



The impact of poor housing and indoor air quality on respiratory health in children

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Poor-quality housing negatively impacts the quality of the air that children breathe in their living environment, which is detrimental to their respiratory health. Urgent action is needed to improve housing quality to improve child respiratory health. <https://bit.ly/3pshb34>

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Abstract

It is becoming increasingly apparent that poor housing quality affects indoor air quality, significantly impacting on respiratory health in children and young people. Exposure to damp and/or mould in the home, cold homes and the presence of pests and pollutants all have a significant detrimental impact on child respiratory health. There is a complex relationship between features of poor-quality housing, such as being in a state of disrepair, poor ventilation, overcrowding and being cold, that favour an environment resulting in poor indoor air quality. Children living in rented (private or public) housing are more likely to come from lower-income backgrounds and are most at risk of living in substandard housing posing a serious threat to respiratory health. Children have the right to safe and adequate housing, and research has shown that either rehousing or making modifications to poor-quality housing to improve indoor air quality results in improved respiratory health. Urgent action is needed to address this threat to health. All stakeholders should understand the relationship between poor-quality housing and respiratory health in children and act, working with families, to redress this modifiable risk factor.

Educational aims

- The reader should understand how housing quality and indoor air quality affect respiratory health in children.
- The reader should understand which children are at most risk of living in poor-quality housing.
- The reader should understand what policy recommendations have been made and what actions need to be undertaken to improve housing quality and respiratory health in children and young people.

Introduction

In the United Nations Convention on the Rights of the Child (UNCRC), article 27 states that every child has the right to “a standard of living adequate for the child’s physical, mental, spiritual, moral and social development” [1]. Further to this, the committee has since committed to evaluating “clean air” in the forthcoming general comment on the UNCRC [2]. In 2019, the UNICEF UK Child Friendly Cities and Communities Team in their “Children’s rights in the new normal” campaign laid out recommendations to councils and partners regarding provision of “safe and well-maintained” housing for children and young people (CYP) in relation to article 27 of the UNCRC [3]. Despite this, and the growing evidence of the impact of housing quality on child health, children are still dying from inadequate and unsafe housing and resultant poor-quality air. In 2020, the death of 2-year-old Awaab Ishak in the UK due to mould exposure in his home [4] was a potent and sobering reminder to healthcare professionals of the impact of our



patients' physical environment and the air that they breathe. The inquest into his death concluded that he sadly passed away due to a severe respiratory condition due to prolonged exposure to mould in his home environment [4].

Our understanding of how the quality of the air that we breathe affects our (respiratory) health has increased over the past few decades. What is becoming increasingly apparent is that indoor air quality (IAQ) is an important determinant of respiratory health, particularly for CYP. CYP are extremely vulnerable in terms of effects on respiratory health due to exposure to air pollution [5] as their respiratory and immune systems still undergoing development, leaving them prone to respiratory sequelae and being poorly protected against the hazardous exposure to pollutants [6]. Moreover, children have relatively high respiratory rates [7] and inspire a larger volume of air relative to their body surface area [5], compared with adults. CYP also spend the majority of their time indoors and it is estimated that CYP spend only ~68 min per day playing outside on average [8]. What has also become apparent is that the quality of the housing in which children and their families live significantly affects the quality of the air that they breathe, and this has a significant negative impact on their respiratory health [8]. It is estimated in the UK that 3.6 million CYP live in poor-quality housing [8]. Throughout this review, we will highlight elements that contribute to housing and IAQ and the effects on respiratory health in CYP, describing which CYP are at most risk. We will then discuss existing policy recommendations to improve housing and IAQ for CYP and what has already been done to address this and discuss the urgent actions that need to be taken next.

What do we mean by “poor-quality housing” and how does it contribute to IAQ?

Poor-quality housing in the UK is generally defined under the “Decent Homes Standard”; if a home cannot provide reasonable thermal comfort, is in a state of disrepair, lacks modern facilities, or has any category 1 housing health and safety rating system hazards (including damp and/or mould that may pose an immediate threat to life), it is deemed unsuitable for living in [9]. Whilst the overall number of decent homes in the UK has improved over the years, almost a quarter of privately rented homes failed this standard in 2021 (compared with a national average of 14% of all homes) [10]. However, the Decent Homes Standard provides a bare minimum of acceptability [9], and therefore will not identify most homes with poor air quality. In the UK, a relatively old housing stock is associated with high rates of structural issues, poor insulation, poor energy efficiency and poor ventilation. The interrelationship between poor-quality housing and IAQ is complex. Elements of poor-quality housing, such as the presence of mould, serves as a direct indoor air pollutant with negative effects on respiratory health [8]. Other elements of housing, such as homes being in a state of disrepair (including leaks) and poor ventilation result in higher levels of moisture and damp, serving as a medium in which biological pollutants such as mould and house dust mites (HDMs) can thrive, having detrimental impacts on IAQ and contributing to indoor air pollution (IAP).

