

Introduction

Chronic wounds are often characterized by an increased bacterial bioburden, which in turn increases the risk of local infection, thereby complicating or delaying wound healing. Despite this fact, antimicrobials which either kill or inhibit the growth and division of bacteria can, when misused, lead to antimicrobial resistance.

Bacteria are also known to be the origin of malodour in wounds while activated carbon is known to 'absorb' malodour¹.

The purely physical principle of 'absorbing' malodour and binding bacteria is known as 'Van der Waals' electrostatic forces. These forces draw bacteria, gas or liquid molecules away from the wound towards the highly structured micropores of the dressing, where they become trapped.

Removing bacteria and malodour from the wound at dressing change can help to prevent infection and can increase healing rate as well as patients quality of life.

Methodology

Tests (triplicates) were performed on the activated carbon cloth (ACC)-containing superabsorbent wound dressing curea P1 DUO active.

Fluorescence microscopy of surface-adherent bacteria

Adherent bacteria (test organisms *Staphylococcus aureus* and *Pseudomonas aeruginosa*) on nonwoven (control) and ACC were stained with the fluorescent dye DAPI (4',6-Diamidino-2-phenylindol), examined in a fluorescence microscope and photographed².

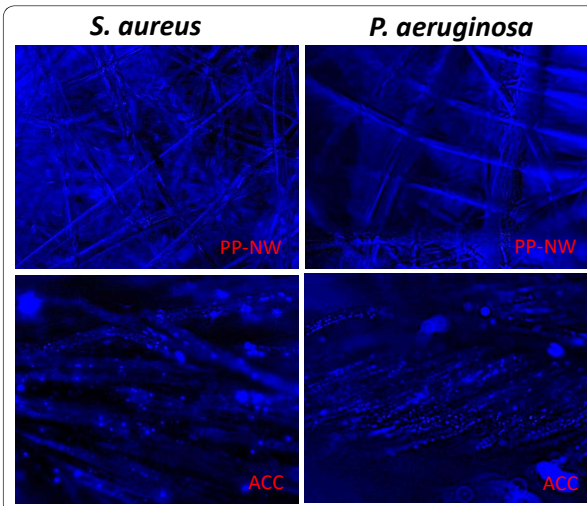
Determination of antibacterial activity of textile products

ACC was tested for its antimicrobial activity against the test organisms *Staphylococcus aureus* and *Klebsiella pneumoniae* according to DIN EN ISO 20743³. Round samples with a weight of 0.4 g were prepared. Reduction values were calculated against control sample polypropylene nonwoven (PP-NW).

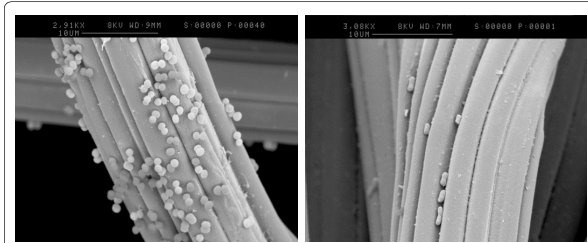
Results

Adsorption properties

Bacteria are bound on the surface of the ACC layer within the superabsorbent dressing curea P1 DUO active (visualized by fluorescence microscopy)².



Scanning electron microscopy images of *Rhodococcus* (below right) and *E. coli* (below left), gram +ve and gram -ve bacteria, immobilised on the surface of ACC filaments*.



Bacteria are attracted to the dressing, but are too big to enter the micropores of the activated carbon. Instead, they become trapped on the surface of the carbon filament.

Reduction of viable bacteria

Significantly less viable bacteria were recovered from the ACC compared to the control sample (PP-NW) following 24 hours incubation. ACC showed a logarithmic reduction level (R_{log}) of 3.84 for the test organism *S. aureus* and a logarithmic reduction level of 4.71 for the test species *K. pneumoniae*. According to DIN EN ISO 20743 standard (appendix F), the effectiveness of the antibacterial effect can be classified as strong for both test organisms³.

