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Properties of Antibacterial Nano Textile for Use in Hospital Environments

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Abstract**—**In hospital environments, there are several problems related to Healthcare-Associated Infections (HAIs), contaminated hospital textiles, can contribute to the spread and transmission of (HAIs), due to retention of viruses and bacteria. The antibacterial metallic nanoparticles immersed in hospital textiles can allow reduction of microorganisms. This paper presents a technological surveillance of the principal properties of antibacterial nanotextiles to be used in hospital environments, based on international standards. Initially, the search equation was determined for "antibacterial" AND "nanoparticle." Subsequently, the main properties were selected, by means of a multiple authors' review. Afterwards, the properties were related to international standards. Finally, we present the results found associated to the materials used to develop nonwoven textiles, and their properties for hospital environments, the sizes of samples and also the equipment required for characterization.

***Keywords* —** Nanoparticles, hospital environments, antibacterial, hospital textiles, non-woven textile, properties, Healthcare Associated Infections (HAIs).

Propiedades del nanotextil antibacteriano para su uso en entornos hospitalarios

Resumen**—**En los ambientes hospitalarios, existen varios problemas relacionados con las infecciones asociadas a la atención de la salud (HAI, por sus siglas en inglés), los tejidos hospitalarios contaminados, pueden contribuir a la propagación y transmisión de los HAIs, debido a la retención de virus y bacterias. Las nanopartículas metálicas antibacterianas sumergidas en tejidos hospitalarios permiten reducir los microorganismos. Este documento presenta una vigilancia tecnológica de las principales propiedades del nanotextil antibacteriano para uso en ambientes hospitalarios, basados en estándares internacionales. Inicialmente, la ecuación de búsqueda se determinó "antibacteriano" Y "nanopartícula". Posteriormente, se seleccionaron las principales propiedades, mediante la revisión de diferentes autores. Luego, las propiedades se relacionaron con los estándares internacionales. Finalmente, se presentan los resultados encontrados asociados a los materiales utilizados para el desarrollo de materiales no tejidos y sus propiedades para ambientes hospitalarios, tamaños de muestras y también el equipo necesario para la caracterización.

Palabras clave**—**Nanopartículas, entornos hospitalarios, antibacterianos, tejidos hospitalarios, tejidos no tejidos, propiedades, infecciones asociadas a la asistencia sanitaria (IAS).

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Propriedades do nano têxtil antibacteriano para seu uso em meios hospitalares

***Resumo*—**Nos ambientes hospitaleiros, existem vários problemas relacionados com as infecções associadas à atenção da saúde (HAI), os tecidos hospitalários contaminados, podem contribuir à propagação e transmissão dos HAIs, devido à retenção de vírus e bactérias. As nano partículas metálicas antibacterianas submergidas em tecidos hospitalários permitem reduzir os micro-organismos. Este documento apresenta uma vigilância tecnológica das principais propriedades do nano têxtil antibacteriano para uso em ambientes hospitalários, baseados em padrões internacionais. Inicialmente, a equação de busca determinou-se "antibacteriano" e "nano partícula". Posteriormente, selecionaram-se as principais propriedades, mediante a revisão de diferentes autores. Posteriormente, as propriedades relacionaram-se com os padrões internacionais. Finalmente, apresentam-se os resultados encontrados associados aos materiais utilizados para o desenvolvimento de tecidos não tecidos e suas propriedades para ambientes hospitaleiros, tamanhos de amostras e também a equipe necessária para a caracterização.

***Palavras-chave*—**Nano partículas, meios hospitalários, antibacterianos, tecidos hospitalários, tecidos não tecidos, propriedades, infecções associadas à assistência sanitária (IAS).

I. Introduction

The healthcare-associated infections (HAIs) represents a high problem in the hospital environments, due to viruses and bacteria adhere to the surfaces of hospital textiles, these microorganisms are derived from bodily substances, such as skin, feces, blood, urine and vomiting [1-5]. Current autoclave laundry and disinfection processes remove dirt but are far from sterile so they are not sufficient to interrupt the transmission of (HAIs) [6].