IAP is affected by both indoor and outdoor factors. Sources of IAP can come from outside (*e.g.* traffic-related air pollution, industrial processes and activity at landfill sites) or from within the home, as described in the joint Royal College of Paediatrics and Child Health and Royal College of Physicians (UK) report “The inside story” [8]. Exposure to IAP depends on the source of pollution and how air is exchanged between inside and outside the home. Focussing specifically on factors of the housing itself (indoor factors), the design of homes/buildings plays an important role; for example, homes designed with open plan kitchens have higher levels of air pollution throughout the home [8, 11]. Different pollutants can also be released from building and construction materials as well as materials use to decorate and manufacture furniture [8]. Flame retardants have also been shown to be linked to health effects [12]. The ventilation within buildings and homes significantly affects IAP. The general principle is to exchange air from inside to outside to reduce the concentration of indoor air pollutants. This can be achieved through opening windows and doors, or by ventilation systems. Some ventilation systems have filters, but it is only high-quality filters that may help in preventing air pollutants from outside entering the home. Within the home, there are numerous processes of normal day-to-day living which contribute to IAP by emitting pollutants such as volatile organic compounds (VOCs), particulate matter (PM), nitrogen oxides (NOx) and carbon monoxide (CO) [8]. Pollutants emitted during cooking processes can be mitigated with adequate and effective ventilation in the form of extractor fans and cooker hoods, however, the filters need to be cleaned regularly for them to remain effective. Cooking with gas hobs, stoves and grills emits higher concentrations of nitrogen dioxide and CO [13]. Burning fuel for a source of heat (*e.g.* open fires and wood-burning stoves) releases a mixture of gases including CO and as well as VOCs and PM [8].

Higher levels of moisture and dampness on surfaces and in materials precipitates a proliferation of microorganisms, including moulds (and other fungi) and bacteria [14]. Moisture can enter the home from outside, particularly if leaks or flooding are present, and from activities of daily living within the home.

Activities of daily living such as showering or drying laundry indoors introduces moisture into the atmosphere and alongside this, cold flooring and walls can enable condensation to be formed. As well as promoting mould growth, moisture promotes increasing numbers of HDMs. Increasing humidity also has a detrimental impact on IAQ as it increases the likelihood of damp and can also precipitate release of formaldehyde from building materials [15]. While activities of daily living can introduce moisture, the Energy Follow Up Survey (EFUS) commissioned by the British government in 2017 found that there was no difference in behaviours such as drying clothes inside, airing the home or bathroom ventilation between the households reporting damp and/or mould compared with those without [16]. The effect of moisture both entering the home from outside and created within the home is potentiated by inadequate ventilation, which traps higher levels of moisture in the home. This moisture then precipitates into condensation on cold surfaces. Cold homes are therefore particularly at risk of damp.

Air that we exhale also affects IAQ. We breathe out carbon dioxide and VOCs which alter the air quality and contribute to air moisture levels. Overcrowding, particularly with low levels of ventilation, potentiates the impact the inhabitants of a home have on IAQ. A study of 567 homes representative of mainland France showed that levels of PM_{2.5} (particulate matter with aerodynamic diameter <2.5 µm) were 68% higher in high density households compared with low density households, as well as finding significant increases in concentrations of VOCs [17].

How does poor housing and IAP contribute to poor respiratory health in children?

We have described factors that contribute to poor-quality housing which in turn affects IAQ, but how does this affect the respiratory health of CYP? Children who live in poor-quality housing in England are more likely to report poorer health and experience worse respiratory health. This is particularly pronounced in children living in private and social rented housing compared with children living in owner-occupied homes [18]. 22% of the modifiable factors contributing to child deaths in England from April 2019 to March 2020 were due to the child's physical environment, including overcrowding and unsuitable housing (including the presence of damp, mould and being in a state of disrepair). Risk to life from the home environment particularly impacted children living in the highest levels of deprivation, where 35% of all child deaths had identifiable modifiable risk factors compared with 24% of deaths in the wealthiest areas [19].

