



Asthma & Indoor Air Quality

Asthma Society of Ireland

2017

A 3 month review of air quality in the home before and after the installation of a CliniAir air purifier from Enviroion. Air quality was monitored using the Cair smart air quality sensor from NuWave



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Foreword

One day, asthma will be cured. There will be no more asthma attacks, no inhalers and no need for asthma management plans. Why am I so confident? Well I am because medical research scientists like Jonas Salk worked out how to develop a vaccine to eliminate polio in 1955 and 150 years before that, by using astute observation, the physician, Edward Jenner did the same for smallpox. Both of these diseases were killers and we beat them by doing research. We can do the same to asthma as long as smart ideas turn into effective actions and good observations allow us to eliminate the triggers that bring on the symptoms.

The research that is necessary to defeat asthma costs a great deal of money and includes the development of new drugs and vaccines. We also need to invent and develop accurate air monitoring devices so that we know immediately the outdoor and indoor levels of triggers like pollen, fungal spores and small chemical particulates. (The presence of any of them often lead to a surprise attack because the smaller ones are invisible to the eye). But most importantly, we need well-funded research programmes in order to train the next generation of young researchers. These are the scientists who will "stand on the shoulders of giants" to defeat asthma and who may one day turn into giants themselves.

The Asthma Society of Ireland is a charitable organization with a mission to help and support sufferers, to advocate and campaign for improvements in their medical care and to fund research to stop the disease in its tracks. This report on "Asthma and Indoor Air Quality" represents a necessary first research step for Ireland to monitor and understand the connection between the quality of our indoor air and the development of asthma symptoms.

We need studies like this simply because we spend most of our life indoors, places where we toast bread, fry bacon, light coal fires and use wood-burning stoves. More than that, your bathroom might have black or green fungus mildew. And it might have little ventilation. In those circumstances you might have to open windows that look straight out onto a busy road full of buses, trucks and cars. All of those circumstances bring small particles, some chemical in nature and some biological, directly towards us. Then we breathe them in.

For those with asthma the number of particles, their sizes and their composition have a direct bearing on health but not in a good way. Very serious effects can result, as many of you reading this report will know. However there are strategies that can help us.

The key to eliminating the particulate triggers is, in the words of Sun Tzu, to "Know your enemy" and in this context that means monitoring indoor air in real-time and with accuracy. That is where this "proof-of-principle" research study is directed towards for nine households in Ireland. Put simply, we first have to quantify the number of particulates and measure the levels of other triggers like VOCs (Volatile Organic Compounds). The important step taken in this study is to relate the number and types of trigger to asthma "events" in a systematic way over a wide range of conditions.

This type of research is at an early stage and many more studies are needed to build on it. For example many more houses and people with and without asthma need to be monitored. Differences in the number of particles measured in different rooms also need to be quantified. But the prize is big because in the future it may prove possible to develop instrumentation that informs you when an asthma attack is likely to occur. Such an early warning system might eventually even be tailor-made for you because it has been tuned directly to your exact triggers and sensitivities.

The main lesson to be learned from this report though is air filtration systems are a real help in reducing the numbers of airborne particulates present in your house. Every asthma management plan should have one.

The Asthma Society should be applauded, in my opinion, for sponsoring this research. The one thing that I have learnt in my own research career is that even a good idea needs “seed-money” to get off the ground. Then the sky’s the limit.

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12 October 2017

Executive Summary

The air we breathe has a significant impact on our health and wellbeing. Given the amount of time we spend indoors, this is a fact especially true of the air we breathe inside our homes, schools and places of work. The impact of poor air quality on our health is well-understood. Contaminated air is linked to an increase in the frequency and severity of respiratory conditions such as asthma, COPD and lung cancer as well as reduced lung function in young children. For people with asthma, in particular, this can be a significant obstacle to normal, day-to-day living. Furthermore, unlike outdoor air quality, it is possible for individuals to actively improve the quality of indoor air and thus engage in direct interventions to improve their health.

Asthma is a very common, chronic condition in which the airways become inflamed and sensitive. This leads to swelling and mucus production, which can cause symptoms such as cough, chest tightness and shortness of breath as well as making breathing extremely difficult. Asthma symptoms are often made worse by exposure to triggers; these are substances which normally cause no problem for non-asthmatic individuals. Certain airborne contaminants such as dust, mould, smoke and particulate matter are known to be particularly common asthma triggers which can lead to worsening symptoms and potentially fatal attacks for a large number of people. Airborne particulate matter is also known to have significant health effects on people with or without respiratory conditions.

This study provides an assessment of the value of air monitoring in tracking and identifying personal asthma triggers and whether there is a role for indoor air purification as part of ongoing asthma management. Air quality within the home was monitored continuously for three months, both before and after the installation of a Cliniair air purifier. Participants tracked the symptoms they experienced through an app linked to the air monitoring system. This approach allowed participants to see improvements in their air quality after the installation of the purifier as well as allowing them to cross reference their symptoms with any changes in air quality.

The vast majority of users experienced a dramatic drop in particulate matter levels after the installation of the air purifier and in most cases were able to match their symptoms with an air quality issue picked up by the sensor. Some users also felt that the installation of the purifier and air monitor improved their quality of life.

“What it does is great, can only be of benefit. Everything combined together has enabled me to have better quality of life, it’s a definite part of the jigsaw. Like joining up the dots, a little bit that was missing before.”

“Having that information [about air quality] allowed me open doors and move away from the fumes until they cleared up. I can’t always identify the problems but using the Cair air monitor has certainly benefited me.”

These findings indicate valuable roles for both air quality monitoring and air purification in asthma management. The Asthma Society of Ireland feels that the results obtained show a need for a larger study to be set up to fully illustrate the potential impact of indoor air monitoring and purification on the personal management of asthma symptoms, which would improve the general health of the population.

Introduction

Asthma is a chronic, life long condition that cannot be cured. However, it can be successfully controlled and managed with proper care and medication. Since the mid-70's the incidence of asthma and asthma related deaths has been on the rise, though an exact cause is not known [1]. A key part of managing asthma and maintaining control is the avoidance of substances which trigger asthma symptoms [2]. However, this is nearly impossible in the case of airborne triggers which are ubiquitous in the environment such as pollen [3] or traffic-related air pollution [4]. It is well understood that the quality of outdoor air can severely impact people with asthma.

However, we spend the majority of our time indoors and as such the quality of our indoor air can have an even bigger impact on our health, especially for people with asthma and other chronic respiratory conditions [5].

Housing was identified as a key area contributing to health and wellbeing in the Irish Government's 'Healthy Ireland Framework' [6]. Many indoor problems which affect asthma such as serious mould, inadequate ventilation and carpeted flooring are expensive to improve. Due to the cost of remedying these issues, many low-income families are living in environments that pose serious risks to their health [7]. These health effects and the importance of good indoor air quality are starting to be recognised internationally [8]. As such it is essential to understand the impact and status of indoor air quality in the Irish context.

This study aimed to assess the air quality in the homes of 9 members of the Asthma Society and monitor their asthma symptoms over a 3 month period. For the first 4-6 weeks of the study, the air quality in their homes was monitored using a Nuwave Cair sensor, while participants logged any asthma symptoms they experienced. After this, a CliniAir unit from Envirion was installed in each of the homes for the remaining 6 weeks. Air quality and any asthma symptoms continued to be logged while the air filtration unit was in the home. The incidence of asthma symptoms before and after the installation of the CliniAir unit was analysed to determine whether air filtration in the home allowed for better asthma control and fewer symptoms. It was found that the use of the CliniAir unit caused a significant reduction in airborne particles present in the home. Further, a high level of particulates in the air appeared to be linked to the occurrence of symptoms [9].

