Paper ID: 97815
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IAF HUMAN SPACEFLIGHT SYMPOSIUM (B3)
Advanced Systems, Technologies, and Innovations for Human Spaceflight (7)

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SUPER-ANTIBACTERIAL & SELF-CLEANING FABRICS FOR EXTENDED SPACE MISSIONS

Abstract

Background Extended space missions, particularly those to Mars, present unique challenges for textile management. Limited washing capabilities and confined spaces create ideal conditions for microbial proliferation, biofilm formation, and persistent odors. Conventional antimicrobial textiles lose efficacy over time and cannot withstand the multi-year duration of interplanetary missions. Advanced solutions are required to maintain crew health, comfort, and environmental safety throughout extended missions without the resource burden of frequent laundering. Methods We developed three complementary antimicrobial fabric technologies: Photocatalytic "Sunlight-Activated" Textiles incorporate titanium dioxide (TiO) nanowires (20-50nm diameter) woven directly into standard textile fibers. These nanowires generate reactive oxygen species (ROS) when exposed to UV wavelengths present in spacecraft lighting systems. To enhance effectiveness under low-intensity UV conditions, quantum dot enhancers were integrated, lowering the activation threshold by 37%. This technology was applied to cotton-polyester blends for crew base layers and habitat upholstery materials. Enzymatic Self-Cleaning Fibers utilize lysozyme enzymes and lipases encapsulated within 50-100nm silica nanocages attached to fiber surfaces. The enzymes target bacterial cell walls and break down oils/sebum, respectively. The specialized nanocage design releases enzymes in response to moisture or mechanical friction while protecting them from premature degradation. Stability testing confirmed enzyme activity retention exceeding 85% after simulated two-year usage cycles. This technology was optimized for intimate apparel including underwear and socks. Bioelectric Antimicrobial Fabric embeds a network of silver-carbon nanotube circuits (5-10m diameter) within polyester-spandex blends. The system generates a controlled 1.5V potential difference across fabric sections, triggering the controlled release of antimicrobial silver ions. Power is supplied through flexible 3mm-thick microbatteries or through triboelectric generators that harvest static electricity from crew movement. This technology was applied to medical garments and high-contact surfaces like exercise equipment. Results Laboratory testing under simulated spacecraft conditions demonstrated ¿99.99% reduction in microbial load across all common spacecraft contaminants including MRSA, E. coli, and Aspergillus species. The photocatalytic fabrics maintained efficacy through 500+ wash cycles. Enzymatic textiles demonstrated continuous self-cleaning for 730 simulated wear days. Bioelectric fabrics showed on-demand antimicrobial activity with negligible silver depletion over two years of accelerated testing. Conclusion These complementary antimicrobial technologies provide comprehensive protection for extended space missions, significantly reducing laundering requirements while maintaining hygienic conditions and crew comfort.