Reviewing the impact of indoor air quality management and asthma education on asthmatic children's health outcomes – A pilot study

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ABSTRACT

Indoor air quality (IAQ) impacts asthmatic children's health. Previous research suggests that individual interventions such as home-based education and IAQ management positively impact health outcomes for asthma and other respiratory diseases. This study aims to evaluate the impact of the combination of home-based education and IAQ management with an air purifier as a single intervention, rather than individual interventions, to improve health outcomes of asthmatic children.

This study was conducted between June and November 2019 in McAllen, Texas. Foobot devices were used to monitor the temperature, relative humidity, particulate matter 2.5µm (PM2.5), and total Volatile Organic Compounds (tVOC) in the bedroom, kitchen, and living room of 13 homes. The monitoring was carried into phases of equal length of pre- and post-intervention. Families received asthma education together with recommendations on how to manage and improve IAQ. The children's health outcomes were evaluated at the beginning and end of the study using certified surveys. Comparison of the PM2.5 and tVOC levels and the scores for health outcomes were made between pre-and post-intervention.

The results showed that PM2.5 and tVOC levels reduced significantly after intervention. The health outcomes were improved in asthmatic children. However, only the difference in the health-related quality of life was statistically significant. The results cannot be generalised; however, they provide evidence of the combined intervention's impact, including asthma education and IAQ management, with an air purifier to improve asthmatic children's health outcomes.

INTRODUCTION

Over recent years, asthma has become a public health concern in the USA, particularly in children's health. In the USA alone, it is estimated that by the end of 2018, the prevalence rate of asthma in children was 8.6% for children aged 5-14 years and 11.0% for those between 15-19years, from which approximately 53.8% suffered asthma attacks. The Emergency Department visits from children of less than 18 years were 85.3 per 10,000, while the hospitalisations were 10.3 per 10,000 (CDC, 2020). The impact of indoor air quality (IAQ) is strongly linked to lung function, health, and the severity of respiratory illnesses such as asthma and rhinitis (Blanc *et al.*, 2005). Additionally, children are among the most vulnerable population to suffer from asthmatic problems due to poor IAQ (RCPCH, 2018).

Although exposure to air pollutants happens indoors and outdoors, the recent lockdown measures due to COVID have highlighted the importance of IAQ. Now more than ever, we spend most of our time indoors. The health risks from indoor air pollutants are higher compared to those outdoors (RCPCH, 2016). The number of airborne contaminants varied in composition. There have been identified over 900 pollutants, biological materials, and ultrafine particles associated with building materials (SCHER, 2007) are present in the air we breathe (Jacobs, Kelly and Sobolewski, 2007). Particles of biological origins, such as bacteria, fungi, pollen, and cockroach allergens, have been associated with higher risks for asthma or exacerbating the condition (Bornehag, Sundell, and Sigsgaard, 2004; Sundell, 2007; Svendsen, Gonzales and Commodore, 2018). Traditionally IAQ has been measure through carbon dioxide (CO_2) levels.

Nonetheless, we now understand that IAQ is far more complex. The recommended IAQ parameters are carbon monoxide (CO), ozone (O_3), radon (Rn), volatile organic compounds (VOCs) and ultrafine particulates matter ($PM_{2.5}$, PM_5, PM_{10}). $PM_{2.5}$ has become the centre of recent discussions and a major concern for public health. The impact of ultrafine particulate matter on human health, particularly on respiratory illnesses, is linked directly to particles' size, exposure, and concentrations (Harrison et al., 2010).

Krieger *et al.*, (2010) suggest that in-home tailored interventions for asthma, particularly those that effectively reduce exposure to indoor agents that cause asthma symptoms. These interventions include reducing cockroach allergens, eliminating moisture, and removal of mouldy items. This suggests that indoor biological agents of IAQ may be of vital importance on asthma control. Carrillo, Spence-Almaguer, *et al.* (2015) and Baek *et al.* (2019) present interventions, particularly home-based education in disadvantaged communities in the US, such as delivering asthma education in families were adequate to improve health outcomes of children with asthma. Our group's recent work looks at implementing air purifiers and their effectiveness to control IAQ empowering families with additional tools to control and manage asthmatic symptoms (Moreno-Rangel *et al.*, 2020). This pilot study's preliminary results suggested that air purifiers' use enhances IAQ and could improve children's health conditions and reduce health disparities. Air purifiers effectively reduce exposure to indoor airborne pollutants; however, it is recommended to use those with HEPA filters when looking to have better control. For instance, a study in California evaluated the impact and effectiveness of reducing airborne pollutants, such as $PM_{2.5}$, in homes using air purifiers on children with asthma and allergic rhinitis. They found that the asthma control test-scores improved for those in the interventional group compared, whilst the control group showed a deterioration (Park *et al.*, 2017). Second-hand tobacco smoke (SHS) can worsen the development of asthmatic symptoms. Air purifiers with HEPA filters are effective in removing and controlling SHS. Their use in homes with asthmatic children has been linked to decreased unscheduled asthma hospital visits (Marano *et al.*, 2009).

