Polypropylene nanoplastic exposure on a human airway barrier-on-chip and protein corona formation insights through multiscale analysis

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INTRODUCTION

Plastic pollution, one of the most pressing global concerns today, poses not only ecological but also significant human health risks [1]. Polypropylene (PP), one of the most commonly produced and utilized plastic types worldwide, can degrade into nanoplastics (NPs) under environmental stressors. Inhaled NPs may interact with the lung epithelial barrier (EB), triggering inflammatory responses and barrier dysfunction [2]. In this study, a biomimetic microfluidic EB platform was designed to investigate the cytotoxic effects of inhalable doses of NPs under optimized flow conditions. Both wet-lab experiments and computational approaches were employed: morphological and cytotoxic alterations on the EB were systematically analyzed, while NP-protein interactions were further explored through molecular dynamics simulations [3].

METHOD

PPP Synthesis & Characterization

Polypropylene nanoplastics (PPP) were produced by **chemically degrading** 5 mm PP beads under varying solvent (chloroform, toluene, xylene), temperature, and reaction time conditions. Products were homogenized using a rotor-stator, filtered under vacuum, dried, and used for downstream analyses.

Microfluidic Epithelial Barrier-on-a-chip

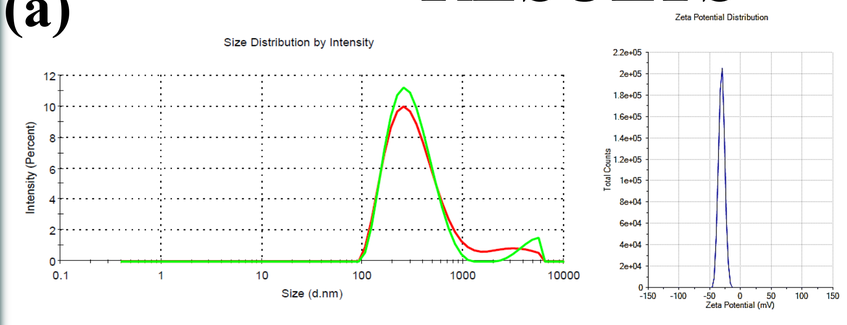
A two-channel PDMS device (1.6×4 cm) separated by a porous PET membrane was fabricated to model the **air-liquid interface**. Calu-3 epithelial cells cultured on the membrane were exposed to 210 µg/mL PPP. Barrier integrity was assessed using ZO-1 immunofluorescence. The chip was perfused dynamically using a flow system.

Protein-Polymer Interaction (In Vitro & In Silico)

SDS-PAGE: PPPs were incubated in 10% FBS-DMEM or plasma (37°C, 24 h), denatured, and run on 10% SDS-PAGE (80 V, 90 min).
MD Simulations: Coarse-grained PPPs (~48k beads) and HSA (1AO6) were simulated under 310 K, 1 bar conditions for 500 ns ; interactions analyzed from trajectories.

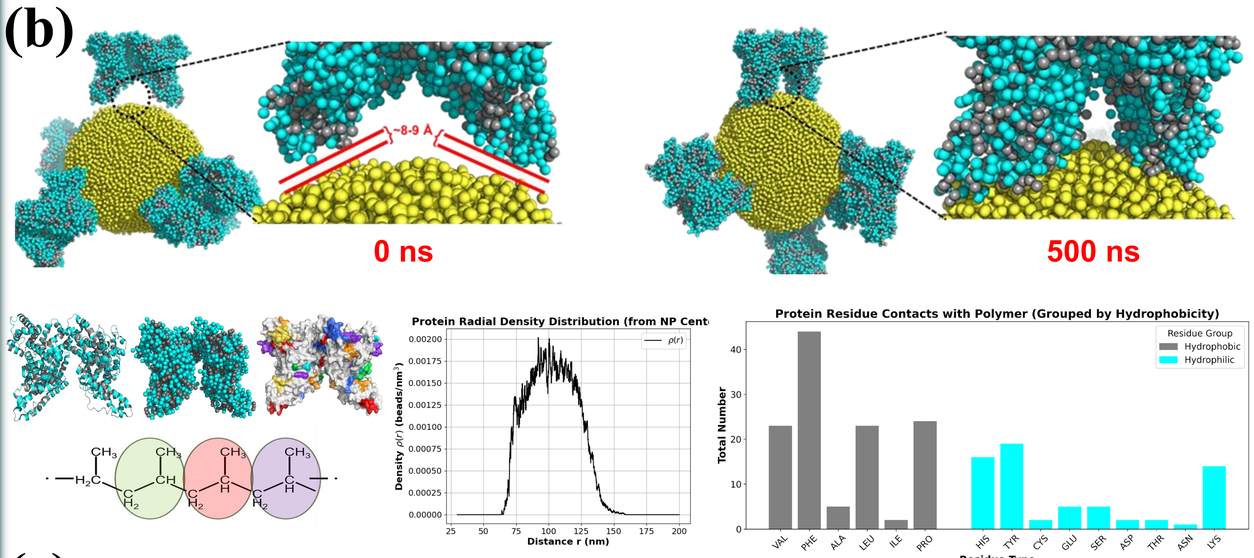
RESULTS

(a)

