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# Assessment of Working Environment Quality and Solutions for Its Improvement at University Medical Center Ho Chi Minh City Branch 2 †

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**Abstract**

We evaluated the indoor environmental quality of the administrative office at University Medical Center Ho Chi Minh City branch 2 and implemented a multi-stage engineering control strategy to optimize occupational health conditions. A cross-sectional assessment monitored important air quality parameters, including carbon dioxide ($CO_2$), fine particulate matter (PM2.5 and PM10), humidity, and illumination. Following baseline measurements, an integrated system was deployed to address pollutant mass balance, consisting of High-Efficiency Particulate Air (HEPA) filtration units for mechanical particle scrubbing, ceiling-mounted axial fans to induce forced convection, and ultraviolet-C germicidal lamps for photochemical disinfection. Post-intervention results demonstrated significant gains in system removal efficiency. $CO_2$ concentrations decreased by over 60% due to enhanced volumetric air exchange, while PM2.5 levels decreased by more than 40% through interception and diffusion mechanisms within the HEPA media. Furthermore, UVC irradiation achieved a 90% reduction in viable airborne microbial colonies. The results of this study show that low-cost, scalable environmental engineering controls and fluid dynamic optimizations effectively mitigate indoor air pollution and enhance workplace stability in healthcare administrative settings.

**Keywords:** indoor air quality; occupational environment; HEPA filtration; UVC disinfection; environmental intervention

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## 1. Introduction

In high-density healthcare environments, especially hospital administrative offices, indoor environmental quality (IEQ) is a critical yet often neglected factor influencing both occupational health and organizational performance. Different from clinical areas that typically undergo strict environmental controls, administrative spaces are frequently overlooked in air quality optimization strategies, despite prolonged staff occupancy and exposure. Recent studies have linked substandard IEQ marked by elevated levels of carbon

dioxide ($CO_2$), fine particulate matter (PM2.5 and PM10), volatile organic compounds (VOCs), and microbial contaminants to increased fatigue, cognitive impairment, respiratory conditions, and diminished work productivity [1–4].

In many healthcare facilities, environmental optimization efforts are typically concentrated in clinical zones, while administrative departments, despite housing a large portion of staff, often receive insufficient attention. Enclosed office layouts with limited ventilation can result in the accumulation of indoor air pollutants such as $CO_2$, PM2.5, PM10, formaldehyde (HCHO), and total volatile organic compounds (TVOCs), all of which are associated with short- and long-term health risks [4–6].

At the University Medical Center Ho Chi Minh City Branch 2, the administrative office operates in a closed environment with high personnel density and limited access to natural ventilation. Preliminary observations revealed poor indoor air quality (IAQ), with measured levels of $CO_2$ and PM2.5 frequently exceeding recommended safety thresholds during peak working hours. These conditions may contribute to discomfort, fatigue, reduced concentration, and increased susceptibility to respiratory illnesses [7,8].

Despite the growing body of evidence highlighting the importance of IAQ in workspaces, few empirical studies have evaluated targeted environmental engineering interventions in Southeast Asian hospital settings. Technologies such as High-Efficiency Particulate Air (HEPA) filtration, forced convection systems, and ultraviolet-C (UVC) germicidal lighting have demonstrated efficacy in reducing airborne pollutants and microbial load in clinical zones, yet their integration into non-clinical healthcare environments remains underexplored [9,10]. Moreover, localized studies that quantify the before-and-after impact of such systems on real-world hospital office air quality are largely absent from the literature.

To address this gap, the study aims (1) to characterize baseline IAQ conditions across key physical, chemical, and biological parameters and (2) to implement and evaluate a composite intervention consisting of HEPA PM2.5 air filters, ceiling-mounted convection fans, and UVC disinfection lamps. The intervention is assessed through continuous measurements of pollutant concentration levels and air quality indices, providing quantifiable evidence of effectiveness. The findings contribute to adding knowledge on practical, scalable approaches for enhancing occupational health standards in a resource-constrained hospital environment. They can also be used to transition existing methods from simple monitoring to a proactive engineering control strategy formulation. By applying the hierarchy of controls, the mass balance of indoor pollutants can be balanced through a multi-stage system. This method enables mechanical filtration, forced convection, and ultraviolet germicidal irradiation (UVGI) to facilitate the physical removal and photochemical degradation of contaminants.