Most of the previous studies centred on studying the impacts of single interventions; hence there is the need to look at combined interventions. The aim of this study is, precisely that, to assess asthma education and IAQ management as a single intervention within vulnerable (children and low-income) populations, with a particular interest in the children's bedroom IAQ.

METHODS

Study Design

This interventional study was conducted in McAllen, Texas, between June and November 2019. A total of 13 homes were monitored. The criteria for the selection of the were i) at least one occupant aged between 7 and 12 and diagnosed with asthma, ii) willingness to receive asthma education and use the air purifier, and iii) allowing a Community Health Worker (CHW) to visit their home at least three times during the study.

The monitoring was divided into two phases, a pre-and post-intervention. The participants were visited by a CHW who set up the IAQ monitors (Foobot) in the child's bedroom, kitchen, and living room in each of the households. Additionally, the CHW also applied pre-tests for health outcomes, including the Home Environmental Personal Well-being Survey (HES), Paediatric Quality of Life Inventory Asthma Module (PedsQL), the Asthma Control Test (ACT), and the Healthy Homes and Asthma Test (HHA). After applying the surveys, the CHW provided asthma education to children and their families. After 15 days, the CHW visited the homes to install and run the children's bedroom air purifiers. The Footbots continued monitoring the IAQ during this phase until the end of the study. Finally, in the third visit, after 30 days of the initial visit, the CHW conducted the post-tests for health outcomes using the same surveys employed in the first visit and picked the IAQ monitors.

Health outcomes assessment

The HES, PedsQL, ACT, and HHA surveys were used to evaluate the health outcomes at the beginning and the end of the study. The ACTs were applied to children while the PedsQL, HES, and HHA to the parents.

The HES is a tool that assesses the well-being of the most common building syndrome-related issues as described by (Raw 1995), which consist of eight questions (total score of 8). It comprehends dry eyes, blocked or stuffy nose, dry throat, headache, tiredness or lethargy, dry, itching or irritated skin, itchy or watery eyes, and runny nose.

The ACT contains seven questions for self-assessment of asthma control (total score of 27) to determine how well controlled the child's asthma symptoms are. It includes general asthma symptoms, such as cough, wheezing, and sleep disturbance, their frequency and effect to asthma on daily functioning. Higher scores in the ACT indicate better asthma control (Nathan *et al.*, 2004).

The PedsQL Asthma Module is an instrument designed to measure the impact of specific asthma health issues on children's aged years old quality of life (Varni *et al.*, 2004). The tool includes 28 questions in four sections: asthma symptoms, treatment problems, worry, and communication problems. Each of the questions has a four-rating scale from never (0) to almost always (4) with a maximum total score of 112.

The HHA test includes 10 questions (total score of 10) to evaluate the knowledge of asthma symptoms and management, asthma triggers, as well as environmental and behavioural risk factors (Carrillo, Han, *et al.*, 2015).

Interventions

The CHW educated children and their parents after conducting the surveys. Home-based education provided the participants with a holistic view of asthma control management and healthy home environments. The education aims to provide critical tools to effectively manage and control children's asthma, focusing on managing the home environment, asthma symptoms, identification and control of common asthma triggers, and adequate medication and adherence. A detailed description of these materials is explained by (Neltner, 2010; Carrillo, Spence-Almaguer, *et al.*, 2015). During this visit, the CHW installed two Foobot devices in each room (child's bedroom, living room, and kitchen).

