IAQ and environmental health literacy: lived experiences of vulnerable people

CONNOR SMITH
ALICE DRINKWATER
MALINA MODLICH
DAN VAN DER HORST
RUTH DOHERTY

ABSTRACT
Like other environmental concerns that affect human health, indoor air quality (IAQ) needs to be understood not only scientifically but also by the citizens who are affected by it. Six online focus groups sessions were conducted with people living in London who could be considered particularly vulnerable to air pollution exposure, namely older people, parents with young children and people with underlying health conditions. Each session involved an iterative process of group discussion, information provision and reflection/further discussion. A deductive thematic analysis guided by an environmental health literacy (EHL) lens was used to explore participants’ awareness of, and lived experience with, IAQ. The findings contribute to a better understanding of the EHL of vulnerable people, whilst also suggesting that learning more about IAQ (given the participants’ low level of prior knowledge) can be effective in increasing people’s willingness to make behavioural changes in indoor contexts. Several practical measures could be taken by various stakeholders to reduce residents’ exposure, especially those who have limited agency due to vulnerability (e.g. reduced mobility) or other personal circumstances (e.g. residing in a rental property).

POLICY RELEVANCE
The findings from this study contribute to a better understanding of the EHL of vulnerable London residents, whilst also suggesting that information provision in the format of iterative discussion and group learning is effective at increasing people’s willingness and ability to make behavioural changes in indoor contexts. They also underscore the importance of providing occupants with information that not only encourages the use of ventilation systems but also includes awareness-raising materials concerning the sources and negative health impacts of poor IAQ. Furthermore, filtration technology should be made affordable which could require subsidies as part of national or regional air pollution policy; or new legislation to require air filtration systems in all new build or rented properties. Meanwhile, action from other stakeholders, notably landlords and housing authorities/associations, is also required to ensure good IAQ in rental properties, whilst tailored building design is needed to support people with reduced mobility.

TO CITE THIS ARTICLE:
1. INTRODUCTION

Air pollution is an environmental and public health crisis, with varied sources arising both indoors and outdoors, polluting the air we breathe (EEA 2023; WHO 2023). In the context of climate change, air pollution exposure is increasingly important; higher temperatures and extreme weather events are expected to increase particulate matter (PM) emissions from, for example, wildfires and soil dust, leading to increased air pollution exposure and subsequent negative health impacts (UN 2023). Furthermore, air pollution and carbon emissions often arise from the same sources (such as coal-powered factories, transport emissions, etc.), meaning that these issues are inextricably linked. Tackling air pollution, therefore, often has the dual benefit of protecting health and reducing carbon emissions at the same time (Zielinski 2023).

There are wide-ranging potential negative health impacts from air pollution exposure, which range from sensory irritation to chronic obstructive pulmonary disease (COPD), neonatal disorders, poor mental health to cancer (WHO 2009; Lee et al. 2020). Environment strongly influences exposure—e.g. living in an urban area closer to a greater density of air pollution sources, or occupation, such as working in a factory (Marshall et al. 2009). Meanwhile, certain vulnerabilities can increase the risk of health-related impacts from air pollution. Age (for both children and older persons) can exacerbate health impacts, as can underlying health conditions such as COPD and asthma (RCP 2016; Lee et al. 2020; Maung et al. 2022).

Air pollution is a significant threat to health in the UK, causing an estimated 28,000–36,000 related deaths per year (Public Health England 2019). London, being the UK’s most populous city, is significantly impacted by air pollution. In 2019 in Greater London, an estimated 3600–4100 deaths were attributable to air pollution (Dajnak et al. 2021). If no action to reduce air pollution in London is taken, by 2050 the estimated cumulative cost to the National Health Service (NHS) and social care in the city is estimated to be £15.4 billion (Webber et al. 2020).

Historically, outdoor air pollution has been awarded significantly more attention than indoor air quality (IAQ) (González-Martín et al. 2021), possibly because the sources are greater and more easily noticed by people interacting with the environment (such as smoke from factories or vehicle exhaust fumes). Sources of air pollution in the indoor environment are therefore frequently overlooked when discussing air pollution, despite this being where much of the population spends most of its time (ONS 2023; González-Martín et al. 2021). Moreover, in studies where IAQ is considered, it is often from a technical perspective, with significantly less attention given to the role of citizen behaviour and day-to-day practices (Oliveira et al. 2022).

