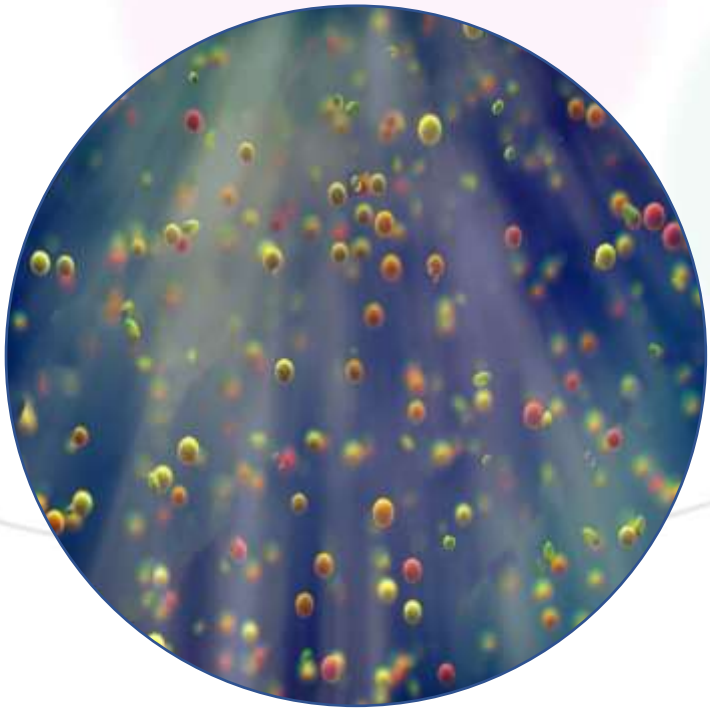
Discovery and Innovation Grant project



Efficacy evaluation of an air handling system (ENHANCE) in mitigating aerosol exposure in enclosed spaces at a transport hub

Abhishek Tiwary, Athul Krishnan, Beth Swallow, Maitreyi Shivkumar

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Snippet: The project demonstrated that the ENHANCE system can offer a robust, continuous intervention for simultaneously reducing both air pollution and pathogen loading, with PM2.5 reduction potential of over 97% and TVOC of up to 95%. Based on the efficacy evaluations, the system is deemed suitable for its deployment in a transport environment to reduce exposure in a constrained space, such as waiting lounge and lifts. We reckon full-scale deployment of the ENHANCE system in such locations would serve two-fold purpose – first, provide a control measure in any future pandemic preparation; second, offer an active health intervention at public transport facilities, specifically alleviating the health risk posed from air pollution and pathogen exposure to vulnerable population, who tend to use these facilities more frequently.

Lay summary

This is a proof-of-concept study towards developing a methodological capacity to assess the efficacy of an innovative air treatment unit (henceforth the ENHANCE system) in enclosed spaces. It is motivated by its potential deployment in public transport microenvironments such as lounge, lifts and stairways to simultaneously control pathogens and improve the air quality. The first part of the project mainly focused on developing a measurement protocol for the ENHANCE system (and systems like it). It involved performance testing of the system through an inlet-outlet monitoring scheme in controlled lab environment under three different ventilation scenarios (closed room, closed room with in-flow through a vent, open room with a cross-flow); two identical portable equipment were used for monitoring air pollutants - particulate matter (PM10 and PM2.5), total volatile organic carbon (TVOC, including benzene, toluene) and the microenvironment (temperature and humidity).

In the next step, the performance of the system for reduction in virus loading was evaluated in a controlled virology lab. Human coronavirus (HCoV)-OC43 and mouse norovirus 1 (MNV-1) were used as model enveloped and non-enveloped viruses; aerosolised air samples were collected on the upstream and downstream locations in a control chamber, and their infectivity (TCID50) and viral genomes (qPCR) was measured. For both viruses, we observed ≥ 4 log10 reduction in infectivity, with negligible infectious virus detected in the output samples. Further, no viral genomes were detected in the downstream samples. Following dedicated efficacy evaluations under lab conditions, a CFD modelling was conducted to ascertain the placement of the system in a real-world setting, mimicking a real train station lounge in terms of the air freshness level, for three options – front (near entrance), centre (with air exchange through 4-way blow ceiling mounted cassette), far end (assuming window closed/ calm zone). The air freshness at head height level for both the mid-point and far end locations in the lounge is found to be less than 10 minutes, which implies that the maximum air cleaning performance of the ENHANCE system can be achieved when the system is placed anywhere beyond the middle part of the lounge.

The study has demonstrated that the ENHANCE system can offer a robust, continuous intervention for simultaneously reducing both air pollution and pathogen loading, with PM2.5 reduction potential of over 97% and TVOC of up to 95%. We have also presented a case study, suggesting an analytical approach for strategic location of the system in the lounge space at a train station, with due consideration to the seating/occupancy patterns and existing ventilation arrangements, in order to maximize the scope of offering fresh, clean (air pollutant and pathogen free) air in the deeper parts of the lounge when it is fully occupied.

Based on the efficacy evaluations, the system is deemed suitable for its deployment in a transport environment to reduce exposure in a constrained space, such as waiting lounge and lifts. We reckon full-scale deployment of the ENHANCE system in such locations would serve two-fold purpose – first, provide a control measure in any future pandemic preparation; second, offer an active health intervention at public transport facilities, specifically alleviating the health risk posed from air pollution and pathogen exposure to vulnerable population, who tend to use these facilities more frequently.

Efficacy evaluation of an air handling system in mitigating aerosol exposure in lifts and enclosed waiting spaces at a transport hub in Leicester

Abhishek Tiwary[1,*], Athul Krishnan[1], Beth Swallow[2], Maitreyi Shivkumar[2]

1 School of Engineering & Sustainable Development, De Montfort University (DMU), The Gateway House, Leicester, LE1 9BH, UK
2 Infectious Diseases Research Group, Faculty of Health and Life Sciences, De Montfort University (DMU), The Gateway House, Leicester, LE1 9BH, UK

* Corresponding author: abhishek.tiwary@dmu.ac.uk

Abstract

This study presents a set of proof-of-concept evaluations towards developing a methodological capacity to assess the efficacy of an innovative air treatment unit (henceforth the ENHANCE system) in enclosed spaces. Based on an inlet-outlet monitoring scheme, the overall $PM_{2.5}$ removal efficacy ranged between 97-100%, irrespective of the time of the day and season. The 10-min averaged total volatile organic carbon (TVOC, including benzene, toluene) concentrations however showed varied levels of removal efficacies, ranging between 25-95%; typically, higher TVOC removal efficacies were noted when the inlet concentrations were high. However, the outlet concentrations were lower than inlet on all occasions (and ranged between 50-150 µg m^{-3}, which has been considered acceptable limits in indoor UK settings). Controlled upwind-downwind chamber experiments in virology lab, using both human coronavirus (HCoV)-OC43, enveloped virus, diameter ~80-120 nm) and mouse norovirus 1 (MNV-1, non-enveloped virus, diameter ~25-40 nm), showed ≥4 log_{10} reduction in infectivity. A CFD-based analytical case study, exploring the optimal placement strategy of the system in a real train station lounge environment, offered some operational best practice in order to maximize the scope of offering fresh, clean (air pollutant and pathogen free) air in the deeper parts of the room when the lounge is fully occupied. Our evaluations demonstrate the system is deemed suitable for its deployment in a transport environment to reduce exposure in a constrained space, such as waiting lounge and lifts. We reckon full-scale deployment of the ENHANCE system in such locations would serve two-fold purpose – first, provide a control measure towards any future pandemic preparation; second, offer an active health intervention at public transport facilities, specifically alleviating the health risk posed from air pollution and pathogen exposure to vulnerable population, who tend to use these facilities more frequently.