Whilst there is a wealth of literature regarding outdoor air pollution and effects on respiratory health, evidence regarding the impact of IAP specifically is sparser. As aforementioned, there is a complex relationship between different factors relating to housing quality and IAQ. In the following sections we will describe the effects of exposure to various housing conditions and pollutants on respiratory health in CYP.

Damp and mould

Two systematic reviews have shown a clear association between the presence of damp and mould in the home and risk of wheezing and asthma in infancy and older childhood [20, 21]. DICK *et al.* [20] in their systematic review of 135 papers consistently found a correlation between visible presence of mould in the home and developing asthma before the age of 9 years (OR 1.5), and an increased risk of wheezing at age 2 years with visible damp or mould (OR 1.4). Cohort studies found children who were exposed to damp in early life were significantly more likely to develop asthma at age 3 years (OR 7.1) [20]. In older children, CASTRO-RODRIGUEZ *et al.* [21] in their systematic review with meta-analysis showed that children living in a home with damp or mould were 50% more likely to have asthma or wheezing. Studies from across the globe have shown that up to 14% of childhood asthma is attributable to living in a home with damp or mould [22–24]. A case-control study in New Zealand including 640 children demonstrated that the presence of damp or mould in the home is associated with an increased risk of hospitalisation with pneumonia [25]. A further prospective case-control study in New Zealand assessed the impact of housing quality, with assessors blinded to outcomes using the Respiratory Hazard Index (RHI), on risk of hospital admission from a respiratory tract infection [26]. They showed that a higher RHI was associated with an increased risk for hospitalisation. The damp-mould index showed a dose-response relationship with admission for a respiratory tract infection. They also estimated that by reducing this harmful exposure, the admission rate would have been reduced by 19% [26]. Furthermore, in their data looking at 891 homes in New Zealand using the RHI, they found a dose-response relationship where per each unit increase in the RHI score there was an 11% increased risk of having an episode of wheeze over the last year and an 11% increased risk of having an asthma attack in the last year, after adjusting for crowding index, age, sex and household smoking [27]. In the houses of poorest quality, if the children were moved to better-quality housing there would be an estimated 33% reduction in respiratory symptoms [27]. In their questionnaire-based cross-sectional study, DALES *et al.* [28] showed that presence of damp or mould in the home was associated with an increased risk of respiratory symptoms. In their meta-analysis with the

Institute of Medicine (USA), Fisk *et al.* [29] showed that in buildings with reported damp or mould there was an associated OR of 2.04 for upper respiratory tract symptoms, OR of 1.65 for cough, OR of 1.66 for wheeze and OR of 1.45 for current asthma compared with buildings without damp or mould. Exposure to mould in the living environment can result in respiratory morbidity by allergic and non-allergic pathways. Mould components such as microbial VOCs and β -glucans could exert pro-inflammatory responses, but by non-IgE-mediated mechanisms. Thus, mould in the living environment can act as an allergen or an irritant to the airways [30].

Overcrowding

Overcrowding occurs when there is a mismatch between household size and dwelling size, and in the UK is defined by either the “room standard” (evaluating the number and sex of occupants sleeping in the same room) or the “space standard” (evaluating the number of occupants against either the number of rooms or floor space). Importantly, this definition focuses on privacy rather than the air quality risks of overcrowding and dismisses the impact overcrowding has on children [31]: children under the age of 10 years either do not count in the room standard or count as less than one person in the space standard. Overcrowding impacts respiratory health by increasing rates of transmission of respiratory infections. A systematic review led by the World Health Organization in 2018 found high certainty evidence that overcrowding increases the risk of respiratory infections and acute respiratory illness, in particular tuberculosis, influenza and respiratory syncytial virus (RSV) in both adult and paediatric populations [32].

Overcrowding also increases the levels of moisture and air pollutants in a home, and this is particularly prevalent in households with a younger average age. A Swedish study reviewing data from apartment buildings, using mathematical simulations of differing occupancy level, found that increasing occupancy correlated to increasing moisture supply [33]. As discussed throughout this review, increased levels of moisture correlate with increased risk of mould. Indeed, a systematic review in 2021 found that overcrowded homes were associated with an increased presence of mould, allergens, pests and increased use of biocides [34]. Causality was difficult to ascertain as: 1) definitions of overcrowding differed between countries; and 2) both overcrowding and poor housing are inextricably linked to socioeconomic deprivation.