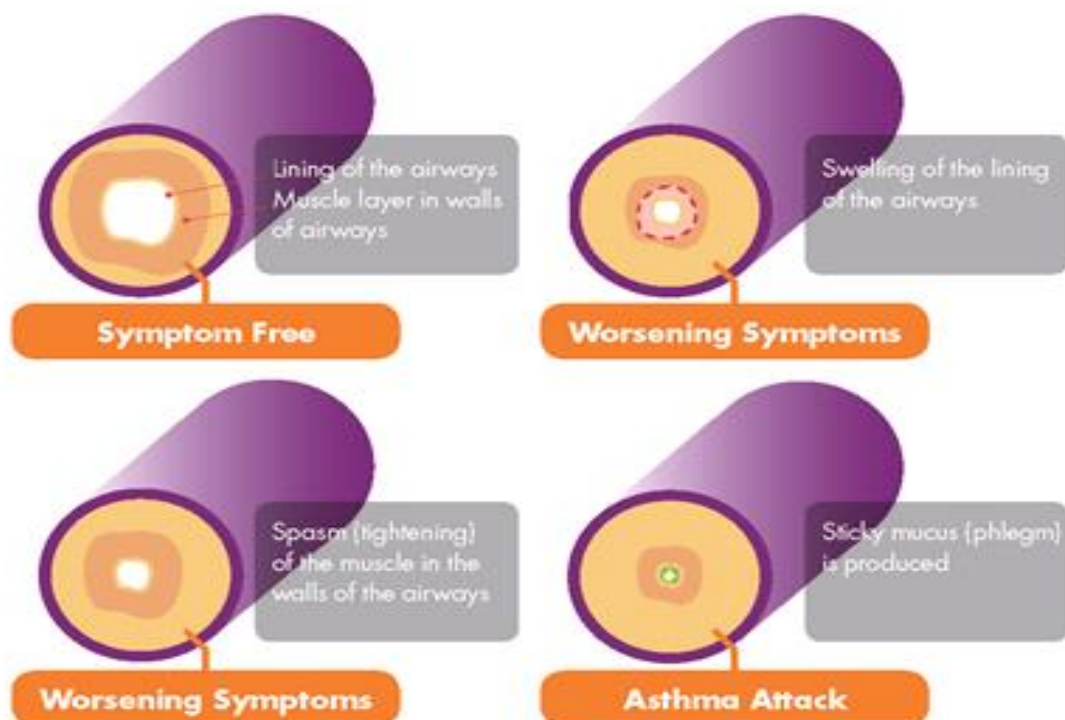
These findings are in keeping with previous research which has highlighted the role of particulate matter in increasing the frequency of asthma symptoms [10] and the efficacy of air filtration in reducing the particulate load of indoor air [11].

Asthma

What is asthma

Asthma is a common chronic disease, which leads to inflammation of the airways and can make it harder to breathe [12]. The airways are the small tubes that carry air in and out of the lungs. In asthma, the airways are over-sensitised and react to things that would normally be harmless such as cold air or dust mites. These are called triggers.

When asthma symptoms begin, the lining of the airways becomes swollen, leaving less room for air to move in and out. At the same time, the muscles around the walls of the airways can get tighter, making the space for air even smaller. As the lining of the airways swell, sticky mucus is produced that clogs the already narrowed space inside the airways and can lead to them being blocked completely. It is the combination of these effects, which leads to the difficulty in breathing that is associated with asthma [2].



Asthma affects 1 in 5 children and 1 in 10 adults in this country, making it the most common chronic disease in Ireland [13]. Despite the prevalence of the disease, it is estimated that 60% of people with asthma in Ireland do not have their asthma under control and are therefore at risk of a serious attack. This results in someone with asthma visiting the emergency department every 26 minutes as a result of their condition, this makes up a total

of 20,000 visits each year. Further, asthma is responsible for 50,000 visits each year to G.P. out-of-hours services and is estimated to cost €500 million per annum [7].

More worryingly, uncontrolled asthma can also be fatal. In Ireland, one person each week dies from asthma [13]. However, 90% of these deaths are preventable and it is because of this that correct treatment and ongoing management of asthma are essential for all people living with the condition [7].

Asthma Symptoms and Triggers

Asthma is identified by a number of breathing-related symptoms:

- **Shortness of breath:** possibly triggered by exercise or excitement
- **Wheezing:** a characteristic whistling sound that happens during asthma when air is breathed through narrowed airways.
- **Chest tightness:** sometimes described as chest pain or a tummy ache by young children.
- **Coughing:** usually dry and recurring. May occur at night or during exercise.[2]

A person with asthma may have only one symptom or any combination of these symptoms. Additionally someone with asthma may find that they experience symptoms only at night, during or after exercise or in response to a particular trigger [13].

A trigger is any factor that irritates the sensitised airways and brings on the symptoms of asthma. Some people may react to only one trigger while other may react to a wide variety. Given the diverse nature of asthma triggers it can be difficult to pinpoint what has caused the appearance of symptoms. However identification is crucial as trigger avoidance is an essential element of asthma management [14].

Common asthma triggers include [2]:

- **House Dust Mites:** these are tiny insects that live in the warm, damp places of every home. Mattresses, carpets, soft toys and furnishing are all favourite dust mite habitats. It is impossible to get rid of dust mites completely; however their numbers can be reduced through simple interventions.
- **Tobacco Smoke:** this is one of the most common and potent triggers of asthma. Tobacco smoke can increase the risk of developing serious lung infections such as pneumonia and bronchitis and can also lessen the effect of necessary asthma medication.

- **Mould:** Mould releases spores which can trigger asthma. Mould is usually found in damp areas such as bathrooms, kitchens, woodland areas or fallen leaves.
- **Temperature Changes:** Changes in temperature and weather can trigger asthma symptoms especially around the start of spring and autumn.
- **Air Pollution:** Both indoor and outdoor air pollution can bring on asthma symptoms. Examples of indoor air pollution include aerosol sprays, fumes from heating systems, smoke from coal fires and chemical fumes from cleaning products [13].

Asthma Management

Controlling and managing asthma is the ultimate goal of asthma treatment. This means the person with asthma has well controlled symptoms; does not experience exacerbations; has close to normal lung function and can maintain their normal levels of activity [12].

However, achieving and maintaining good control relies on a number of factors outside of simple medication. Asthma management usually involves a written plan, which details your medication; gives information on how to recognise a worsening condition; advises on steps to improve asthma control and provides information on how to handle an attack. Often, this plan is supplemented by use of a peak flow meter to monitor lung function. This process can often act as an indicator of how well controlled someone's asthma is. Other interventions include checking inhaler technique regularly, maintaining up to date flu and pneumonia vaccines and ensuring a nutritious diet [2].

Preventative measures are also a key part of asthma management, in particular the avoidance of known allergens and asthma triggers [12]. Each person's written asthma management plan will contain the details of their individual asthma triggers, if these have been identified [13].

Avoiding triggers is a crucial component of good asthma management but in the case of certain triggers such as pollen [3] or road-traffic pollution [4], avoidance is extremely difficult due to the prevalence of these factors in the environment. In these circumstances, measures can be taken to reduce trigger exposure although complete avoidance is almost impossible.

Asthma and Allergic Rhinitis

Allergic rhinitis (or hay fever) is a condition that occurs in 60-80% of people with asthma. Like asthma, there is no known cure but the condition can be successfully managed with proper care [15].

Allergic rhinitis occurs as the result of an allergy to normally harmless substances such as pollen. Pollen is a fine powder produced by plants which is commonly (but not always) a source of hay fever symptoms. Unlike asthma, allergic rhinitis primarily causes irritation of the nose and eyes. This irritation takes the form of itching, watering eyes and runny or blocked nose caused by the inflammation of the nasal passages [16].

Allergic rhinitis symptoms can occur seasonally or perennially (year round). Seasonal allergic rhinitis is largely due to an allergy to pollen or fungal/ mould spores and symptoms will appear and disappear as airborne levels of these allergens rise and fall. Perennial allergic rhinitis on the other hand is due to allergies to everyday substances that do not come and go seasonally. Examples of these types of allergens include house dust mites, pet fur or household chemicals [15]. Indoor air quality is a greater concern with perennial rhinitis as the allergens are often present in our everyday environment and small domestic interventions may lead to significant improvement in symptoms [10]. In this respect, improving the symptoms of hay fever can have a knock on benefit for people with asthma as uncontrolled allergic rhinitis is known to make asthma symptoms worse [15].