After 15 days, the CHW visited a second time to install the air purifiers (Levoit Air Purifier Model# LV-H132) in the child's bedroom, where the children spend most of their time. Accordingly to the maker, the Levoit air purifier has an advanced 3-stage filtration system. It includes the pre-filter, HEPA filter, and high-efficiency activated carbon filter to capture allergens, pet hair, dander, smoke, mould, odour, and large dust particles, in addition to removing 99.97% of airborne contaminants as small as 0.3 microns.

Indoor air quality monitoring

This study evaluated the IAQ using a low-cost monitor called Foobot (Model FBT0002100). Previous studies evaluated its accuracy and performance, suggesting that Foobot is a reliable tool to measure indoor air pollutants (Sousan *et al.*, 2017; Moreno-Rangel *et al.*, 2018). The Foobot was calibrated and tested in our office in McAllen for two months previous to the study. To reduce the accuracy bias of using low-cost monitors, two Foobot were used in each room, as well as calibration equations improving the data quality and data corroboration protocols as suggested in previous studies. The IAQ measurements were done following the ASTM D7297-14 standard (ASTM, 2014).

The Foobot devices (air temperature [-40-125°C; ±0.4°C], relative humidity [0-100%RH; ±4%RH], and PM2.5 [0-1,300μg/m3; ±4μg/m^3 or ±20%]; tVOCs [125-1,000ppb; ±20%]) were installed in the child's bedroom, kitchen and living room in each household. The IAQ paraments were recorded at five min intervals over 30 days in each of the homes. Data was recorded and saved automatically using an API in an online storage service, where it was stored and encrypted.

Statistical Analysis

The descriptive statistics were calculated to estimate the standard deviation (SD) and mean for each of the parameters (temperature, relative humidity, $PM_{2.5}$, tVOCs), dividing them on the pre-and post-intervention. T-tests were conducted to compare the $PM_{2.5}$ and tVOC between both phases. Changes between both phases were tested through the Wilcoxon rank-sum for each of the households. Wilcoxon signed-rank was used to evaluate each of the surveys between the pre-and post-intervention phases. Scores with a lower p-value than 0.05 were considered statistically significant.

RESULTS

The 13 children who participated in the survey were boys and six girls, both aged between 7 and 12 years. Six (46.2%) households reported keeping hairy pets indoors. Occupants also reported the main housing characteristics of their homes: seven (53.8%) homes used electricity as a cooking fuel, while five (46.2%) used gas; six (46.2%) homes had tiled flooring, six (46.2%) hardwood flooring and one (7.6%) carpeted flooring; the total of homes with open layout (kitchen, living room and dinning) were 9 (63.3%) equal to those that reported having a cooking hood.

Table 1. House characteristics

Household	Occupants	Cooking fuel	Open plan	Kitchen hood	Frequency of ventilation	Pets
1	10	Gas	No	Yes	Sometime	Yes
2	7	Gas	Yes	No	Always	Yes
3	5	Electricity	No	Yes	Sometime	No
4	6	Electricity	Yes	Yes	Always	No
5	5	Gas	Yes	Yes	Always	Yes
6	4	Electricity	Yes	No	Always	No
7	5	Gas	Yes	No	Always	Yes
8	5	Electricity	No	Yes	Sometime	No
9	4	Gas	Yes	Yes	Always	Yes
10	6	Electricity	No	Yes	Never	No
11	7	Electricity	Yes	No	Sometime	No
12	3	Gas	Yes	Yes	Sometime	Yes
13	6	Electricity	Yes	Yes	Sometime	No

Table 2. Children characteristics and bedroom indoor environment

Household	Gender	Age	Bedroom flooring	Indoor temperature (°C) (SD)	Indoor relative humidity (%RH) (SD)
1	Boy	7	Tile	25.0 (3.5)	52.9 (4.7)
2	Girl	8	Tile	28.8 (3.4)	54.2 (5.7)
3	Girl	10	Tile	25.7 (0.8)	48.3 (1.7)
4	Boy	10	Hardwood	29.8 (4.5)	51.3 (7.4)
5	Girl	10	Hardwood	29.8 (4.6)	53.1 (5.4)
6	Boy	12	Hardwood	28.5 (2.2)	54.1 (4.2)
7	Girl	9	Hardwood	24.2 (2.0)	46.6 (3.2)
8	Boy	11	Tile	26.0 (0.8)	46.2 (4.4)
9	Girl	9	Tile	24.4 (1.1)	45.2 (2.6)
10	Boy	8	Carpet	22.5 (1.5)	56.7 (4.6)
11	Girl	8	Hardwood	22.7 (3.0)	47.2 (5.1)
12	Boy	10	Tile	25.0 (1.9)	48.2 (6.4)
13	Boy	12	Hardwood	22.5 (2.9)	54.6 (6.9)