1. Introduction

During the COVID-19 pandemic, transport hubs have been identified as a super spreader of infection [1]. At the same time, the release of health-implicating air pollutants from fuel combustion in transport micro-environments encountered along journeys, such as enclosed public transport spaces, have been a longstanding concern [2]. A strong correlation between increment in NO2 and PM2.5 levels and an increase in the risk of COVID-19 transmission has been reported in inner city space [3]. Several studies have emphasised the need for good ventilation, highlighting the idea that fresh air into enclosed spaces can aid the removal of air that contains viral particles [4]. However, poorly ventilated areas, including stairways, lifts and waiting areas in public transport station may result in retention of air containing virus particles for a prolonged amount of time. This is particularly detrimental for vulnerable population, who are frequently reliant on additional access facilities at public transport hubs, such as waiting lounges, lift, etc. Hence, there is a business need to develop preliminary evidence of efficacy of an optimised, production-ready and market-acceptable integrated air-handling unit in a real-world setting, capable of regulating both air quality and pathogens in constrained spaces in a public transport facility.

Ultraviolet germicidal irradiation (UVGI) technology using either low-pressure mercury vapor, xenon or light-emitting diode lamps have been widely used for air and surface disinfection [5]. Typically, upper-air (also commonly called upper-room) devices are widely installed in occupied spaces to control bioaerosols (e.g. suspended viruses, bacteria, fungi contained in droplet nuclei) in the space. In-duct systems are installed in air-handling units to control bioaerosols in recirculated air that may be collected from many spaces, and to control microbial growth on cooling coils and other surfaces. An automated triple-emitter whole room UVGI system has shown efficacy to disinfect the Middle Eastern respiratory syndrome coronavirus (MERS-CoV) on surfaces with a >5log10 reduction [6]. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has provided guidelines on application of UVGI in surface treatment and building maintenance [7]. UV-C radiation (200 nm to 280 nm) is the most effective wavelength for disinfecting surfaces [8] and already considered as an alternative antimicrobial approach to containing localised infections [9]. While UV-C zapping techniques, using mobile platforms or galvanised steel cabinets, have grown in popularity during Covid, they are only as good as all the surfaces are fully exposed, with nothing between them causing shadows. Thus, UVGI is specifically suited for treatment in modern buildings, typically mounted in HVAC ducts for upper-air treatment or wall mounted for room environment in large open-plan spaces. This proof-of-concept study evaluates the efficacy of an innovative air treatment unit (henceforth the ENHANCE system) in simultaneously removing airborne pathogens and pollutants for its potential deployment in suitable public transport sites.

2. Methods

The evaluations have been conducted in three parts:

2.1 Air pollution removal

As a first step, the performance of the ENHANCE system was tested under different ventilation strategies. Lab-testing of the unit were conducted in summer and autumn 2023. For the purpose of capturing the distinct flow and pollution reduction characteristics under different sampling strategies, the sample profiles were vertically split into 5 zones (Fig. 1).

- Air flow was measured at the inlet and outlet using Vane anemometer (zones 4 and 1 respectively). (Fig. 2)
- Air pollution removal (particulate matter, PM10 and PM2.5, total volatile organic carbon, TVOC including benzene, toluene) were also measured using inlet-outlet sampling (zones 1 and 4 respectively) (Fig. 3)
- Air temperature and humidity was measured in all five zones to capture the vertical profiling of the flow.

Fig. 1 Vertical partitioning of the sampling zone for the ENHANCE system.

Fig. 2. Air flow measurements using Vane Anemometer in zones 1 and 4.

Fig. 3. Particulate matter and VOC measurements in zones 1 and 4 with portable samplers using inlet-outlet monitoring scheme.

The lab evaluations were conducted over continuous operation (>24 hrs), and this exercise mainly tested the efficacy of the system in reducing aerosols (PM_{10} and $PM_{2.5}$) and Volatile organic carbon (VOC) concentrations utilizing the interventions introduced in the system. The VOC monitoring equipment included specifically Formaldehyde using electrochemical sensor, and other VOCs including benzene, toluene as TVOC using semiconductor.

The ENHANCE system uses a mercury vapour lamp and emits UV at 254nm (UV-C), The concern of inadvertent ozone (O_3) formation from photolysis in 254 nm UV-C is considered negligible and therefore O_3 monitoring was not included in the scope of lab testing. This is owing to the low-pressure mercury vapor lamp envelop used in the system being capable of masking the lower wavelength (184 nm) radiations, which is considered the main source for generating ozone [10].

The mean age of air was considered as the proxy for the CO_2 concentration in the room space, which was modelled as Freshness parameter (see Section 2.3). We acknowledge, CO_2 and NO_2 are good markers of the local transport microenvironment, however, given the ENHANCE system has no feature to control their concentrations, they were excluded from the scope of the lab evaluations. Further, East Midlands Railways already have a dedicated monitoring station at Leicester train station platform using AQMesh, which continuously measures concentrations of nitrogen dioxide (NO_2) and particulate matter (PM) every 15 minutes [11].

2.2 Pathogen reduction

The scope of pathogen reduction in this proof-of-concept study was limited to viral load reduction. The bioaerosol sampling focused on smaller common cold virus aerosols from air samples, which tend to remain airborne for longer time, unlike larger bacterial and fungal spores. A real-time quantitative PCR (RT qPCR) technique was adopted from the literature methods [12,13]. Air sampling bench was set up in a controlled chamber in a dedicated virology lab using upstream-downstream filter sampling technique, followed by detailed lab analysis as per literature method. Both human coronavirus (HCoV)-OC43 (enveloped virus, dia ~80-120 nm) and mouse norovirus 1 (MNV-1) (non-enveloped virus, dia ~25-40 nm) were used as model viruses.

2.2.1 Air sample collection

For air sample collection, virus (7.75 log10 TCID50/mL) was diluted 1/10 in phosphate buffered saline (PBS). The diluted virus sample was then aerosolised using a 6-jet Collision Nebuliser (modified Microbiological Research Establishment, CH Technologies) (Fig. 4), using compressed air at a regulated output pressure of 20psi following the guidelines in the instruction manual [14].

In the first step, to develop a robust sampling protocol, two different sample collection surfaces were tested – a stainless steel metal disc and polycarbonate 0.015µm filter membranes (LabShop, 110601). In the preliminary experiments, the selected surface was mounted on a petri dish and positioned directly in level with the aerosol outlet, approximately 1 cm distance away (Fig. 5).

