Title: Green engineering of water-insoluble PVA/PAA nanofiber respiratory membranes for efficient particulate matter filtration with low pressure drop

Author names: Ashraful Islam , Sudip Kumar Lahiri , Md. Akil Akhter , Muhammad Imran , Dong Mengmeng , Yanbo Liu

Abstract: Air pollution is a major concern due to rising particulate matter (PM) levels, requiring efficient filtration technologies for respiratory protection, and integrating eco-friendly fabrication methods further enhances environmental sustainability. We report water-insoluble nanofibrous membranes that combine high filtration efficiency (FE) with a low pressure drop (ΔP) for use in such masks. Using 18 % (w/v) polyvinyl alcohol (PVA) and polyacrylic acid (PAA) solutions in water, we electrospun four types of nanofiber membranes under optimised conditions (25 kV, 20 cm, 25 °C, 50 % RH). These included a pure PVA membrane and three PVA/PAA (60/40 wt%) composite membranes containing PAA of 3 kDa (NFM-1), 50 kDa (NFM-2), and both 3 kDa and 50 kDa (NFM-3). To induce crosslinking, all membranes were heat-treated at 100–160 °C for 25 min. Filtration tests showed that NFM-2 heat-treated at 140 °C achieved ~99 % FE for particles ≥0.5 μm, with a ΔP of only 48 ± 1 Pa. Scanning electron microscopy (SEM) revealed smooth fibers with an average diameter of ~192 nm and 59 % porosity for NFM-2.

Fourtrinfrar(FTIR) spectroscopy confirmed the formation of ester linkages (–C O–O–R) at ≥120 °C between PVA and PAA, indicating successful thermal crosslinking and improved stability. After crosslinking, NFM-2 also exhibited a water contact angle (θ) of ~90° and retained 100 % of its weight after immersion in 70 °C water, demonstrating complete water insolubility. The nanofiber membranes were further integrated with polypropylene (PP) spunbond and meltblown nonwovens in multilayer assemblies (up to four layers) to evaluate composite filter performance. This water-based, organic-solvent-free electrospinning process offers a green approach to producing high-performance respiratory filters.

Keywords : Electrospun nanofiber membranes PVA/PAA composite Filtration efficiency Respiratory pressure drop Thermal crosslinking

10.1016/j.polymer.2026.129634

https://www.sciencedirect.com/science/article/abs/pii/S0032386126000819