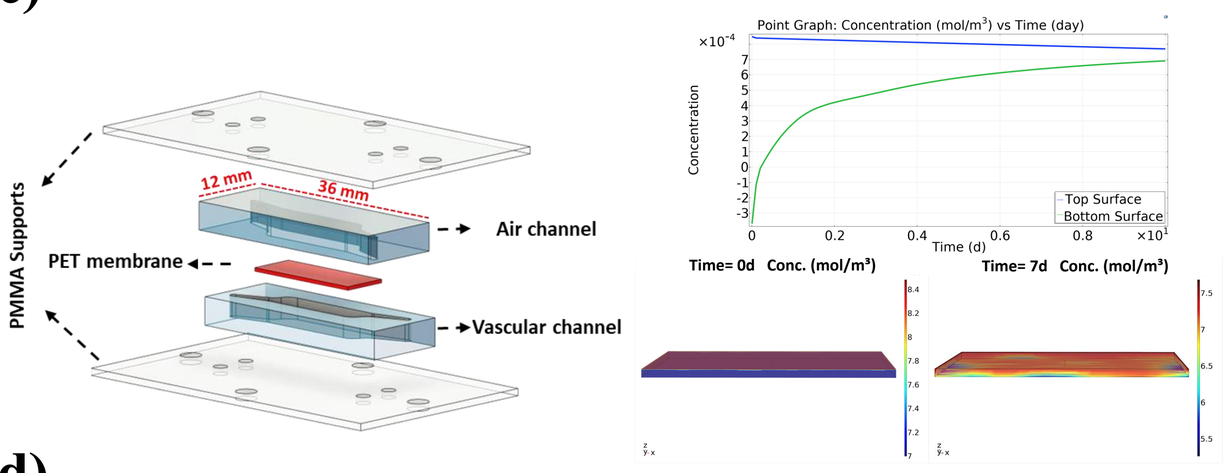


Average Size and Zeta Potential Analysis
Z-Average (d.nm): 288.5
PdI: 0.259
Zeta Potential (mV): -30.4 ± 4.9

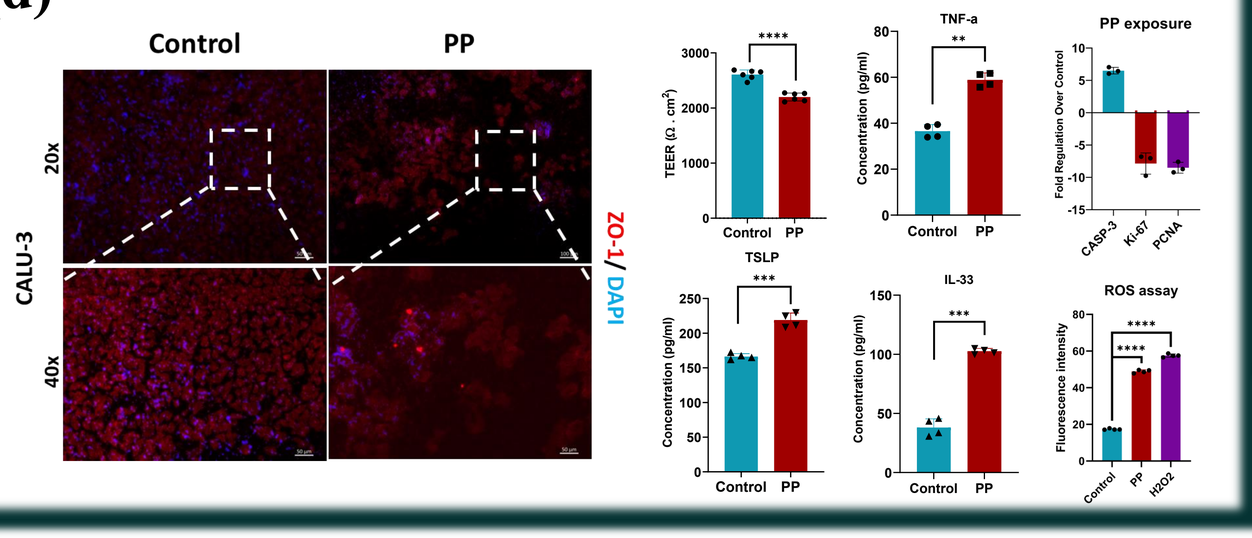
(b)