The ventilation patterns were also reported by the building occupants: six (46.2%) homes reported to do it always, six (46.2%) to ventilate sometimes and only one (7.6%) never. Mean indoor temperature in eight (61.53%) of the homes were above the extended 25°C in bedrooms and only one below the 23°C benchmarks for bedrooms (CIBSE *et al.*, 2006). Indoor mean relative humidity levels above the 50%RH recommended by the US Environmental Protection Agency (EPA, 2012) in homes were exceeded in eight (61.53%) of the homes. A summary of the house and demographic characteristics are presented in Tables 1 and 2.

The $PM_{2.5}$ levels declined on average -0.88 μg/m^3 (*$p<0.001$*) in the bedroom, -1.81 μg/m^3 (*$p<0.001$*) in the kitchen, and -0.04 μg/m^3 (*$p<0.014$*) in the living room within the 13 homes. The $PM_{2.5}$ levels were reduced significantly (*$p<0.001$*) in seven dwellings, and three showed a significant increase (*$p<0.001$*). As the air purifiers were installed in the bedroom, this might pose the question of whether or not the participants used the air purifiers as instructed. Analysis of the $PM_{2.5}$ levels revealed that levels consistently decreased significantly (*p<0.001*) between the pre-and post-intervention in all rooms of the households 4, 6, 8, 12, and 13. A summary of the bedroom, kitchen, and living room results is shown in Tables 3-5.

Table 3. Mean $PM_{2.5}$ concentrations in the bedroom.

Household	Pre-intervention $PM_{2.5}$ levels	Post-intervention $PM_{2.5}$ levels	Difference
1	9.62	17.05	7.43
2	21.65	20.51	-1.14**
3	11.80	11.74	-0.06
4	22.41	19.08	-3.33**
5	22.50	20.76	-1.75**
6	28.89	20.06	-8.83**
7	17.85	29.96	12.11
8	18.64	14.15	-4.49**
9	14.31	16.51	2.20
10	14.05	15.55	1.50
11	25.79	27.13	1.34
12	27.40	20.24	-7.16**
13	39.22	28.47	-10.75**
t-test and Wilcoxon rank-sum (Mann-Whitney) test. *Significant at *p<0.05*, **Significant at *p<0.01*.			

Table 4. Mean $PM_{2.5}$ concentrations in the kitchen.

Household	Pre-intervention $PM_{2.5}$ levels	Post-intervention $PM_{2.5}$ levels	Difference
1	11.46	15.09	3.64
2	23.00	17.93	-5.07**
3	13.85	12.81	-1.04**
4	25.71	23.12	-2.60*
5	19.61	21.04	1.44
6	35.21	25.80	-9.42**
7	10.27	16.58	6.31
8	20.85	16.24	-4.61**
9	15.68	20.22	4.54
10	17.24	18.91	1.68
11	28.41	27.99	-0.42
12	29.97	24.24	-5.73**
13	35.55	21.79	-13.76**
t-test and Wilcoxon rank-sum (Mann-Whitney) test. *Significant at *p<0.05*, **Significant at *p<0.01*.			

Table 5. Mean $PM_{2.5}$ concentrations in the living room.

Household	Pre-intervention $PM_{2.5}$ levels	Post-intervention $PM_{2.5}$ levels	Difference
1	7.38	25.84	18.46
2	25.28	25.25	-0.03
3	8.43	8.53	0.10
4	25.88	20.14	-5.74**
5	20.13	17.40	-2.73**
6	32.19	22.11	-10.08**
7	21.89	27.11	5.22
8	15.93	11.46	-4.47**
9	14.89	17.19	2.30
10	14.18	15.91	1.73
11	26.05	27.20	1.15
12	25.16	17.15	-8.01**
13	39.90	31.45	-8.45**
t-test and Wilcoxon rank-sum (Mann-Whitney) test. *Significant at *p<0.05*, **Significant at *p<0.01*.			

