Delivery of an indoor air quality campaign in social housing:

IAQ data impacts (briefing 2)

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Acknowledgements:

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Key points from this briefing

- This briefing reports on a 12-month campaign to improve the air quality of more than 200 homes in the Cheshire and Merseyside region (Liverpool, St Helens, Warrington). Its aim was to improve respiratory health for young children (under 11 years) living in social housing.
- Beyond: Cheshire and Merseyside ICB Children and Young People's Transformation programme funded the campaign and its evaluation. Torus Housing Group (Assets) provided match funding to secure additional monitors. Torus Foundation (the charitable part of Torus) delivered the campaign through its Healthy Neighbours project.
- The IAQ results presented includes data from up to 206 homes across Liverpool, St Helens and Warrington. While IAQ measurements were made in 206 homes, only 136 homes had a follow up intervention that allowed for a quantitative comparison. Moreover, only 71 homes had a completed questionnaire that permitted analysis of IAQ data against certain social variables.
- There is a general story of improved IAQ across all of the locations. However, there are homes in all locations that are outliers for most pollutants, and these homes could be targeted for further support / advice.
- The trends for different air pollutants are relatively consistent across the locations. However, for PM_1 and $PM_{2.5}$ the trends are much less clear. This suggests a range of different indoor and outdoor sources that are not consistent across different locations.
- Increased knowledge of air quality / indoor air quality may lead to increased anxiety around the issue, which suggests careful attention should be paid to how results are presented to tenants.

Background

Poor air quality has been highlighted as the world's greatest environmental health risk (1), linked with several short- and long-term health consequences. These include impacts on lung development in children, heart disease, strokes, cancer, and asthma (2). In the UK, between 28,000 and 36,000 deaths a year are estimated to be associated with poor air quality (3). However, these figures are based primarily on outdoor air pollution, despite the average person in the UK spending ~90% of their time indoors (4), where the brunt of these exposures occur. Additional to outdoor air pollution coming indoors, there are a range of other sources of poor indoor air quality (IAQ) including emissions from cleaning products, building materials, cooking and heating, and tobacco products. Moreover, poor building conditions can exacerbate IAQ through high humidity leading to damp, condensation, and mould (5).

The challenges and opportunities of improving IAQ are particularly prescient at the moment owing to a series of high-profile reports in 2022, including from the UK Government's Air Quality Expert Group (6), and explicit mentions in the Chief Medical Officer's Annual Report on Air Pollution (2). Public and political attention is also exemplified by media and government focus following the death of a toddler, Awaab Ishak, caused by mould exposure in his family's social housing (7).

The Indoor Air Quality campaign

This briefing reports on a campaign to improve indoor air quality (IAQ) in social housing, which was delivered across Liverpool, St Helens and Warrington in the Cheshire and Merseyside region. The campaign's aim was to improve respiratory health for young children living in social housing through the use of digital technology. Beyond: Cheshire and Merseyside ICB Children and Young People's Transformation programme funded the campaign and its evaluation. Torus Housing Group (Assets) provided match funding to secure additional monitors. Torus Foundation (the charitable part of Torus) delivered the campaign through its Healthy Neighbours project.

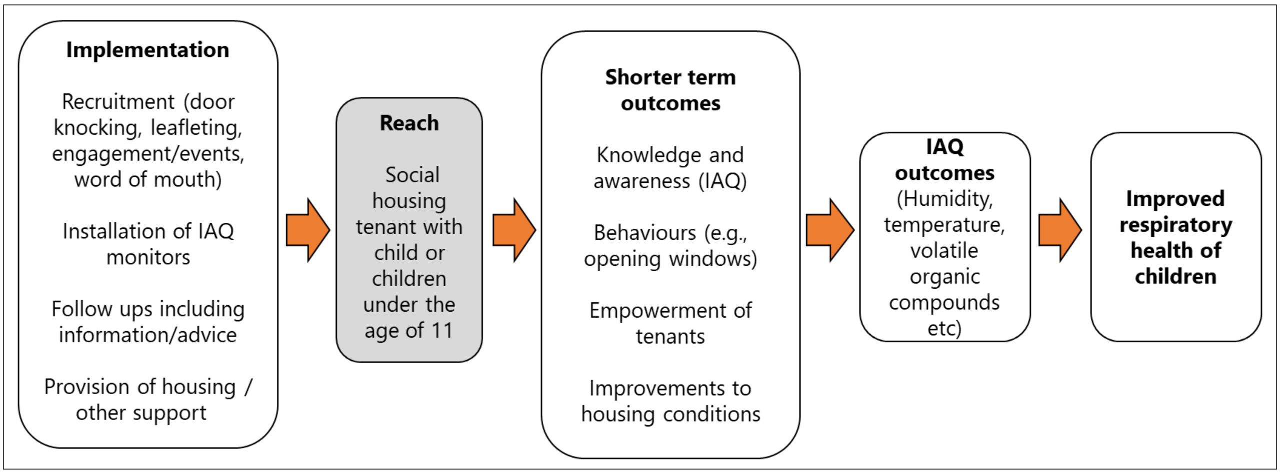
To qualify for a free monitor, a tenant needed to:

- Be a Torus housing customer
- Have a child or children under the age of 11 (initially under 5 years then extended)
- Live in one of the specific areas under the pilot scheme.

Where families expressed interest in taking part, they were offered smart IAQ monitors to detect the levels of humidity, temperature, volatile organic compounds and ambient pollutants. Following the identification of eligible families, the campaign involved the following stages: (i) recruitment and engagement (ii) installation of monitors (iii) follow up visits/contacts involving the provision of advice/information and or support from housing or other providers. Figure 1 provides an overview of the campaign's delivery and its intended outcomes.

Staff and volunteers from the Torus Foundation and its Healthy Neighbours project were closely involved with the campaign's delivery, on hand to promote uptake, support the set-up of devices, maintain engagement and troubleshoot. The Healthy Neighbours project is delivered across Torus neighbourhoods in Liverpool, St Helens and Warrington, commissioning local organisations to help to deliver targeted activities to tackle local health issues. Each area has a dedicated volunteer - coordinator and volunteers who are helping to encourage community members to take part in a range of activities.

Figure 1: Indoor air quality campaign logic model



About the evaluation

In 2022, Lancaster University and NAQTS (National Air Quality Testing Services Ltd.) were commissioned to deliver an evaluation of the campaign. The evaluation used mixed methods.

- Monitor data was shared with NAQTS who analysed this to understand IAQ in households at the start of the campaign, and to assess IAQ changes following thir installation.
- Interviews were held with Healthy Neighbour and Torus Foundation staff involved with delivery of the campaign (n=6 staff members).
- Telephone interviews with social housing tenants who had installed monitors (n=7 tenants).
- Two focus groups with tenants, Healthy Neighbour staff and Torus Foundation staff (17 tenants and staff).

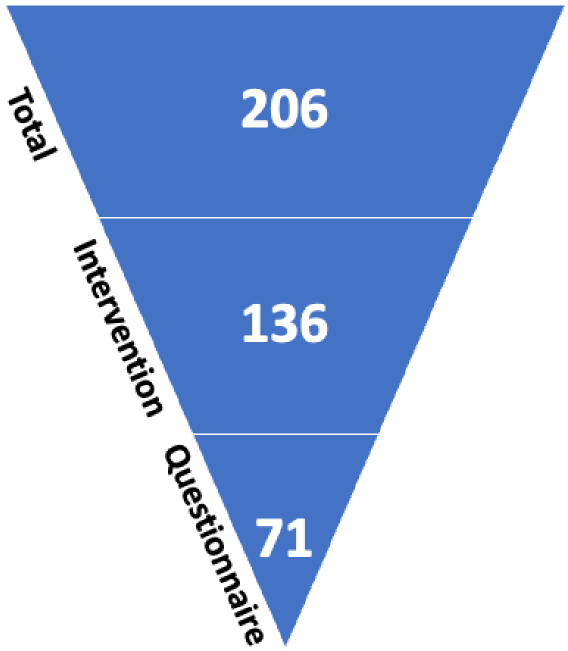
This is one of a series of briefings reporting the evaluation's findings. In this briefing we focus on the reach of the campaign and whether IAQ within the home has changed, based on the analysis of the IAQ monitor data across the participating households.

All the briefings from this evaluation are available at the following link:
http://www.torusfoundation.org.uk/indoorairquality

What did we find?

These analyses include data from up to 206 homes across Liverpool, St Helens and Warrington. While IAQ measurements were made in 206 homes, only 136 homes had a follow up intervention that allowed for a quantitative comparison. Moreover, only 71 homes had a completed questionnaire that permitted analysis of IAQ data against certain social variables (see Figure 2).

Figure 2: number of households for certain types of analysis



The IAQ data are presented to characterise the current air quality situation within participant homes (e.g. before the intervention), and the effectiveness of the interventions. These results neither include calculations for statistical significance, nor consider seasonal effects. The IAQ data are based on daily means, and shorter-term concentrations are not considered (e.g. hourly).

The data are visualised using boxplots, where the lower and upper box boundaries represent the 25th and 75th percentiles respectively, the horizontal line is the median, and the circle is the mean. Where three boxplots are presented, these represent the different areas (e.g. Liverpool, St Helens, and Warrington). They are labelled as follows: LV is Liverpool, STH is St Helens, and WA is Warrington. They can also be identified through different colours: green is Liverpool, blue is St Helens, and orange is Warrington.

