 0.5, and 1 µg/mL) in Baar Media for the initial time interval (0 h) using a dynamic particle size analyzer, the concentration of the dependent increase in medium hydrodynamic size was observed only to 1 µg/mL of NP treatment of TiO_2 in all conditions.	(34)
Biofilm of *Enterococcus Fecalis*	Au nanoparticles	A qualitative phytochemicals analysis was carried out for the Determination of different kinds of components in the peel extract following the methods by Ghani. Chloroauric acid (HAUCL4) was used for the synthesis of AuNPs. It was mixed over 2 ml of peel Extract to 25 ml of HAuCl4 and remained at 353 K for 20 min. The characteristic change of color from pale yellow to dark red wine indicated the synthesis of gold nanoparticles	The qualitative phytochemicals analysis of the aqueous extract of The paradisiacal shell revealed the presence of tannins, flavonoids, quinones, phenols, steroids, and fitosteroides. After the AU ions reaction, the color change from pale yellow to dark red wine denotes the formation of gold nanoparticles. The stability of gold nanoparticles can be investigated using UV-Vis absorption spectroscopy.	(35)
Organic Dye Removal	Nanoparticle TiO_2	Some pan powders were dissolved in DMF at a concentration of 13 WT% and then submitted to magnetic agitation at 60 °c to obtain at 6h a homogeneous solution. The polymer solution at this concentration possessed an appropriate viscosity for the spinning electro.	The pan prepared with nanofibers on a smooth surface is immersed in the suspension solution. Nanoparticles of TiO2 surround it, and these nanoparticles are led to bombard the nanofibers under ultrasound and finally anchored on their surfaces.	(36)
Biofilms of *Pseudomonas Fluorescens*	Nanoparticles of Ti	To prepare nano TiO_2/PS composites, nanopowder of 0.01 $goftio_2$ (size O25 nm) was added to 10ml of Tetrahydrofuran (THF) and sonication for 30 minutes of ultrasonic bath (trans sonic460/437kHz). Dispersion mixed with 10% WT/Vol. The THF solution of the Pico Segundo (MW 192,000 g/mol) was agitated for 3h. The solvent was eliminated by the slurry casting in the glass and dried under environmental conditions for 24 h.	The XRD spectrum of Titania Nanopowders belonging to both anatase (JCPDS89-4921) and rutile (JCPDS 89-4920) of TiO_2. An average glass size was estimated at 14 nm using the Striker equation between Titania reflections in the spectrum of fractions of the film TiO_2/Ps exhibited, similar to those of nanopowder, which indicates that there are structural changes of the filling on the manufacture of Component.	(37)

Macro-Porous Carbon	TiO_2 nanoparticles	30% of the weight sucrose was used as a carbon precursor. The monodispersed SiO2 spheres were prepared by emulsion polymerization. The SiO2 colloidal glass was soaked in a sucrose solution (30 WT%) for 20 min. The colloidal glass template filled with sucrose dried at 80 C for 4 H, followed by 150 ºC for 6 h	It is shown that SiO2 particles were spherical with a uniform diameter of about 400 nm. After removing the template, the interconnected 3DOM frame consisted of macro-pores and mesopores, which was beneficial for transporting substrates and the internal colonization of bacteria to facilitate TSE (extracellular electron transfer).	(38)
Fresh water biofilms	TiO_2 nanoparticles	To explore the response phase of biofilms to NPS TiO_2 such as the production and chemical characteristics of EPS fractions and related toxicity mechanisms, three types of NPS TiO2 (50 mg/L, anatase, rutile, and P25) were used to be Exposed to mature freshwater in biofilms of the ball filters, respectively, in glasses with a suspension of 2 liters of sterilized water extracted from the lake to simulate a more realistic environmental exposure scenario, buffered with 10 mm	Concerning the effects of three NPS TiO_2 in the production of TB-EPS and LBEPS, first, the EPS fractions in biofilms exposed to UVC only (LB-eps increased by 8.9% and TB-EPS decreased by 2.2% compared to the control, respectively) or P25 (in the Dark) (LB-eps increased by 7.6% and TB-EPS increased by 16.4% compared to control, respectively)	(39)