Whilst beyond the scope of this review, overcrowding also negatively impacts mental health and educational achievement, and increases the risk of behavioural problems and accidental injury and burns for CYP.

Cold homes

Cold homes happen due to energy inefficient housing stock without proper insulation, and inefficient, expensive or underused heating systems. The implications of cold homes for child health are relatively underexplored in comparison to the effects of cold temperatures on adult health. A national longitudinal study of children in Ireland found that infants living in “affordability related” cold homes were 41% more likely to experience any respiratory illness and 47% more likely to have wheeze [35]. In this study, the association between cold homes and respiratory ill health decreased for older children aged ≥ 9 years [35]. Cold indoor temperatures have a direct impact on respiratory health, and an indirect impact through increasing risk of damp. Viral survivability improves in colder temperatures, with virus transmission, particularly for RSV and influenza, peaking at temperatures around 5°C in temperate countries such as the UK. Moreover, cold air can impact respiratory tract defences by reducing mucous clearance and causing bronchoconstriction. Colder temperatures may also impact child lung function. In a prospective cohort study of 286 children with asthma in New Zealand, lower bedroom temperatures had a small but significant association with reduction in lung function. This was particularly prevalent at temperatures below a threshold of between 9°C and 11°C [36].

PM and other pollutants

Table 1 demonstrates the sources of PM and other pollutants within the home environment. In a prospective cohort study of 150 children aged 2–6 years diagnosed with asthma in the USA, it was shown that increasing concentrations of $PM_{2.5}$ and $PM_{2.5-10}$ (particulate matter with aerodynamic diameter 2.5–10 μm) were associated with increased asthma symptoms and need for reliever medication use [37]. Furthermore, it has been demonstrated in asthmatic children that increasing concentrations of $PM_{2.5}$ in the home are associated with poorer lung function (decreased percent predicted forced expiratory volume in 1 s/forced vital capacity (FVC) and forced expiratory flow at 25–75% of FVC), and in the same study population, no such association was seen with outdoor concentrations of $PM_{2.5}$ [38]. Exposure to indoor and outdoor $PM_{2.5}$ is associated with increased respiratory-related infant mortality [39], and is also related to delayed lung growth [40]. A case–control study in Australia demonstrated that VOC concentrations in the homes of asthmatic children are higher compared with non-asthmatic controls [41]. Looking at patients

TABLE 1 Sources of indoor particulate matter

Outdoor particulate matter (industry, traffic, etc.)
Cooking (gas versus induction, cooker hoods)
Fireplaces (wood and coal)
Combustion heating
Smoking or e-cigarette/vaping devices
Dust
Biological matter (mould spores, house dust mites, pet dander, pest droppings)
Scented candles/incense
Aerosols (from cleaning, air fresheners, etc.)
Information from [8].

enrolled in a bronchopulmonary dysplasia registry in the USA, 75% of infants were exposed to at least one type of combustible source of air pollution which was associated with a need for hospitalisation due to respiratory illness [42].

Poor ventilation

Homes with poor ventilation increase exposure to indoor air pollutants by increasing their concentrations and the length of exposure time. Poor ventilation within homes has been shown to be associated with increased risk of asthma exacerbations and respiratory tract infections in children [43]. Improving ventilation in homes reduces the concentration of HDMs and particulates that can exacerbate respiratory symptoms. It has also been shown that children living in homes with adequate ventilation are at a significantly lower risk of suffering from respiratory tract infections [44].

HDM

Exposure to HDMs has long been described as associated with the prevalence of asthma and as a trigger of symptoms and acute asthma attacks. Exposure to HDM allergen, particularly in atopic children, increases the risk of allergic sensitisation [45], which in turn is an independent risk factor for developing asthma with a dose–response relationship [46, 47]. It has also been demonstrated in asthmatic children with evidence of sensitisation to HDM that exposure to higher levels of HDM is associated with a greater degree of airway hyperresponsiveness [46, 48].

Pests

The presence of pests including cockroaches and rats poses a serious risk for children with asthma, particularly in those living in substandard housing [49]. Across eight inner-city regions in the USA, it has been shown that for children with asthma having evidence of allergic sensitisation to cockroach allergen and being exposed to high levels of this allergen meant they were 3.5 times more likely to be hospitalised with asthma and more likely to make unscheduled healthcare visits due to asthma, as well as having significantly more days of wheezing and missed school days [50]. Presence of reported rats is associated with an increased risk of current asthma diagnosis in children [51]. Exposure to mouse antigen in those sensitised is associated with emergency healthcare use due to asthma [52].