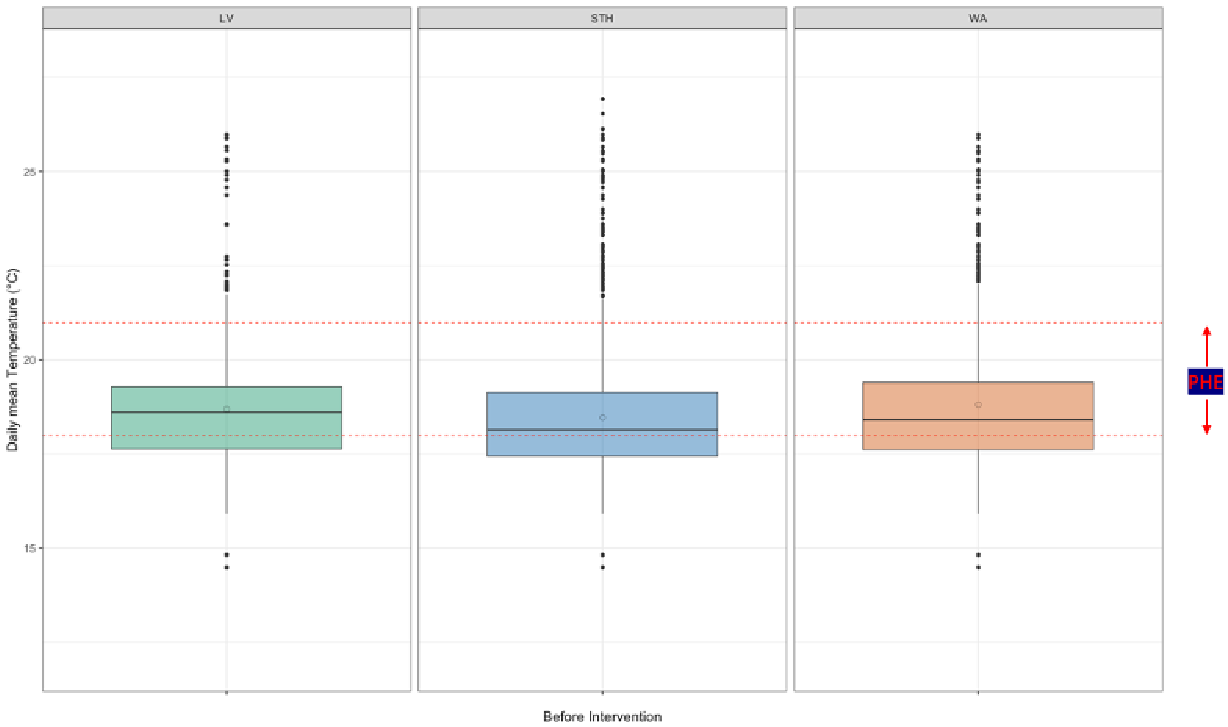
Current air quality situation within participant homes

These analyses include data from up to 206 homes. Figures 9 and 10 looking at the effect of smoking in the household, and distance from the road are based on data from 71 homes.

Temperature

Thresholds for acceptable temperature ranges that are included on Figure 3 are based on Public Health England's (PHE) *Minimum home temperature thresholds for health in winter* which recommends 18°C – 21°C (8). It is important to note that these thresholds do not include maximum temperatures, which are more applicable for the cooling season (e.g. the summer months). These thresholds have not been included as the measurements for this project primarily come from the heating season, rather than the cooling season. Most homes across all three locations sit within the recommended range of temperatures. In all locations the mean and median are towards the lower end of the threshold range, with homes in St Helens being the coldest. In all locations some homes are outside of the recommended temperature range, with the majority of those being above the temperature threshold. However, there are also a few that are below the minimum recommended temperature.

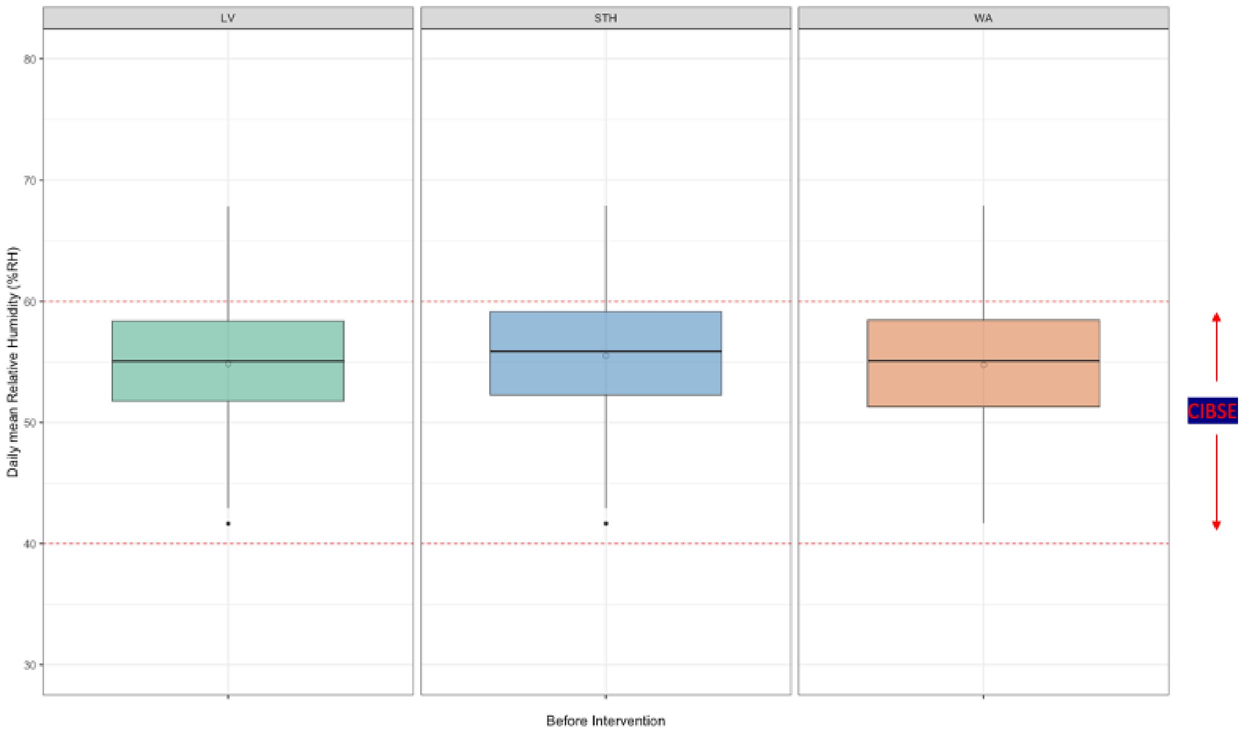
Figure 3: Temperature in the participant homes before the intervention



Relative Humidity

Thresholds for acceptable relative humidity (RH) ranges that are included on Figure 4 are based on the Chartered Institution of Building Services Engineers (CIBSE) TM40:2020 which recommends that RH should be 40-60% in homes (9). Most homes across all three locations sit within the recommended range of RH. In all locations the mean and median are towards the upper end of the threshold range. In all locations some homes are outside of the upper recommended RH range.

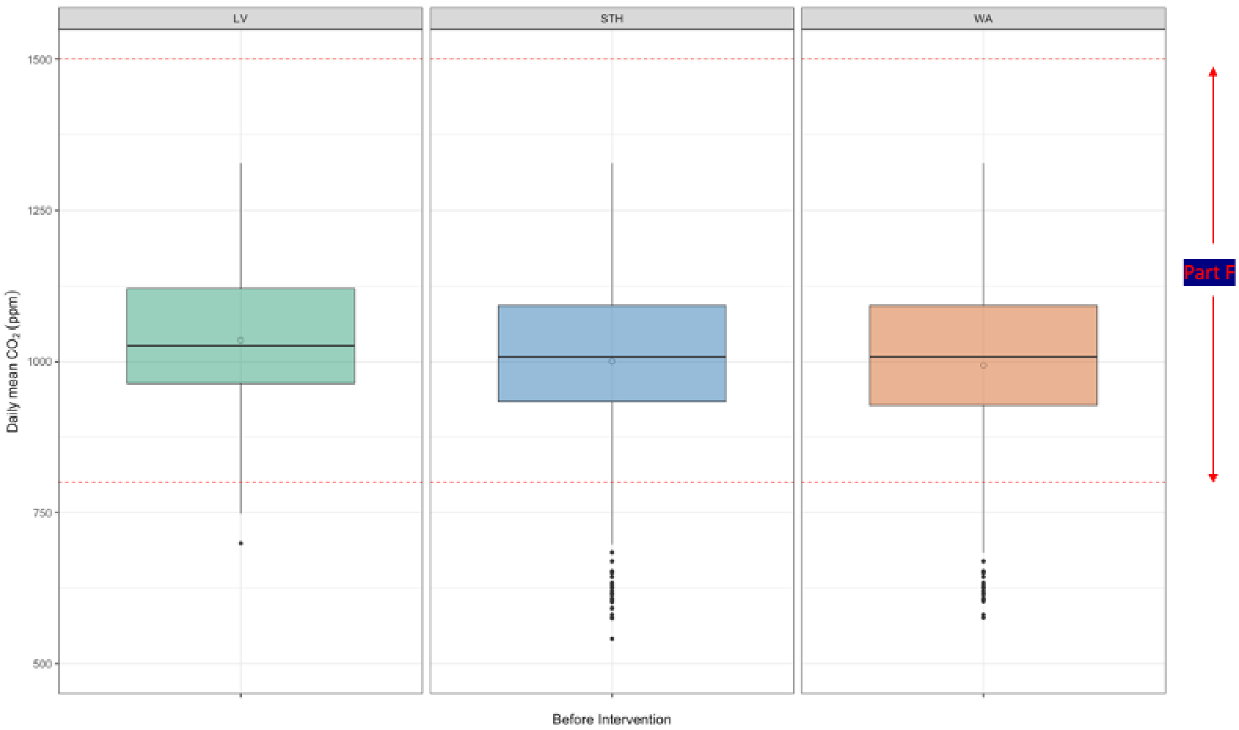
Figure 4: Relative humidity in the participant homes before the intervention



Carbon dioxide

Thresholds for acceptable carbon dioxide (CO_2) ranges that are included on Figure 5 are based on Approved Document F of the Building Regulations which outlines that concentrations of less than 800 parts per million (ppm) indicate that a space is well ventilated, and concentrations greater than 1500 ppm indicate poor ventilation (and that action should be taken to improve ventilation) (10). Most homes across all three locations sit between the well ventilated and poorly ventilated range of CO_2 concentrations. In all locations the mean and median are towards the middle of the threshold range. In all locations some homes are below the well-ventilated threshold.