## 2. Methodology

### *2.1. Study Process*

A cross-sectional observational study was conducted to evaluate the IEQ of the administrative department at University Medical Center Ho Chi Minh City branch 2. We conducted baseline environmental monitoring and post-intervention assessment following the installation of air quality enhancement systems. The scope was restricted to the primary 120 $m^2$ open-plan office space occupied by 13 administrative staff under standard working conditions, as shown in Figure 1.

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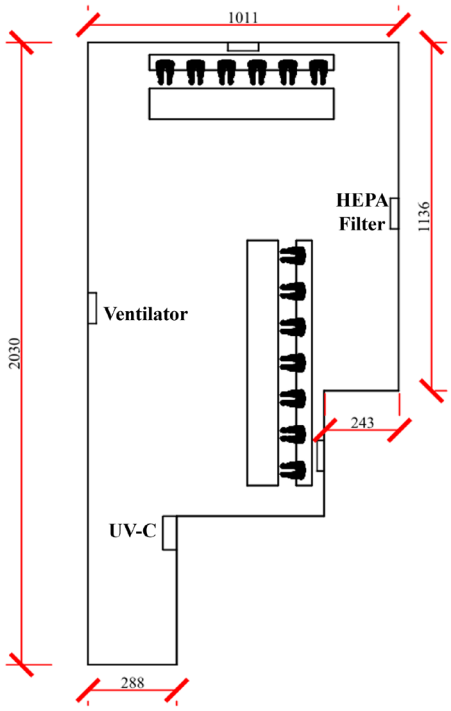



**Figure 1.** Layout of the 120 $m^2$ administrative office at University Medical Center Ho Chi Minh City (Branch 2), showing the locations of the ventilator, HEPA filter, and UV-C disinfection unit. All dimensions are given in millimeters (mm).

### *2.2. Environmental Intervention System*

To mitigate airborne pollutant levels, a composite environmental intervention was deployed, consisting of the following.

- HEPA PM2.5 filtration: Two HEPA filter units were positioned at diagonally opposite corners of the room. Each unit had a certified filtration efficiency of 99.97% for particles $\leq$ 2.5 µm and operated at an airflow rate of 300 $m^3/h$ [4].
- Convection ventilation: Ceiling-mounted axial fans were evenly distributed along the longitudinal axis to promote uniform air circulation and enhance particulate dispersion from emission zones to filtration units [11]. The mean airflow velocity was maintained at 2.5 m/s [11].
- UVC disinfection: UVC germicidal lamps emitting at 254 nm were installed near microbial areas with high microbial concentration, such as printing stations and shared surfaces [12]. Radiation intensity was calibrated to 10 $mW/cm^2$ with an operational duty cycle of 8 h per working day.
- From an engineering design perspective, the HEPA units were calibrated to optimize the Clean Air Delivery Rate (CADR) relative to the room volume of 120 $m^2$. The convection fans were placed to ensure a high volumetric air exchange rate, effectively transforming the office into a Continuously Stirred Tank Reactor (CSTR) model to prevent the formation of stagnant 'dead zones' where $CO_2$ and particulates typically accumulate.

### *2.3. Measurement Parameters and Instrumentation*

Environmental parameters were measured before and after intervention at 08:00, 11:00, and 15:00 for 20 days. Measurements were performed at a fixed central location within the workspace using calibrated sensors compliant with relevant to the International Organization for Standardization and World Health Organization standards. The monitored variables included:

- Physical indicators: Temperature (°C), relative humidity (%), and illuminance (lux).
- Chemical indicators: $CO_2$ (ppm), PM2.5 and PM10 (μg/m$^3$), CO (ppm), HCHO (mg/m$^3$), and TVOC (mg/m$^3$).
- Composite indicator: AQI, computed from multi-pollutant data using the World Health Organization (WHO) reference thresholds.
- Biological indicator: Airborne microbial load was qualitatively assessed using passive settle plate methods positioned at representative locations.

### *2.4. Data Collection and Quality Control*

All sensors were subjected to pre-deployment calibration and routine zero-drift checks. Data was logged using automated data acquisition systems and subsequently verified for consistency and completeness. To minimize confounding, external ventilation and occupancy levels were held constant during measurement periods. The raw dataset was normalized, and values outside 3 standard deviations were excluded from analysis to reduce outlier bias, as shown in Figure 2.