Indoor Air Quality

Context

The World Health Organisation (WHO) attributes 24% of global disease burden and 23% of all deaths to environmental factors [17]. Of these, 4.3 million deaths are attributed to indoor air pollution [5]. It is undeniable that our homes have a substantial impact on our health. However, not everyone is fully in control of their home environment. In Ireland, close to half a million homes are made up of rented accommodation and social housing. The hundreds of thousands of people living in these homes are reliant on private landlords, local authorities and voluntary housing associations to maintain the health and safety standards of their domestic environment [18].

While some interventions may be relatively cheap and can be carried out easily, others such as replacing carpet with wood flooring or improving ventilation systems may be prohibitively expensive. Many people with low income may be living in environments which are doing long term damage to their health [7]. Cost aside, families renting or living in social housing are unlikely to be able to make changes to the permanent fixtures or structures of their homes without permission from a private landlord or local authority. In that sense, many people living with asthma are not fully in control of their indoor air quality and are therefore at risk of increasing symptoms and a greater chance of attack [18].

In the 'Healthy Ireland Framework' the Irish government acknowledged the role of housing as a key contributor to the health and wellbeing of the public [6]. In keeping with this, the 2016 Warmth and Wellbeing Pilot Scheme covered the full cost of installing new energy or heating systems in the homes of people with asthma over 55 or less than 12 years of age living in households that receive the fuel allowance. However, this scheme was applied to just a handful of areas in Dublin. The Better Energy Warmer Homes Schemes also offers funding for home energy improvements but the scheme is only available to certain groups of social welfare recipients [7]. These initiatives, while beneficial to the applicable groups, are problematic in that many people with asthma may not be eligible and their health may suffer as a result. Economic barriers to health like this are a form of health inequality, which poses significant challenges in terms of social justice. From an economic perspective, health is an essential factor in a nation's productivity and therefore directly linked to national economic wellbeing. In this sense, the health of the individual can be understood as a crucial social and economic resource [19].

The importance of good indoor air quality is recognised by European Union legislation [20, 21]. However, some individual countries have not yet formalised the protection of clean air in their own legislation [8]. The European Federation of Allergy and Airways (EFA) has recently provided input into the European Union's forthcoming Energy Performance of Buildings Directive, recommending the development of a mandatory air quality certificate. If adopted, this certificate will ensure that factors affecting indoor air quality such as volatile organic compounds (VOCs), humidity and temperature will be kept within safe levels [20]. The

UK is also in the process of developing a new air pollution framework, [8] which will aim to introduce clean air zones in 5 major cities [20]. While this framework is a positive step, Asthma UK are currently lobbying for a more comprehensive plan that will empower local authorities to counter air pollution in their cities directly [8]. This more localised approach will allow cities to tailor interventions to the needs of their population and will benefit people with asthma who live outside of the 5 major cities listed in the framework.

For the above reasons, it is essential to look at the quality of indoor air and its impact on health and disease. There is a distinct lack of data relating to indoor air quality in the Irish context, particularly as regards people with respiratory conditions. Given the prevalence of asthma in Ireland this lack of data represents a significant challenge from awareness and campaigning perspectives [9].

Health Effects

People spend a great deal of their time indoors. For young children and elderly people it is estimated that up to 90% of their time is spent inside [5]. In the Velux Healthy Homes Barometer 2015 proper home ventilation ranked second in a list of 9 factors important to the health of Europeans. Fresh air and appropriate humidity were listed among the 5 most important characteristics of a healthy home and health improvement ranked second in the list of reasons to undertake home renovation [19].

It is thought that exposure to indoor air pollutants such as particulate matter, second hand smoke, moulds and allergens such as pet dander and house dust mites can modify the severity of asthma and make attacks more likely [22]. Further, Poor indoor air quality is linked to a reduction in lung function growth in young children [23]. Particulate matter, in particular, has been associated with a marked increase in asthma symptoms with some severe enough to negatively impact children's level of activity [10]. Additionally, in contrast to issues with outdoor air pollution, it may be significantly easier for people to remedy indoor air pollution exposure and improve their health substantially with relatively little effort [10]. It is also worth noting that sensitivity to one allergen often indicates the presence of multiple sensitivities, in this sense environmental interventions are much more likely to be successful if directed towards several known allergens of the individual [24].

The domestic environment contains many potential sources of indoor air pollution and is also subject to contaminations from outdoor sources of air pollution e.g. traffic-related air pollution. Sources of indoor pollution can vary greatly in their potential impact on health as well as in their prevalence across locations, lifestyles and socio-economic groups [10]. In other words, the indoor air pollutants of greatest concern in one area will not necessarily warrant the same focus elsewhere. The spectrum of concern ranges from insufficient ventilation to more serious microbial contamination of indoor air, with the latter becoming the focus of much attention in recent years [25].

Investigations of the effects of indoor air pollution have largely focused on the impact of airborne moulds, particulate matter, house dust mite particulates and volatile organic compounds (VOCs) [23]. Research to date suggests that a reduction in indoor air pollutants can reduce asthma symptoms. However more research is needed to determine the most effective interventions to reduce effects on asthma symptoms.

House Duse Mites

House dust mites are a ubiquitous issue in homes [13] and all indoor environments including schools and offices [26]. While measures can be taken to reduce dust mite populations indoors, there is no way to get rid of them entirely [2]. However, research has shown that the allergic response to house dust mites is related to the amount of exposure. This suggests that reducing the amount of dust mite allergen present in the home may still be beneficial for the individual sufferer [28].

Levels of dust mite allergen are strongly linked to humidity levels as dust mites rely on airborne water vapour as their primary source of water [26]. Given the high humidity levels found in Irish homes, particularly during the winter months [9], house dust mite allergens are likely to be a significant source of symptoms for sensitive individuals in Ireland. Dust mite allergens are generally associated with bigger airborne particulates, which tend to settle faster. In keeping with this fact, allergen levels are found to be lower during the night, suggesting that daily activities indoors may lead to larger amounts of the allergen in circulation and therefore a greater incidence of asthma and rhinitis symptoms [26].

While the research outcomes are mixed in relation to the benefits of dust mite avoidance in adults, there is evidence that aggressive anti-house dust mite interventions may be particularly useful for children with asthma [3].

Mould

The effects of mould and fungi on asthma and respiratory disease have been examined in a number of studies. The research has shown what appears to be a link between exposure to damp, mouldy conditions and the development or increased severity of asthma [25].

The presence of allergenic mould spores is particularly likely in buildings with high humidity or chronic water damage. If exposed to mouldy conditions, sensitive individuals can also develop allergies such as allergic rhinitis [27].

Many studies have shown a consistent link between damp, mouldy conditions in the home and childhood respiratory issues including chest illness, wheezing, coughing and general irritation. Further, a study of asthma patients found that patients who were hospitalised were far more likely to live in homes with mould and damp problems. However, more research is needed to definitively confirm the relationship between mould exposure

and asthma diagnosis [25]. It may prove that the effects of mould are most visible in groups that are already susceptible to allergy and respiratory illness.

Some studies have focused on the effect of anti-mould interventions on asthma symptoms. Results have been somewhat mixed, with some studies showing fewer hospitalisations and decreased symptoms while others showed little to no effect. It is likely the extent and intensity of the interventions in question may influence the overall impact on asthma symptoms [28].

It is worth noting that it is difficult to separate the effects of mould and damp from those of house dust mites, which also thrive in humid conditions and are known to negatively impact asthma symptoms [25].