The nanotechnology is a science, that represents an opportunity to improve properties of materials, by means of the use of particles of sizes of 10-9m incorporated in them [7]. Nano-particles can be applied in textile material to provide properties such as (self-cleaning surfaces, stain resistance, water repellency, electrical conductivity, antimicrobial resistance, hydrophilicity or controlled hydrophobicity, wrinkle resistance, anti-static, anti-odor, fire resistance, UV radiation protection, abrasion resistance, shrink resistance, etc.) [7]. Nanoparticles have a high surface area ratio and a high energy surface, have a better affinity for the fabric, due to of their nanometric size penetrate deeper into the fibers [8].

Metal and metal oxide antibacterial nanoparticles immersed in textiles provide protection properties against microorganisms [9]. A type of metal antibacterial nanoparticle is those silver (Ag), its microbicide mechanism acts suppressing respiration and microbial basal metabolism, inhibiting its multiplication and growth [10]. The application of silver nanoparticles in textiles makes them resistant to odors, so they are applied in socks in order to inhibit the growth of bacteria [8].

The oxide metal antibacterial nanoparticles are Titanium dioxide (TiO2) and Zinc oxide (ZnO) these have photocatalytic activity, being irradiated by ultraviolet light with greater energy than their band separations, electrons and holes interact with the oxygen and H2O molecules that are adsorbed on the surface of the nanoparticles to produce reactive oxygen species (ROS), hydroxyl radical, etc., which interfere with the organic material by decomposing the bacteria [7, 11-17].

Non-woven textiles are widely used in hospital environments due to their random fiber conformation, filtration capacity, permeability and porosity [18-20]. The properties of the nonwoven textiles with antibacterial nanoparticles incorporated in their fibers are the reason of the present study, in which a technological surveillance was developed around the subject.

II. Methodology

A technological surveillance was developed using the search equation with the terms "antibacterial" and "nanoparticles" through the use of the Scopus database, these contains the largest bibliographical references of scientific literature, with over 18,000 titles from 5,000 international publishers [21]. The term "Antibacterial", and the term "nanoparticles" produces 4,099 results. In order to limit the results, the term "electrospun" was added to the search equation, which produced a total of 93 results.

A. Analysis of documents by author. Between 2007 and 2017, 10 authors have published about the properties that antibacterial nanoparticles offer to nonwoven. Among the most relevant authors are Kim, H.Y. with 4 publications, Pant, H.R with 4 publications also, Bai, J; Cui, W; Fan, C; Heo, D.N; Kim, C.S; Kwon, I.K; Lee, S.J; Li, C; with 3 publications each one of them (Table 1) [22]:

The Fig. 1, shows the relationship between the authors and the total number of articles associated with each of them [22]:

Table 1. Authors and Documents

Author	Number of documents
Kim, H.Y	4
Pant, H.R	4
Bai, J	3
Cui, W	3
Fan, C	3
Heo, D.N	3
Kim, C.S	3
Kwon, I.K	3
Lee, S.J	3
Li, C	3

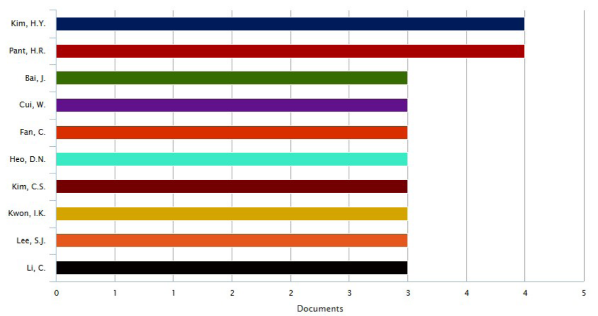

Fig. 1. Documents by author

B. Properties analyzed by authors. Technological surveillance will be approached from the 10 authors mentioned above, due to it is pertinent to consider the properties antimicrobial of nonwoven fabric for hospital environments, these authors recognize the characterization of this type of material as their main objective.

1. Weight: Mass per unit area (g / m^2), It was measured by dividing the mass and area of this material [23-25].

2. Thickness: Sample thicknesses were measured using a digital micrometer with an accuracy of 1μm. 10 parallel measurements were taken for each sample and mean values were used as the film thickness [26-31].

3. Air Permeability: This procedure allows the measurement of the amount of air sucked laterally between the ring and the sample. Air permeability is expressed in units of millimeters over seconds (mm/s) [23, 30, 32-35].