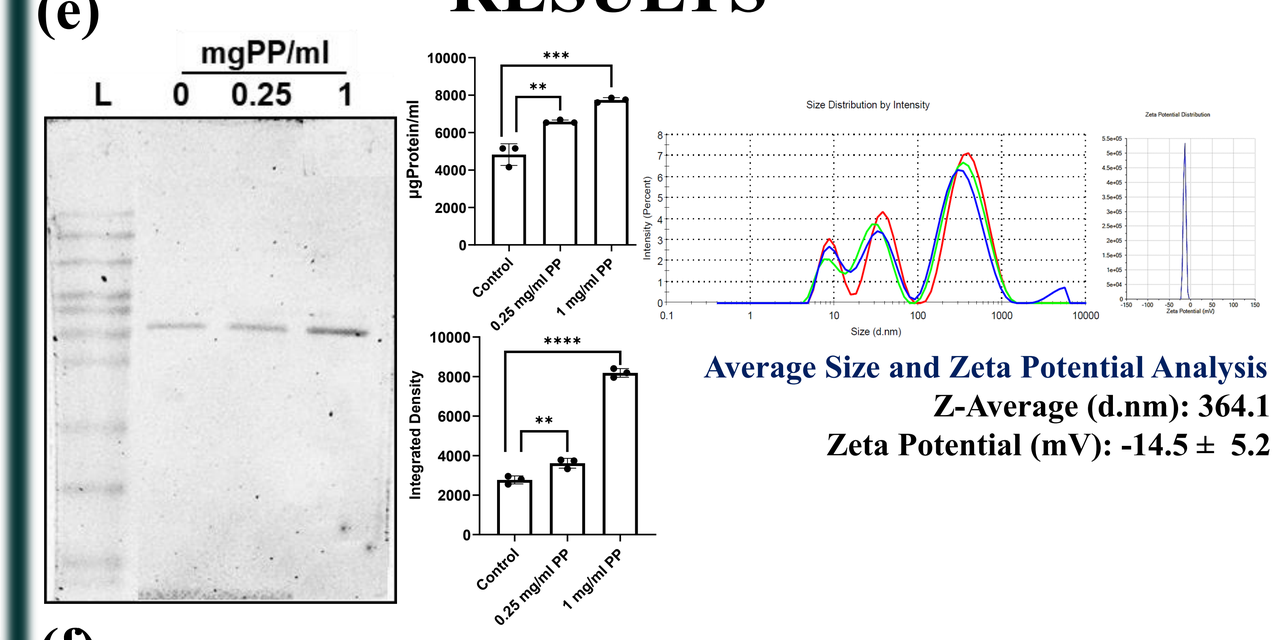
(c)



(d)



(e)



Average Size and Zeta Potential Analysis
Z-Average (d.nm): 364.1
Zeta Potential (mV): -14.5 ± 5.2

(f)

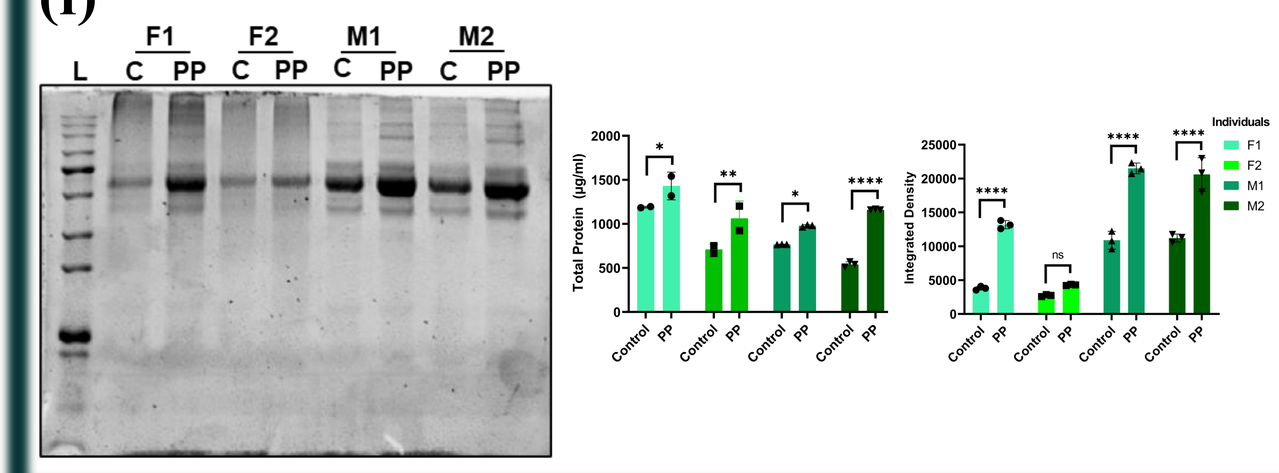


Figure 1. **Multiscale characterization of polypropylene (PP) nanoplastic exposure on an airway barrier-on-chip system.**(a) Physicochemical characterization of PP nanoparticles (size distribution, PDI, zeta potential). (b) Molecular dynamics analysis of protein-polymer interactions and residue-level contact profiles. (c) Schematic of the microfluidic airway barrier platform and concentration distribution modeling. (d) Barrier response to PP exposure assessed by immunofluorescence (ZO-1/DAPI) and inflammatory/oxidative markers. (e-f) Protein corona formation and quantitative protein analysis under increasing PP concentrations.

REFERENCES
[1] MacLeod et al., Science (2021) – Global plastic pollution threat
[2] Sert et al., Scientific Reports(2025) – Plant-based airway barrier-on-a-chip for aerosol exposure modeling
[3] Sert et al., Allergy (2026) – Polypropylene nanoplastics in airway barrier-on-chip

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