Research Proposal — *Improving ICU patient outcomes by targeting indoor air quality: interventions, monitoring, and clinical impact*

Krutika Sharma — *Air quality analysis & control in adult intensive care units: from real-time monitoring to patient-centred outcomes*

Background & Rationale:
Airborne particles and bioaerosols in ICUs are implicated in healthcare-acquired infections (HAIs) and may contribute to ventilator-associated pneumonia (VAP), fungal infections in immunocompromised patients, and overall pathogen transmission. Engineering controls (ventilation, HEPA, UVGI) demonstrably lower airborne counts, but high-quality evidence that these interventions reduce *clinical* infection rates is limited. A multidisciplinary research combining environmental monitoring, microbiology and clinical epidemiology can fill this gap and produce actionable hospital guidance.

Overall Aim:
To evaluate whether targeted air-quality interventions (in-built HEPA filtration in the air systems) triggered and optimised by real-time monitoring — reduce airborne pathogen burden and translate into reduced ICU-acquired infection incidence.

Specific Objectives:

1. Design and pilot a robust ICU air-quality monitoring protocol (PM1/2.5, CO_2, temperature/humidity, active air samplers + qPCR/culture) and test feasibility in 4–6 ICU rooms.
2. Evaluate the effectiveness of (a) HEPA filtration and/or (b) UVGI + BMS system intervention in lowering airborne microbial/particle loads and surface contamination.
3. Determine whether interventions are associated with reductions in ICU-acquired infections (VAP, bloodstream infections, nosocomial fungal infections) using an appropriately powered quasi-experimental design.

Methods —

Study A — Pilot feasibility

- Settings: 4 ICU single-patient rooms in a partner hospital.
- Measurements: continuous PM1/2.5/CO_2 logging, pressure differentials, door opening sensors; active air sampling (e.g., 1 m^3 samples) twice daily for culture and qPCR (total bacteria, fungal targets, selected pathogens). Surface swabs daily.
- Outcomes: data completeness, sampling logistics, lab workflows, baseline variability, estimates for sample size calculation.
- Deliverable: validated SOPs and power estimates.

Study B — Environmental intervention

- Design: crossover or stepped-wedge at room level (each room experiences baseline → HEPA → HEPA+UVGI; sequence randomised).
- Primary environmental outcomes: reduction in airborne CFU/m^3 and target pathogen qPCR copies; secondary: surface contamination, PM/CO_2 levels.

- Analysis: mixed-effects models accounting for room, time, occupancy and staff movement.

Study C — Clinical outcomes evaluation

- Design options (choose based on hospital logistics; both feasible):
    - **Stepped-wedge cluster trial** across ICU beds/wards implementing HEPA+UVGI sequentially; or
    - **Controlled before–after (quasi-experimental)** with matched control ICU (if partner hospital network available).
- Primary clinical outcome: ICU-acquired infection rate per 100 patient-days (lab-confirmed fungal infections).
- Secondary: antibiotic days, length of stay, mortality, staff respiratory illness rates.
- Sample size: to be derived from pilot

Ethics, governance & feasibility:

- Early engagement with ICU director, infection control, facilities/engineering and microbiology lab. Obtain HREC approval and hospital data governance sign-off. Ensure staff safety with UVGI; contractor/engineering input for installations. Budget for consumables, sampler equipment, lab assays and a part-time research assistant.

Impact & Way forward -

Directly addresses the evidence gap linking environmental controls to patient outcomes. Results can inform hospital HVAC policy, provide cost-effectiveness data, and support scalable implementation (especially in older hospitals).