Tobacco Smoke

Tobacco smoke is a well known and very common asthma trigger that can impact symptoms in a number of ways. People with asthma who smoke tend to experience more frequent hospitalisation and exhibit less control and more exacerbations than those who have never smoked. More worryingly, research suggests that inhaled corticosteroids (the front line and most effective treatment for asthma) show reduced efficacy in smokers [3]. This in turn makes smokers with asthma more likely to experience asthma symptoms and puts them at higher risk of experiencing an asthma attack, even if tobacco smoke is not normally a trigger for them.

Research has suggested a similar link between passive smoking and asthma exacerbation. One study suggested that more than half of asthmatic non-smokers were exposed to second hand smoke [28]. Public smoking bans have been used to address the issue of passive smoking in Ireland, Scotland and parts of the USA and these initiatives have shown some success in reducing the number of hospital and G.P. visits for severe asthma symptoms [3]. However, these bans do not apply to the private, domestic environment and as such may be of limited use to people with asthma who are exposed to smoke from a family member or room mate. Some studies suggest that second hand smoke may have a greater influence over the severity of asthma rather than its development [23].

For children and adults who are exposed to second hand smoke, research suggests the use of a HEPA (High Efficiency Particulate Air) filter in the home may be beneficial. One study examining the use of HEPA filters to improve second hand smoke exposure found that using the filters results in an 18.5% reduction in asthma-related primary care visits throughout a 12 month follow up period [28].

Smoking cessation is commonly suggested as a simple measure to reduce tobacco smoke exposure, particularly in the case of people with asthma or other chronic respiratory diseases [11]. Additionally, because cigarette smoke is considered to be a major contributor to indoor particulate matter pollution [10], it is thought that the cessation of smoking may

also improve aspects of indoor air quality beyond reducing the effects of tobacco smoke as a trigger.

Particulate Matter

Particulate matter is a key contributor to indoor air pollution. Particles originate from diverse sources, which can be natural or man-made. Natural sources include mould spores, pollen, pet dander and plant debris. Man-made sources are often linked to combustion processes include cigarette smoking, cooking emissions and wood, peat or coal burning in fireplaces. Of course, some particulate matter may originate from the outdoor environment [10].

Particle size is also an important factor as the health effects can be different. For this reason we categorise particles into three groupings. Coarse particles are the largest and about 5-10 of them can sit side by side in the width of a human air example. They can reach the central airways. Fine particles (about 20 can sit in a hair) reach the outer lungs where gas exchange takes place; they can also get into the blood stream to cause cardiac problems. Ultra fine particles (about 500 can sit in a hair) are able to reach the heart and brain barrier [4]. This large range of sizes for particulate matter is an important issue for people with asthma or other respiratory conditions because micro-organisms such as bacteria and viruses can be carried on the particle surface, potentially causing an infection [11]. Illness, particularly colds and flu, is considered a powerful trigger for asthma and respiratory illness [2].

While there has been little research into the relationship between particulate matter (PM) and asthma, some studies have found indoor PM exposure to be a significant risk factor for infant wheezing [5] while others have identified an association with reduced lung function in children not using inhaled corticosteroids. In other studies, PM was associated with a significant increase in asthma symptoms such as cough, wheeze and chest tightness. Others have associated fine PM with increased use of reliever medication and worsening symptoms [10]. Outside of associations with asthma, PM has been strongly linked to a higher risk of lung cancer, stroke and Parkinson's disease [11].

Air filtration is often recommended as a measure to reduce indoor exposure to PM pollutants. This approach may be particularly beneficial for people with chronic respiratory diseases. Previous studies have demonstrated a significant reduction in indoor PM levels when using an air filtration device. In one study, the use of an air purifier was also found to improve air quality, increase the number of symptom free days, reduce asthma triggers and improve health outcomes in general [29]. In dealing with high levels of particulate matter, HEPA filters or combined filtration systems are most effective [11].

Volatile Organic Compounds

Volatile organic compounds (VOCs) are carbon-containing chemicals, which evaporate rapidly and are considered harmful to human health or the environment when present in the air [30]. Common VOCs include benzene and formaldehyde from furniture, polycyclic aromatic hydrocarbons (PAHs) from combustion [11], perfumes, aerosols [31] and fumes from cleaning sprays [3].

Previous studies have shown an association between VOC exposure and asthma in young children. Many individual VOCs were found to increase the risk of asthma (and cancer) development, particularly in the case of benzene. Another study found that the presence of propylene glycol and glycol ethers in the air of children's bedrooms was linked to a 1.5 fold increase in the risk of asthma development [5].

Formaldehyde is known to negatively impact people with asthma. In particular, symptoms such as chronic cough, wheezing and poor lung function were found to be more prevalent among adults living in homes with high formaldehyde levels. Additionally formaldehyde, toluene and terpenes have been associated with incidence of nocturnal cough [23].

Outside of asthma related symptoms, VOCs such as formaldehyde and benzene are known to increase the risk of developing leukaemia [11].

Polycyclic aromatic hydrocarbons (PAHs) are a form of VOC which are produced during the combustion of solid fuels or during food cooking. PAHs can exist in solid, liquid or gas form and therefore can also contribute to PM pollution. Poor ventilation and improper cooking facilities can lead to a high level of PAHs in domestic air [11]. While there is evidence to suggest a role for PAHs in asthma development and increased severity, no consistent link has been determined [23].

Due to the health risks posed by VOC exposure, the EU has strict legislation in place to control and curtail VOC emissions over a range of activities which rely on solvent use such as printing, pharmaceutical manufacture and car painting [21].

To reduce the level of VOCs in the home it is recommended to avoid the use of cleaning sprays known to generate VOCs, select furniture or building materials with low VOC emissions and ensure proper ventilation to prevent a build up of airborne chemicals [3].

Methods

The study aimed to monitor air quality in the home before and after the installation of an air purifier. This data was then analysed against incidents of asthma symptoms which occurred in the participants during the same time frame. Participants were drawn from the Asthma Society's group of members. 9 people with asthma were selected to take part in the trial from the start of October 2016 to the 17th of January 2017.

The study took place in two phases, focusing on air quality monitoring followed by air quality improvement. In the first phase, each participant installed a CairTM smart air quality sensor from NuWave Sensors in their home and used the CairTM app to log their personal asthma symptoms throughout the 3 month period of the study. According to the manufacturer, the CairTM smart air quality sensor monitors temperature, humidity, large and fine particulate matter and VOCs in real-time, alerting the user when any of these variables exceed the optimum range. Additionally, the app will become personalised over time as the device recognises symptom patterns and can be integrated with the Amazon Alexa home assistant.

The sensor gathered data continuously while active and communicated with a cloud server over the local Wi-fi network in order to monitor, analyse and store air quality data on an ongoing basis.

The CliniAir air purifier unit from Envirion was installed in the second phase of the study as close to 28th November 2016 as possible and was kept in the home for a further 6 weeks. According to the manufacturer, the CliniAir is a HEPA room air cleaner which targets particulates, moulds, house dust mites, pollen and airborne microbes. The unit is equipped with two HEPA standard filters, is designed to change the air up to 10 times an hour and has a running cost of 44w. It is recommended that the filters be changed every 3 months; however this was not necessary due to the length of the study. The unit is not designed to eliminate airborne VOCs.

Phase One: Air Quality Monitoring

The study commenced in October 2016. During this phase of the study, no attempts were made to alter or improve air quality. The participants logged any asthma symptoms that occurred using the CairTM app while the sensor monitored air quality in the home. This phase lasted for 4-6 weeks.

Phase Two: Air Quality Improvement

This phase began on the 28th November 2016. The participants installed a CliniAir air purifier unit from Envirion. The air purifier was used in the home for the remaining 6 weeks of the study. Throughout this time air quality continued to be monitored and the participants continued to log their asthma symptoms.

Results

Usage

Each user connected their air quality sensors at different times. The sensors were not all continuously active and were kept running for varying lengths of time. The length of time each participant used their sensor for is shown below.