Housing in a state of disrepair (including holes in ceilings or walls, leaks and water damage) has been shown to be associated with increased levels of cockroach allergen [53]. Substandard public housing in Boston (USA), which was in a state of disrepair was found to have higher levels of cockroach allergen [54]. Neighbourhood socioeconomic status (SES) level was found to be lowest for families living in public housing and this housing was more likely to be inhabited by families of ethnic minorities. Moreover, children living in public housing were found to be more likely to have asthma [51].

Which children are at most risk of poor respiratory health due to poor-quality housing?

CYP are more likely to live in poor-quality housing than families with no dependent children [16]. The UK EFUS survey in 2017 found that 39% of households with dependent children reported damp and mould compared with 23% of households without children [16]. Lone parent households were particularly at risk, with 48% of respondents experiencing damp and/or mould [16]. Similarly, the 2022 English Housing Survey (EHS) found that overcrowding disproportionately impacts children in England, with 68% of overcrowded households containing dependent children [55]. In this section, we will review which children are more likely to be exposed to poor IAQ through living in poor-quality homes, and which children are clinically most susceptible to the impact of poor IAQ.

Low-income families

Families with low income are at particular risk of the effects of poor housing quality and its contribution to adverse respiratory health. First, low-income families are more likely to live in areas of high outdoor pollution, despite creating the least air pollution: 66% of all carcinogenic air pollutants produced in England are emitted into the most deprived areas of the country [56], where it then enters homes and contributes to IAP. Secondly, low-income families have increased exposure to air pollutants created indoors, as they are more likely to live in non-decent homes (as per the Decent Homes Standard) [57], and are more likely to live in flats in high density, multi-unit buildings and therefore have higher exposure to pollutants from neighbouring households [58]. Families living below the poverty threshold in England are twice as likely as the national average to live in damp, overcrowded homes [59], and 16 times more likely than the wealthiest quintile [60]. Thirdly, children from low-income families are likely to spend more time at home than their wealthier counterparts, as their families face barriers to accessing after school clubs and extracurricular activities [58].

Home ownership status

Children in renting households are at higher risk of living in homes with poor air quality than children whose family own their home. Renting families may have less control over repairs or modifications to the home, and landlords may not fully understand or appreciate the potential health effects for the family caused by poor-quality housing or have the impetus to dedicate costs needed for home improvements. In the UK, Citizen's Advice found in 2018 that renters who complained about damp or mould in their home had an almost 50% risk of being evicted in the 6 months following the complaint [61]. In 2021–2022, the EHS found that 11% of privately rented homes were estimated to have damp, over twice as high as rates in social housing (4%) and five-times higher than rates in owner-occupied homes (2%) [10]. Overcrowding in homes is also a rising risk to children in rented properties in the UK. Overcrowding in rented properties (both social and private) has almost doubled in the past 20 years. 8% of social housing, 5% of private rentals and just 1% of owner-occupied homes were deemed overcrowded in 2021; however, current estimates are probably an underestimate as the EHS and census data do not consider bedroom size and include communal areas such as living rooms.

Young children

Throughout this review, we have discussed why CYP are a very vulnerable group in terms of the impact of poor housing quality on respiratory health. When considering exposure to damp and/or mould, it has been demonstrated that younger children are more vulnerable to effects on respiratory health [20, 27]. Being housed in a cold home was found to be a greater risk to respiratory health for children under 9 years of age [35] and living in overcrowded housing a greater risk for children under 10 years of age as, in the UK, they are not counted in the room standard, or count as less than one person in the space standard.

Antenatal determinants of poor respiratory health

When considering children at risk of poorer respiratory health due to the contribution of poor-quality housing, it is important to first consider antenatal determinants of lung development and the environment in which the mother lives when she is pregnant. Evidence assessing the effects of intrauterine exposure to IAP specifically is lacking. In terms of IAP originating from sources within the home, LEE *et al.* [62] demonstrated that per unit increase in prenatal CO exposure in expectant mothers, there were poorer lung function measures in their children. As described above, IAQ is affected by numerous factors, including outdoor pollutants entering the home. Intrauterine exposure to PM is associated with reduced lung function in the newborn [63] and preschool period [64]. Children born to mothers who were exposed to higher levels of PM during their pregnancy have a higher risk of wheezing at in infancy [65] and increased risk of asthma in childhood [66]. Furthermore, intrauterine exposure to PM is also associated with increased risk of respiratory tract infections in childhood [67]. In these studies, exposure is based on PM associated with outdoor air pollution, mainly traffic-related air pollution [62].

