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Opinion

The Development of Antimicrobial Textiles By Green Synthesis Involving Activities in the Discovery and Applications of New Antimicrobial Agents

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Abstract

The present time should focus on integrated hybrid models to advance and provide solutions that promote sustainability in textiles that is becoming an important issue and prevent problems with the control of the undesirable effects of microbes (bacteria).

Introduction

Arreche et al. [1] evaluated the fungal growth resistance of waterborne coatings obtained with siliceous solids as additives, by a procedure similar to the standard method ASTM D5590 [2]. An electrochemical point of view to understand microbial inhibition of corrosion, suggesting that the role of microorganisms can be compared with the role of corrosion inhibitors used in corrosion control [3]. The direct addition of metallic nanoparticles in an acrylic waterborne paint was evaluated [4,5], in one work is focused on materials that can provide solutions to biodeterioration by synthesizing hygienic paints with antimicrobial additives, such as Ag inclusion in silica-based materials [6]. Textiles are known to be the best substrates for growing a variety of microorganisms efficiently at appropriate temperatures and humidity in contact with the human body [7]. Currently, increasing public concern about hygiene has been driving many investigations about antimicrobial surface modification of textiles. Lee et al. [7] have recently reported that mechanical signals may be exploited to control growth factor release from hydrogels, and this could provide a novel approach to guide tissue formation in mechanically stressed environments [8].

Human skin contains a complex mixture of microorganisms, even with "clean" skin that has a typical population of between 100 and 1000 microbes/cm^2. But when ideal growing conditions are provided, microbes multiply rapidly and can preferentially cause problems with odor generation, loss of yield, discoloration of textiles, and possibly infection [9]. For the antimicrobial activity test, a first general classification of the method to be used is carried out depending on the type of evaluation of the microorganism population. Reduction to intimate contact with an-agar culture medium inoculated with the test bacteria (DIN EN ISO 20645 - 2001, AATCC 147). If diffuse, or leaching, antibacterial activity is present, it will be possible to observe a clear area around the treated sample compared to the surrounding area of bacterial growth and the untreated control sample after the same contact time. However, this method cannot be applied to non-diffusible or fixed antimicrobial substances [10].

Agar diffusion method (SN 195920-1992)

To study the antibacterial efficacy of the impregnated fabrics, the agar-based diffusion method was used (SN 195920-1992). The bacterial strains to be tested were *E. coli* and *S.*

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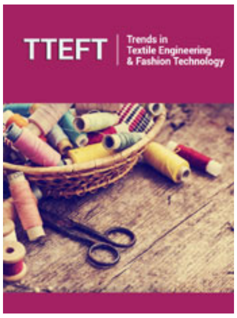

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aureus. They were selected because they are abundant in the environment and are related to pathologies that affect human health. The MCAB culture medium used consists of 5g of NaCl, 5g of yeast extract, 10g of casein peptone and 15g of bacteriological agar for 1l of distilled water. Then, plates were prepared with 15ml of the MCAB culture medium and inoculated with the previously prepared inoculum, which was spread throughout the plate with sterile swabs. Lastly, the treated and untreated fabrics were added. The plates were incubated for 24 h at 37 °C [10,11]. The inoculum was made from 24h cultures that were in an oven at 37 ºC. Suspensions with physiological solution were obtained by adjusting the turbidity to 0.5 of the Mc Farland scale ($1.5x10^8$Ufc/ml). Then a dilution was carried out to obtain a bacterial suspension of $1.5x10^6$. Once the incubation period of the plates inoculated with the selected strains had elapsed, the Zone of Inhibition (ZOI) was recorded.

Pad-dry-cure method

In Figure 1 the photographs of the test and those observed through the magnifying glass of the fabrics against *E. coli* are shown. It can be seen that there is a halo of inhibition that is identified as a contiguous space to the fabric that only has culture medium (transparent). There are no noticeable differences regarding the ZOI measurements of the fabrics containing the additives despite the washing cycles, therefore it can be concluded that the impregnation method has high durability against washing. Taking into account the ZOI values, 0.6±0.2 for KBI and 0.7±0.2 for K3BI (K: silica; B: basic hydrolysis; I: impregnation; lav: washes), it can be said that after 20 washing cycles there is a decrease in the antibacterial effect. In Figure 1 the photographs of the agar diffusion test against *S. aureus* are shown, in which an inhibition halo is observed for the fabrics impregnated with the biocide while in the control fabric there is growth throughout the plate. The photographs obtained through the magnifying glass clearly show the fabric-culture medium-bacterial growth interface for the fabrics with biocide, thus affirming their inhibitory effect. Regarding the washing cycles, they have the same tendency as that described for *E. coli*, producing a slight decrease in the activity only in the washing cycle number 20 [12,13]. Since most of the works focus on the inhibitory effect of Ag against bacteria, the mechanisms of inhibition or lethality of surfaces with antifungal compounds are poorly understood. But it is observed, in practically all the works on this subject, a generalization of the mechanisms of action against both fungi and bacteria [14,15].