4. Contact angle measurement (WCA): Is a procedure to calculate the surface properties (surface tension and dispersion) of a polar or non-polar liquid on a substrate [27, 36, 37].

5. Water Absorption: This method determines the relative water absorption rate of the plastics when they are submerged [23, 37, 38].

6. Stability of nanoparticles: Accelerated washing tests evaluate color fastness and staining of all types of textiles. This test is used to investigate the stability of the nanoparticles in the samples. The samples are tested under suitable conditions of temperature, detergent solution, bleaching and abrasive action in such a way that the color change is similar to that which occurs in five hand-washing with or without chlorine [39, 40].

7. Water vapor permeability (WVT): This method allows to determine the passage of water vapor through plastic films, which are not more than 32mm of thick [23, 30, 31, 33, 34, 41].

8. Flammability test: This procedure makes it possible to determine the response of the polymer materials to the flame under controlled laboratory conditions, thereby indicating their acceptability with regard to flammability for a particular application [42].

9. Tensile Strength: This procedure allows the determination of the maximum tensile stress that the nonwoven material can withstand before breaking [27-29, 43-45].

10. Abrasion resistance: This procedure quantitatively determines the duration of the nonwoven in its normal use, subjecting it under laboratory conditions to an Martindale abrasion tester [23].

C. Relationship of properties with international standards

The properties mentioned by the authors are related to international standards (Table 2), in order to provide a higher quality applicable to non-woven textiles containing antibacterial nanoparticles, improving the healthiness in the hospital environment.

Table 2. Relationship of Properties with International Standards

Properties	International Standards
Weight	NTC 2598- EN29073-1
Thickness	NTC2599-EN29073-2
Air Permeability	ASTM D737
Contact angle measurement (WCA)	ASTM D7490
Water Absorption	ASTM D570
Stability of nanoparticles	AATCC 61 2(A)
Water vapor permeability (WVT)	ASTM E96
Flammability test	UL94
Tensile Strength	NTC 2600- ISO9073
Abrasion resistance	ASTM D3884

III. Results and Discussion

In this study, a technological surveillance was developed around the subject of the properties of non-woven textiles with antibacterial nanoparticles incorporated, for use in covers and curtains of hospital environments. Among the most notable results are the materials used to develop nonwoven textiles, the sizes used for the evaluation of the properties and the equipment used for their morphological and mechanical characterization.

A. Materials used to develop nonwoven textiles.

The authors in their respective studies developed nonwoven textiles from different materials according to their properties and the application of these (Table 3).

Table 3. Materials Used to Develop Nonwoven Textiles

Materials	Properties of materials	Application of nonwoven
Nylon (PA6) 6-Polyamide 6	It is a biodegradable, biocompatible and synthetic polymeric material that has good mechanical properties, such as its hardness, elasticity, toughness and resistance to abrasion, wear, oils, heat and chemical and the capacity of easy processing.	It is used in automobile parts, wipes, battery separators, synthetic suede, brush bristles and protective garments. Nanofibers of nylon-6 have been reported as effective means of water filtration.
Gelatin type A	It is a polymer with compositions and biological properties almost identical to those of collagen, it is soluble in water and economical.	Gelatin nanofibers are used for tissue scaffolds, wound healing, health care devices and other biomedical applications.
Polyimide (PI)	PI are a class of high performance polymers that combine high thermal stability with good mechanical properties, heat resistance and chemical resistance to solvents.	It features various applications, including protective clothing for firefighters and filtration membranes.
Polyurethane (PU)	It has properties such as low temperature flexibility, abrasion resistance, controllable hardness, transparency, and excellent hydrolytic stability.	Polyurethanes have been used in garments and textile coatings for garments, such as raincoats and industrial safety clothing..
Polylactide (PLA)	It has excellent mechanical properties, is compostable, biocompatible with respect to cells, tissues and organs and is biodegradable.	PLA can be used to prepare foams, films, fibers and nonwoven.
Polyester (PET)	It is semi-crystalline, transparent and thermoplastic with high strength.	It is widely used to produce fibers, films and packaging materials with high barrier properties, clothing, and industrial fabrics.
Agar, k-carrageenan and carboxymethyl cellulose (CMC)	They are biodegradable, biocompatible, renewable annually and abundantly available.	With good property of formation of antimicrobial films.
Poly (lactic-co-glycolic acid) (PLGA)	PLGA formed by polyglycolic acid (PGA) and polylactic acid (PLA) is biocompatible and biodegradable material.	It is used as a platform for the release of TiO_2 nanoparticles into the environment.
Polypropylene (PP)	The fibers are economical, lightweight, have high chemical resistance and high absorbency.	It is used for sanitary applications such as surgical masks, diapers, filters, bands, etc., that need to show antibacterial effects.