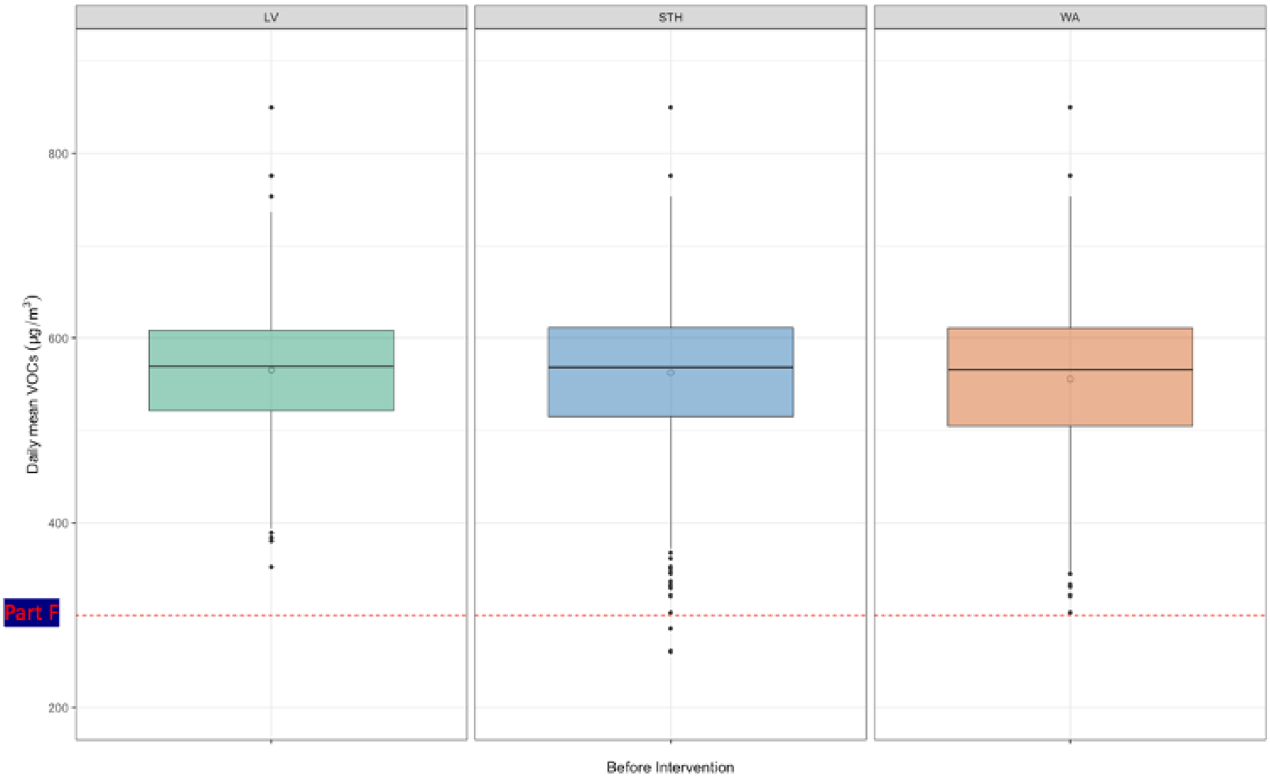
Figure 5: Carbon dioxide (CO_2) in the participant homes before the intervention



Volatile Organic Compounds

Thresholds for acceptable Volatile Organic Compounds (VOCs) ranges that are included on Figure 6 are based on Approved Document F of the Building Regulations which recommends concentrations of less than 300 micrograms per cubic metre (µg/m^3). Of all of the monitored air pollutants, the houses experience the relatively highest concentrations of VOCs, with concentrations substantially above the Approved Document F threshold in all locations, with only a few below the threshold in St Helens.

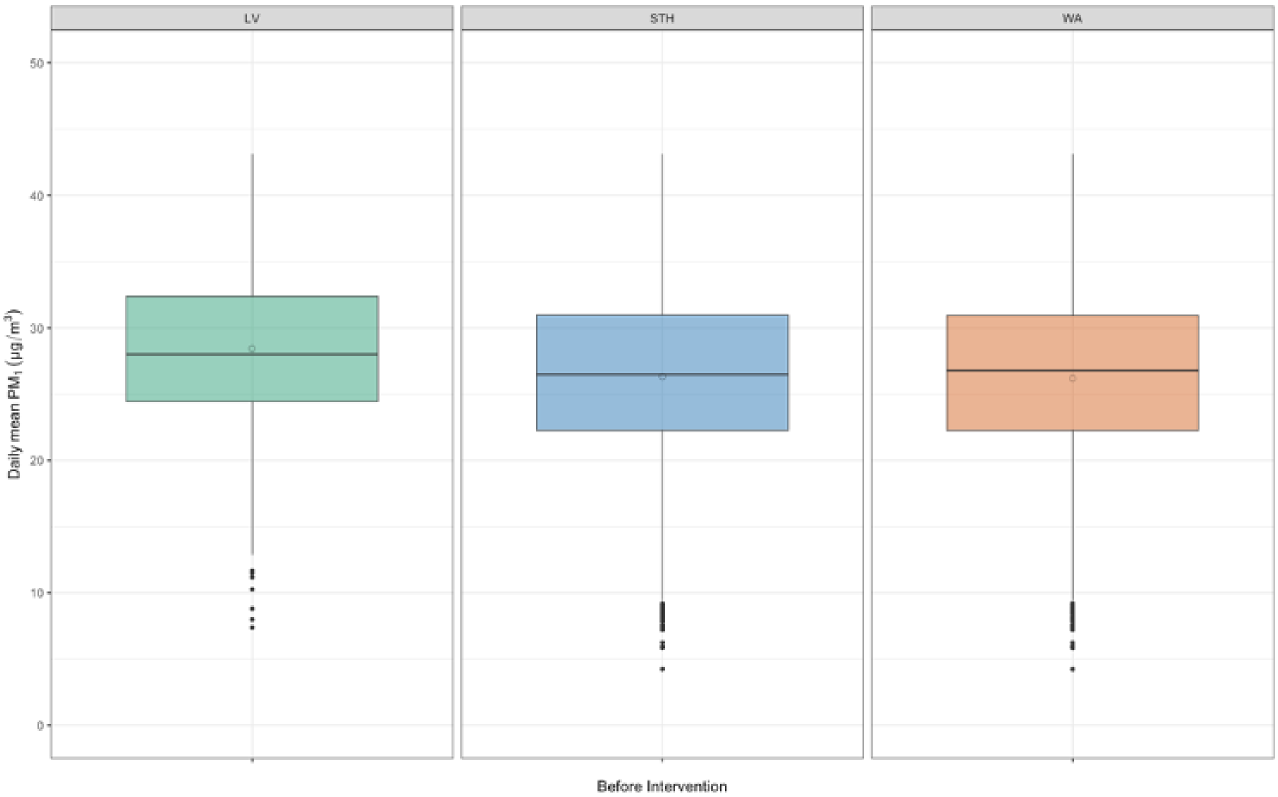
Figure 6: Volatile Organic Compounds (VOCs) in the participant homes before the intervention



PM_1

Particulate Matter with a diameter of less than 1 micron (PM_1) is unregulated in air quality standards, and no thresholds for acceptable concentrations exist. PM_1 are still included in the analysis because they are an important indicator of combustion related sources (e.g. outdoor traffic, candles, and cooking). Concentration profiles appear relatively similar across all three locations.