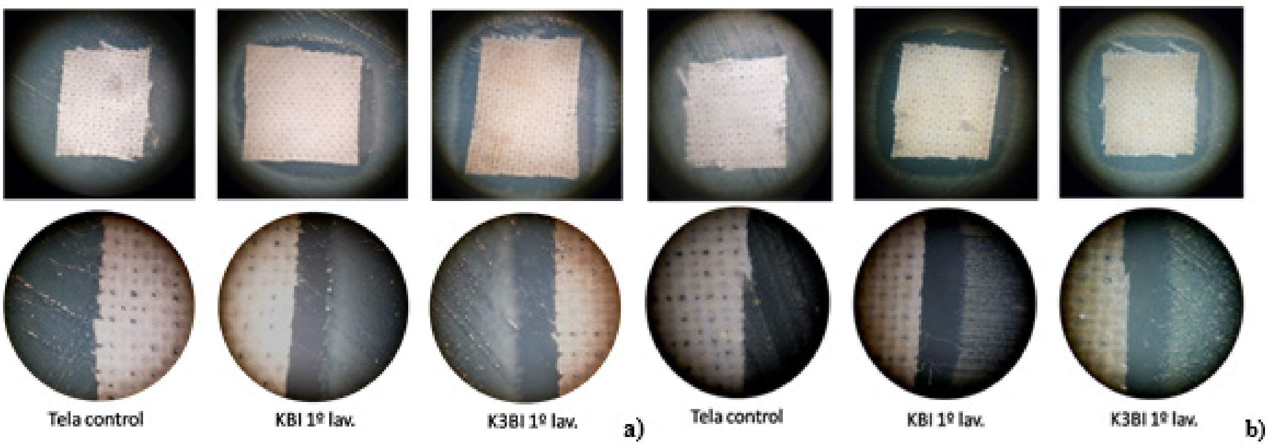

Figure 1: Photographs with a magnifying glass of the control fabric and the fabrics impregnated with the pad-dry-cure method, tested against *Escherichia coli* (a) and *S. Aureus* (b) [10].

Sustainable strategies to improve the level of antimicrobial fabrics

The development of antimicrobial textiles has been one of the most active and important research areas in recent years, involving activities in the discovery and applications of new antimicrobial agents, new functional fibers, new chemical finishes and nanotechnologies. Antimicrobial textiles are expected to be able to address many challenges ranging from the increased spread of infectious diseases, especially drug resistant ones, around the world, including bacteria, viruses, spores and fungi to concerns about common hygienic issues such as microbes that generate odors in clothing and hospital clothing [16]. Due to the vastly diversified applications of antimicrobial textiles and the expected roles for the intended uses of textiles, significant progress has been made in recent years in the development of new antimicrobial agents and technologies A review of clothing microbiology [17]. In addition to the power of antimicrobial functions on textile products, the durability of the functions is a tough challenge, especially the washing and storage durability. Differing from other functions on textiles, antimicrobial agents or functions are consumed daily and continuously since fabrics and clothing are always in surface contact with microorganisms [18]. The options to solve the challenge are either incorporating an unlimited supply of the agents to textiles or frequently replenishing the agents on the textiles, otherwise the functions could be lost as the products are used and left in the air during storage. In recent years, increased consumer demand for hygienic clothing and athletic wear, as well as the need to reduce HCAIs, has made the antimicrobial textile industry one of the fastest-growing markets in the textile sector [19].

Present and uncertain future during the pandemic

The global COVID-19 pandemic has attracted considerable attention toward innovative methods and technologies for suppressing the spread of viruses. Although significant efforts have been made to develop antibacterial surface coatings, the literature remains scarce for a systematic study on broad-range antiviral coatings [20]. In the context of the spread of the virus that causes COVID-19, the global public has become hyper-aware of one instance in which clothing and microbes are related, the use of masks to prevent pathogens (in the case of COVID-19, viruses) from travelling from one person to another. Laundering, along with the rising interest in maintaining the efficacy of laundering for the removal of soils and microorganisms, while minimizing its environmental impacts by means such as reducing water temperatures, is another instance in which people have become acquainted with the notion of microbes in textiles. However, the relationship between clothing and microbes is far broader [21]. With this in mind, the notion of a circular model of textile production rather than the current linear economy model has begun to gain traction over the past several years. In the linear model, resources are extracted, processed, distributed, consumed and ultimately discarded as waste. By contrast, the circular model aims for an economy in which textiles are maintained at their highest value during use and re-enter the economy after use to reducewaste [22].

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