Considering this context, the aim of this study is to explore vulnerable Londoners’ lived experience of IAQ and the extent to which information provision may increase participants’ willingness and ability to change behaviours to reduce exposure. Focus group discussions are used to gather the qualitative data required which are analysed using deductive thematic analysis guided by an environmental health literacy (EHL) lens. Exploring public knowledge of IAQ through an EHL lens and in the context of various vulnerabilities can help us to achieve the following research objectives:

- to contribute to a better understanding of the EHL of vulnerable Londoners, and the extent to which information provision can improve the EHL of IAQ, thereby helping influence future educational interventions and communication strategies
- to better understand built environment implications, i.e. design, operation, user interface(s)
- to glean an insight into the limits of agency for individual citizens, thus recognising where interventions (by other actors, policy or legislation) are required.

The paper is structured as follows. Next, the existing literature concerning EHL and IAQ is reviewed in relation to the built environment. The methodology is then presented. Following this, key findings are presented and their significance is considered in relation to both the aim of this study and the existing literature.
2. LITERATURE REVIEW

2.1. ENVIRONMENTAL HEALTH LITERACY (EHL)

Finn & O’Fallon (2017: 496) propose that the basis of EHL is ‘an understanding of the connection between environmental exposures and human health’. This is fundamental to building the knowledge and skills individuals and communities need to make informed decisions around their environment, through their improved awareness (Gray 2018; Gray & Lindsey 2018; Lindsey et al. 2021). Another component investigated in many literacy studies are people’s attitudes (e.g. Lichtveld et al. 2019; Martins et al. 2020), in this case towards the broader environment and environmental health risks. Like the related concepts of environmental literacy and different health literacies, EHL incorporates the dimension of taking health-protective actions based on this understanding and knowledge, in both the individual and community-level contexts (Gray 2018).

Around IAQ specifically, Tomsho et al. (2022) found that the driving force behind public interest and concern for IAQ comes from concerns for members of their households, highlighting sensory awareness (such as smells and feelings on the skin) as a way in which people become aware of pollutants. Participants felt more personal control over home environments as opposed to other indoor settings, due to the amount of time spent there and the accessibility of personal actions to reduce air pollution exposure.

Similarly, Unni et al. (2022) found that increased knowledge resulted in improved attitude and behaviour towards IAQ. For example, participants were more willing to bear the cost of home improvements, and more likely to share information with their community. This indicates the value of clearly communicating IAQ information to the public to increase healthy behaviours and resonates with previous studies such as Ramirez-Andreotta et al. (2016), Davis et al. (2018) and Ramirez et al. (2019) who all highlight a lack of clarity and reach as key barriers to effective EHL communication. Understanding public EHL with regards to IAQ can highlight which areas are often overlooked (or more poorly understood), potentially leading to increased exposure. By understanding the limitations of current communication approaches, future communication of IAQ information can be made clearer and more effective (e.g. Cleary et al. 2017). Interdisciplinary knowledge and research designs can help to improve clarity and extend reach. For example, Fogg-Rogers et al. (2021) leveraged social psychology theory and citizen-focused source apportionment modelling to develop tailored communications to make groups more aware that ‘people like me’ create pollution, and have (at least some) agency to reduce their impact.

2.2. ENVIRONMENTAL JUSTICE, INEQUALITIES AND VULNERABLE GROUPS

Environmental justice as a concept and research field has its origins in studies that analyse exposure to toxic and hazardous waste across different demographic and socio-economic groups, often finding that low-income communities and people of colour are disproportionately affected worldwide (Reed & George 2011; Hajat et al. 2015). It has since grown to become considerably more interdisciplinary and vastly expanded in scope beyond the issue of exposure to toxic waste (Agyeman et al. 2016). However, the population groups that are most affected by negative environmental influences such as air pollution, for example, often tend to remain the same. In the UK, too, several studies indicate that ambient air pollution tends to be highest in the most deprived areas (e.g. Brainard et al. 2002; Walker et al. 2003; Pearce et al. 2010), as well as in locations with a more sizeable non-White population (Fecht et al. 2015). Mitchell & Dorling (2003) found that areas that produce the least pollution themselves (which tend to be lower income areas) have higher levels of air pollution exposure due to location (e.g. located near busy roads or factories), creating environmental injustice. Although less environmental justice research has been conducted in the context of IAQ, a recent review by Ferguson et al. (2020) found that IAQ tends to be poorer in dwellings of people with a lower socio-economic status (SES), meaning they are often disproportionately exposed to dangerous pollutants such as PM and nitrogen dioxide (NO₂) within their home environments.