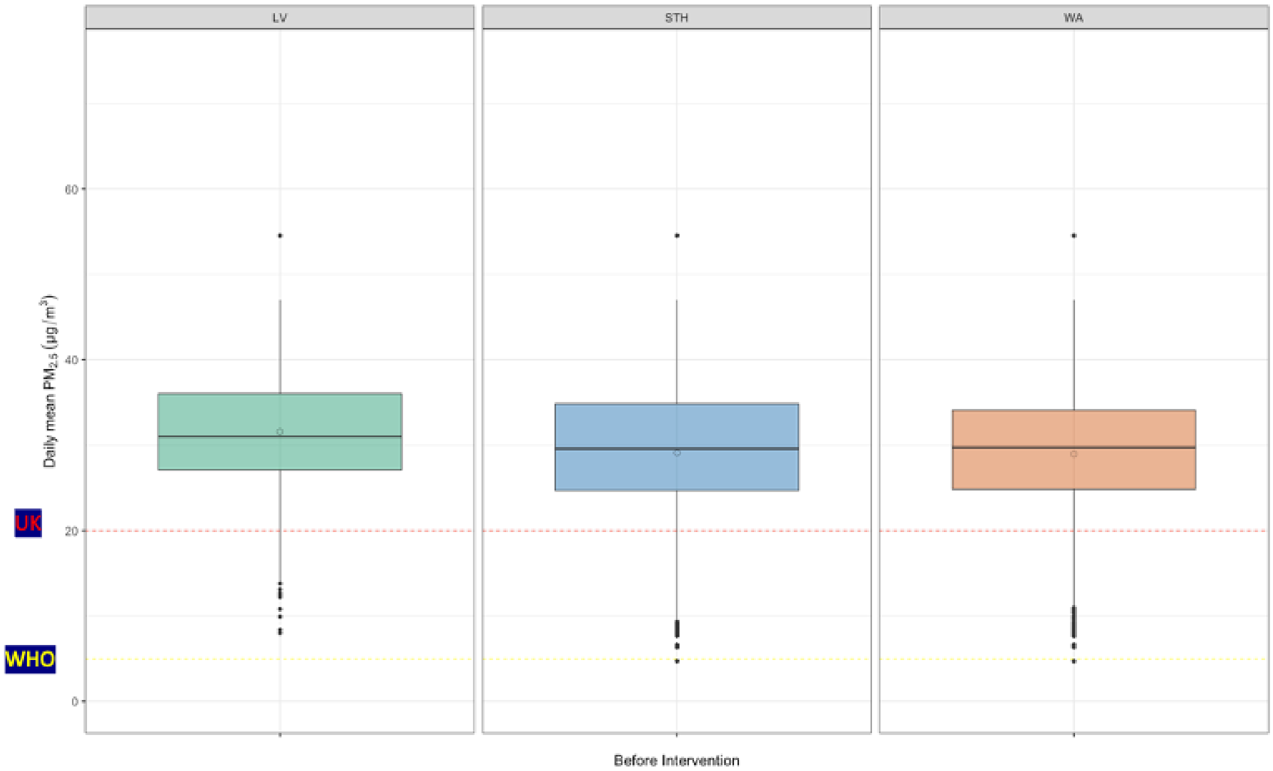
Figure 7: PM_1 in the participant homes before the intervention



$PM_{2.5}$

Particulate Matter with a diameter of less than 2.5 microns ($PM_{2.5}$) limit values included in Figure 8 are based on both UK air quality objectives and World Health Organization (WHO) guidelines, which outlines annual concentrations of less than 20 and 5 micrograms per cubic metre respectively ($\mu g/m^3$) (11,12). Please note that these values are based on outdoor air quality, as no indoor $PM_{2.5}$ values currently exist. In all locations the houses experience the relatively highest concentrations of $PM_{2.5}$ with mean and median concentrations substantially above both the UK air quality objectives and WHO guidelines. In all locations some houses are below the UK air quality guidelines, but not the WHO guidelines (which is just for some in St Helens and Warrington).

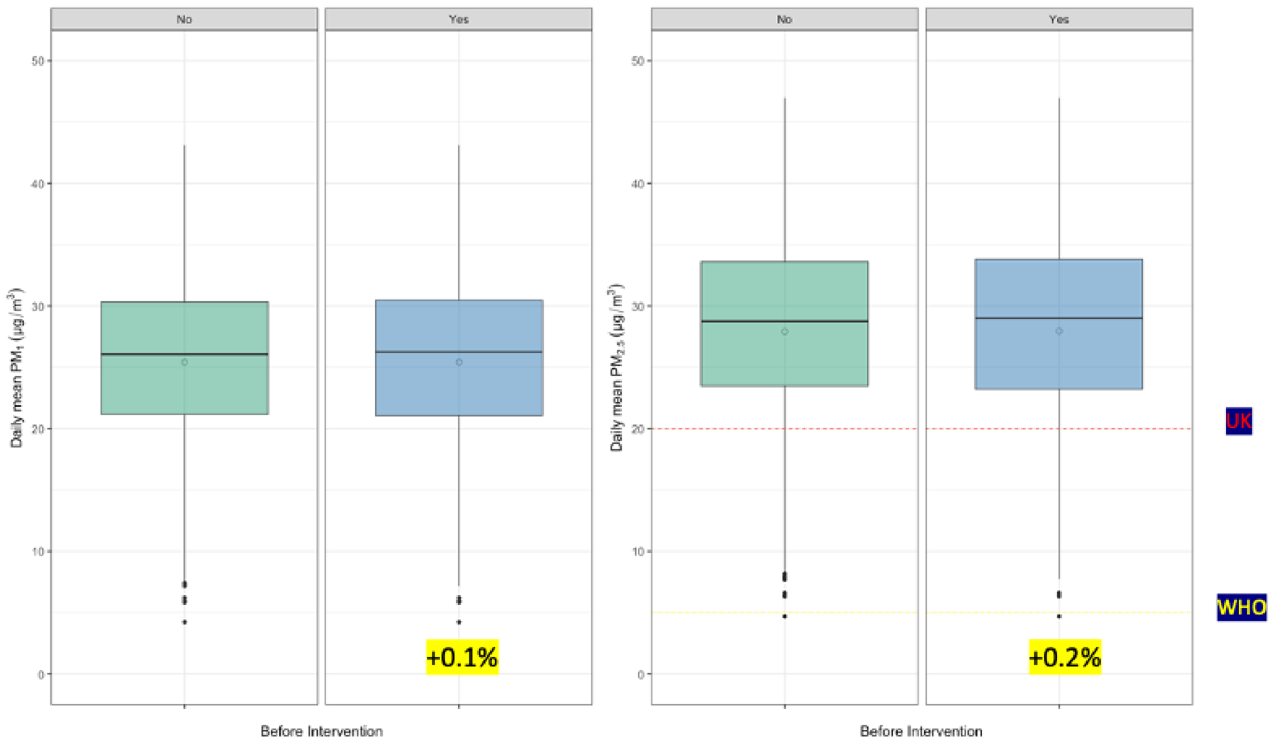
Figure 8: $PM_{2,5}$ in the participant homes before the intervention



Smokers in the household

Due to the high concentrations of PM_1 and $PM_{2.5}$ that were observed, the analysis looked at the effect of smoking in the household, as this is a large potential source of PM_1 and $PM_{2.5}$ indoors. There is a marginal increase in both the PM_1 and $PM_{2.5}$ concentrations of homes that have a smoker (0.1% and 0.2% respectively), although this increase is very small and demonstrates a potential other source that is driving high PM_1 and $PM_{2.5}$ concentrations indoors.

Figure 9: The difference in PM_1 and $PM_{2.5}$ in households that did or did not have a smoker in the household



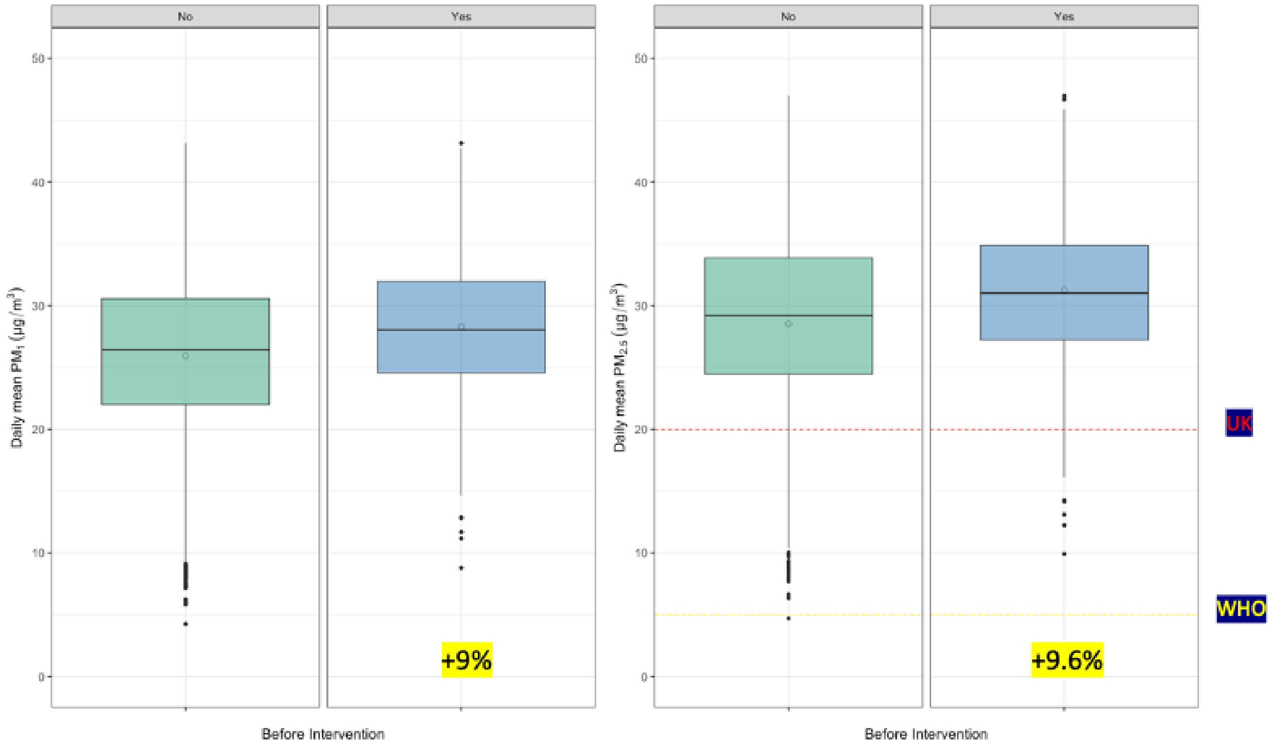
Despite some tenants observing that their smoking behaviours affected the concentrations within their homes, these shorter-term spikes of *PM_1 and $PM_{2.5}$* do not appear to have affected the longer term averages:

> When my friend is around and she's been outside, had a cigarette and then come back in, which was really like 'Wow'... Even though she's gone outside, she's smoked outside. She's still bringing that pollution back into the house. [Tenant Participant 6]

On a main road

Likewise, due to the high concentrations of $PM_{2.5}$ that were observed, the analysis looked at the effect of whether or not the houses were on a main road as this is a large potential source of PM_1 and $PM_{2.5}$ indoors. There is a much stronger increase in both the PM_1 and $PM_{2.5}$ concentrations for homes that are on a main road (9% and 9.6% respectively) that suggests that ingress of outdoor traffic pollution is a potential source of indoor PM_1 and $PM_{2.5}$.