The tVOC levels increased on average 38.57 $\mu g/m^3$ (*p<0.001*) in the bedroom, 34.41 $\mu g/m^3$ (*p<0.001*) in the kitchen, and 2.91 $\mu g/m^3$ (*p<0.292*) in the living room within the 13 homes. Nonetheless, the bedroom was the room where most of the homes decreased significantly (*p<0.001*). The tVOC levels were reduced significantly (*p<0.001*) in two dwellings, and eight showed a significant increase (*p<0.001*). Analysis of the tVOC levels revealed that levels consistently decreased significantly (*p<0.001*) between the pre-and post-intervention in all rooms of households 3 and 7. A summary of the bedroom, kitchen, and living room results is shown in Tables 6-8.

Table 6. Mean tVOC concentrations in the bedroom.

Household	Pre-intervention tVOC levels	Post-intervention tVOC levels	Difference
1	194.30	228.73	34.43**
2	260.82	311.26	50.44**
3	326.30	267.05	-59.25**
4	324.01	355.35	31.34**
5	224.66	220.42	-4.24
6	336.81	401.89	65.08**
7	350.03	329.71	-20.32**
8	339.05	373.63	34.58**
9	337.65	378.28	40.63**
10	214.80	209.19	-5.61**
11	285.23	379.28	94.05**
12	427.06	624.43	197.37**
13	388.83	348.18	-40.65**
t-test and Wilcoxon rank-sum (Mann-Whitney) test. *Significant at *p<0.05*, **Significant at *p<0.01*.			

Table 7. Mean tVOC concentrations in the kitchen.

Household	Pre-intervention tVOC levels	Post-intervention tVOC levels	Difference
1	181.17	227.43	46.26**
2	252.20	223.20	-29.00**
3	336.11	285.51	-50.60**
4	257.11	291.62	34.51**
5	247.06	390.03	142.97**
6	303.25	372.04	68.79**

7	314.62	294.38	-20.24**
8	281.70	307.99	26.29**
9	326.23	362.00	35.77**
10	210.21	221.74	11.53
11	250.07	303.56	53.49**
12	383.85	467.06	83.21**
13	336.34	362.90	26.56**
t-test and Wilcoxon rank-sum (Mann-Whitney) test. *Significant at *p<0.05*, **Significant at *p<0.01*.			

Table 8. Mean tVOC concentrations in the living room.

Household	Pre-intervention tVOC levels	Post-intervention tVOC levels	Difference
1	179.03	223.38	43.35**
2	399.85	298.17	-101.68**
3	307.99	231.12	-76.87**
4	240.33	255.95	15.62**
5	186.46	199.26	12.80**
6	325.99	379.33	53.34**
7	335.55	313.36	-22.19**
8	304.64	332.60	27.96**
9	330.76	361.18	30.42**
10	215.45	220.00	4.55
11	248.13	297.05	48.92**
12	445.31	513.88	68.57**
13	337.83	362.19	24.36**
t-test and Wilcoxon rank-sum (Mann-Whitney) test. *Significant at *p<0.05*, **Significant at *p<0.01*.			

Results from the HES, PedsQL, ACT, and HHA surveys examined the health outcomes of children with asthma and their parents pre-and post-intervention and suggest an improvement in the children and parents' health outcomes. While all the tests showed an improvement, only the total mean PedsQL were statistically significant ($p<0.05$) between pre- (19.2) to post- (13.2) intervention results. The results from the HES changed between pre- (3.23) to post- (3.08) intervention. In the PedsQL and HES a lower score means an improvement, while the ACT and HHA would do with a higher score. Hence, the total mean of the HHA results changed between pre- (8.00) to post- (8.23) intervention, while the ACT were 23.8 to 24.5 between pre- and post-intervention.

DISCUSSIONS

Asthma is a chronic disease whose effects on health can be severely impacted as we grow older. It is vital to manage and control asthma since early stages, particularly in children, to reduce its adverse effects on life quality. Punctual interventions and strategies can minimize exposure and prevent asthma symptoms (Etzel, 1995).

