Flow Evaluation of Traditional and Electrospun Enhanced Filtration Media

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The COVID-19 pandemic stressed supply chains as manufacturing facilities struggled to meet the rapid increase in demand for air purifying respirators. [1, 2] NIOSH approved testing facilities quickly became inundated with new filtration media that required safety certification before being included in the fabrication chain. In this work, a practical, cost effective, easy to fabricate, and reliable NIOSH-like method (Figure 1) to determine filtration efficiency and breathing resistance per area was developed. Baseline demonstration of the method was performed with filters made from polypropylene (PP), a certified medium traditionally used for filtration. In addition, we present a composite filter fabricated from PP fabric enhanced through modification with electrospun polycaprolactone (PCL) fibers. The PCL filter layer was fabricated with precise fiber morphologies and minimal thickness to promote efficacious filtration and minimal breathing resistance (Figure 2).

Presented work will include design of the filtration testing apparatus, methodologies for monitoring filtration efficiencies and breathing resistance, and a mathematical model used to provide the minimum area required for a given filtration media to meet NIOSH standards. Flow coefficient equations were used to predict flow through a given filtration media of a specified size with a 95 % confidence interval (Figure 3). PP filters enhanced with electrospun fibers exhibited significantly higher filtration efficiencies when the fibers were deposited in crosshatch or random alignment patterns (Figure 4). Results showed the 0.3 μm filtration efficiency of PP fabric can be increased significantly (up to 11 times higher) with the addition of a randomly aligned electrospun PCL layer. This work demonstrated significant enhancement of PP filtration media by addition of morphologically distinct electrospun fibers, and an efficient and low-cost methodology to provide a preliminary NIOSH-like evaluation of filtration media.

[1] N. Savidge, "California recalls N95 masks from Santa Clara Company with $90 million state contract," *The Mercury News*, San Jose, California, pp. 1–1, Sep. 18, 2020. [Online]. Available: https://www.mercurynews.com/2020/09/18/california-recalls-n95-masks-from-santa-clara-company-with-90-million-state-contract

[2] CDC, "Interim Guidance for Conserving and Extending Filtering Facepiece Respirator Supply in Non-Healthcare Sectors." 2020. [Online]. Available: https://www.cdc.gov/coronavirus/2019-ncov/community/conserving-respirator-supply.html

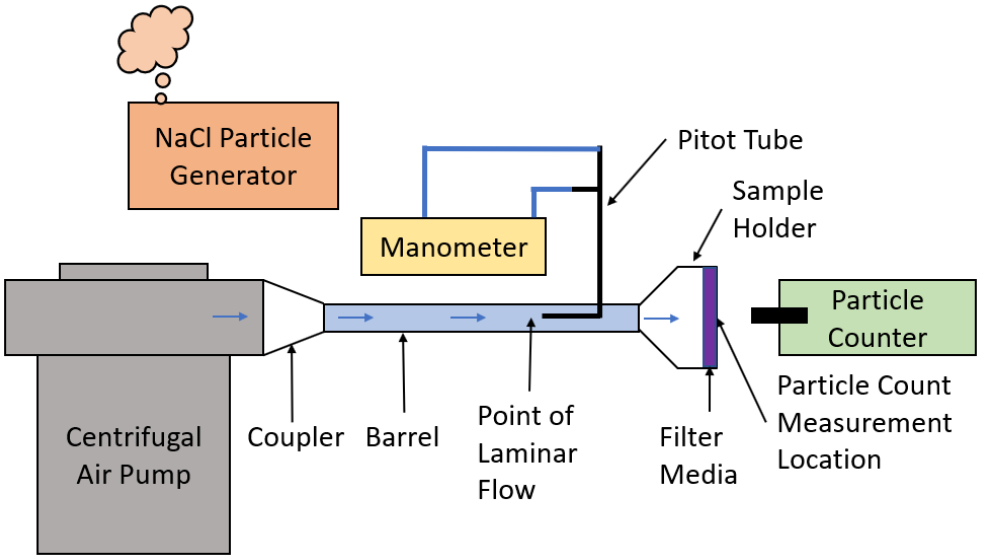

Figure 1: Diagram of the NIOSH-like testing apparatus that was developed to evaluate the filtration efficiency and breathing resistance of filtration media. Measurements obtained with this method are consistent and accurate, allowing for cost effective and expedient evaluation of filtration media before NIOSH certification takes place.

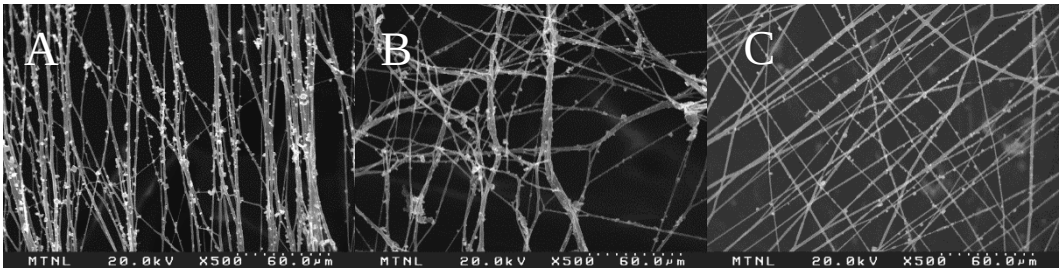

Figure 2: Electron micrographs (post filtration testing) of the precise morphologies (A: Aligned, B: Cross-hatch, and C: Random) of the electrospun filters added to widely available fabrics and filtration media to enhance filtration efficiency with minimal increase in breathing resistance.

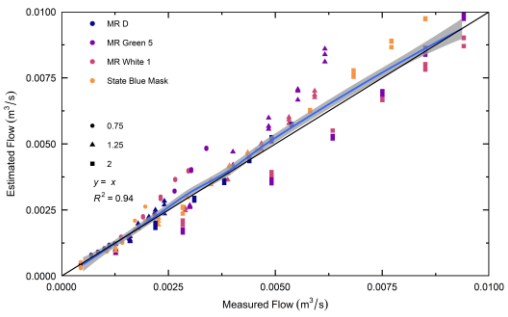

Figure 3: Linear model fit of flows estimated using the proposed equation and flows obtained experimentally. Proposed flow coefficient equations predict the flow through a given filtration media of a specific size with a 95% confidence interval.

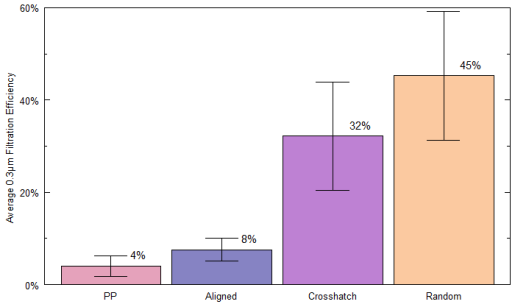

Figure 4: Bar graph detailing the increased filtration efficiency for each PCL fiber alignment compared to the standard PP fabric. The aligned, crosshatch, and random composite samples exhibited 100 %, 700 %, and 1025 % increases in 0.3 μm filtration efficiencies, respectively.