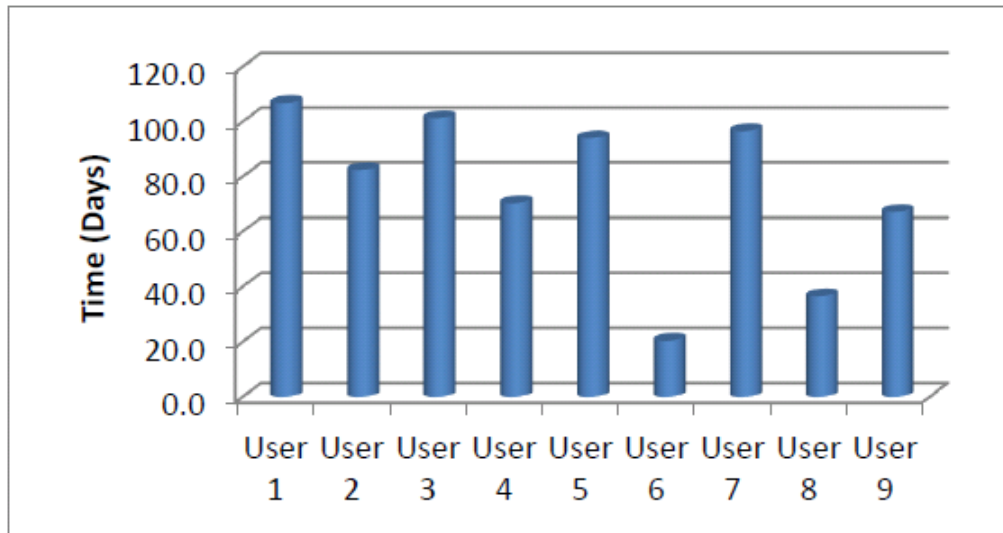


Figure 1: Time online per user (days)

Similarly, the number of unique events logged by each user was different. The number of events logged by each user is shown below.

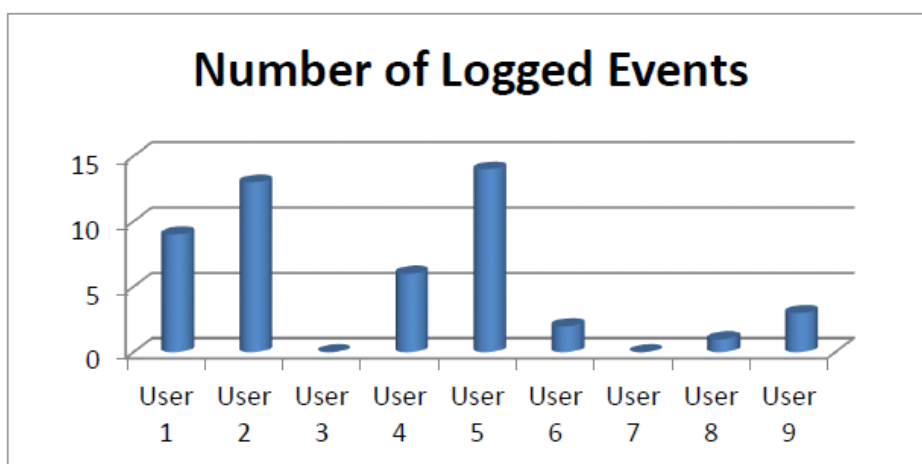


Figure 2: Number of logged events per user

Individual user Summary

The average values from a range of variables were calculated for each individual user. This was carried out to account for anomalous changes in sensor readings and provide a more accurate picture of each user's data over the length of the study. The defined comfortable, warning and alert values for each variable are outlined below. The Cair™ app indicates the status of each variable to the user through colour changing widgets.




Optimal Levels			
	 OK	 Warning	 Alert
Large Particle Index	0 - 40	40 - 75	75 - 100
Small Particle Index	0 - 40	40 - 75	75 - 100
Odour Index	0 - 40	40 - 75	75 - 100
Humidity	35% - 65%	25% - 35% / 65% - 80%	0% - 25% / 80% - 100%
Temperature	18°C - 24°C	15°C - 18°C / 24°C - 28°C	< 15°C / > 28°C

Figure 3: Comfort level thresholds

For example, any temperature below 14°C or above 28°C will result in the app displaying a red widget. Temperatures between 14-18°C or between 24-28°C will result in the appearance of an amber widget. Finally, a measurement between 18-24°C will result in a green widget, indicating that the temperature is within the optimum range.

The average day and night time temperature for each user were calculated. These values are shown below.

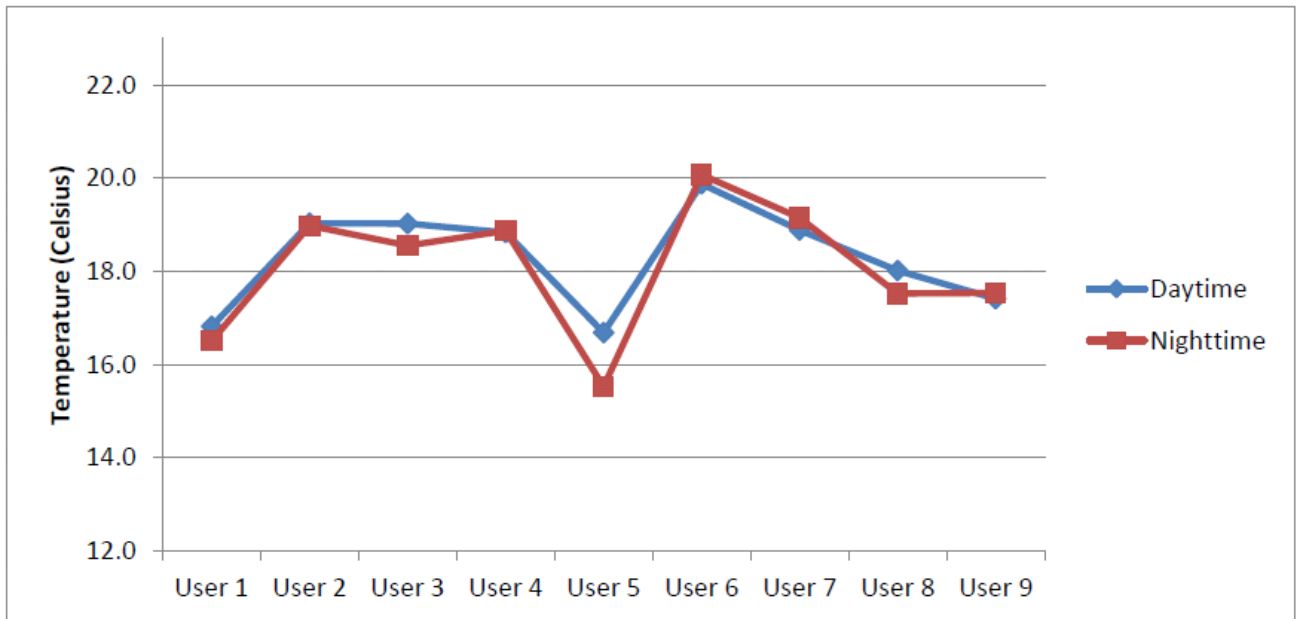


Figure 4: Average temperature per user

For the majority of users, the average temperature remained within the comfortable range. Only users 1 and 5 experienced values outside of the optimum range. This suggests that for both users, the day to day temperature in the room would have been below the comfort value for a significant length of time. In particular, the lower than average reading for user 5 suggests that the house may be unoccupied and unheated for periods during the day or alternatively, that the sensor may have been placed on a window sill where the temperature is colder than that of the room itself.