Biofilm by Gram-negative bacteria	Ag nanoparticles	The precursor synthesis of the AG, Chlorotris Silver (triphenylphosphine) (I) (AG (PPH3) BalsÃ), was performed using a previously modified method. All other chemicals were purchased from Sigma Aldrich and used without further purification. The nanoparticle films AG was produced in the water toluene interface.	The XPS spectra in silver nanoparticle films are shown in composition with the elemental atomic percentage's surface. As expected in a silver film, the dominant element found is silver. The compulsory energy of the 3d 5/2 AG was found to be 368.8 EV. This is 0.5 EV higher than in the accepted reference value of 368.2 EV for Bulk AG.	(40)
Fungal biofilm	ZnO nanoparticles	Zinc oxide nanoparticles (ZnO-NPs) were prepared following the chemical method of wet briefly, the soluble starch of 0.1% was cooked in a microwave oven for use as the stabilizing agent, then 0.1 mol zinc nitrate and 0.2 mol hydroxide Sodium were added to the starch solution under stirring.	The four fungal species were inoculated on PDA plaques with increased ZnO-NPs concentrations (0, 0.125 and 0.25%) to assess the effects on plankton growth. P. Pinophylum was the most sensitive species with a reduction of 57% of growth diameter of p. Chrysogenum 36% A. Alternating 27%. The less sensitive fungus was A. Niger.	(41)
Modification of 1, 2, 3-triazole	Pd nanoparticles	Six types of PSU membranes were evaluated. These included four different concentrations of triazole (0%, 23%, 49% and 94%) functionalized to PSU membranes. They are called PSU-trin-0%, PSU-trin-23%, PSU-trin-49%, and PSU-trin-94% because only the PSU membrane Trin 94% can embed the ions PD and nanoparticles, the PSU-TriN-94% membrane containing palladium ions (PSU-TriN-ions) or palladium nanoparticles (PSU-TriN-NPs) were evaluated.	Triazole modification of the PSU membranes increased the PSU membranes' hydrophilic, except when PSU-TriN-94% was chelated with PD ions. The PSU-TriN-NPs membrane showed the highest hidrofília (47.7 °) compared to all other tested membranes, ranging from 58.6 ° to 84.3 °. Among all tested membranes, the PSU-TriN-NPs membrane had the rougher surface topography (RA = 58.9).	(42)
Momordica Charantia Fruit Extract	Ag nanoparticles	Approximately 200 g of fresh bitter pumpkins were collected from the district of Noakhali. They were thoroughly washed with double distilled water, cut into fine pieces and boiled in 1000 mL of distilled water for approximately 1h. The extract was cooled at room temperature and leaked In cotton and filter paper.	The result revealed that the extract contains a notable amount of alkaloid, phenolic, and saponin compounds and the aqueous extract *of M. Charantia*. We also found the presence of tannins, glycosides, proteins, sugar reducers, etc.	(43)
Hydrophobia modulation in antibacterial potential	Fe nanoparticles	For the synthesis of nanoparticles of magnetic iron (MNPs), thermal coprecipitation was adopted using $FECL_3$, $FeSO_4$, and 35% of ammonia solution. Briefly, 5.5 g of $FeCl_3$ and 2.75 g of $FeSO_4$ were weighed and dissolved in water (1 L). The solution was heated to 70 ∘ C for 30 min. 5 mL of ammonia solution was added until a black precipitate was formed (magnetite FE_3O_4)	The XRD analysis results shown in supplementary materials are following the typical pattern of γ-Fe_2O_3 as initially predicted from the change of its black to brown color. Transmission electron microscope imaging revealed that the size of MNP was 6 – 15 nm and that they were spherically shaped.	(44)
Fecal *Enterococcus* Removal	CA and CA nanoparticles $(OH)_2$	Twenty-one single, non-carious permanent premolar roots, extracted for orthodontic reasons, were used in 0.01% w/v of the Thymol solution until the beginning of the study. A coronal root segment of each tooth was prepared at a length of 4 mm by sectioning 1 mm below the enamel cement Union, using a diamond disc	In the Co, CH and positive control groups, CLSM showed formation of biofilm on the wall of the root canal and dense penetration of E. Fecalis, within the dentinal tubules, no dead bacteria were observed, in the negative control group, all the bacteria They died along a depth of 500 µm from the surface of the root canal.	(45)