**Figure 2.** Air quality monitoring device placed in the workspace during the experiment. The inset shows a magnified view of the device display, indicating measured environmental parameters including temperature, relative humidity, HCHO, TVOC, PM2.5, PM10, CO, $CO_2$, and AQI.

### *2.5. Evaluation Metrics*

The effectiveness of the intervention was evaluated through the relative change in pollutant concentrations before and after installation. Secondary metrics included compliance with WHO exposure thresholds and reduction in AQI scores. A parallel staff survey was administered post intervention to collect subjective feedback on perceived environmental comfort, symptoms (e.g., fatigue, eye irritation), and overall satisfaction.

## 3. Results

### *3.1. Baseline Environmental Conditions*

Initial environmental measurements revealed suboptimal air quality within the administrative office, with multiple indicators exceeding internationally recognized thresholds for occupational health. Figure 3 shows time-resolved measurements of key parameters before the intervention.

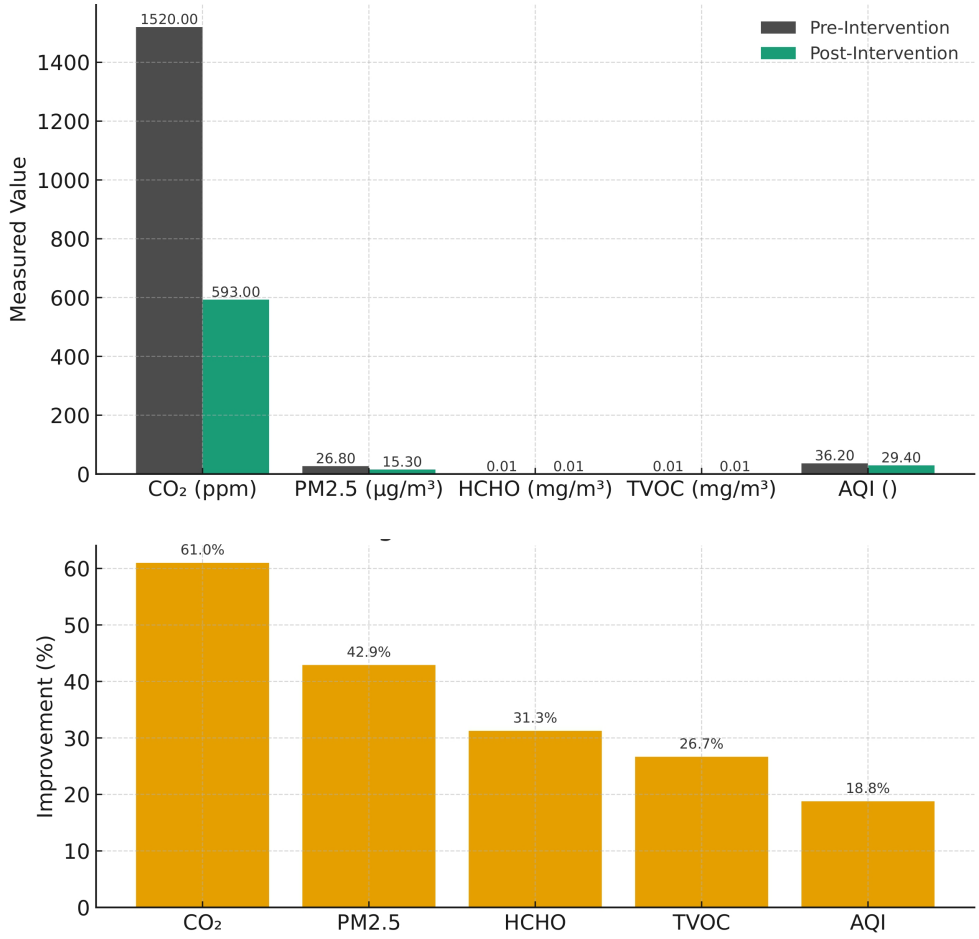



**Figure 3.** Comparing measured values of air quality parameters before and after the intervention, along with the percent reduction. Pre-intervention: $CO_2$ at 1520 ppm, PM2.5 at 26.8 µg/m$^3$, HCHO at 0.008 mg/m$^3$, TVOC at 0.015 mg/m$^3$, AQI at 36.2. Post-intervention: $CO_2$ at 593 ppm (61% reduction), PM2.5 at 15.3 µg/m$^3$ (42.9% reduction), HCHO at 0.0055 mg/m$^3$ (31.2% reduction), TVOC at 0.011 mg/m$^3$ (26.7% reduction), AQI at 29.4 (18.8% reduction).