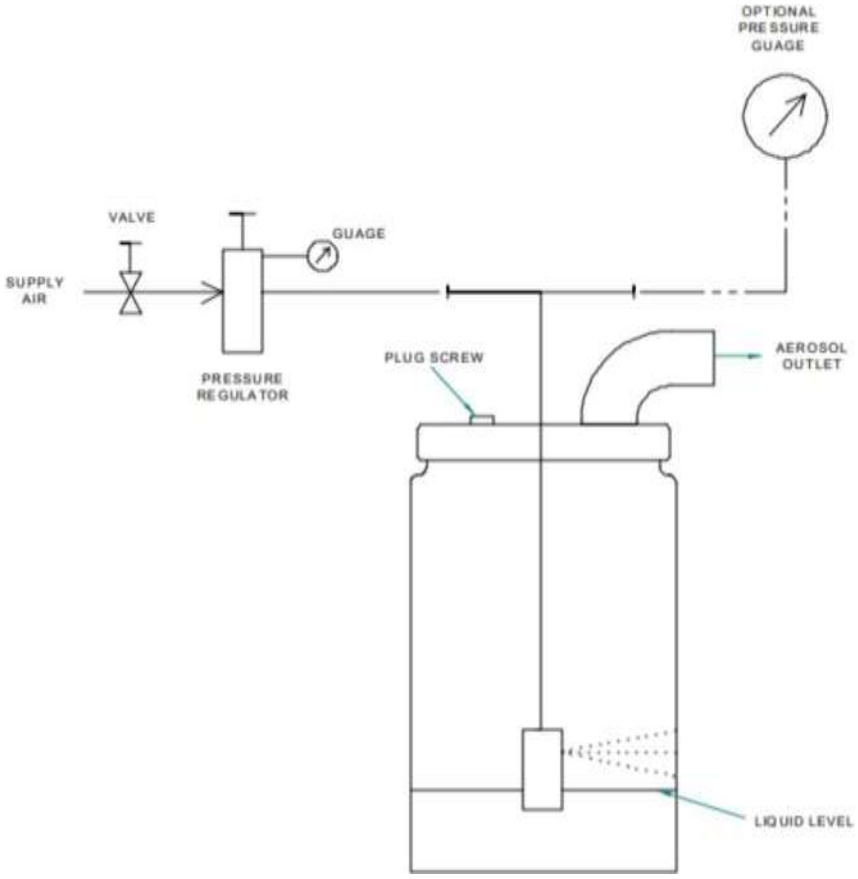

Fig. 4. Schematic diagram showing configuration of the nebuliser set up (source: Instruction Manual, CH Technologies, USA).

Fig. 5. Determination of sampling protocols of representative viral loadings in the upstream-downstream bioaerosol samples.

The compressed air was passed through the nebuliser for 5 minutes through the virus sample, and the aerosolised virus particles were emitted from the aerosol outlet, onto the selected mounted surface. The collection surface was removed and shaken vigorously in 3 ml PBS for 30 seconds, to transfer any viral particles. The solution was then aliquoted and stored at -80°C before quantifying virus infectivity and viral genomes.

To test the system efficacy, virus (7.75 $\log_{10}$ $TCID_{50}$/mL) was diluted 1/10 in PBS and aerosolised as described before. Aerosolised virus particles emitted from the aerosol outlet were passed through PVC tubing attached to the UV irradiation system (Fig. 6). Samples were collected on upwind ("input sample") and downwind ("output sample") of the ENHANCE system. All experiments were conducted in three biological replicates.

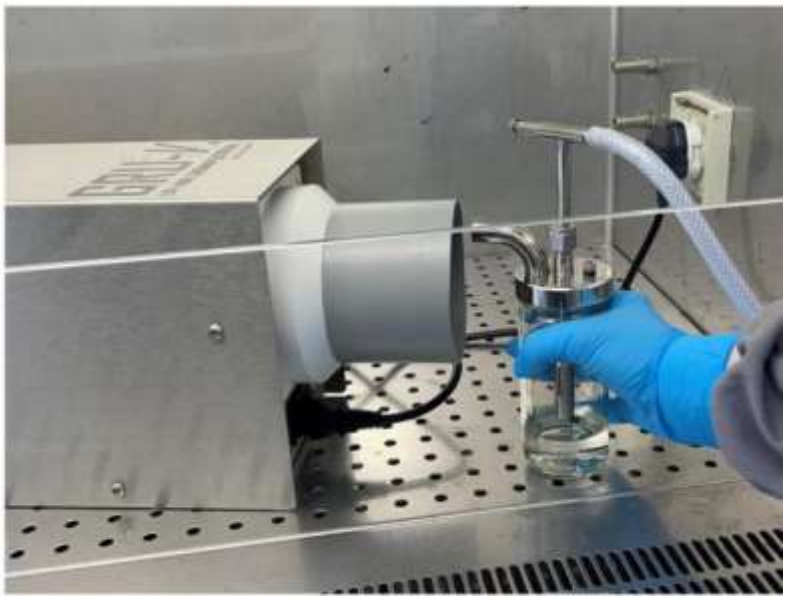

Fig. 6. Filter sampling of the aerosolised viral particles in chamber experiment.

2.2.2 Sample preparation

HCT-8 epithelial cells (CVCL_2478) cells were cultured in RPMI-1640 (Lonza) supplemented with 10% foetal bovine serum (FBS; HyClone), 100 IU mL^{-1} penicillin and 100 µg mL^{-1} streptomycin (Pen/Strep; Lonza). BHK-21 fibroblasts (CVCL_1915) and BV-2 microglial cells (CVCL_0182) were cultured in Dulbecco's Modified Eagle Medium (DMEM; Lonza) supplemented with 10% FBS, 100 IU mL^{-1} penicillin and 100 µg mL^{-1} streptomycin. All cells were grown at 37 °C, 5% CO_2.

Human coronavirus (HCoV)-OC43 and mouse norovirus 1 (MNV-1) were used as model enveloped and non-enveloped viruses. HCoV-OC43 virus stocks were cultured in HCT-8 cells in RPMI supplemented with 5% FBS and Pen/Strep for 7 days at 33 °C. Virus-containing supernatant was harvested from the supernatant, centrifuged (3000*g*, 4 min) to remove cell debris, and virus aliquoted and stored at -80 °C until use. MNV-1 virus stocks were cultured in BV-2 cells in DMEM supplemented with 10% FBS and Pen/Strep for 2 days at 37 °C. Virus was harvested and stored as above.

2.2.3 Viral infectivity evaluation

To determine viral infectivity, HCoV-OC43 virus suspensions were serially diluted in DMEM and transferred onto BHK-21 fibroblast cells (CVCL_1915) seeded in a 96-well format. Plates were incubated at 33 °C, 5% CO_2 for 4 days before scoring wells for cytopathic effect (CPE). The 50% tissue culture infectious dose ($TCID_{50}$) was calculated using the Karber method [15].

MNV-1 virus suspensions were serially diluted in DMEM and transferred onto BV-2 cells seeded in a 96-well format. Plates were incubated at 37 °C, 5% CO_2 for 3 days before scoring wells for CPE. $TCID_{50}$ was calculated using the Karber method, as above.

2.2.4 Viral genome determination

Viral RNA was extracted from 200 µL input and output samples as per manufacturer's instructions (Monarch Total RNA Miniprep Kit, NEB). RNA was eluted in 100 µL nuclease-free water and frozen at -20 °C until use. To quantify viral genomes, a one-step qRT-PCR kit (SuperScript III One-Step RT-PCR System with PlatinumTM Taq DNA Polymerase, ThermoFisher) was used according to manufacturer's instructions, with following HCoV-OC43 specific primers: (forward primer, 5-AGCAACCAGGCTGATGTCAATACC-3; reverse primer, 5-AGCAGACCTTCCTGAGCCTTCAAT-3); probe ([6FAM] TGACATTGTCGATCGGGACCCAAGTA [TAM]). No template and no reverse transcriptase controls were included. cDNA synthesis and PCR amplification was performed as follows: 50 °C for 15 min, 95 °C for 2 min, 40 cycles of 95 °C for 10 s and 60 °C for 20 s, using an Applied Biosystems QuantStudio5 5 real-time PCR system.