Figure 10: The difference in PM_1 and $PM_{2.5}$ in households that did or did not live on a main road



Summary

- The trends for different air pollutants are relatively consistent across the locations.
- Temperature: The majority of homes are within the PHE guideline range. However, there are many outliers, and the means are towards the minimum threshold.
- Relative humidity: The overwhelming majority of homes are within the CIBSE recommended range. However, means are towards the maximum threshold, representing a potential greater risk of mould.
- CO_2: The majority of homes are below the Approved Document F threshold that indicates poor ventilation. However, few homes are below the threshold that indicates good ventilation.
- VOCs: The overwhelming majority of homes are considerably above the Approved Document F guideline value. However, we do not know how harmful these VOCs are, or their primary source.
- $PM_{2.5}$: The majority of homes are above the UK air quality objective. Based on analyses of smokers in the household, and homes on a main road, this suggests there is some contribution from outdoor sources, but potential indoors sources should be explored further.

Effectiveness of interventions

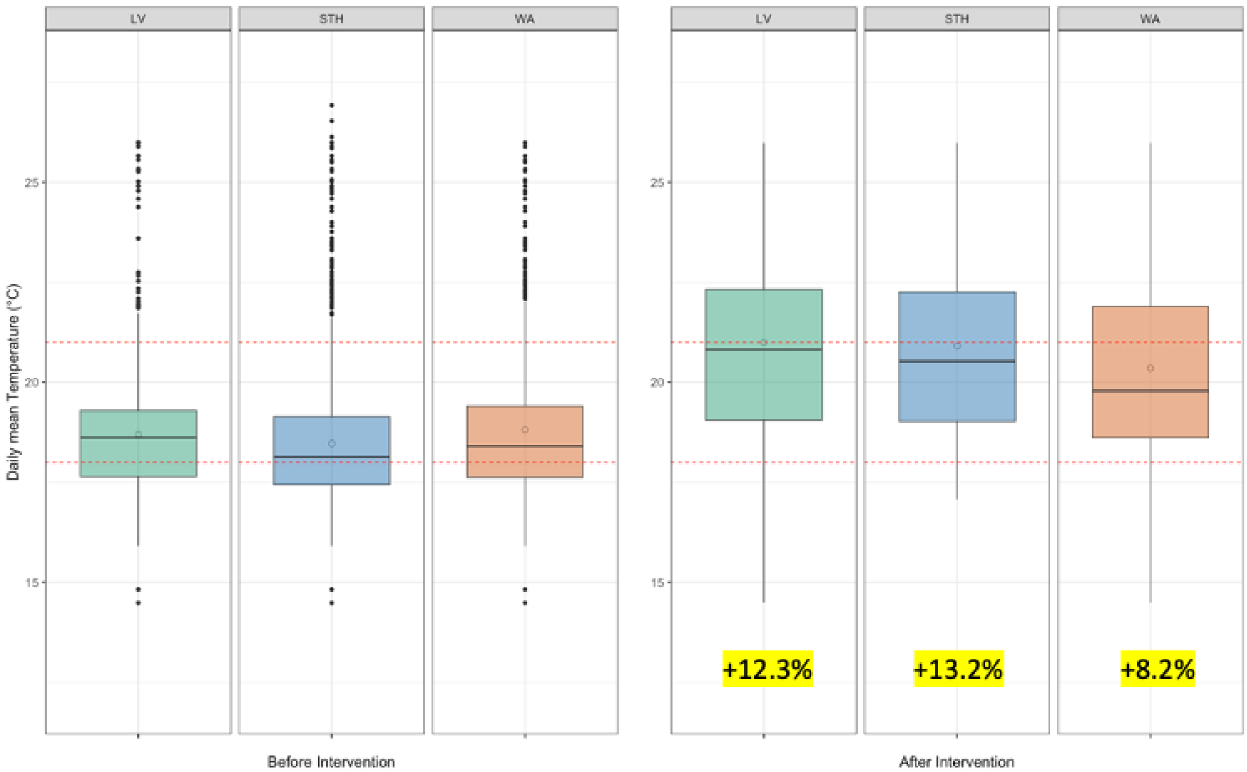
Interventions were assessed from two weeks after the 1st visit (installation) to allow some time for tenants to implement potential changes, and behaviour change to set in.

Temperature

To reiterate, thresholds for acceptable temperature ranges that are included on Figure 11 are based on Public Health England's (PHE) *Minimum home temperature thresholds for health in winter* which recommends 18°C – 21°C (8). It is important to note that these thresholds do not include maximum temperatures, which are more applicable for the cooling season (e.g. the summer months). These thresholds have not been included as the measurements for this project come primarily from the heating season, rather than the cooling season. Measurements for the intervention period both came from within the heating and early cooling seasons. Therefore, the decision was made to use the same thresholds for Figure 11.

A general increase was observed in all locations, with homes in Liverpool, St Helens, and Warrington seeing a 12.3%, 13.2%, and 8.2% increase respectively. This is largely due to the intervention period occurring in months with warmer average outdoor temperatures. Temperatures in Liverpool homes are closest to the upper threshold of acceptable wintertime temperatures. However, exceedances to this threshold do not necessarily indicate overheating situations, given the use of a winter threshold that includes data from both the heating and cooling season.

Figure 11: Temperature changes in the participant homes before and after the intervention

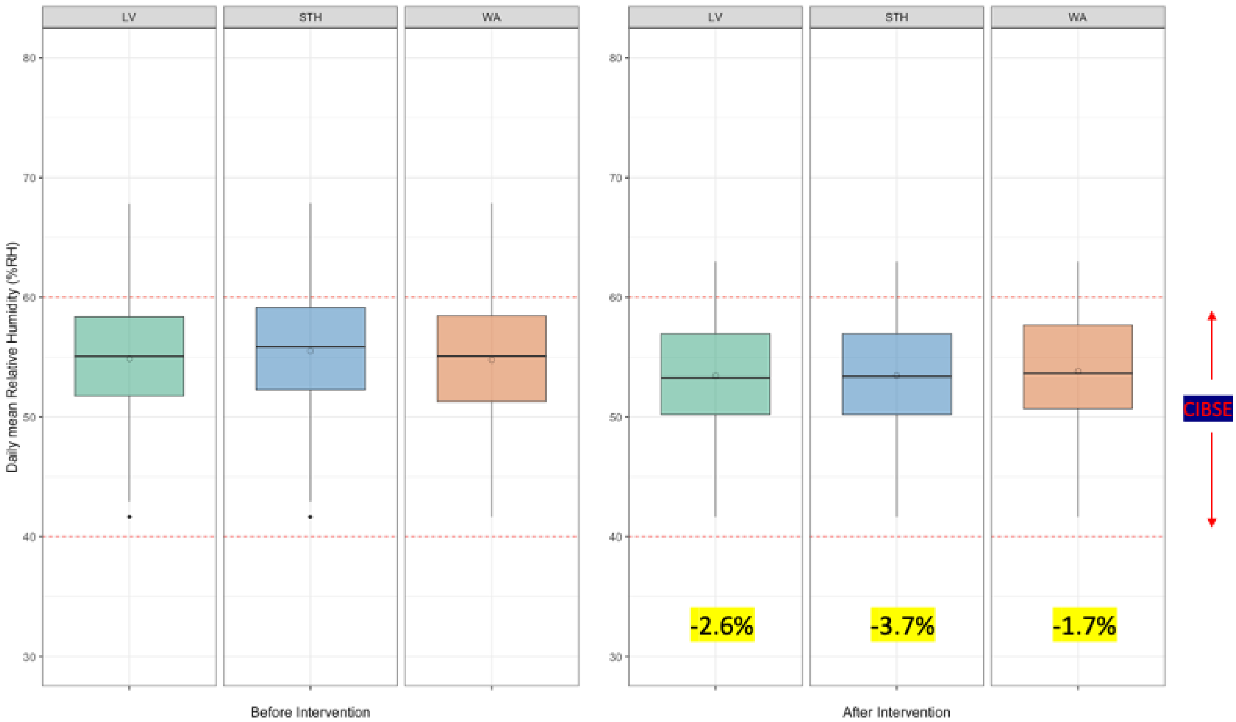


Relative Humidity

To reiterate, thresholds for acceptable relative humidity (RH) ranges that are included on Figure 12 are based on the Chartered Institution of Building Services Engineers (CIBSE) TM40:2020 which recommends that RH should be 40-60% in homes (9).

A modest decrease was observed in all locations, with homes in Liverpool, St Helens, and Warrington seeing a 2.6%, 3.7%, and 1.7% decrease respectively. Mean and median RH are within the recommended range in all locations. However, all locations also see some homes slightly above the recommended range.