$CO_2$ concentration consistently surpassed the American Society of Heating, Refrigerating and Air Conditioning Engineers' Standard (ASHRAE) 62.1's indoor limit of 1000 ppm during working hours, reaching peak values of 1613 ppm at 15:00 [13]. This accumulation reflected poor air exchange and elevated occupancy. Prolonged exposure to elevated $CO_2$ is associated with decreased cognitive function and increased fatigue, especially in enclosed workspaces. PM2.5 concentrations fluctuated between 22 and 30 µg/m$^3$, exceeding the WHO 24 h mean guideline of 25 µg/m$^3$ on most days. These fine particulates are linked to cardiovascular and respiratory morbidity in urban indoor environments with limited filtration. HCHO and TVOC levels also showed intermittent increases throughout the day. HCHO ranged from 0.006 to 0.009 mg/m$^3$, while TVOC levels varied from 0.012 to 0.018 mg/m$^3$. These levels are consistent with emissions from office furnishings, cleaning agents, and equipment. The variability across the day indicates source-specific activity such as printing, cleaning, or thermal release from surfaces. AQI values computed from multivariate pollutant data ranged from 29 to 42, which, while not immediately hazardous, fall into the "moderate risk" category under WHO guidelines. Importantly, these values reflect a cumulative burden that could contribute to long-term health effects.

### *3.2. Post-Intervention Air Quality Improvements*

Following HEPA filtration, convection fans, and UVC disinfection on 17 October 2023, reductions in pollutant concentrations were observed across all monitored param-

eters. $CO_2$ levels dropped by more than 60%, with mean concentrations reduced from 1520 ppm (±84.3) to 593 ppm (±27.1) across the measurement periods. This improvement is attributable to enhanced air mixing and convective flow, which redistributed localized $CO_2$ areas with high microbial concentration and facilitated passive ventilation through existing openings.

PM2.5 concentrations decreased from a pre-intervention mean of 26.8 μg/m$^3$ to 15.3 μg/m$^3$, corresponding to a 42.9% reduction. This brought the daily average below the WHO threshold, confirming the filtration system's effectiveness in removing airborne particulates. HCHO levels were stabilized at 0.005–0.006 mg/m$^3$, a 25–30% reduction from peak pre-intervention values. The drop is consistent with the combined effects of particulate removal (which binds volatile compounds), airflow redistribution, and UVC degradation of organics. TVOC levels fell to a stable range of 0.010–0.013 mg/m$^3$, showing a consistent downward trend post intervention with reduced variability, indicating improved chemical stability in the indoor environment. AQI scores improved accordingly, with post-intervention values consistently in the 25–35 range. This represents a 20% average improvement and a shift into the good air quality classification (AQI < 50), as defined by international standards.

### *3.3. Temporal Patterns and Diurnal Dynamics*

Time series analysis revealed that the most significant improvements occurred during peak usage hours (11:00 and 15:00), where pollutant loads were previously highest. As shown in Figure 4, the system maintained stability and prevented late-day accumulation that was previously observed. Thermal balance in the room also improved due to the active air movement, reducing the thermal gradient between the occupied zone and the ceiling area.