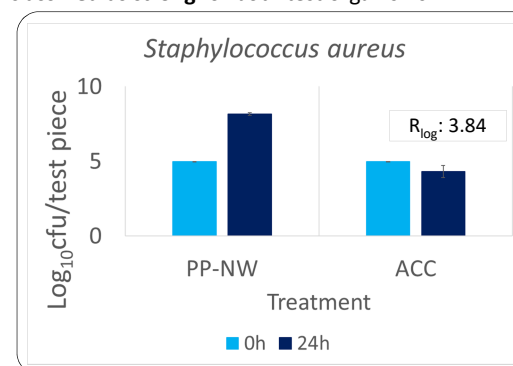


Figure 1: Quantity of viable *Staphylococcus aureus* recovered from test dressings following 24 hours incubation. (PP-NW: negative control; ACC: activated carbon cloth; R_{log} : logarithmic reduction level; cfu: colony forming unit)

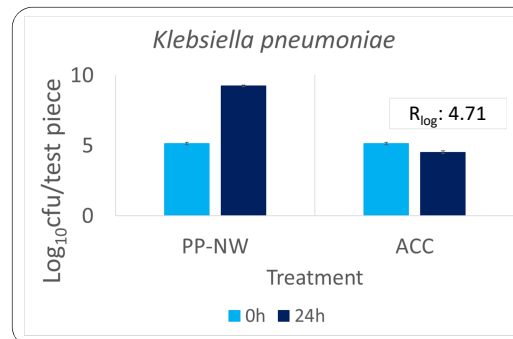


Figure 2: Quantity of viable *Klebsiella pneumoniae* recovered from test dressings following 24 hours incubation. (PP-NW: negative control; ACC: activated carbon cloth; R_{log} : logarithmic reduction level compared to negative control; cfu: colony forming unit)

Discussion & Conclusions

Fluorescence microscopy images and scanning electron microscopy images demonstrate the adhesion of bacteria on ACC surface, acting purely physical by 'van der Waals forces' as bonding mechanism.

In-vitro study according to DIN EN ISO 20743/Absorption-method shows a 99.9 % reduction of bacterial growth for *S. aureus* (gram-positive) and 99.99 % reduction for *K. pneumoniae* (gram-negative) after 24 hours by the activated carbon cloth within the curea P1 DUO active superabsorbent wound dressing, suggesting a bacteriostatic effect^{4,5}. This is achieved through electrostatic tension which builds up in the trapped bacteria until the tension overcomes the tensile strength of the cell walls, at which time the cell walls of the bacteria rupture, killing the bacteria. Released endo- and exotoxins are trapped within the micropores of the ACC.

Results demonstrate that with every change of the wound dressing, bacteria are eliminated from the wound. In addition, MMP's are bound^{6,7}. Unlike silver products that should not be used for more than 14-30 days, a superabsorbent dressing containing an activated carbon cloth allows for an unlimited repeated use, which in addition to extended antimicrobial and malodorous prevention action, is also ensuring excellent absorption and retention of excess exudate.

Key conclusions:

- ❖ Reduction of bacterial load
- ❖ 'Cleansing effect' in regards to exo- and endotoxins
- ❖ MMP modulation^{5,6}
- ❖ Safe absorption and retention of excess exudate
- ❖ No risk of (cyto-)toxicity
- ❖ No risk of microbial resistance

*Flexzorb of Chemvion Carbon Limited

¹Haynes (2018). A clinical evaluation of a charcoal dressing to reduce malodour in wounds. British Journal of Nursing, Vol. 27, No. 6 / Product Evaluation:

²ITV Denkendorf Produktservice GmbH, test laboratory division biology, Denkendorf, Germany

³Test report no L20/0264.1, 'Determination of antibacterial activity of textile products' according to DIN EN ISO 20743:2013-12, Chapter 8.1 Absorption method (test bacterial suspension is inoculated directly onto specimens), Dr. Brill & Dr. Steinmann Institute for hygiene and microbiology, Hamburg, Germany

⁴Pankey, GA & Sabath LD (2004). Clinical Relevance of Bacteriostatic versus Bactericidal Mechanisms of Action in the Treatment of Gram-Positive Bacterial Infections. Clinical Infectious Diseases 38,6: 864-870

⁵According to ASTM (American Society for Testing and Materials) F838-15a

⁶Carney, J., Thomas, H. and Westgate, S.J. (2019). Antimicrobial Properties of, and Proteinase Modulation by, an Activated Carbon Cloth and Other Market-Leading Products. (Poster EWMA 2019 – Chemvion Carbon Limited/Perfectus Biomed Limited)

⁷Sabine Eming et al. (2008). The inhibition of matrix metalloproteinase activity in chronic wounds by a polyacrylate superabsorber. Biomaterials 29: 2932-2940