Research suggests that inequalities and vulnerabilities in relation to IAQ extend beyond SES and ethnicity. Older people are particularly vulnerable to indoor air pollution exposure and associated negative health impacts (Mata et al. 2022) because they are more likely to experience deterioration
of biological functions, including weakened immune defences (Mata et al. 2022). Children constitute another group who are especially vulnerable to poor IAQ, because (1) their lungs and immune systems are still developing, (2) they are often physically active and therefore have long periods of increased breathing rate, and (3) they are often oral, as opposed to nasal, breathers—meaning fewer pollutants are filtered (Bateson & Schwartz 2007; Esposito et al. 2014). People who suffer from a pre-existing health condition, including, but not limited to, chronic respiratory illnesses, are also particularly vulnerable to poor IAQ and more likely to experience significant negative health consequences when exposed to pollutants (Horton et al. 2022).

### 2.3. IAQ AND THE BUILT ENVIRONMENT

Indoor air pollution is often overlooked in both air quality studies and public communications around air quality, even though this is where the population spends most of their time (ONS 2023; González-Martín et al. 2021). Studies have shown that poor IAQ can lead to a variety of health conditions, discomfort and lower performance in school or workplaces of occupants (e.g. De Giuli et al. 2012; Al horr et al. 2016; Altomonte et al. 2020; Maung et al. 2022).

The IAQ implications for building design are increased ventilation and air purification systems in housing. However, these solutions need to be accessible to encourage occupant usage (e.g. Miu et al. 2019; Harputlugil & de Wilde 2021). Ventilating using outdoor air will be dependent upon the outdoor environment, as bringing in poor outdoor air for ventilation could increase air pollutant exposure (Leung 2015; Spiru & Simona 2017). Any installed engineering systems to improve ventilation also must balance energy efficiency, in the move towards net-zero housing (Yu & Kim 2012). A variety of other factors are also considered when designing new homes, such as thermal, acoustic and visual comfort, which must go alongside air quality systems to create liveable pleasant housing (Al horr et al. 2016; Altomonte et al. 2020). During the COVID-19 lockdowns people spent more time indoors than ever before. This changed patterns of ventilation, with occupants relying less on natural ventilation, opening windows less frequently, especially during the heating season (Tahmasebi et al. 2021). Furthermore, occupants were more frequently using cleaning products and air fresheners (Domínguez Amaroillo et al. 2020). This meant that IAQ was more important than ever, and poor IAQ was seen to increase the risk of infection from COVID-19 indoors (Agarwal et al. 2021). In terms of building design, therefore, IAQ is now an essential consideration, with touchless designs of ventilation and air purification becoming increasingly used (Megahed & Ghoneim 2021).

### 3. METHODOLOGY

#### 3.1. PARTICIPANT RECRUITMENT AND DATA COLLECTION

Online focus groups were used to gather the rich qualitative data needed to understand people’s lived experience and perceptions of air pollution. Focus groups have long been a staple methodology of social scientists thanks to their ability to investigate complex social issues (e.g. Wilkinson 1998; Nyumba et al. 2018). Since the COVID-19 pandemic, many people have become more familiar with video calling applications such as Zoom, Microsoft Teams and Skype. This technological familiarity, combined with the convenience and comfort of being able to participate in research from your own home, means that online focus groups are at present an attractive alternative to in-person formats. Research also suggests that online formats are more likely to enable recruitment of non-White participants and those of different education levels (Rupert et al. 2017). This held true for the present study where a diverse range of participants was recruited (through the help of a professional participant recruitment company) across ethnicity, occupation and SES. More specifically, the household income of participants ranged from £20,000–30,000 to £150,000 plus per annum. Participants identified as White British, Black British, White Irish, Caribbean, White European, African and Mixed/Multiple ethnicities. They were administrators, receptionists and homemakers, as well as postdoctoral researchers, business owners and civil servants. The youngest participant was 19 years old; the eldest was 78 (for full participant details, see Table S1 in the supplemental data online). Participants were paid £50 each upon completion of focus group sessions to cover any costs associated with childcare or taking time off work, but also to encourage the participation of people without prior interest in the topic.
A total of six online focus groups were conducted over a six-week period, each lasting an average of 1 hour 45 minutes. There were 31 participants in total, with each group consisting of between four and seven participants. Each session was facilitated by two researchers (one guiding the conversation, the other mainly observing), and all were audio recorded. Each session comprised a unique group, as summarised below, with geography and vulnerabilities as group variables:

- FG 1: Inner London, pre-existing health condition
- FG 2: Inner London, older people (65+)
- FG 3: Inner London, parent with a young child
- FG 4: Outer London, pre-existing health condition
- FG 5: Outer London, older people (65+)
- FG 6: Outer London, parent with a young child

Participants were explicitly informed that they shared a common characteristic with everyone else in their focus group session (i.e., a health condition, parent with a young child or older person). Participants were also informed that this (their shared group characteristic) was one element that the research team was particularly interested in better understanding in relation to their lived experience of air pollution. It should be noted that the participant selection criteria did not exclude participants who held more than one vulnerability (e.g., someone with a health condition was not excluded from participating because they were also a parent with a young child). This approach to participant selection was designed to avoid the creation of extremely niche groups wherein insights would be less likely to resonate more widely (e.g., only a very small percentage of older people do not also have a health condition).