2.3 Case study - System placement strategy for maximum performance

Following lab-scale evaluations of pollution removal and viral load reduction efficacies in previous steps, this step evaluated the placement options for maximizing the performance potentials of the ENHANCE system in a real-world setting. The newly refurbished lounge space on platform 1-2 at Leicester Train station was used for this evaluation. Computational fluid dynamics modelling was considered appropriate to understand the air flow patterns and its freshness for end users, including hot-cold spots within the space, any dead zones, etc. This was deemed essential to develop a strategy for installing the ENHANCE system for maximum performance returns in a high occupancy transport environment.

The room configuration is shown in Fig. 7 and the modelling parameters used are listed below. This also includes simulation of an existing Air conditioning Cassette air supply system which was already installed in the refurbished lounge.

- Room Dimension =10 mx10 mx3.5 m
- Space conditioning = 20^{o}C
- AC Cassette air supply rate = 0.028 $m3\ s^{-1}$
- Scenario 1: Hot day (dry bulb temperature = 28 ^{o}C)
- Scenario 2: Cold day (dry bulb temperature = -6 ^{o}C)

All the model outputs shown on the following pages were obtained at three locations – 1. near the entrance, 2. in the middle of room, 3. near the far window (sealed). This

was considered to identify the possible suitable location/s for the ENHANCE system. All scenarios were modelled for this study in the software package Integrated Virtual Environment – Virtual Environment (IES-VE v.2019.2.0).

Fig. 7 – The lounge space showing the seating arrangement (upper panel). Frontal entrance (lower left panel), Rear window - sealed (lower right panel)

3. Results and Discussion

3.1 Pollution reduction

The PM2.5 removal efficacy was found to be pretty good for most the operational ventilation strategies tested, irrespective of the time of the day. The overall efficacy ranged between 97-100%, with few exceptions when the inlet concentrations were deliberately spiked (Fig. 8). This could be attributed to the overwhelming of the particle-laden air flow entering the ENHANCE system leading to some particles escaping the air flow trajectory and getting sensed directly by the downwind monitor.

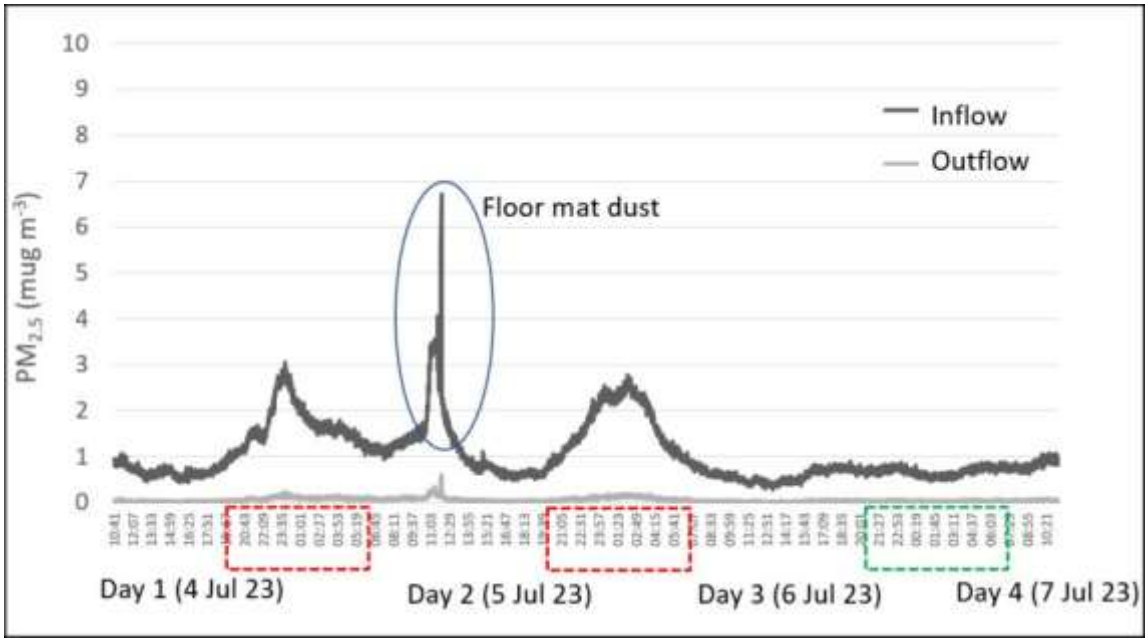

Fig. 8. $PM_{2.5}$ removal efficacy of the ENHANCE system from upwind-downwind monitoring during summer experiment.

The continuous monitoring of NO_2 and PM emissions, recorded by East Midlands Railways at Leicester train station are shown in Table 1. These capture the level of train emissions on a diurnal basis, however, are mainly meant to provide an indication of regulatory exceedances (if any).

Table 1. Air pollutant emissions from AQMesh monitoring at Leicester train station

Pollutant	**Measurement type**	**Mean measurement (µg m^{-3})**	**Max measurement (µg m^{-3})**	**Air quality objective in England (µg m^{-3})**
NO_2	1-hr mean		123.9	200 – not to be exceeded more than 18 times per year
	Annual mean	29.9		40
PM_{10}	24-hr mean	13.6	31.4	50 – not to be exceeded more than 35 times per year
	Annual mean	13.6		40
$PM_{2.5}$	Annual mean	9.2		25

(source: East Midlands Railway Clean Air Report)

The 10-min averaged inlet and outlet total volatile organic carbon (TVOC) concentrations showed varied levels of removal efficacies ranging between 25-95% (Fig. 9). This was typically higher when the inlet concentrations were high, which demonstrates its robustness in controlling the outlet concentrations. However, on some occasions the outlet concentrations were found to be erratically high. This could be attributed to the abundance of the TVOC in the ambient air, leading to limited control on the outlet monitoring in the absence of a ducted sampling approach. However, it is noteworthy that the peak TVOC concentrations on all occasions were lower in the outlet, and within the range of 50-150 µg m^{-3}, which has been considered acceptable limits in indoor UK settings (TVOC levels shouldn't exceed 400 µg m^{-3}).