This table indicates that both synthetic and natural polymers are being used for use in hospital environments due to their biocompatibility and biodegradability as well as good mechanical properties. Nylon-6 is the most widely used polymer for the creation of non-woven antibacterial textiles as indicated by multiple authors, so further research is recommended around this material to better understand their properties with embedded nanoparticles.

B. Properties, sizes and equipment

In various articles analyzed in the present investigation, about the properties of nonwoven textile with antibacterial nanoparticles immersed in it. The authors reported sample sizes used for their characterization and equipment to develop these assessments (Table 4).

This information allows to clarify for each one of the properties of the non-woven, the required sample sizes, and the necessary equipment to develop their respective characterization, in order to provide tools that allow to speed up their analysis.

Table 4. Properties, Sizes and Equipment

Properties	Sample sizes	Equipment
Weight	Three test pieces,each of a minimum area of 50,000 mm^2	Scales
Thickness	Three test pieces, each of a minimum area of 2500 mm^2.	Micrometer
Air Permeability	Ten circular test pieces, each of a minimum area of 5 cm^2.	Frazier Air Permeability Tester
Contact angle Measurement (WCA)	Three test pieces, each of A minimum area of 3 * 10 cm.	Contact angle analyzer
Water Absorption	Three samples of diameter 1,5 cm and a thickness of 1 mm	Dryer oven Scales Watch crystal
Stability of nanoparticles	Three sample sizes 50 x 150 mm	Atomic absorption spectroscopy.
Water vapor permeability (WVT)	Three circular sample sizes (7.5 * 7.5 cm)	Vaporometer - permeameter
Flammability test	Three samples of length 125 mm * Width 13 mm * Thickness 1.5 mm	Test equipment for flammability of 45 degrees, or vertical.
Tensile Strength	Five test pieces of 50 mm + -0.5 mm wide. With a length sufficient to allow separation of jaws of 200 mm.	Universal machine
Abrasion resistance	Ten square samples of approximately 15 cm	Martindale abrasion tester

V. Conclusion

The objective of this research was to construct a technological surveillance as a basis for studying the nonwoven textiles with antibacterial nanoparticles immersed in their fibers, in order to better understand the properties that improve in these to be reinforced, different authors have addressed the topic of non-woven textiles for various applications including tissue regeneration membranes, water filters, and protective clothing.

Between 2007 and 2017, the number of publications in this field increased significantly, especially in specialized journals with materials, chemistry and biomedical sciences. The countries with the highest number of papers between these years are China with 28 papers and Korea South with 24 papers, but in Scopus there are no reports yet of Colombia, which makes it necessary to increase the R & D processes in our country to provide healthy improvements in hospital settings. At present, only 6 articles produced in Colombia are reported in Scopus in relation to the subject of non-woven mainly in applications of water filters in engineering applications, coatings for Stents in health applications and Geotextiles in applications of earth sciences. Therefore, it is necessary to explore in greater depth the properties of non-woven to be used other multiple applications among them in a hospital environment.

The properties analyzed by the different authors for non-woven textiles are associated with the standard NTC 5366 "Textiles for hospital and institutional use", which describes the minimum requirements that a textile for hospital use must meet. By associating properties with international standards, higher quality can be provided to non-woven textiles through characterization tests.

Various types of natural and synthetic polymers have been used to develop non-woven textiles, according to their properties they present a variety of applications in the biomedical field. International standards for non-woven fabrics specify the appropriate sample sizes and equipment for the characterization protocols. In future studies, the durability of the nonwoven fabric and the time of effect of the antibacterial nanoparticles could be considered, in order to provide more information regarding the useful life of this type of reinforcement.

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