The schedule of the focus group discussions is given in Table 1, whilst for full details of the information supplied, see the supplemental data online.

<table>
<thead>
<tr>
<th>Part</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 1</td>
<td>Explore pre-existing knowledge and concern regarding air pollution and the mitigating behaviours that individuals may employ in their day-to-day lives</td>
</tr>
<tr>
<td>Part 2</td>
<td>Introduce information on pollutants NO$<em>2$ and PM$</em>{2.5}$. Discuss</td>
</tr>
<tr>
<td>Part 3.1</td>
<td>Introduce the ventilation and cooking scenario. Discuss</td>
</tr>
<tr>
<td>Part 3.2</td>
<td>Introduce the ULEZ scenario. Discuss</td>
</tr>
<tr>
<td>Round-up</td>
<td>Explore what participants will take away from the session</td>
</tr>
</tbody>
</table>

Table 1: The schedule for focus group discussions
Note: ULEZ is London’s Ultra Low Emission Zone.

As the schedule in Table 1 and the supplemental data online show, focus group sessions involved an iterative process of discussion, information provision and reflection/further discussion. Part 1 asked participants to discuss what they already know, think and feel about air pollution. This allowed the research team to characterise participants’ current level of awareness and attitudes, and the extent to which they may already employ mitigating behaviours in their day-to-day lives, whilst concomitantly establishing a baseline against which the impact of information provision could be assessed later in the session. In Part 2, participants were provided with information derived from the academic and organisational (grey) literature describing the health impacts of NO$_2$ and PM$_{2.5}$, including statistics of associated deaths in the UK per year (for more details, see the supplemental data online). For Parts 3.1 and 3.2, the information provided to participants was derived from novel modelling data developed by the APEX project (An Air Pollution Exposure Model to Integrate Protection of Vulnerable Groups into the UK Clean Air Act) and centred around cooking and ventilation in the home; and the Ultra Low Emission Zone (ULEZ) in London (for more details, see the supplemental data online).$^1$

### 3.2. DATA ANALYSIS

The data was analysed leveraging thematic analysis (Braun & Clarke 2006, 2020). For the purpose of this paper, the thematic analysis is combined using an EHL lens. This meant the analysis was more deductive (i.e., top down— informed by existing theory) than inductive (i.e., bottom-up—
driven by the data) (Braun & Clarke 2006 for more details concerning the differences between deductive and inductive thematic analysis). The three interconnected dimensions of awareness, attitudes and behaviours were the core aspects studied in relation to participants' lived experience of air pollution, and the impact of information provision.

In practice, then, following the focus groups, the research team (four of the five co-authors) each listened to the digital recordings of the six sessions as follows:

- Step 1: To familiarise themselves with the dataset
- Step 2: To identify relevant codes (what participants said in relation to the pre-identified, i.e. deduced, areas of interest)
- Step 3: To search for high-level themes (patterns wherein what participants said resonates more widely, either within an individual group or across sessions as a whole)

A series of internal discussions then occurred to compare our individual notes and analysis: cases where each researcher's analysis (i.e. identification of codes and themes) converged were recognised as verified results (i.e. validated; Step 4); cases where analyses conflicted or were not shared by everyone were revisited by the lead author who relistedened to the relevant section(s) of the audio recordings to assess whether that code/theme warranted inclusion in the results (Step 5). This process ensured an appropriate level of rigour and robustness without the need for full transcription. This mode of analysis was made possible by our deductive approach (i.e. the EHL lens meant that the authors were searching for codes that spoke to the pre-identified categories of awareness, attitudes and behaviour as opposed to building from the bottom-up). It would not have been suitable for an inductive approach, which would likely require a more systematic (and possible software-assisted) analysis pathway. It should also be noted that the use of a deductive qualitative approach emphasised trustworthiness to a greater extent than validity or generalisability. According to Murtagh et al. (2022: 14), when conducting qualitative research:

> standards of trustworthiness, comprising fidelity and utility, are more appropriate than concepts of validity and statistical generalisability applicable for many quantitative methods. Fidelity to the subject matter entails aiming to capture lived experience through rich description, based on adequate data. Utility includes contextualisation and contribution of meaning.