Figure 12: Relative humidity changes in the participant homes before and after the intervention

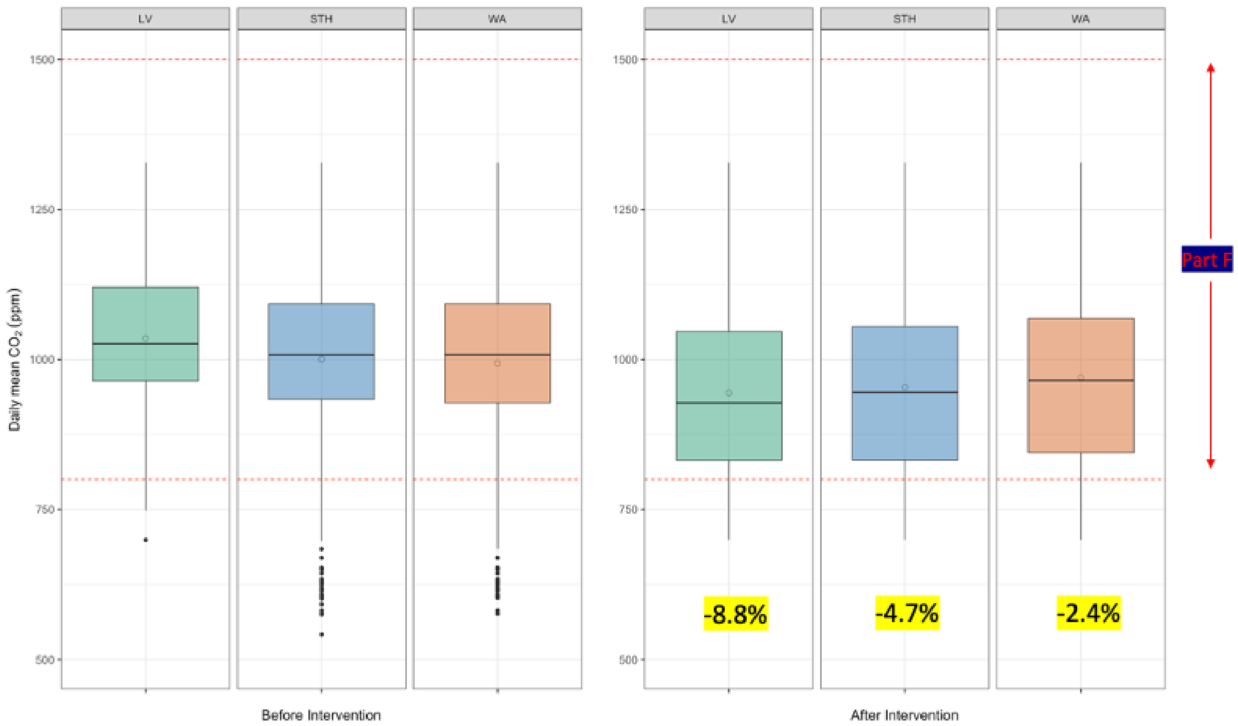


Carbon dioxide

To reiterate, thresholds for acceptable carbon dioxide (CO_2) ranges that are included on Figure 13 are based on Approved Document F of the Building Regulations which outlines that concentrations of less than 800 parts per million (ppm) indicate that a space is well ventilated, and concentrations greater than 1500 ppm indicate poor ventilation (and that action should be taken to improve ventilation) (10).

A range of decreases were observed in the locations, with homes in Liverpool, St Helens, and Warrington seeing an 8.8%, 4.7%, and 2.4% decrease respectively. This is likely due to increased ventilation practices (e.g. opening windows) due to higher average outdoor air temperatures. Most homes across all three locations sit between the well ventilated and poorly ventilated range of CO_2 concentrations. In all locations the mean and median are towards the lower end of the threshold range. In all locations some homes are below the well-ventilated threshold.

Figure 13: Carbon dioxide (CO_2) changes in the participant homes before and after the intervention



Volatile Organic Compounds

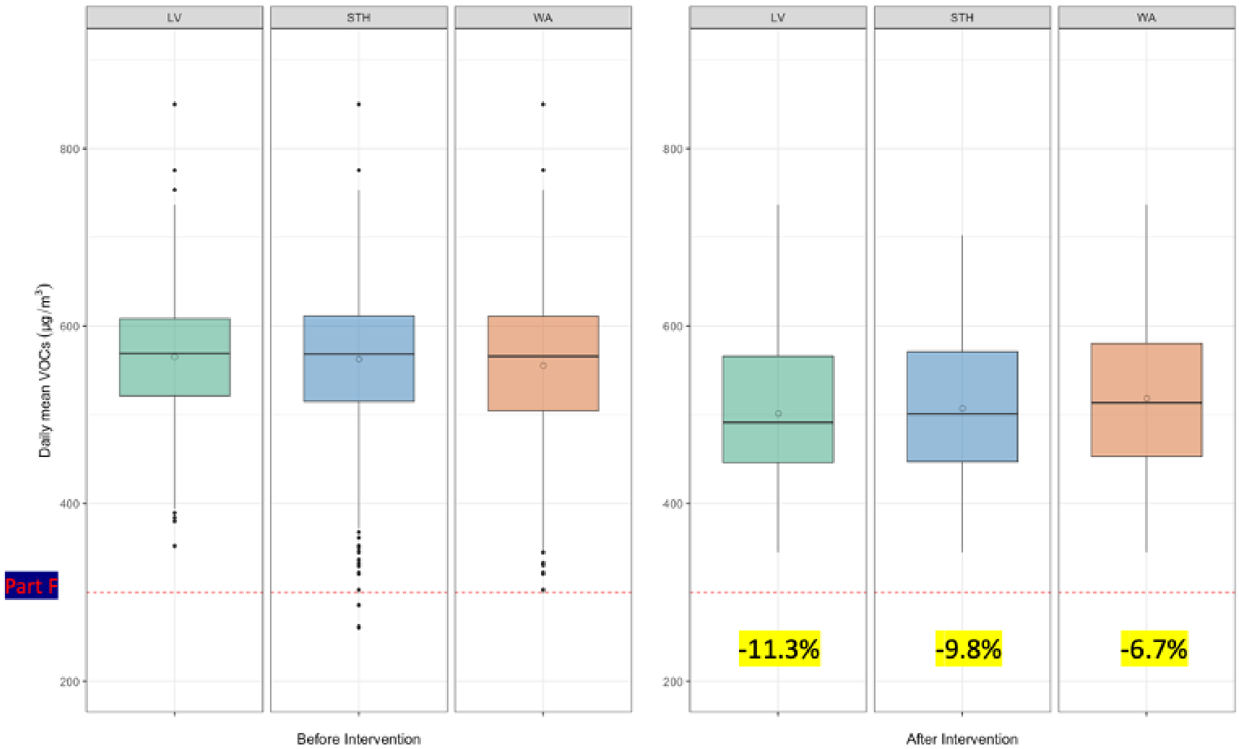
To reiterate, thresholds for acceptable Volatile Organic Compounds (VOCs) ranges that are included on Figure 14 are based on Approved Document F of the Building Regulations which recommends concentrations of less than 300 micrograms per cubic metre (µg/m^3).

A range of decreases were observed in the locations, with homes in Liverpool, St Helens, and Warrington seeing a 11.3%, 9.8%, and 6.7% decrease respectively. Nonetheless concentrations remain substantially above the Approved Document F threshold in all locations. We recommend further testing of VOCs to understand specific structural / behavioural sources, and potential health effects. This can be achieved used thermal desorption tubes that are analysed through gas chromatography mass spectrometry (GC-MS).

The results substantiate the qualitative findings from briefing 3 which outlined that observing the IAQ monitor's display empowered certain tenants to make beneficial adjustments to cleaning habits to limit the impact on air quality:

> *You can tell when you've used like just the type of chemicals inside the room as well because it does pick that up... So with, for example the fly spray, I won't use it in the living room. Now I'll only use it in the kitchen... [Tenant Participant 3]*

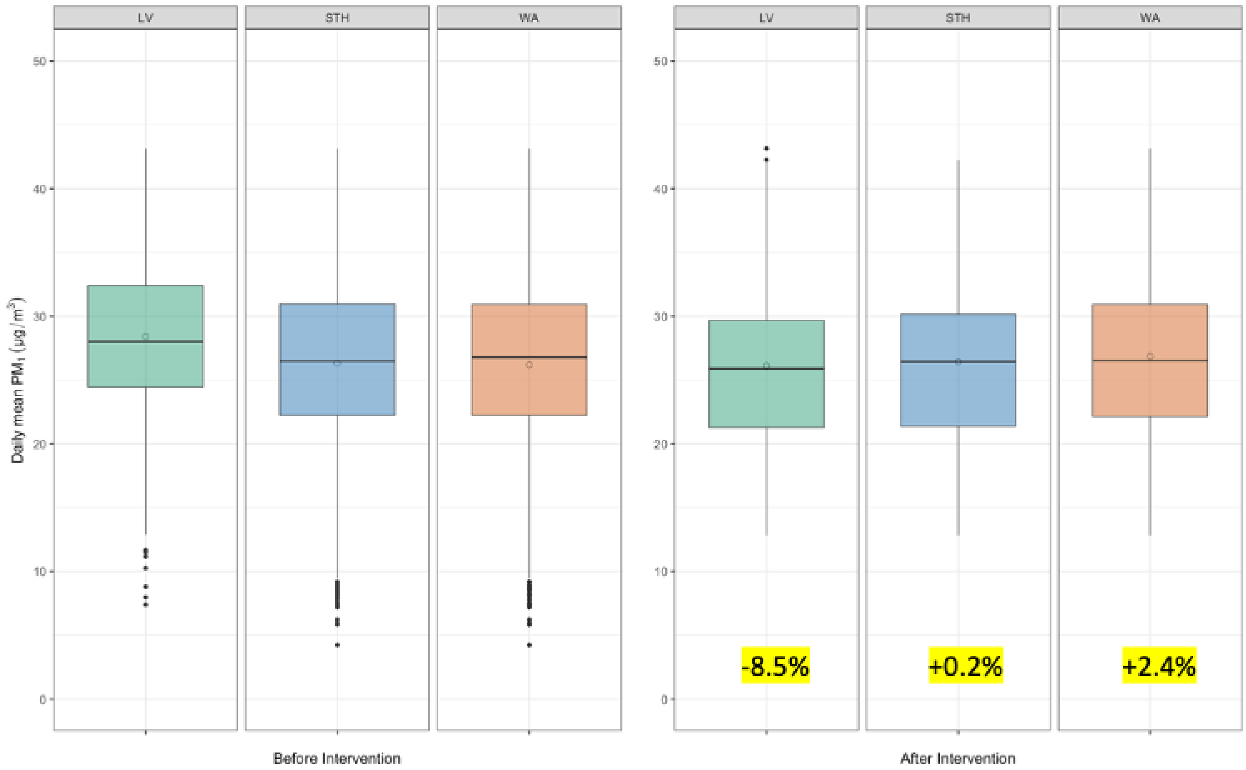
Figure 14: Volatile Organic Compound (VOCs) changes in the participant homes before and after the intervention