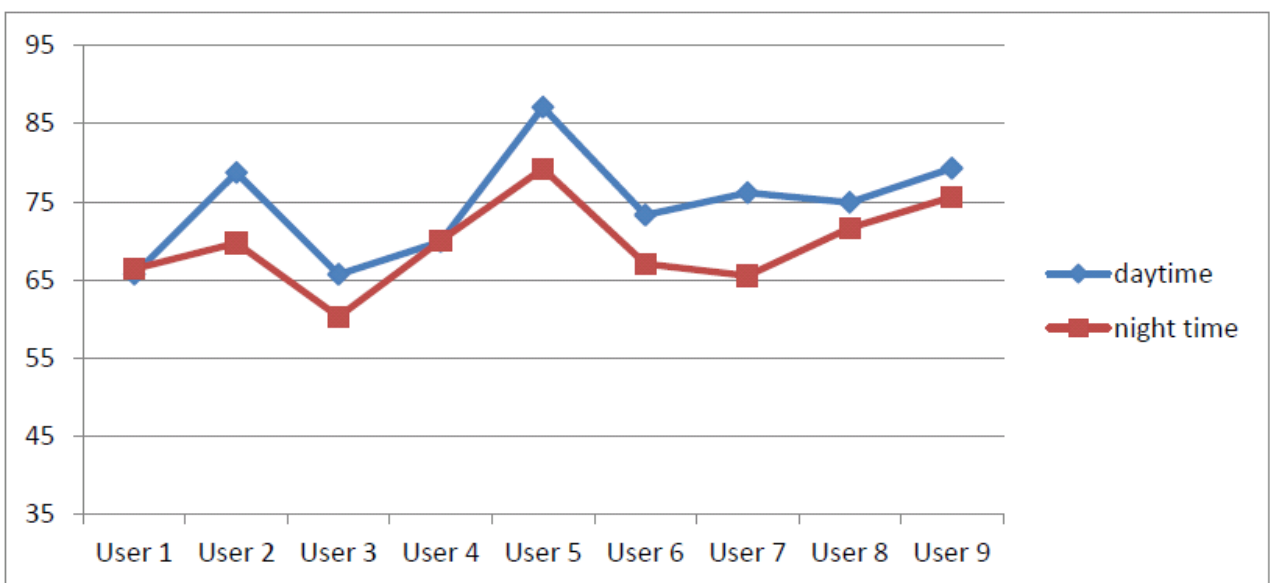


Figure 5: Average humidity per user

The same rationale can be used when looking at humidity. All of the study participants were found to have average humidity values that approached the top end of the optimum range. While humidity may have been lower at points during the study, the results suggest that humidity was high in these homes for the majority of the time.

High humidity is expected in houses in Ireland during the winter period. This can be problematic for people with asthma as humidity is known to affect asthma directly as a trigger and also indirectly as it encourages the development of dust mites, moulds and fungi which may in turn trigger asthma symptoms.

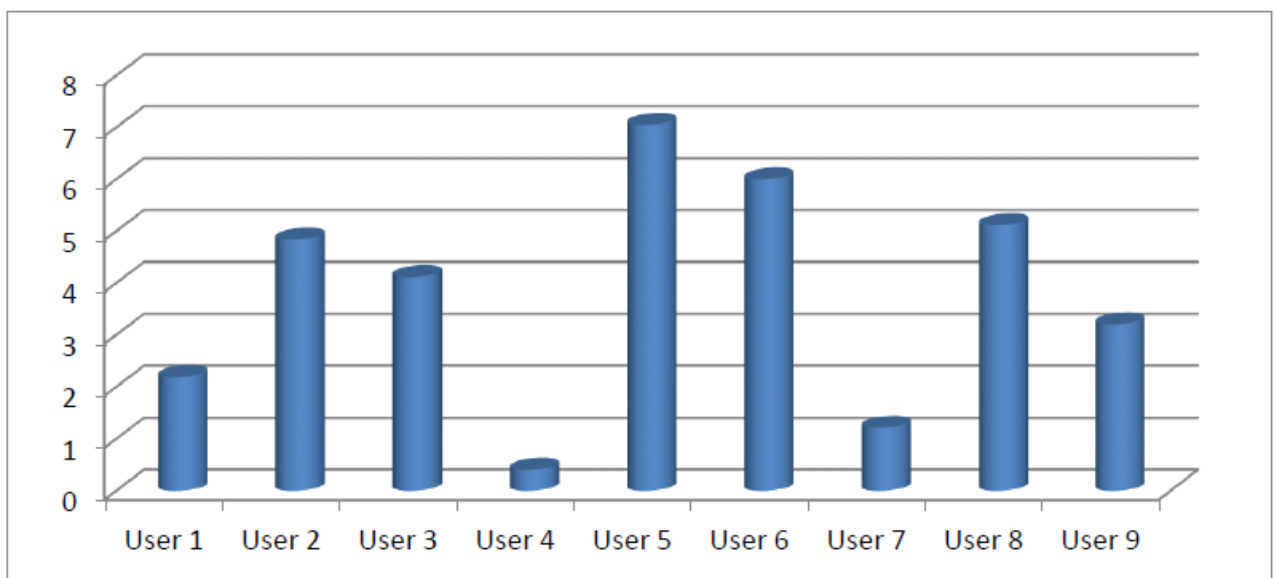


Figure 6: Percentage of time odour index was above comfort level threshold

The odour index sensor monitors the volatile organic compounds (VOCs) or chemicals in the air e.g. fumes from cleaning products. Many people, with and without asthma, find their breathing is affected by airborne chemicals. The average reading for each user over the course of the study was zero, which is in keeping with the intermittent use of airborne chemicals in a domestic setting. However, the percentage of time each user had an odour index outside the optimum range provides much more information on the incidence of airborne chemicals in the home. A high VOC reading can result from a number of daily activities such as the use of cleaning products, aerosols, perfumes, scented candles and open fires, among many others. As the Cliniair air purifier is not designed to eliminate VOCs, no change in VOC levels in the home was calculated.

Outside of temperature, humidity and VOCs, the presence of particulate matter in the air is a major contributor to air quality. The Cair™ sensor measures small (1-2µm) and large (3-20µm) particles from. For example, house dust particles typically measure around

20 μ m while smoke particles are much smaller at around 2 μ m. The measurement of air quality variables such as temperature or humidity will change gradually over the course of a day. Particulate matter sensors on the other hand are much more sensitive to more immediate changes. Typically, particle measurements will show a great deal of variation during the day and may fluctuate rapidly over a short time frame.

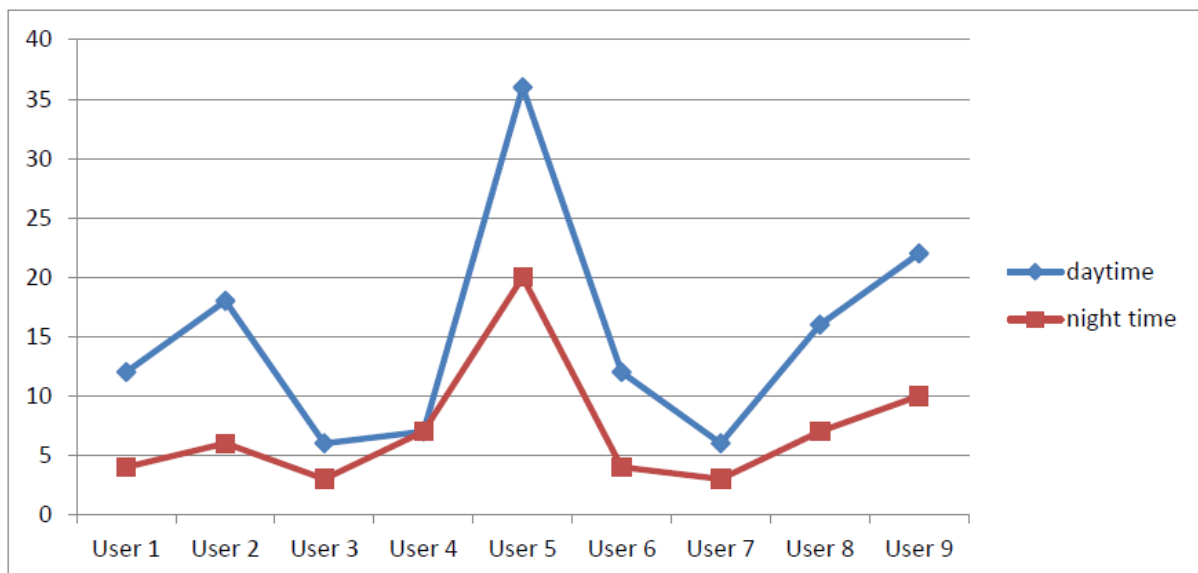


Figure 7: Average small particle readings per user

Due to these rapid variations, an average reading was calculated for each user to determine the level of small particulate matter (1-2 μ m) present in the air throughout the course of the study.