### 4. FINDINGS

The high-level themes that were identified in discussions were: (1) low initial awareness of IAQ across all vulnerabilities; (2) a concern for (vulnerable) others and recognition of greater responsibility in home environments; and (3) an untapped potential for behavioural change indoors. These findings (and their nuances) are elaborated on in the following subsections, whilst Table 2 provides an overview.

<table>
<thead>
<tr>
<th>VULNERABLE GROUPS</th>
<th>EHL levels</th>
<th>PRE-EXITING HEALTH CONDITION</th>
<th>PARENT WITH A YOUNG CHILD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OLDER PEOPLE</strong></td>
<td>Low initial awareness of air pollution and IAQ across all vulnerabilities</td>
<td>• Lack of awareness regarding the sources of indoor pollution</td>
<td>• Lack of awareness regarding the sources of indoor pollution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Some awareness regarding the importance of ventilation in the home more broadly (airing the house)</td>
<td>• Lack of awareness regarding the importance of ventilation in the home</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Aware that, generally, air pollution is bad for human health</td>
<td>• Aware that, generally, air pollution is bad for human health</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Very low awareness regarding the severity and extent of impacts on human health</td>
<td>• Very low awareness regarding the severity and extent of impacts on human health</td>
</tr>
<tr>
<td><strong>PRE-EXITING HEALTH CONDITION</strong></td>
<td>Low initial awareness of air pollution and IAQ across all vulnerabilities</td>
<td>• Very little awareness regarding the sources of indoor pollution</td>
<td>• Lack of awareness regarding the sources of indoor pollution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lack of awareness regarding the importance of ventilation in the home</td>
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</tr>
</tbody>
</table>

Table 2: Overview of focus group findings in relation to environmental health literacy (EHL) and indoor air quality (IAQ), categorised by vulnerable groups and EHL levels
4.1. LOW INITIAL AWARENESS OF IAQ ACROSS ALL VULNERABILITIES

Awareness of the broader issue of air pollution was high among the participants. However, awareness related almost exclusively to ambient (outdoor) sources as opposed to indoor sources. In most cases (five of the six focus groups) indoor sources were not discussed by participants until directly prompted by the facilitator. Similarly, awareness of the efficacy of mitigating behaviours and technologies in relation to IAQ (e.g. increased ventilation and filtration systems) was extremely low; the only exception here related to the older people groups who appeared to have greater awareness of the importance of ventilation in the home more broadly in relation to the value of ‘airing’ the house. Lack of awareness led to surprised reactions from the participants later in sessions when receiving information about IAQ, including sources of indoor pollution and the efficacy of mitigating behaviours. In terms of day-to-day experience of air pollution, participants (especially those who travelled in and around Inner London frequently) reported a range of sensory responses, such as strong smells, feeling soot or other particulates on their skin, and noticing residue on their clothing after travelling. This is in stark contrast to sensory-related findings in indoor contexts, e.g. that some indoor smells, such as from candles and cooking emissions, were recognised and enjoyed rather than being associated with poor IAQ and subsequent negative health impacts.

Almost all participants made the connection between exposure to air pollution and poor health, with health, particularly respiratory health, being the first thing many talked about when air pollution was raised. Despite health-related impacts of air pollution being most participants’ point of reference for air pollution, knowledge of their extent was generally low. Participants expressed surprise over both the diversity and the magnitude of air pollution health impacts. Knowledge of specific pollutants such as NO\textsubscript{2} and particulate matter (PM\textsubscript{2.5}, PM\textsubscript{10}) was extremely low.

Several participants reported that they did not pay attention to (outdoor) air pollution information when they came across it (e.g. through a weather app on their smartphones or emails from Transport for London—TFL). Nevertheless, most participants suggested that public awareness campaigns that aimed to reach as diverse an audience as possible, e.g. using social media, television and radio, would be valuable going forward.
4.2. CONCERN FOR (VULNERABLE) OTHERS AND RECOGNITION OF GREATER RESPONSIBILITY IN HOME ENVIRONMENTS

There was a clear connection between participants’ perceptions of vulnerability and level of concern. This concern extended to others around them who they perceived as vulnerable, including, but not limited to, family and friends. One participant was already an air pollution activist before taking part in the focus groups, and it was a concern for her community in London that sparked this. Concerns could even extend to significant life decisions, e.g. a participant moving house was considering air pollution as a factor in where to live.