PM_1

Particulate Matter with a diameter of less than 1 micron (PM_1) is unregulated in air quality standards, and no thresholds for acceptable concentrations exist. PM_1 are still included in the analysis because they are an important indicator of combustion related sources (e.g. outdoor traffic, candles, and cooking). Concentration changes in the intervention period were mixed across the different locations with an 8.5% reduction in Liverpool, no significant change in Warrington (0.2% increase), and a small increase in Warrington (2.4%).

Figure 15: PM_1 changes in the participant homes before and after the intervention



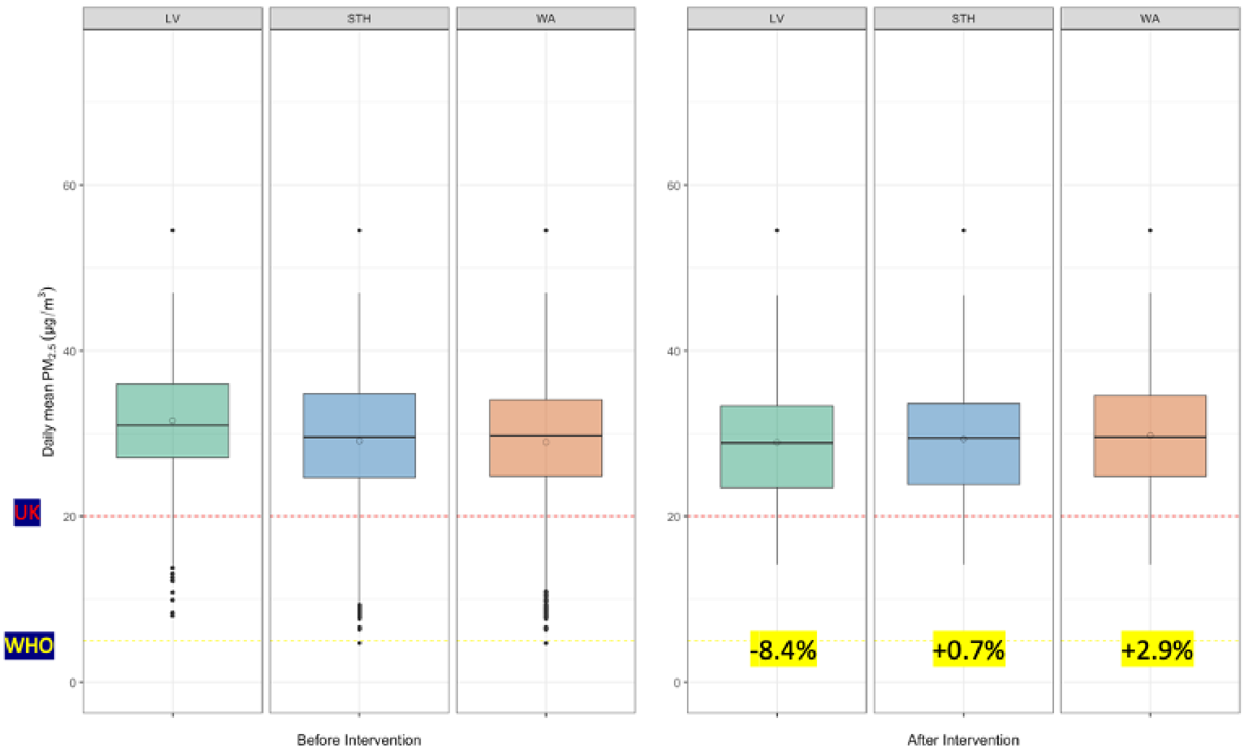
$PM_{2.5}$

To reiterate, particulate matter with a diameter of less than 2.5 microns ($PM_{2.5}$) limit values included in Figure 16 are based on both UK air quality objectives and World Health Organization (WHO) guidelines, which outlines annual concentrations of less than 20 and 5 micrograms per cubic metre respectively ($\mu g/m^3$) (11,12). Please note that these values are based on outdoor air quality, as no indoor $PM_{2.5}$ values currently exist.

The results for the PM_1 and $PM_{2.5}$ are largely the same (owning to similar sources), with mixed results across the different locations: 8.4% reduction in Liverpool, a similar result in Warrington (0.7% increase), no significant change in Warrington (2.9%). Median and mean concentrations remained above the UK air quality objectives and WHO guidelines. In all locations some houses are below the UK air quality guidelines, but not the WHO guidelines.

We recommend further exploration into the sources of $PM_{2.5}$ to better understand / behavioural contributions. This includes analysis of localised outdoor air quality.

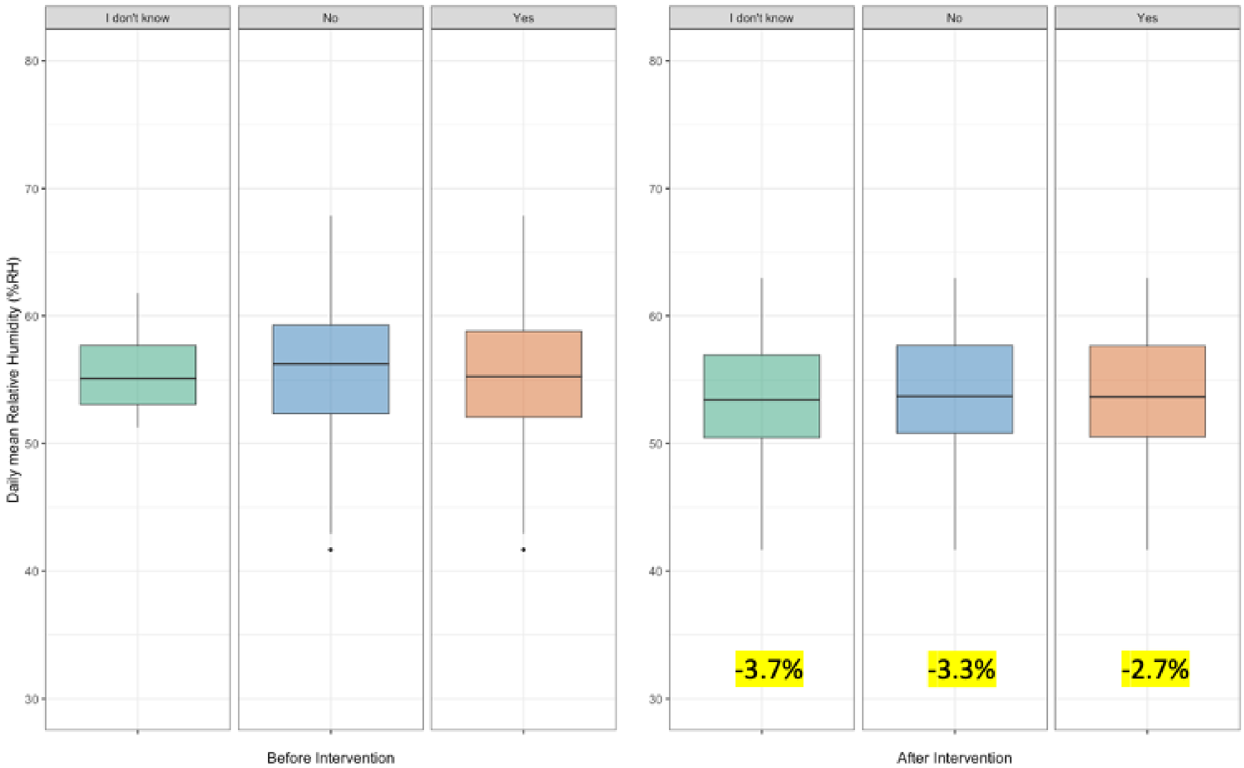
Figure 16: $PM_{2.5}$ changes in the participant homes before and after the intervention



Presence of mould

Self-reported presence of mould was compared pre and post intervention against relative humidity (RH), an indicator of potential mould. There was no real difference between those that did report mould (2.7% reduction in RH), and those that did not (3.3% reduction in RH).