An optimum reading for particulate matter is considered to be anything below 40. While all of the users fell below this threshold, there were significant differences between the average readings found for each user. User 5 showed the highest reading of particulate matter at just over 35, while users 9 and 2 showed slightly lower readings at just over 20 and just under 20 respectively. It is worth noting that given the fluctuating nature of particulate levels in the air, an average reading of 10 or more is considered high.

A high average reading may indicate environmental characteristics such as the presence of an open fire or another ongoing source of particulate matter. Alternatively, it may be that the sensor was placed in a kitchen where particles tend to be high as a result of cooking or close to an open fire. For someone with asthma, this may act as useful indicator of areas where small, easy interventions could positively impact their health and asthma management.

Air Purifier Conclusions

Air purifiers are commonly used to remove particles from the air. A CliniAir HEPA air purifier from Enviroion was installed in the homes of all participants as close to the 28th November 2016 as possible.

The average change in all particulate matter measured before and after the installation of the air purifier is illustrated below. The vast majority of users experienced a dramatic drop in airborne particulates after the installation of the purifier. Only user 2 and user 7 did not experience this decrease. User 2 in particularly experienced an increase in particulates of just under 20% while user 7 reported a negligible increase in particulate levels. This may be due to the user having the air purifier and sensor in different rooms or possibly having the air purifier turned off to not having the air cleaner in the same room as the sensor or, in fact, not having the air cleaner turned on.

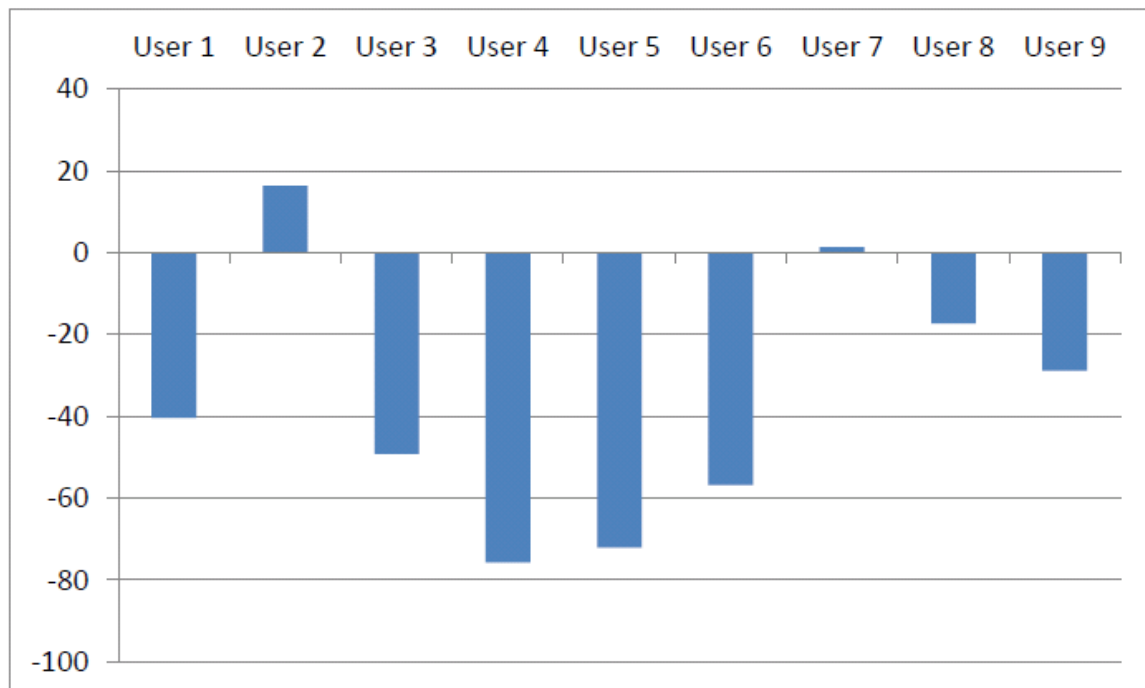


Figure 8: percentage change in all particles measured before and after 28th November 2016

If it is assumed that all of the participants installed the air purifier and the sensor in the same room, it can be concluded that the air purifier had a positive effect on airborne particulate levels. For the majority of user

Logged Events

This refers to the asthma symptoms logged by the users through the Cair™ app. In total, 48 events were logged throughout the course of the study.

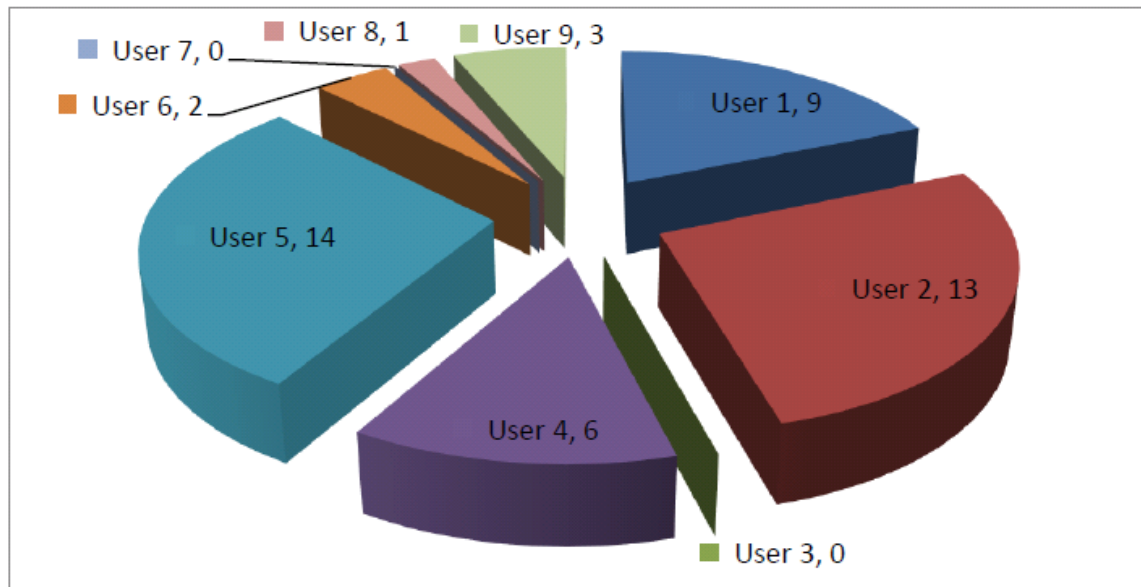


Figure 9: Distribution of logged events per user

The distribution of these events between users is illustrated above.

It is immediately clear that user 5 and user 2 logged the majority of asthma events, experiencing 14 and 13 unique events respectively. User 1 and user 4 followed, logging 9 and 6 unique events in turn. The rest of the participants logged very few events throughout the course of the study.

