Biocidal Textiles and Prevention of Transmission of Infectious Diseases

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Transmissions of infectious diseases such as methicillin-resistant *Staphylococcus aureus* (MRSA) in healthcare facilities have been an important and urgent challenge to infection control community. A recent study revealed that MRSA infections in US academic medical facilities have doubled during the years of 2003-2008 [David, 2012]. MRSA can be transmitted by surface contacts of persons to devices and person to person. Most of the transmissions are linked to textile materials such as bed linens, towels, dresses, and surgical uniforms [Fijan, 2012; Dancer, 2008]. More importantly, people in hospital environments including healthcare workers and patients are potential carriers of *Staphylococcus aureus* (SA) and MRSA, and experimental results have revealed that SA lives on human bodies in pretty high rates regardless ages, genders, and professions [Wertheim, 2005]. Nasal carriage of SA has been the most important source of the disease with 100% rate on all human SA carriers, and has been more frequently found from nurses than physicians. These facts just confirmed that healthcare workers are sources of pathogens, and with these moving sources available the infection control is indeed a complicated and difficult mission to accomplish in hospitals [Albrich, 2008].

Meanwhile, pathogenic microorganisms carried by human bodies could be transmitted by hand touching noses and then textiles or other surfaces, possibly spreading them to all areas [Munoz-Price; 2012]. Eventually, hand hygiene has been considered critical in infection control [Weber, 2010], however, only has limited effect if the bacteria reservoirs are always available for the hands. Furthermore, microorganisms could survive on medical textiles for weeks and months and can contribute to secondary transmission from these materials to hands and other surfaces [Blanchard, 2009; Galvin, 2012; Maclean, 2010].

According to the transmission paths of pathogens, if surfaces of textiles and devices possess antibacterial functions that can provide instant kill to any germs transmitted onto the surfaces, such materials should be able to cut off the chain reactions of transmissions and consequently reduce the cases of infections [Dancer, 2008; Cardo, 2010], and such functions have been considered as a necessary protective measure on all medical textiles including uniforms, dresses, bed linens, curtains, and furniture [Dancer, 2011]. During the entire life and repeated uses, the antibacterial medical textiles should rapidly and continuously kill any pathogens upon contact so as to provide the absolute clean surfaces. Thus, the killing power, speed, durability and effectiveness of the functions against a range of microorganisms such as bacteria, viruses, and even spores, would be critical and very important to be evaluated, and such functions are naturally different from the needs for consumer products.

Antimicrobial functions on materials could range from general inhibition of microbe growth on the surfaces to complete elimination of microorganisms. If textiles could quickly and completely inactivate all microorganisms within a certain range of bacterial cell density (10^{3-5} colony forming units) in a relatively short time (< 30 min), the term of "biocidal" function can be used to describe it. Longer contact times to inactivate the pathogens could leave more opportunities for potential transmission during the course of the function, which is not considered as perfect antimicrobial properties. Rapid elimination and inactivation of entire microorganisms on the surfaces of textile are the mostly desired functions on medical textile and devices. Thus, regular antimicrobial textiles that could only inhibit growth of microorganisms during a long contact time are not enough in prevention of cross-transmission of pathogens, though such functions are effective in reducing biodegradation of the materials or for odor control applications. Thus, it is absolutely necessary to differentiate the antimicrobial functions based on the power of the functions, as well as the intended applications.

A recent clinical study demonstrated the use of antimicrobial medical scrubs could reduce bacteria populations on the materials but did not provide complete elimination of microorganisms (Table 1) [Bearman, 2012]. The differences of log colony forming unit (CFU) were quite significant, particularly for MRSA, indicating the antimicrobial functions. But, the residual live CFUs of MRSA were also significantly high. Such a result is consistent with the mechanism of antimicrobial functions and potential outcomes offered by biocides on the textiles, not possessing rapid and powerful biocidal ability.

Table 1. Comparison of Difference in Apparel Mean Log Colony-Forming Unit (CFU) Count Overall [Bearman, 2012]

Mean log CFU count on overall samples					
	Study (samples, *n*)	**Control (samples, *n*)**	**Difference**	**SE of difference**	***P***
MRSA					
Leg cargo pocket	6.71 (12)	11.84 (16)	5.13	1.1493	0.0002
Abdominal area	7.54 (25)	11.35 (25)	3.81	1.23	0.0056
VRE					
Leg cargo pocket	0 (0)	12.68 (1)	12.68	NA	NA
Abdominal area	12.68 (1)	12.27 (5)	0.41	2.8917	0.9013
GNR					
Leg cargo pocket	4.41 (1)	13.02 (1)	8.61	NA	NA
Abdominal area	9.14 (3)	10.36 (2)	1.22	3.4376	0.7569

Halamine polymers and treated textiles all demonstrated powerful and speedy biocidal functions against a broad spectrum of microorganisms. Halamine polymers have been developed into solid drinking water disinfectants and received EPA approval in 2009. Halamine treated cotton fabrics have been widely used in dish cloth, incontinence pads, wipers and mops, medical uniforms, and bed linens. Biocidal functions of halamine treated cotton and cotton/polyester fabrics were proven excellent, both in killing speed and log reduction (Table 2) [Sun, 2001].

Table 2. Biocidal functions of halamine treated cotton fabrics [Sun, 2001]

Microorganism	Log Reduction		
	Contact time	Cotton	Cotton/PET (35/65)
E. coli	2 min	6	6
Staphylococcus aureus (SA)	2 min	6	6
Salmonella choleraesuis	2 min	7	6
Shigella	2 min	6	7
Candida albicans	2 min	6	6
Brevibacterium	2 min	8	8
Pseudomonas aeruginosa	2 min	6	6
Methicillin-resis. SA (MRSA)	2 min	3	6
Vancomycin-resis. *Enterococcus* (VRE)	2 min	6	6

*AATCC test method 100. Both fabrics were plain woven treated by 6% 1,3-dimethylol-5,5-dimethyl hydantoin.

Such antimicrobial functions are quick and powerful without generating resistance from microorganisms, a potential technology that could meet the requirement for prevention of transmission of MRSA in hospitals. The biocidal functions of the halamine treated textiles can be repeatedly recharged in chlorine bleach solution. Such rechargeable biocidal functions is mostly meaningful for reusable and environmentally friendly medical textiles such as doctors' uniforms, nurses and patients' dresses, linens, and wipes and mops.

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