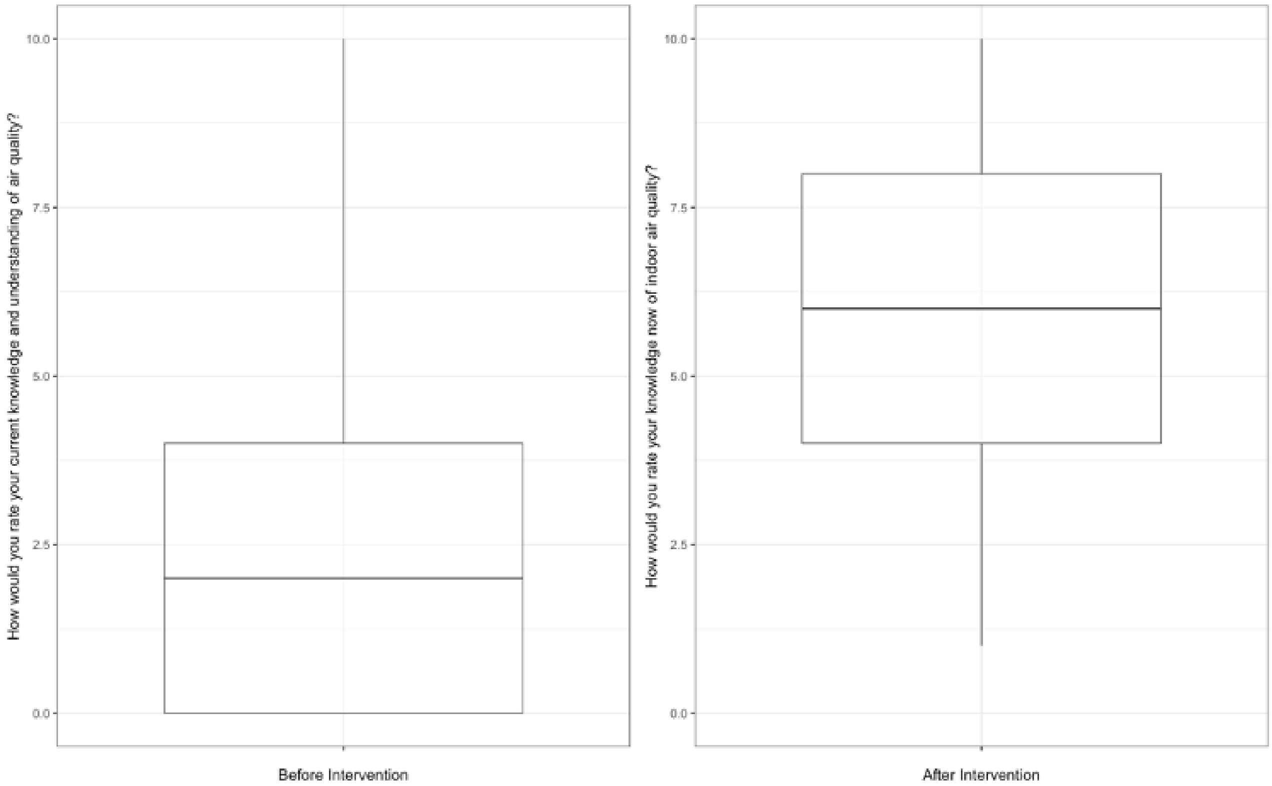
Figure 17: Changes in relative humidity based on presence of mould reporting before and after the intervention



Knowledge

Tenant knowledge of air quality / indoor air quality were evaluated before and after the intervention. Please note that this is not a like for like comparison as the pre intervention question asked about air quality knowledge, and the post intervention asked about *indoor* air quality knowledge. Nonetheless, an observable increase in knowledge on air quality / indoor air quality was observed.

Figure 18: Changes in knowledge of air quality / indoor air quality before and after the intervention



These results are corroborated in Briefing 3, which showed that families' awareness of IAQ was poor, reflecting wider trends in awareness in the general population:

> *I think what we recognize is that you know indoor air quality and cleaner indoors is something that's quite new to people you know, it's not something that a lot of families have really …thought about or spoken a lot about. [IAQ Professional Interview 2]*

> *I think one or two, maybe 10% of the parents would have said that they were sort of maybe a 7 [with respect to their levels of awareness]. The rest of them was absolutely no. … even the young mum that has got the son, that's really, really poorly with asthma. She thought that her knowledge was pretty mediocre. [IAQ Professional Interview 4]*

Moreover, that – according to the professional interview participants – changes in knowledge and awareness were the main outcome observed through the campaign:

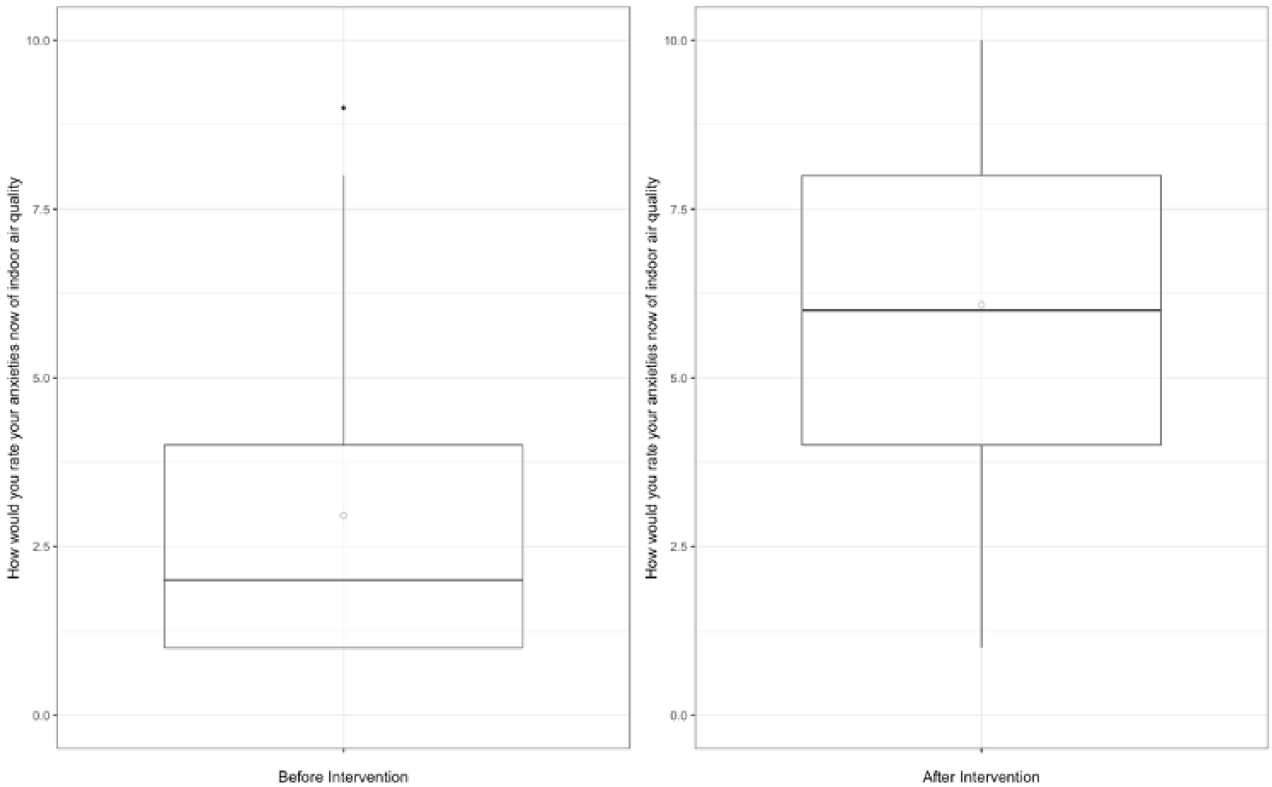
> *For mum, it's been a real eye opener. So right from the offset review that we did do with her, she was looking at the products that she's using in the household, ... She always likes the air to smell what she thinks she's clean. And so we have a conversation, what does clean look like? What can you do to obviously look at different solutions? So she's really gone out there. I've got a second review with her actually next week. It'll be really interesting to see because I've popped on [the dashboard] and had a look and from us having the conversation and all of her VOC's and things have come really, really down... [IAQ Professional Interview 4]*

> *Air quality was so new for people, ... tenant[s] rated their knowledge and understanding at 2.3 out of 10 [in the baseline questionnaire], which again highlighted towards that, it's very new to people. People don't know too much about it. And then based off the follow up, which is of course just after one follow up that's gone up to 5.7 out of 10... [IAQ Professional Participant 2]*

Anxieties

Tenant anxieties around IAQ were evaluated before and after the intervention. Perhaps mirroring the increased knowledge of IAQ, an observable increase in indoor air quality anxiety was observed.

Figure 19: Changes in anxieties of indoor air quality before and after the intervention



Summary

- There is a general story of improved indoor air quality across all of the locations.
- There are homes in all locations that are outliers for most pollutants, and these homes could be targeted for further support / advice.
- The trends for different air pollutants are relatively consistent across the locations. However, for PM_1 and $PM_{2.5}$ the trends are much less clear. This suggests a range of different indoor and outdoor sources that are not consistent across different locations.
- Increased knowledge of air quality / indoor air quality may lead to increased anxiety around the issue, which suggests careful attention should be paid to how results are presented to tenants.

Conclusion

This briefing summarises key findings about the reach of the campaign and whether IAQ within the homes changed, based on the analysis of the IAQ monitor data. There is a general story of improved indoor air quality across Liverpool, St Helens, and Warrington. However, there are homes in all these locations that are outliers for certain pollutants, and these homes could be targeted for further support and/or advice. The trends for different air pollutants are relatively consistent across the locations. However, for PM_1 and $PM_{2.5}$ the trends are much less clear. This suggests a range of different indoor and outdoor sources that are not consistent across different locations. It should also be noted that there was an observable increase in anxieties around indoor air quality following the project, largely coming from an increased knowledge on the subject. Therefore, how indoor air quality is communicated is important, to not unwittingly add to tenants' problems and concerns.

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