The participants were generally of the opinion that responsibility for controlling outdoor air pollution lies with the government. There was a perception that individual actions in this space were not sufficient to make an impact upon outdoor pollution sources (e.g. changing transport systems at scale and reducing factory emissions), therefore the government should have responsibility for outdoor source reduction. However, for indoor sources, the question of responsibility was more nuanced. Participants felt they had more personal control over their indoor environment, and therefore had responsibility in their homes. Interventions in the indoor environment were perceived as more accessible (e.g. opening windows). However, the participants qualified that if they did not own their home, then the responsibility to ensure good IAQ would lie with the landlord or housing authority (e.g. installing extractor fans and other ventilation systems in the residence and checking with tenants regularly to reflect on the quality of their indoor environment).

Distinct groups had different views of the future. Those with young children (or younger people with health conditions themselves) were interested in future trends, whereas the group of older individuals were more accepting of indoor air pollution as a part of life. The groups with underlying health conditions were especially concerned with environmental justice, raising concerns regarding differential impacts of air pollution based on socio-economic factors and race, e.g. that they expect both indoor and outdoor air pollution will be worse in built-up and relatively deprived areas (such as high-rise flats). The groups comprising parents with small children were concerned with future trends of air pollution and emphasised the importance of education moving forwards (especially regarding IAQ, for which population knowledge is generally lower). Younger participants also seemed more interested in activism and making changes for the future. On the other hand, the groups made up of older participants were reflective of past trends, e.g. remembering growing up in a cold house. There was a sense that they had survived (comparatively worse) air pollution so far, which led to a discounting in the health risks. Interestingly, this came across mostly when participants spoke of themselves, but did not notably detract from their concern for others.

There was a strong feeling among the participants that information regarding outdoor and indoor air pollution should be more accessible and that education around IAQ specifically would be extremely beneficial for public health. All participants indicated that information regarding air pollution (both indoor and ambient) would be most trusted if it came from organisations with expertise in environmental health impacts, such as the NHS and World Health Organization (WHO). Several participants also suggested that such a campaign would be helped if it had the endorsement of a well-known and respected figure such as Sir David Attenborough.

4.3. UNTAPPED POTENTIAL FOR BEHAVIOURAL CHANGE INDOORS

Some participants shared that they already behaved in a manner that limited exposure to both outdoor and indoor air pollution (e.g. exercising at certain times to avoid peak pollution; keeping children out of the kitchen when cooking). However, it was found that, overall, behaviour change to mitigate against exposure was much more prevalent in outdoor, as opposed to indoor, contexts.

As part of the cooking and ventilation modelling scenario section of the research design, the participants were asked for information on their current behaviours around ventilation when cooking. There was a mixed response: some opened windows and doors and ran extractor fans while cooking; others made no adjustments. A few participants did not know how to use extractor fans, or assumed they were to remove unpleasant smells from the kitchen rather than pollution. Participants with reduced mobility (primarily in the older people focus groups) reported that even
if they wanted to, they often struggle to open windows. Participants also raised concerns about temperature (especially over winter) when opening windows while cooking. This was more of an issue for the younger participants, especially parents with young children.

Initially, participant response to the modelling results was surprise at how much difference ventilation and filtration can make to modelled air pollution levels from cooking. Participants subsequently indicated that they intended to change behaviour as a result of what they had learnt in the focus groups, such as intending to use extractor fans and to open windows while cooking. A few expressed interest in purchasing high efficiency particulate absorbing (HEPA) filters for their home, although some were concerned over the cost of such equipment and questioned whether they could not be fitted in new homes as standard. Looking to the future, almost all participants (across every category) suggested that they would share their newly acquired IAQ knowledge (from the focus groups) with their networks, often with great enthusiasm. Intention to change behaviour and share knowledge clearly demonstrates that the vast majority of the participants had indeed developed a much-improved public literacy concerning IAQ. This suggests that information provision consisting of iterative discussion and group learning can be effective in improving public literacy of IAQ; however, this approach may not be practical across entire populations due to the significant time and resource commitments requires. The suggestions put forward by participants would likely be more practical (i.e. accessible information campaigns led organisations with expertise in environmental health impacts and endorsed by well-known and respected public figures); however, further research would be required to evaluate their effectiveness.

More broadly, participants suggested that their behaviour over the study period (winter 2022/23) was impacted by the ongoing cost-of-living crisis and effects of the COVID-19 pandemic. Participants were both opening their windows less frequently (to save energy by heating less) and spending more time at home. The same applied to the use of trickle vents: of those participants who recalled having trickle vents installed, most did not know how to use them most efficiently and reported keeping them closed once temperatures dropped.