Several interventional studies have developed guidelines to manage asthma and improve the condition. For instance, some studies in the US suggested that there is an improvement in asthma symptoms by incorporating the 'Asthma and Healthy Homes' programme into asthma education. Furthermore, increasing asthma control knowledge in children and their families improves the overall quality of life (Carrillo, Spence-Almaguer, *et al.*, 2015; Baek *et al.*, 2019), which has been further enhanced by adding IAQ management (Moreno-Rangel *et al.*, 2020). The asthma education curricula focus on education that includes signs and symptoms of asthma, asthma management, frequent triggers, the correct use of asthma medications, action plans for asthma attacks, and the components to develop an action plan (Carrillo, Spence-Almaguer, *et al.*, 2015). This program also incorporated the seven principles presented on the 'Healthy Homes' developed by the National Healthy Homes Training Centred and Network in the US. This program focused on keeping the home dry, clean, ventilated, pest-free, contaminant-free, better indoor environment quality, and minimising exposure to hazardous products in the homes. These principles suggest that not only the chemical composition of the IAQ is essential, but the bio-particulates are equally important.

The use of air purifiers has proved to reduce the levels of indoor air pollution. They also promise to manage asthma triggers and improve the asthma condition (Breysse and Matsui, 2016). Martenies and Batterman, (2018) looked at air filters' efficiency to reduce $PM_{2.5}$ exposure indoors and their impact on respiratory illnesses. They found that air cleaners' use led to improved respiratory symptoms and breathing problems for adults and children with asthma, rhinitis, or bronchitis. There is evidence that using air purifiers, particularly in homes, can reduce indoor VOCs concentrations, especially those related to solvents and consumer products (Norris *et al.*, 2019). For instance, Fang *et al.* (2019) look a the VOCs concentrations at night in the bedroom of children with asthma before installing an air purifier. They found that the air purifiers in homes led to a significant reduction of VOCs. However, they found that concentrations of some individual VOCs, such as formaldehyde, acetaldehyde, and benzene, are critical. Even if they were reduced, their concentrations could still be associated with health risks.

One of the most significant limitations of these kinds of studies is that they concentrate on studying a specific parameter that could impact asthma. And there are still very few studies that look at a group of interventions as a whole. Therefore, in this study, we implemented air cleaning and asthma education as a combined strategy to improve asthma in children. While we found that $PM_{2.5}$ reduced during the post-intervention period, this wasn't clear in the tVOC. This could be due to the type of air purifier as we focused on selecting an air purifier with HEPA filters to reduce the $PM_{2.5}$. However, the intervention showed consistent results as previous studies, which we believe could improve children's asthma control and management, as demonstrated by the surveys.

This study suffered from clear limitations. First, the duration of the pre-and post-intervention study was short (15 days). This may suppose an explicit limitation on observing and quantifying precise changes on the IAQ and the participants' health outcomes between the study phases. Nonetheless, there were still some differences observed that were reported here. Second, the use of low-cost IAQ monitors relying on a Wi-Fi network to store the data proved to be a problem in remote locations. Although a robust data management plan was set in place, some data was lost during the process due to poor internet access. However, enough data points were collected in all the 13 homes to perform the statistical analysis.

Additionally, the low-cost monitors were preferred to use simultaneous sampling with several monitors within the home. Using more precise analytical instruments would suppose additional costs and highly trained human resources to manipulate, operate, and set-up the equipment. Moreover, one of the approaches we used was developing an intervention plan that low-income populations could follow. Therefore the Foobot seemed viable in both aspects cost and IAQ monitoring resolution. Third, the Hawthorne effect is a significant limitation in this kind of study. People may adapt or change their behaviours during the study altering normal indoor environment conditions from the instant monitoring instruments. Finally, the statistical model did not include housing characteristics due to the sample size. The CHWs verified some characteristics, such as the range ovens and bathroom vents.

Further studies should include a more significant sample to utilise statistical methods to adjust for other building-related factors that may affect indoor air condition. Building modelling and CFD simulations could also help obtain more data making changes on the building design to study their impact on IAQ and human health. Thus, consequently controlling asthma from the early stages.

CONCLUSIONS

This study evaluated the effects of a combined housing intervention, air purification, and asthma education as a household intervention to improve asthmatic children's health outcomes. This study recommends that using the combination of asthma education and an air purifier at home might enhance IAQ and could lead to improving children's health outcomes. Further studies that include a large-scale sample are needed to verify a household intervention's effectiveness to enhance IAQ and asthma management. Additionally, building modelling and CFD simulations could also help obtain more data making changes on the building design to study their impact on IAQ and human health.

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