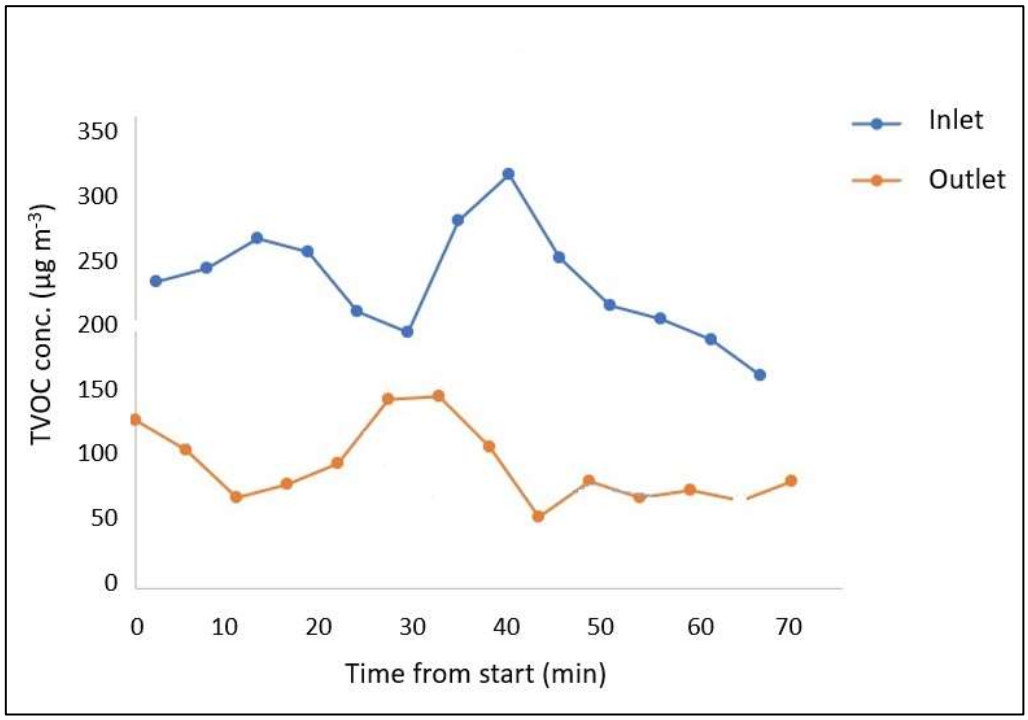

Fig. 9. TVOC removal efficacy of the ENHANCE system under controlled environment (10-min hourly averaged, showing a lag of 5 min in the outlet concentration to allow for the removal from the entrained flow).

3.2 Viral load reduction

During initial filter sampling protocol development, the recovery from the polycarbonate membranes were found to be higher than the stainless-steel disks. For both viruses, we observed ≥ 4 $\log_{10}$ reduction in infectivity, with no or negligible infectious virus being detected in the output samples. The viral infectivity evaluation results are shown in Tables 2 and 3.

Table 2. HCoV-OC43 viral infectivity (expressed as mean ± SEM). Where one or more samples reached the limit of detection (0.80 log_{10} $TCID_{50}$/mL), data is expressed as ≤ log_{10} $TCID_{50}$/mL.

Collection surface	Viral infectivity (log_{10} $TCID_{50}$/mL)		
	Inoculum	Input sample	Output sample
Polycarbonate membrane	4.80 ± 0.00	4.11 ± 0.08	≤1.21 ± 0.41

Table 3. MNV-1 viral infectivity (expressed as mean ± SEM). Where one or more samples reached the limit of detection (0.80 log_{10} $TCID_{50}$/mL), data is expressed as ≤ log_{10} $TCID_{50}$/mL.

Collection surface	Viral infectivity (log_{10} $TCID_{50}$/mL)		
	Inoculum	Input sample	Output sample
Polycarbonate membrane	7.97 ± 0.00	6.20 ± 0.17	≤0.80 ± 0.00
Stainless steel	7.83 ± 0.00	4.95 ± 0.22	≤0.80 ± 0.00

Table 4 shows the viral genomes abundance; we detected viral genomes in the input samples, but we detected no viral genomes in the output samples. These evaluations suggest the efficacy of the ENHANCE system in inactivating/reducing the viral exposure.

Table 4. Quantification of HCoV-OC43 viral genomes (expressed as relative C_t values, mean ± SEM). N.D., not detected.

Collection surface	Relative C_t value			
	Negative control	Inoculum	Input sample	Output sample
Polycarbonate membrane	37.97 ± 0.43	16.65 ± 0.04	28.23 ± 0.77	N.D.
Stainless steel	37.46 ± 0.30	15.68 ± 0.07	34.62 ± 4.27	N.D.

3.3 System placement strategies

3.3.1. Air flow patterns inside the lounge space

The CFD modelling allowed visualization of the air flow patterns inside the lounge space at the train station. Comparing figures for different location air movement, it was noted that the air movement is weaker at the far ends and stronger at the mid portion. This is attributed mainly to the air flow induced from the AC cassette installed on the ceiling in the middle part of the room. However, the air dynamics inside the room does not appear to depend much on the variation with outside air temperature (i.e. Hot vs. Cold day). These results for the two scenarios are shown respectively in Fig 10 a-c and Fig 11 a-c.

Scenario 1: Hot Day (dry bulb temperature = 28 ºC)

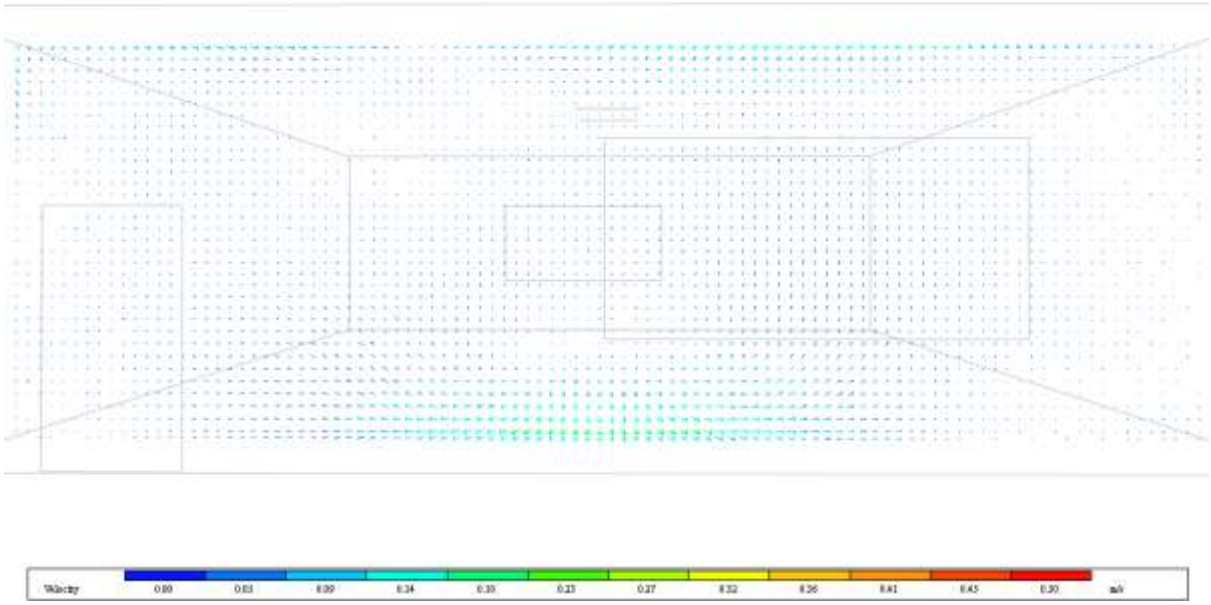

Fig. 10a Air movement 1m away from the from the front door.