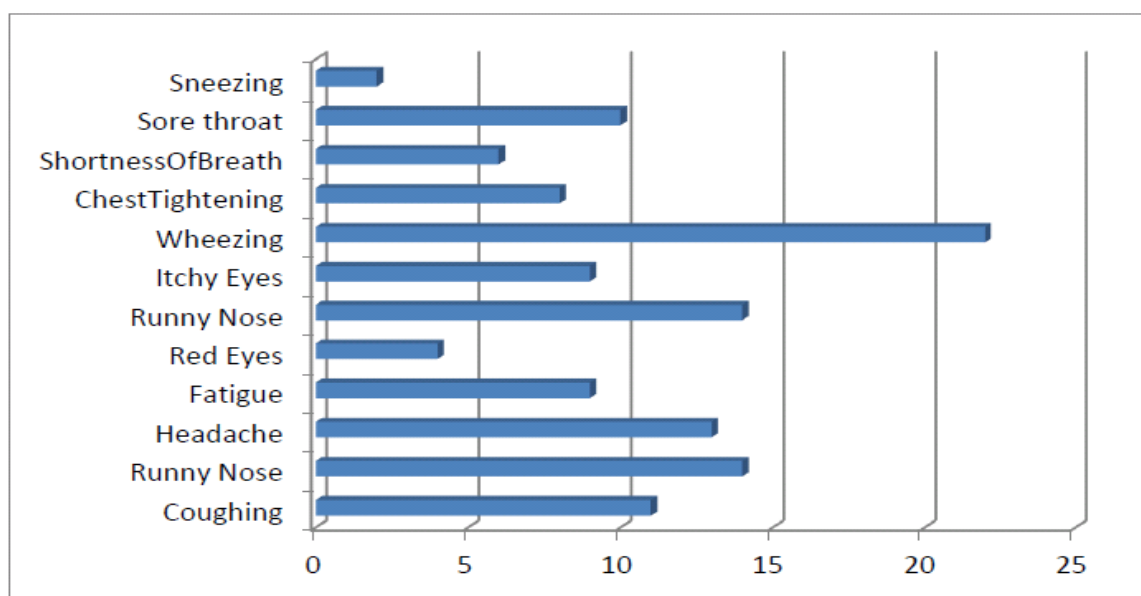


Figure 10: Logged asthma events

Figure 10 above illustrates a breakdown of the logged events by the symptoms described.

It is clear that wheezing was the most common complaint, comprising not quite half of the total events. This was followed by runny nose and headache which made up approximately 14% and 13% of logged events. Coughing and sore throat were the next most frequent, featuring in approximately 11% and 10% of events. Itchy eyes, fatigue, chest tightening and shortness of breath featured 5-10% of the time. Red eyes and sneezing were the least frequent symptoms, appearing in less than 5% of the featured events.

The events logged above were matched against instances in which a variable was outside the comfort zone.

High particles and odour index were found to occur alongside the majority of the logged events. High humidity and rapid temperature change were associated with a small number of events. 13 events were found to have occurred during optimum conditions. These were included and analysed in the machine learning algorithms to identify any potential correlations.

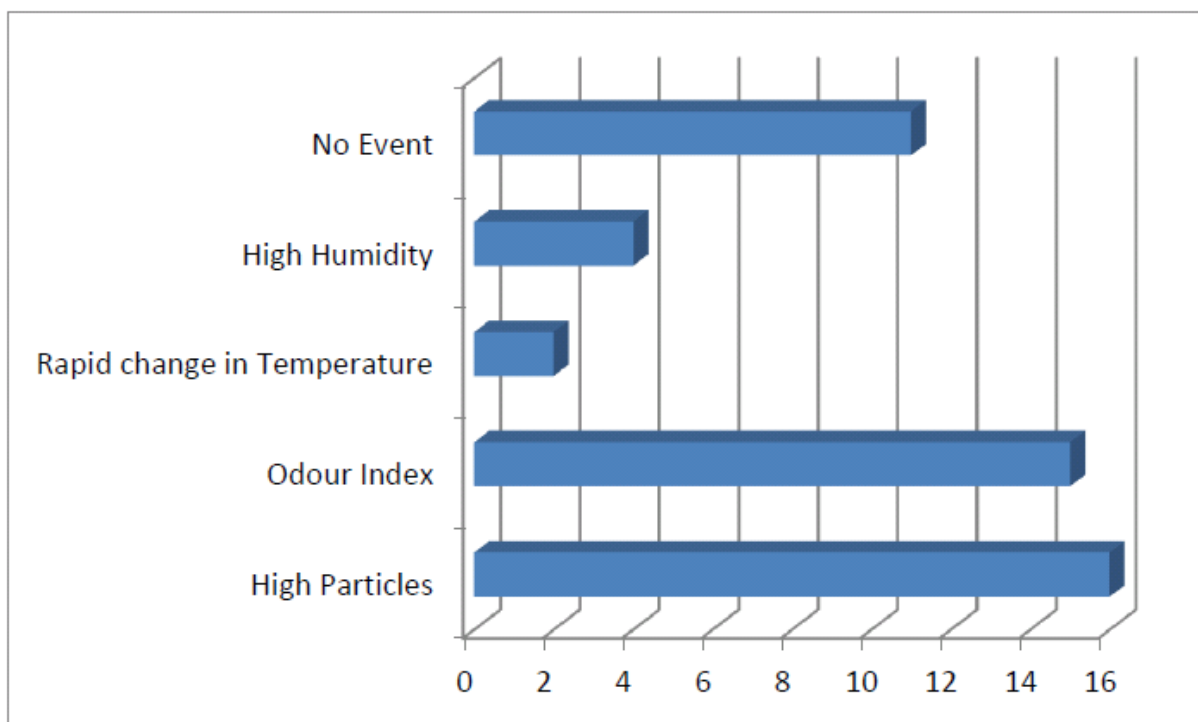


Figure 11: Number of anomalous instances corresponding with a logged asthma event

Conclusion

The study concluded that Cliniair unit significantly reduced the concentration of small particles in the home environment. Given the health consequences of high particulate matter discussed above, it is likely that this would be beneficial for the inhabitants of the home.

The data suggests a possible relationship linking high humidity, high dust levels and low air temperature with asthma symptoms. This is in keeping with the known negative impact of these factors on people with asthma and allergies and suggests a valuable role for air monitoring in asthma management.

These findings are in keeping with previous research which has highlighted the role of particulate matter in increasing the frequency of asthma symptoms [10] and the efficacy of HEPA air filters in significantly reducing the particulate level in indoor air [11]. This not only highlights the value of indoor air monitoring in tracking and identifying asthma triggers but also indicates a potential role for air purification as part of ongoing asthma management. Asthma Society of Ireland believes these findings warrant a larger study over a longer time frame to confirm the results and fully determine the positive impact of air monitoring purification on asthma symptoms and the general health of the public as a whole.

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Appendix A

Asthma Friendly Homes Leaflet



Asthma 1800 44 54 64
Adviceline: Mon - Fri: 9am ~ 5pm



Asthma Friendly Homes

Simple steps to an asthma friendly home

Asthma is a common chronic disease which inflames the airways. The airways are the small tubes that carry air in and out of the lungs. Asthma is made worse by coming into contact with certain things. These are called triggers.

It is important to be aware of triggers to minimise their effects and if possible, avoid them. The home environment can present a number of triggers which can aggravate asthma. Overleaf are some common triggers in the home and some tips for creating an asthma friendly home.



The Asthma Society of Ireland. Fighting asthma with every breath.

Charity registration number CHY6100 (Ireland). Asthma Society of Ireland, 42/43 Amiens Street, D1.



Asthma Friendly Homes



Vacuuming

- Replace carpets with tiles/wood flooring
- Vacuum your mattress weekly with a specially designed mattress vacuum cleaner
- Consider a vacuum with specially designed tools for removing pet hair



Dust Mites

- Use anti-dust mite covers on bedding
- Wash bedding weekly at 60 degrees
- Dust regularly using a damp cloth
- Avoid soft toys especially in the bedroom



Pets

- Where possible, keep pets outdoors
- Keep pets out of bedrooms and ensure the doors are closed at all times
- Keep pets away from fabric covered furniture, carpets and stuffed toys



Mould

- Fix any leaks around taps or pipes which are damaged
- Ensure good indoor ventilation and air rooms regularly
- Avoid drying clothes indoors or on radiators



Smoke

- Avoid tobacco smoking, especially indoors
- Avoid wood fires, kerosene heaters and open fires in the home
- Turn on extractor fans when cooking



Air Quality

- Minimise the use of chemical cleaning products
- Use natural/odourless cleaning products where possible
- Consider a purifier with a built-in air quality sensor to remove allergens and pollutants from the air
- Consider a humidifier to hydrate the air