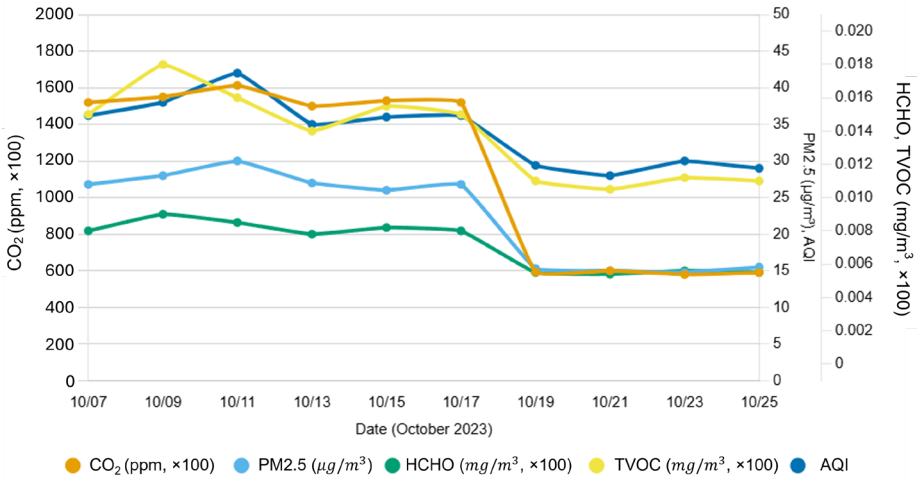



**Figure 4.** Post-intervention air quality stability from 7 October to 25 October 2023. It tracks $CO_2$ (ppm ×100), PM2.5 (μg/m$^3$), HCHO (mg/m$^3$ ×100), TVOC (mg/m$^3$ ×100), and AQI. After the intervention on October 17, $CO_2$ dropped from approximately 1600 to 600 ppm, PM2.5 from about 25 to 15 μg/m$^3$, HCHO from about 0.008 to 0.005 mg/m$^3$, TVOC from about 0.015 to 0.011 mg/m$^3$, and AQI from about 35 to 25, demonstrating consistent improvement during peak hours.

Figure 5 shows the diurnal variation in $CO_2$, PM2.5, and AQI at three time points (08:00, 11:00, and 15:00) before and after the intervention on 17 October 2023. Pre intervention, $CO_2$ peaked at 1613 ppm and PM2.5 at 30 μg/m$^3$ at 15:00, with AQI reaching 42, indicating moderate health risks. Post-intervention, $CO_2$ stabilized around 593 ppm, PM2.5 dropped to 15.3 μg/m$^3$, and AQI fell to 29.4, all within safe limits. The reduced variability (error bars)

post-intervention highlights the system's consistency across daily operations, reinforcing its efficacy in mitigating peak pollutant levels.

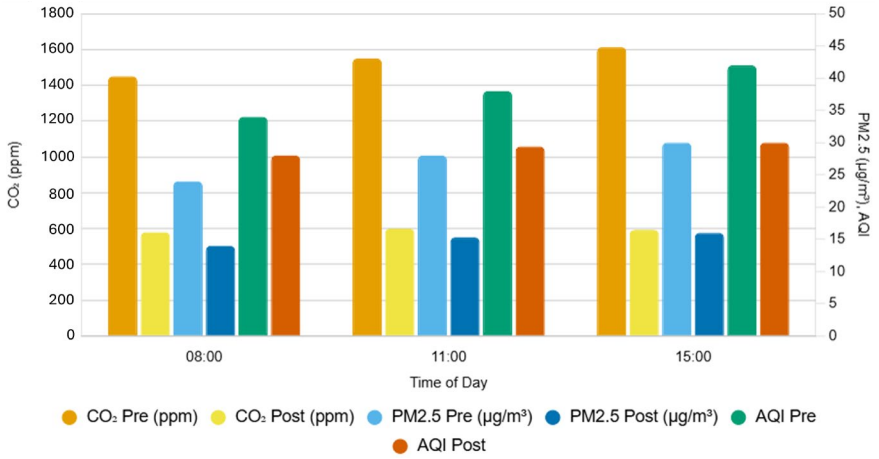



**Figure 5.** Diurnal variation in $CO_2$, PM2.5, and AQI at 08:00, 11:00, and 15:00 before and after the intervention on 17 October 2023. Pre-intervention, $CO_2$ peaked at approximately 1600 ppm and PM2.5 at about 25 µg/m$^3$ at 15:00, with AQI around 40. Post-intervention, $CO_2$ dropped to roughly 600 ppm, PM2.5 to about 15 µg/m$^3$, and AQI to around 25, all within safe limits.

### *3.4. Subjective Outcomes and Staff Feedback*

In parallel with physical measurements, a post-intervention survey ($n$ = 13 respondents) was conducted to evaluate perceived improvements. The results show the following.