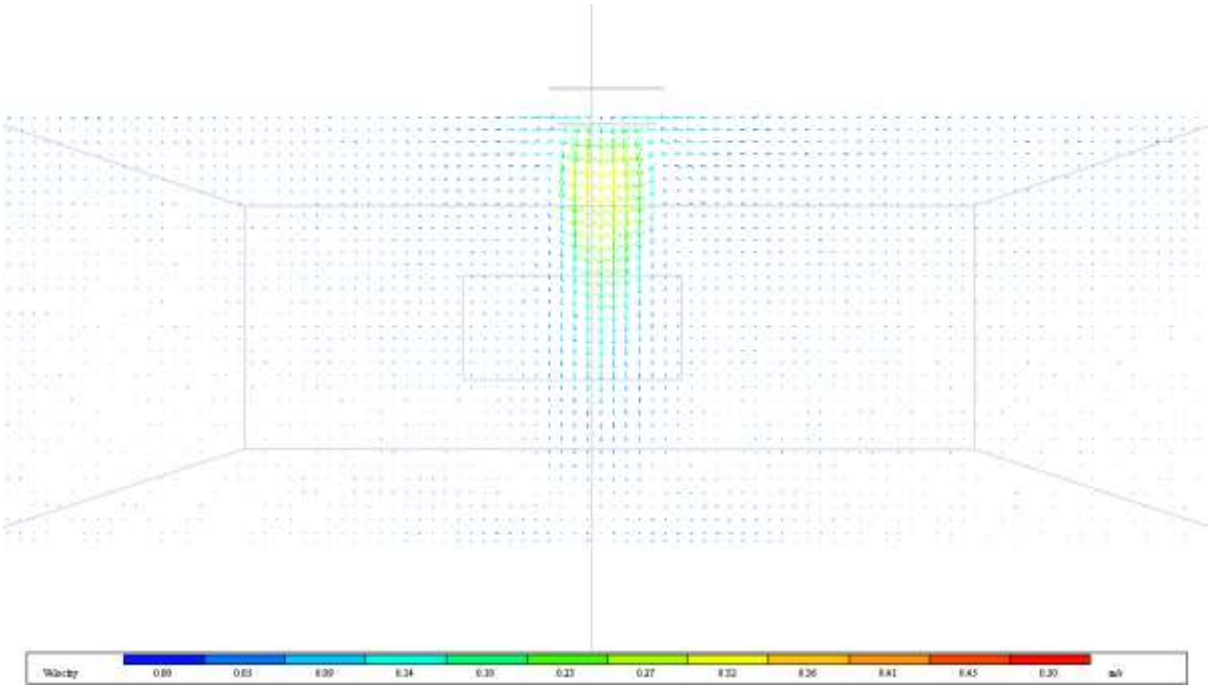

Fig. 10b Air movement in the mid portion.

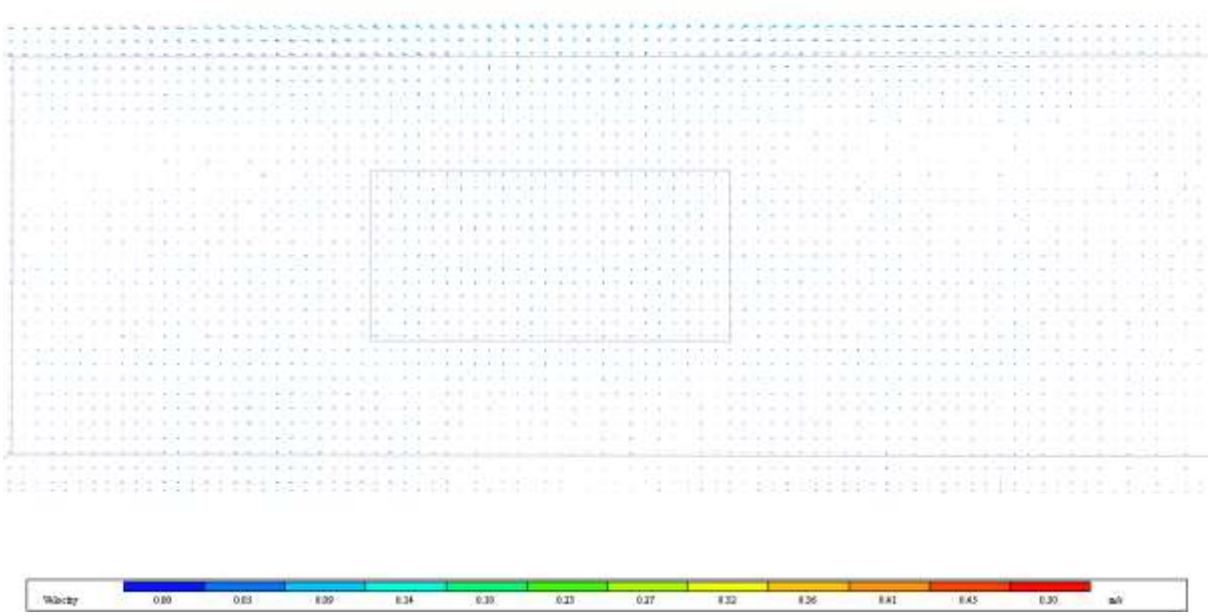

Fig. 10c - Air movement 1m away from the back window.

Scenario 2: Cold Day (dry bulb temperature = -6 ºC)

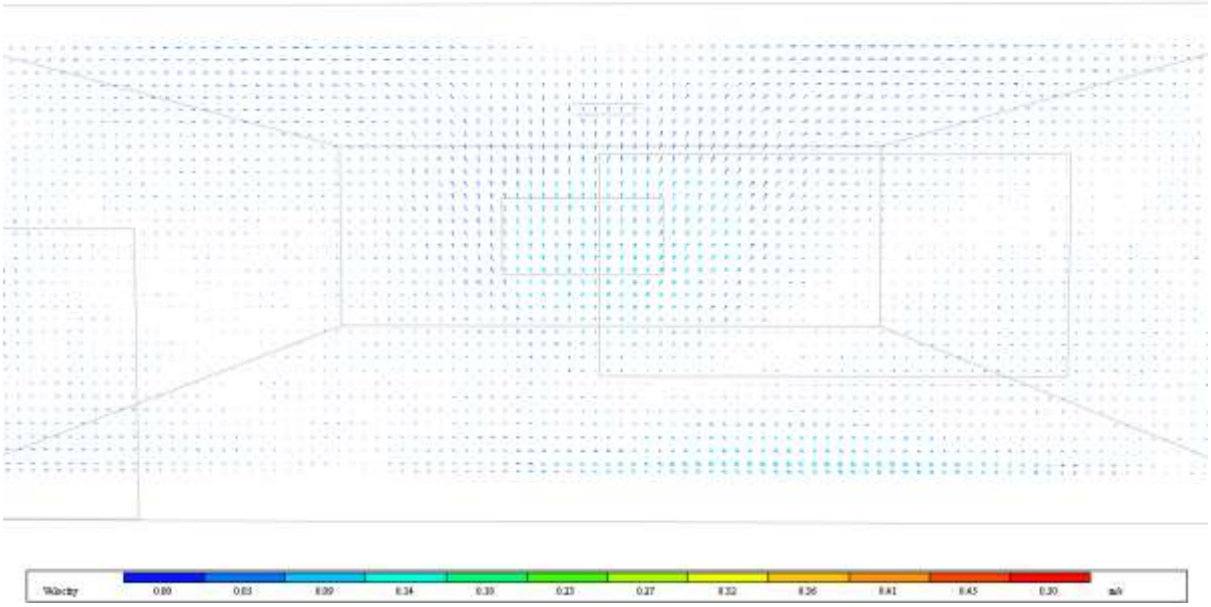

Fig. 11a - Air movement 1m away from the front door.