Cathelicidina LL-37 and Ceragenina CSA-13	Magnetic nanoparticles	To obtain amino silane-coated magnetic nanoparticles, the coprecipitation of iron Salts and polycondensation of (3-aminopropyl) trimethoxysilane (APT). In the next step, Glutaraldehyde's reaction was carried out to obtain a CSA-13 immobilization platform through the Laminin junction.	The spectra of ATR FT-IR show several functional bands characteristic of the group, including bands Siloxal, Imina Bond, imide in the bands/carbonyl bond plane. The C-H stretching modes further confirm a silica shell's presence on the MNP surface and immobilization CSA-13/LL-37.	(46)
Nitrogen removal	CuO nanoparticles	Biofilm culture was carried out in SBBR with a volume of 3 liters, and activated sludge from the secondary sedimentation tank was inoculated with a concentration of 3000 mg/L in each reactor.	In the anaerobic treatment system with biofilms, most of the ammonia in the influent can be oxidized to nitrite and nitrate. Besides, the achievement of simultaneous nitrification and denitrification (SND) in a SBBR system can further decrease the concentrations of nitrite and nitrate.	(47)
Biofilms of *P. Fluorescens*	Ag nanoparticles	The Silver fluoropolymer nanocomposites (Ag-CF) were deposited in different substrates by spraying of PTFE a target (Goodfellow Ltd) and a pure white AG (Gambetti-Cerac, 99.999%) with ar + ion beams, at ambient temperature and a pressure of 10 PA	The Ag-CFx nanocomposites with different values were deposited as thick films of 150-nm, the TEM AG-CFx Films' images with a Φ value of 0.25 together with the distribution of the size of the silver nanoparticles and the inorganic nanophases. They have an average diameter of 9.0 ± 0.3 nm.	(48)
Marine and Freshwater microalgae	ZnO nanoparticles	Non-coated ZnO-NPs (20 Nm; 99.5% purity) were purchased as nanostructured dry powders and amorphous materials with a specific surface area of 50 m_2/g. ZnO-NPs with modified surfaces with 3-aminopropyl-Trimethoxysilane (A-ZnO-NPs) were synthesized in the Physics department nanomaterials Laboratory, using the same lot of powders of ZnO-NPS zinc oxide (ZnO) and zinc sulfate ($ZNSO_4$).	The types of particles, concentration, culture media, and PH of the media showed interactions in the four test particles (ZnO, ZnO-NPS, A-ZnO-NPS and D-ZnO-NPS). Particle dissolutions followed the order: ZnO-NPS > ZnO > A-ZnO-NPS > D-ZnO-NPS in both culture media at PH 7 and 8. The particles were dissolved better at ph 7 than at ph 8.	(49)
Resistance to *Staphylococcus Aureus*	Ag nanoparticles	TIO2 samples, ag-0, Ag-0.01 and AG-0.1 were soaked in 10 mL of medium TSB and freshwater without agar, in 15 mL of sterile microcentrifuge tubes, followed by successive incubation for 1, 4, 7 and 14 to 37 ° C. After each incubation period, leachates and quantities of silver, calcium ions, phosphorus and titanium were collected.	The apatite-forming capacity of an implant in a physiological environment plays an essential role in cell response and osteointegration. Through the in vitro immersion test in simulated body fluid (SBF), the superficial bioactivity of a biomaterial was estimated, the spherical clusters appeared on the surfaces of the AG-0 samples.	(50)

Conclusions

In this research, the different applications of biofilms and nanoparticles were observed, through studies carried out analyzes the important use of these materials, both in the life of the human being and in the Environment, giving place to the solution of various problems, they are also used in the cosmetics industry. Food, etc. In the case of biofilms, they have great qualities to eliminate polluting elements of the Environment, such as not requiring extra energy to work, not generating toxic waste in their biodegradation processes, etc. The impact they have on the various areas of man makes it worry about working continuously in them, also worth highlighting the vital role of nanoparticles, which have become materials that, thanks to their properties, can Modify the behavior of any other traditional material and provide features that will make it attractive for applications not previously thought.

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