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Development of a Silica-Coated Fibre Radiative Cooling Fabric for Industrial Worker Uniforms in a South African Steel Plant

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Abstract

Industrial workers in steel plants are exposed to intense radiant heat, which can cause heat stress and impair productivity. Conventional uniform fabrics provide limited thermal management. Passive radiative cooling, which dissipates heat through the atmospheric transparency window, offers a potential engineering solution for personal protective equipment. This study engineered and evaluated a novel silica-coated fibre fabric for passive radiative cooling. The objectives were to assess its cooling performance, durability, and suitability for integration into industrial worker uniforms within a South African steel plant environment. A plain-weave cotton fabric was functionalised with a thin, porous silica coating via a sol-gel dip-coating process. Fourier-transform infrared spectroscopy characterised its spectral emissivity within the mid-infrared atmospheric window (8–13 μm). Cooling performance was evaluated under simulated solar irradiation using a thermal imaging camera. Fabric strength and abrasion resistance were tested against industrial laundry standards. The coated fabric demonstrated a high average emissivity of 0.92 within the 8–13 μm band. Under a solar simulator, it achieved a sub-ambient temperature reduction of 4.2°C compared to standard cotton. The coating showed minimal degradation after 50 industrial washing cycles, with a less than 8% reduction in tensile strength. The silica-coated fabric effectively enhances radiative heat dissipation while maintaining adequate durability

for industrial use. It represents a viable passive cooling technology for integration into worker uniforms for high-heat environments such as steel plants. Further field trials in operational steel plants are recommended to validate thermophysiological comfort under real working conditions. Research into optimising coating formulations for different base textiles is also suggested. radiative cooling, silica coating, personal protective equipment, thermal comfort, industrial textiles, heat stress, functional fabric This research contributes a practical textile engineering solution for mitigating heat stress, demonstrating the development and laboratory validation of a durable, silica-coated radiative cooling fabric tailored for industrial uniforms.