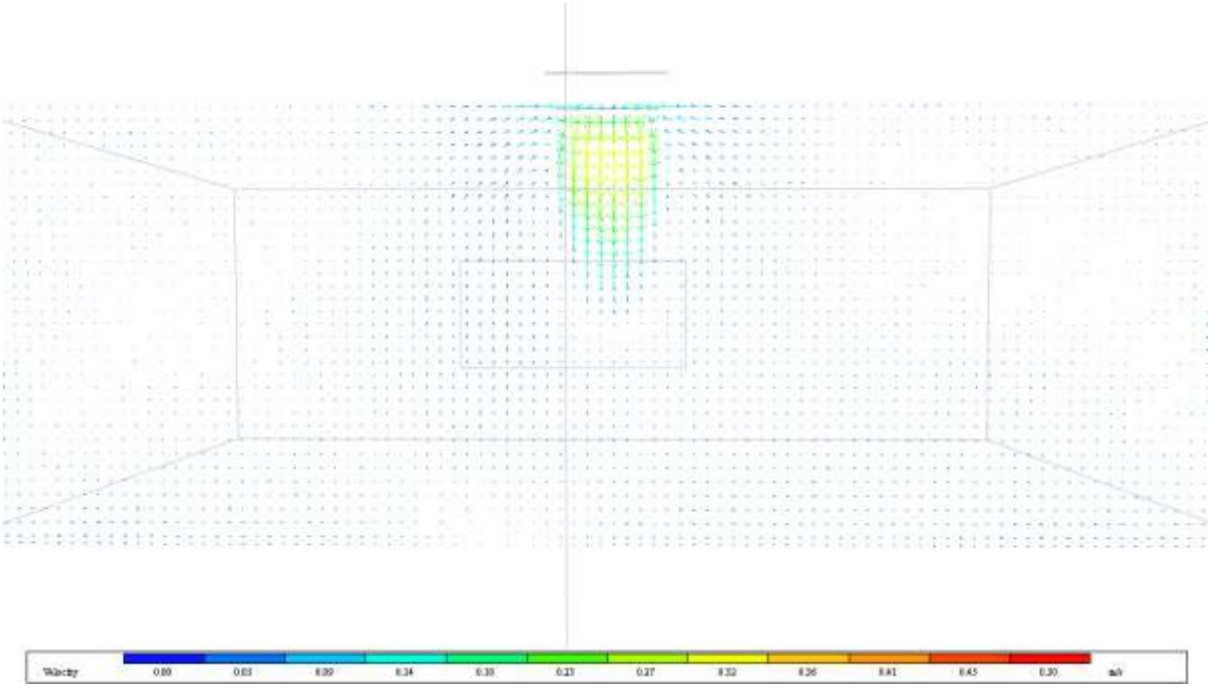

Fig. 11b Air movement in the mid portion.

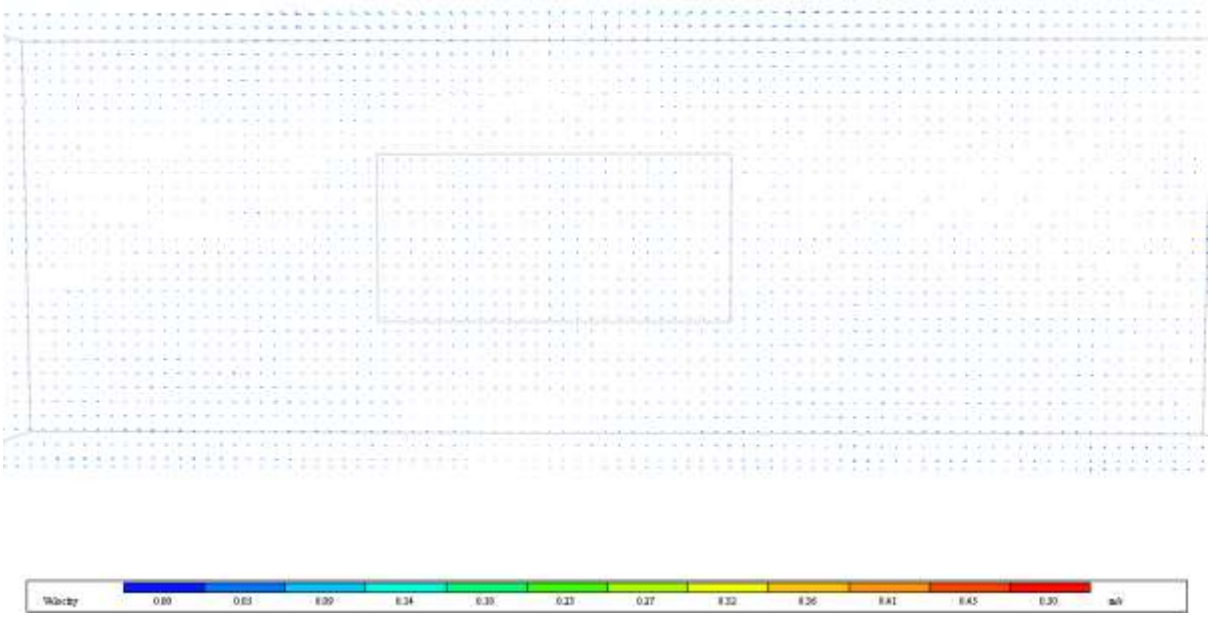

Fig. 11c - Air movement 1m away from the back window.

3.3.2 Local mean age of air

The local mean age of the air (MAA) is considered as the proxy for the mean air freshness level inside the lounge space. For all the simulations, the air was conditioned at 20°C. The results are shown in Fig. 12a-c. The air freshness at head height level is less than 10 min for both the mid-point and far end locations in the lounge. This implies that the maximum air cleaning performance of the ENHANCE unit can be achieved while placing the system anywhere beyond the middle part of the room.

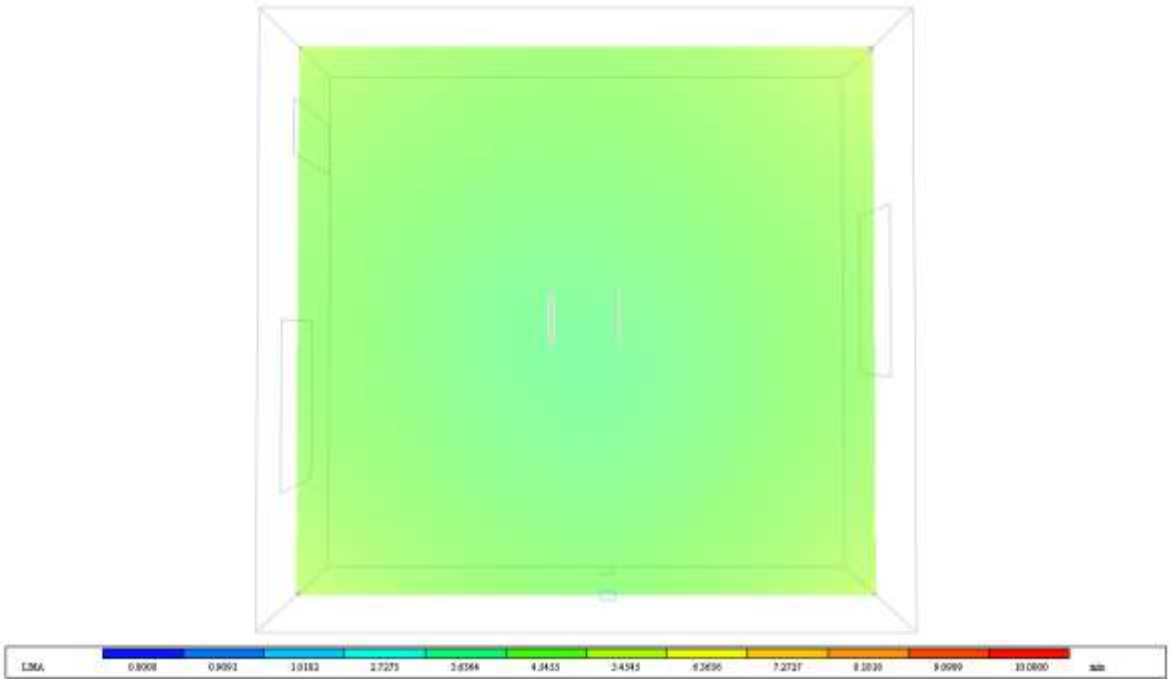

Fig. 12a - Local MAA at head height level at 1m away from the front door.