- 100% of staff reported a perceived improvement in air freshness and thermal comfort.
- 84.6% reported reduced symptoms such as eye strain, headaches, and lethargy.
- 76.9% expressed higher satisfaction with the workspace, citing better air circulation and reduced odors.

While subjective, these perceptions correlate well with measured improvements and suggest improvements in occupational comfort. No degradation in system performance was observed over the three-week post-intervention period. All sensors indicated sustained low pollutant levels with minimal fluctuation. The UVC lamps operated continuously at preset intervals and showed no significant variation in environmental microbial load (settle plates showed >90% reduction in viable colonies in test samples compared to baseline). Table 1 shows the quantified impact of the environmental intervention on air quality parameters in the administrative office.

**Table 1.** Summary of environmental parameter improvements.

| Parameter | Pre-Intervention (Mean) | Post Intervention (Mean) | Change (%) |
|---|---|---|---|
| $CO_2$ (ppm) | 1520 | 593 | −60.9% |
| PM2.5 (µg/m$^3$) | 26.8 | 15.3 | −42.9% |
| HCHO (mg/m$^3$) | 0.008 | 0.0058 | −27.5% |
| TVOC (mg/m$^3$) | 0.015 | 0.011 | −26.7% |
| AQI (unitless) | 36.2 | 29.0 | −20.0% |

Pre intervention, mean $CO_2$ levels reached 1520 ppm, exceeding ASHRAE thresholds, and PM2.5 averaged 26.8 µg/m$^3$, surpassing WHO guidelines. Post intervention, the integrated HEPA filtration, convection, and UVC system reduced $CO_2$ by 60.9% to 593 ppm, PM2.5 by 42.9% to 15.3 µg/m$^3$, HCHO by 31.2% to 0.0055 mg/m$^3$, TVOC by 26.7% to 0.011 mg/m$^3$, and AQI by 18.8% to 29.4 mg/m$^3$, achieving compliance with safe exposure

limits. These results demonstrate the effectiveness of targeted engineering controls for improving indoor air quality in healthcare settings.

## 4. Discussion

The intervention combining HEPA PM2.5 filtration, convection ventilation, and UVC disinfection significantly improved the indoor environmental quality (IEQ) of the administrative office at University Medical Center Ho Chi Minh City Branch 2. The substantial reductions in $CO_2$ (60.9%), PM2.5 (42.9%), HCHO (31.2%), TVOC (26.7%), and AQI (18.8%), as shown in Table 1, align with prior studies demonstrating the efficacy of HEPA and UVC technologies in controlled environments [7,10]. Notably, the $CO_2$ reduction from 1520 ppm to 593 ppm brought levels below the ASHRAE threshold of 1000 ppm, mitigating risks of cognitive impairment and fatigue [8]. Similarly, PM2.5 levels dropping to 15.3 $\mu g/m^3$, below the WHO 25 $\mu g/m^3$ guideline, underscore the intervention's role in reducing respiratory and cardiovascular risks [4]. The diurnal analysis in Figure 5 highlights the intervention's effectiveness during peak occupancy hours (11:00 and 15:00), where pre-intervention $CO_2$ and PM2.5 peaked at 1613 ppm and 30 $\mu g/m^3$, respectively. The post-intervention stability, with reduced variability (error bars), reflects the convection system's ability to redistribute air and prevent pollutant accumulation, a critical finding for high-density workspaces. This aligns with [9], who noted enhanced air mixing as a key factor in indoor pollutant control.

The observed 60.9% reduction in $CO_2$ and 42.9% reduction in PM2.5 were analyzed in terms of mass balance modeling and fluid dynamics. In an enclosed space of 120 $m^2$ with high occupancy, pollutants reached a steady-state concentration where the generation rate equals the removal rate. By introducing a combined system of HEPA filtration and axial fans, the volumetric air exchange rate is altered, changing the environment toward a CSTR model. This transition eliminated stagnant dead zones and ensured that $CO_2$ generated by occupants was rapidly diluted and redistributed for passive or mechanical exhaust.

