Purifire: A Lightweight Regenerative VOC Filter Using Zeolite–TiO2 Photocatalytic Nanoparticles for Firefighters in Wildfire Regions

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Following the infamous January 2025 Palisades Wildfire that devastated our Southern California community, an urgent need was identified for a lightweight respirator capable of protecting firefighters from carcinogenic inhalation from wildfire smoke. SoCal is the most wildfire-prone region in the United States, and firefighters are repeatedly exposed to volatile organic compounds (VOCs) during the suppression and overhaul phase. These gaseous carcinogens penetrate deep into lung tissue and lead to lung cancer, the deadliest cancer. Although firefighters' self-contained breathing apparatus (SCBA) provides particulate protection, it is heavy, restricts mobility, and is not optimal for prolonged VOC mitigation. To address these gaps, we developed PuriFire, a lightweight regenerative VOC filter using a zeolite-TiO2 nanocomposite. The nanocomposite was deposited onto a porous polypropylene matrix. Clinoptilolite zeolite provides high surface area adsorption consistent with Langmuir-type behavior, while UV-activated TiO2 enables photocatalytic VOC oxidation. The heterojunction suppresses electron hole recombination, enhancing charge separation and sustaining reactive oxygen species generation. This dual-adsorption reaction system improves regeneration of active sites and reduces saturation under photon flux. In a sealed chamber with acetone as a VOC proxy, MQ-135 sensor data calibrated against baseline conditions showed approximately 77% removal at 60 minutes, outperforming zeolite (about 50%) and polypropylene (~23%). First order kinetics yielded k = 0.0250 min?¹, confirming enhanced VOC degradation driven by synergistic adsorption and photocatalytic regeneration, which supports the feasibility of Purifire being a lightweight, regenerable filter for firefighters.

Awards Won:
Arizona State University: Arizona State University ISEF Scholarship (valued at up to $32,000 each)
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