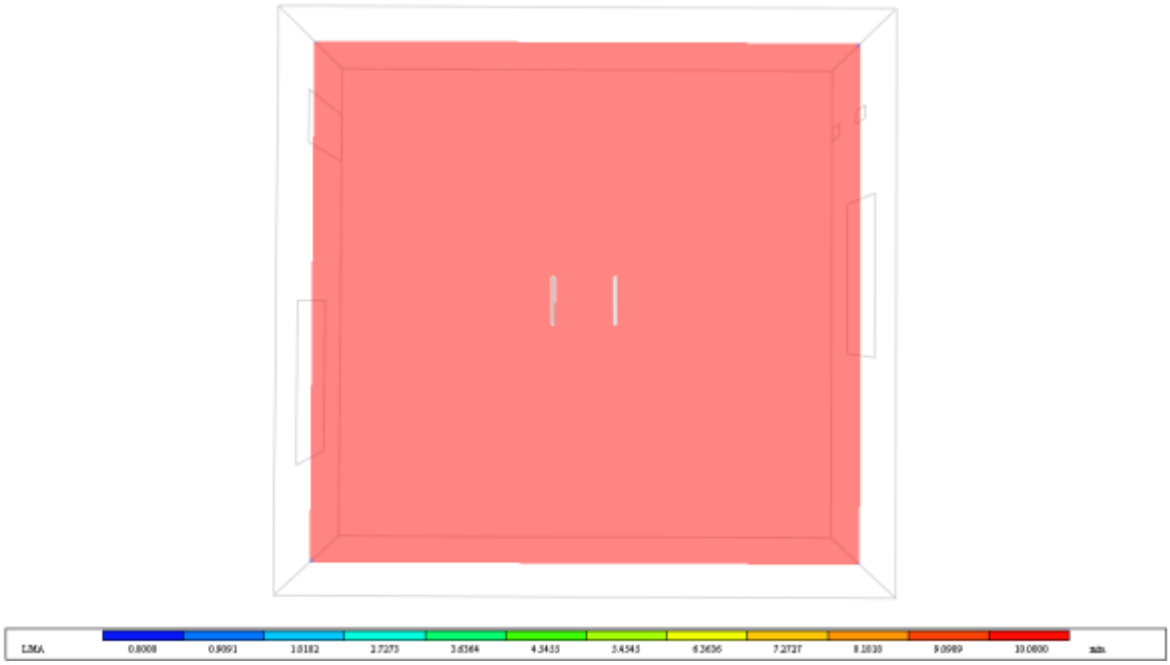

Fig. 12b - Local MAA at head height level in the mid portion.

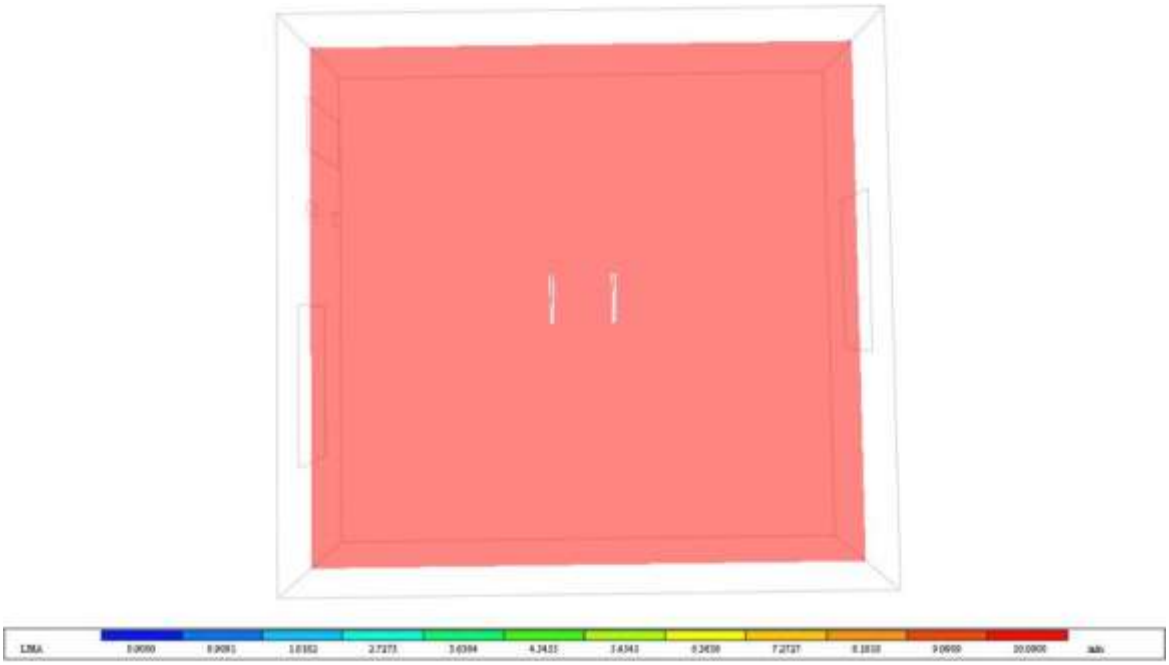

Fig. 12c - Local MAA at head height level at the far end of the room.

It is noteworthy, this analysis is purely based on the air flow patterns in the room and has not considered the fouling of the air by human exhalation (which will further deteriorate the freshness). Therefore, in order to decide on a strategic location of the ENHANCE unit, the occupancy patterns of the lounge space have to be considered alongside, specially to maximize the scope of offering fresh, clean air in the deeper parts when the lounge is fully occupied.

4. Conclusions and Further work

This study presented proof-of-concept evaluations towards developing a methodological capacity to assess the efficacy of an innovative air treatment unit in enclosed spaces. The overall $PM_{2.5}$ removal efficacy ranged between 97-100%, irrespective of the time of the day. The 10-min averaged total volatile organic carbon (TVOC) concentrations however showed varied levels of removal efficacies, ranging between 25-95%; typically, higher TVOC removal efficacies were noted when the inlet concentrations were high. Nevertheless, TVOC concentrations on all occasions were lower at the outlet, and ranged between 50-150 µg m^{-3}, which has been considered acceptable limits in indoor UK settings.

Controlled upwind-downwind chamber experiments in the virology lab, using both human coronavirus (HCoV)-OC43, enveloped virus, dia ~80-120 nm) and mouse norovirus 1 (MNV-1, non-enveloped virus, dia ~25-40 nm), showed ≥ 4 $\log_{10}$ reduction in infectivity. A CFD-based analytical case study, exploring the optimal placement strategy of the system in a real train station lounge, offered some operational best practice in order to maximize the scope of offering fresh, clean (air pollutant and pathogen free) air in the deeper parts when the lounge is fully occupied. Further analysis of the system performance under continuous operation in a real-world setting is warranted to ascertain the operational challenges (efficacy optimisation, increased electrical power demand under stressed operation, maintenance needs, etc.).

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