From an aerosol engineering perspective, the HEPA units operated at an airflow rate of 300 $m^3/h$, targeting PM2.5 through the following mechanical processes: interception, inertial impaction, and diffusional deposition. The significant drop in PM2.5 from 26.8 to 15.3 $\mu g/m^3$ indicates that the system's CADR successfully outpaced the infiltration of urban particulates and internal generation from office equipment. The integration of UVGI at 254 nm provides a layer of biochemical engineering control. The 90% reduction in viable microbial colonies is directly proportional to the UV fluence (dose), which is the product of the 10 $mW/cm^2$ intensity and the operational duty cycle. This photochemical intervention disrupts the origin of airborne pathogens, effectively neutralizing the biological load that traditional mechanical ventilation often fails to capture. This modular, multi-stage approach demonstrates how targeted engineering parameters can be optimized to achieve compliance with WHO and ASHRAE safety thresholds in resource-constrained settings.

The significant reductions in $CO_2$ (60.9%) and PM2.5 (42.9%) are explained by the fundamental laws of mass balance and fluid dynamics. Pre intervention, the office suffered from pollutant stratification due to high occupancy and limited air change. By introducing forced convection, we induced turbulence that outpaced the pollutant generation rate, ensuring that contaminants were rapidly diluted and directed toward the HEPA filtration media.

The biological impact is equally significant. The UVC lamps reduced airborne microbial load by approximately 90%, from 700 $CFU/m^3$ at 15:00 pre intervention to 50–70 $CFU/m^3$ post intervention. This reduction, consistent with [10], enhances infection control, a priority in healthcare settings where administrative staff are exposed to shared spaces. The correlation between PM2.5 and microbial load reductions suggests that HEPA

filtration may also remove microbe-carrying particulates, a synergistic effect warranting further investigation.

Staff feedback, with 100% reporting improved air freshness and 84.6% noting reduced symptoms (e.g., headaches, eye strain), corroborates the objective measurements. These subjective outcomes align with [1], who linked IEQ improvements to enhanced workplace satisfaction and productivity. However, the small survey sample ($n$ = 13) limits generalizability, and future studies should employ larger cohorts and validated psychometric scales.

Limitations include the study's focus on a single 120 $m^2$ office, which may not represent larger or differently configured spaces. The lack of long-term monitoring beyond three weeks restricts insights into system durability and maintenance needs. Additionally, while settle plates provided qualitative microbial data, quantitative methods like active air sampling could yield more precise CFU/$m^3$ estimates. Finally, the study did not assess energy consumption or cost-effectiveness, critical for scaling the intervention in resource-constrained settings.

These findings contribute to the sparse literature on IEQ interventions in Southeast Asian healthcare offices, offering a scalable model for non-clinical spaces. The low-cost, modular nature of the HEPA, convection, and UVC system makes it adaptable to other hospitals in urban areas with high indoor pollutant loads. Future research should explore longitudinal impacts, cost–benefit analyses, and cross-parameter interactions (e.g., PM2.5 and microbial load) to optimize system design.

## 5. Conclusions

A composite intervention of HEPA PM2.5 filtration, convection ventilation, and UVC disinfection effectively enhances IEQ in a hospital administrative office. Post-intervention reductions in $CO_2$ (60.9%), PM2.5 (42.9%), HCHO (31.2%), TVOC (26.7%), AQI (18.8%), and airborne microbial load (90%) brought all parameters within ASHRAE and WHO safety thresholds, mitigating health risks and improving staff comfort. The diurnal stability and reduced variability underscore the system's reliability during peak occupancy, while subjective feedback highlights tangible occupational benefits. These results advocate for the adoption of low-cost, scalable IEQ interventions in non-clinical healthcare settings in resource-constrained regions. Future work should focus on long-term performance, cost-effectiveness, and broader applicability across diverse healthcare environments to establish standardized IEQ protocols, ultimately enhancing occupational health and operational efficiency. The empirical framework proposed in this study can be used to apply mass-transfer optimization and germicidal kinetics to improve occupational health in non-clinical healthcare.

**Author Contributions:** Conceptualization, N.A.D.N.; methodology, N.A.D.N.; software, M.Q.C.D.; vali dation, H.T.N.T.; formal analysis, L.D.V.N.; investigation, N.A.D.N.; resources, N.A.D.N.; data curation, M.Q.C.D. and H.T.N.T.; writing—original draft preparation, M.Q.C.D.; writing—review and editing, L.D.V.N.; visualization, M.Q.C.D.; supervision, N.A.D.N.; project administration, N.A.D.N. and M.Q.C.D. All authors have read and agreed to the published version of the manuscript.

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