5. DISCUSSION

The vast majority of participants across all focus groups came into the sessions with extremely limited knowledge regarding sources of indoor pollution and the efficacy of mitigating behaviours. Information provision vastly increased participant awareness (of sources, health impacts and efficacy of potential mitigating behaviours) enabling the formation of pro-social attitudes (concern for friends, family, vulnerable people, environmental justice, future trends) and expressed intentions to change behaviours to improve IAQ in their home environment, by opening windows and using extractor fans when cooking, and by installing air filtration technology. These findings not only contribute to a better understanding of the EHL of vulnerable Londoners, but also suggest that information provision in the format of iterative discussion and group learning is effective in increasing people’s willingness and ability to make behavioural changes in indoor contexts. In addition, they add nuance to Tomsho et al.’s (2022) observation that the driving force behind public interest and concern around IAQ comes from concerns for members of participants’ households, highlighting that people are also concerned for those they perceive as vulnerable (an insight supported by the fact that some participants took a normative position in favour of environmental justice). Whilst our findings here broadly align with others (e.g. Unni et al. 2022), the present study’s participants should not be perceived as passive recipients of information. Deliberation and discussion within groups contributed to a deepening of perspectives and was likely instrumental to the learning process. This suggests the context of learning is vital (Smith et al. 2022), whilst also resonating with critiques of the information deficit model that call for more multifaceted understandings of decision-making processes (Lehner et al. 2021).

A greater scope for agency exists in the home, owing to participants’ perceptions that positive behavioural changes indoors are relatively simple to make, e.g. opening windows and turning on extractor fans. This finding aligns with previous research (e.g. Tomsho et al. 2022). However, further research is needed to investigate if and how behaviour change related to improved EHL of IAQ plays out in practice. Participants were more willing to take personal responsibility for indoor air
in their own homes, as they perceived this to be within their control. In contrast, participants had little control over the outdoor air quality. This may be because it is more challenging for individual behaviour changes to reduce their exposure to pollution in the outdoor air (e.g. changing transport options may not always be feasible). The behavioural changes necessary to limit indoor air pollution exposure are more personal and directly connected with pollutant sources (e.g. cooking). This contrasts with equivalent changes related to outdoor air pollution sources, which can only be controlled by the emitters (e.g. industry), often under pressure from central and local government.

In terms of building design, the focus groups in this study suggested that ease of use for ventilation systems is very important, a finding that aligns with previous research (e.g. Miu et al. 2019; Harputlugil & de Wilde 2021). Participants, once made aware of the sources and health implications of indoor air pollution, expressed interest in changing their behaviours where possible. However, they emphasised the importance of accessibility and ease of use, for these changes to become habitual. Participants with reduced mobility (for example, in the older person focus groups), reported that they struggled to open windows; such vulnerabilities need to be considered by builders, homeowners and landlords in housing design and retrofit if inequalities (i.e. unequal ability to change behaviours) are to be addressed. The interest from most participants seemed to be more on easy-to-use technology (such as flicking a switch on an extractor fan or HEPA filter) rather than changes to more culturally embedded behaviours (e.g. cooking habits). This highlights the importance of ease of use to encourage positive behaviour change, whilst also highlighting the need to better understand the relationship between culturally embedded practices and EHL in the context of IAQ. It is also worth noting that when discussing HEPA filters, participants emphasised that such technology should be made affordable. This could require subsidies as part of national or regional air pollution policy; or new legislation could be introduced to require air filtration systems in all new-build, or rented, properties, thus ensuring they are integrated into residential built environments as a standard. This reflection speaks to environmental justice, a theme which was frequently raised by participants insofar as any future actions performed to improve air quality are done so in an equitable manner and with recognition that behaviour changes may not be accessible to all. Many participants across our focus groups reported that they did not use ventilation systems (such as extractor fans or trickle vents) currently because they were not aware of how they worked, or the positive impact they can have on IAQ. This could be made clearer through public awareness campaigns as well as via manufacturers’ instructions provided to occupants. These findings demonstrate that there are limits to the agency of individual citizens, highlighting areas where interventions are required whilst also enabling a better understanding of specific built environment implications.

Finally, participants expressed a sincere desire to share the information they learned in focus groups with the wider public, starting with their own friends and family. This suggests that improved EHL of IAQ across the wider population could produce a cascade effect whereby citizens educate one another, leading to greater (community) awareness, more pro-social attitudes and increased potential for behaviour change. Across the focus groups (regardless of vulnerability), communication and education around the importance of IAQ was repeatedly raised as a priority for the future. Many participants expressed their belief that more should be done to educate the public, so that others can make positive changes in the home. This is despite the fact that several participants admitted to ignoring (outdoor) air pollution information on their smartphones. Perhaps a greater willingness to take responsibility in home environments will translate into higher engagement with IAQ-specific communications. Participants emphasised that any information should be clear, with easy, actionable interventions suggested, a finding that aligns with previous research (Ramirez-Andreotta et al. 2016; Ramirez et al. 2019; Davis et al. 2018). Taken together, these findings have the potential to influence future educational interventions and communication strategies.

6. CONCLUSIONS

Across the three vulnerable groups, focus group participants had extremely low awareness of air pollution sources in the home and of the effectiveness of mitigating behaviours such as increased ventilation or the deployment of air filtration technology. In response to the information provided to the participants, they expressed a willingness both to change their behaviours indoors and
to disseminate the communicated information onwards to their networks, unprompted by the researchers and often with great enthusiasm. Participants were eager for easy-to-use ventilation systems in their homes, expressing that technology with clear instructions would make home technology use habitual. However, the fact that many participants already have ‘easy-to-use’ technology (e.g., trickle vents and extractor fans), but have not yet developed the habit of using them regularly, underscores the importance of providing occupants with information that not only encourages the use of ventilation systems but also raises awareness concerning the sources and negative health impacts of poor indoor air quality (IAQ). These findings contribute to a better understanding of the environmental health literacy (EHL) of vulnerable Londoners and have the potential to influence future educational interventions and communication strategies.

Participants expressed a greater willingness to take personal responsibility for their own indoor environment, perceiving their agency in the home as significantly greater than when outdoors. However, discussions revealed that vulnerabilities can restrict agency and capability to take responsibility; this was the case for some of the older group participants who highlighted that some of the windows in their home were inaccessible to them due to mobility issues.

These findings suggest that although future public communication around IAQ would be beneficial to increasing EHL and influencing behaviours (Ramirez-Andreotta et al. 2016; Davis et al. 2018; Ramírez et al. 2019), a consideration of vulnerabilities also needs to be better incorporated into residential building design. Meanwhile, residential status can restrict individuals’ agency and capability to take responsibility, suggesting the need for intervention from landlords and housing associations who participants perceived as responsible for making physical changes to the built environments of the properties they own in order to improve IAQ for tenants (e.g., installing trickle vents in the property). Both findings demonstrate that there are limits to the agency of individual citizens, highlighting areas where interventions are required and enabling a better understanding of specific built environment implications.

This assessment of IAQ perceptions through the lens of EHL revealed some positive news for the future. An overwhelming concern exists for vulnerable others, in tandem with a desire to share knowledge and a willingness to change behaviours (Figure 1). These findings suggest that improved public literacy of IAQ could be key to achieve reductions in indoor air pollution exposure, and that in future research the potential value of EHL should not be considered only in/through individual assessments but also examined within a wider social setting, an insight that is likely to help researchers engaging in interventions to improve IAQ (e.g., should the behavioural dimension include intentions and actions to inform or protect others?).

Figure 1: Segmented pyramid summarising our findings regarding the three dimensions of improved environmental health literacy (EHL) (awareness, attitudes and behaviour) in relation to indoor air quality (IAQ).
NOTES

1. The ULEZ for vehicles is not discussed here as this paper is primarily focused on IAQ. However, outdoor pollution will still be engaged with to the extent that it forms part of participants’ initial awareness of, or attitudes towards, air pollution more broadly.

2. For details regarding researcher positionality, and how this influenced the approach to data analysis, see the supplemental data online.

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AUTHOR AFFILIATIONS

Connor Smith  
School of Geosciences, University of Edinburgh, Edinburgh, UK

Alice Drinkwater  
School of Geosciences, University of Edinburgh, Edinburgh, UK

Malina Modlich  
School of Geosciences, University of Edinburgh, Edinburgh, UK

Dan van der Horst  
School of Geosciences, University of Edinburgh, Edinburgh, UK

Ruth Doherty  
School of Geosciences, University of Edinburgh, Edinburgh, UK

COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY

The focus group data leveraged to inform this study have not been made available in order to ensure the anonymity of participants. Focus groups were audio- and video-recorded; both mediums reveal information that could be used to identify participants and cannot be easily synonymised or otherwise edited to protect participants’ identities. Transcription did not form part of the methodological approach.

ETHICAL CONSENT

The research design was approved by the University of Edinburgh, School of Geosciences, Ethics and Research Integrity Committee (reference number 2022-693). Each participant received an information sheet detailing the aim of the project, their right to withdraw and how their data would be used. Participants gave their informed consent prior to the commencement of focus groups.

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SUPPLEMENTAL DATA

Supplemental data for this paper can be found at: https://doi.org/10.5334/bc.418.s1
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