How can we address respiratory ill health associated with poor-quality housing?

First and foremost, it is imperative that all stakeholders appreciate the relationship between housing quality and respiratory health in children, including medical and healthcare professionals, councils and government, building industries, housing associations and landlords or providers of accommodation (table 2). As highlighted at the beginning of this review, a relatively old and energy inefficient housing stock in England contributes to poor housing, and poorly installed/single measure retrofitting to address energy efficiency can inadvertently exacerbate health impacts of inadequate ventilation [69]. Whilst beyond the scope of this review, incorporating gold standards such as *Passivhaus* low energy design/retrofitting standards into UK Building Regulations will contribute to a much more health- and eco-friendly housing

TABLE 2 Multilevel action to address housing-associated child health**In healthcare**

- Ensure housing and living environment incorporated into all aspects of clinical care
- Specialist clinics designed to address housing issues and how these relate to poorer (respiratory) health outcomes (e.g. Alder Hey Children's Hospital (UK) Clean Air Clinic)
- Research linking health and environmental data, specifically focussed on antenatal and child health

In the building industry

- Affordable new homes and retrofitting in keeping with gold standards [68]

At local council and government level

- Better regulation of housing standards and tenants' rights
- Joined health and housing departments
- UNICEF child's rights impact assessments for housing policies [3]

UNICEF: United Nations Children's Fund.

stock [68]. It is also imperative that all stakeholders understand the inequalities in terms of exposure to poor-quality housing.

Lockdown restrictions during the coronavirus disease 2019 pandemic highlighted huge inequalities in housing and the impact this had on CYP. In response, UNICEF UK published the "Children's rights in the new normal" report series, identifying how local authorities should build back better for CYP [3]. Using a child rights-based approach in all aspects of housing policies and planning is at the heart of UNICEF's recommendations, including use of a child rights impact assessment. The report specifically identifies marginalised communities of children, particularly those living in unregulated accommodation (such as unaccompanied asylum-seeking CYP, care leavers and homeless 16–17 year-olds) [3].

As discussed, families who rent their homes are most at risk of living in poor-quality homes. As such, nongovernmental organisations such as Shelter (in the UK) have been campaigning for better rights for tenants for a number of years. In 2022, the government announced the Renters Reform Bill and the Social Housing Regulations Bill. However, the Social Housing Regulations Bill was tabled in February 2023 to focus on "Awaab's law" to specifically address the issue of damp and mould in social housing.

Research has shown that addressing poor-quality housing by either rehousing or making modifications to the home results in improved respiratory health outcomes in CYP. For example, in the USA, home repairs to remediate damp, poor ventilation and poor heating resulted in improved respiratory symptoms [70]. A further intervention whereby families who rented their home were moved to "asthma-friendly" homes with features such as moisture-proof exteriors, ventilation and heating systems and interior finishes designed to not allow accumulation of dust resulted in improved nocturnal symptoms in children with asthma [71]. An initiative whereby structured assessments were made within homes and improvements to damp/mould, heating and ventilation were shown to result in improved quality of life, reduction in symptoms and reduction in costs associated with hospitalisation due to asthma [72]. The Community Asthma Prevention Programme in Philadelphia (USA) incorporated a community-based approach to education and interventions to remediate exposures to asthma triggers in the home. Partnerships were formed with home repair companies to make structural changes to reduce the exposure of indoor asthma triggers caused by structural deficiencies such as holes in ceilings and walls, and leaks. After these repairs, the number reporting presence of pests such as rats and cockroaches significantly decreased as did reports of asthma symptoms and healthcare utilisation due to asthma [73].

Putting it all together

Throughout this review we have highlighted the determinants of IAQ and how this relates to housing quality and how poor housing quality contributes significantly to poorer respiratory health in children (figure 1). The story does not necessarily start in childhood, however, as there is compelling, albeit limited, evidence suggesting that the effects of poor air quality on respiratory health in children starts *in utero*. We must also consider not only the homes that children live in, but the homes of pregnant women too. Children at risk of poor respiratory health due to poor housing quality include those who are from lower-income backgrounds and younger children.

As described above and as demonstrated in table 2, there is need for multilevel action to address the issue of poor-quality housing for CYP. For clinicians this means that there is a need for assessments of housing and IAQ in routine clinical assessments. Specialist clinics for CYP who have significant health issues

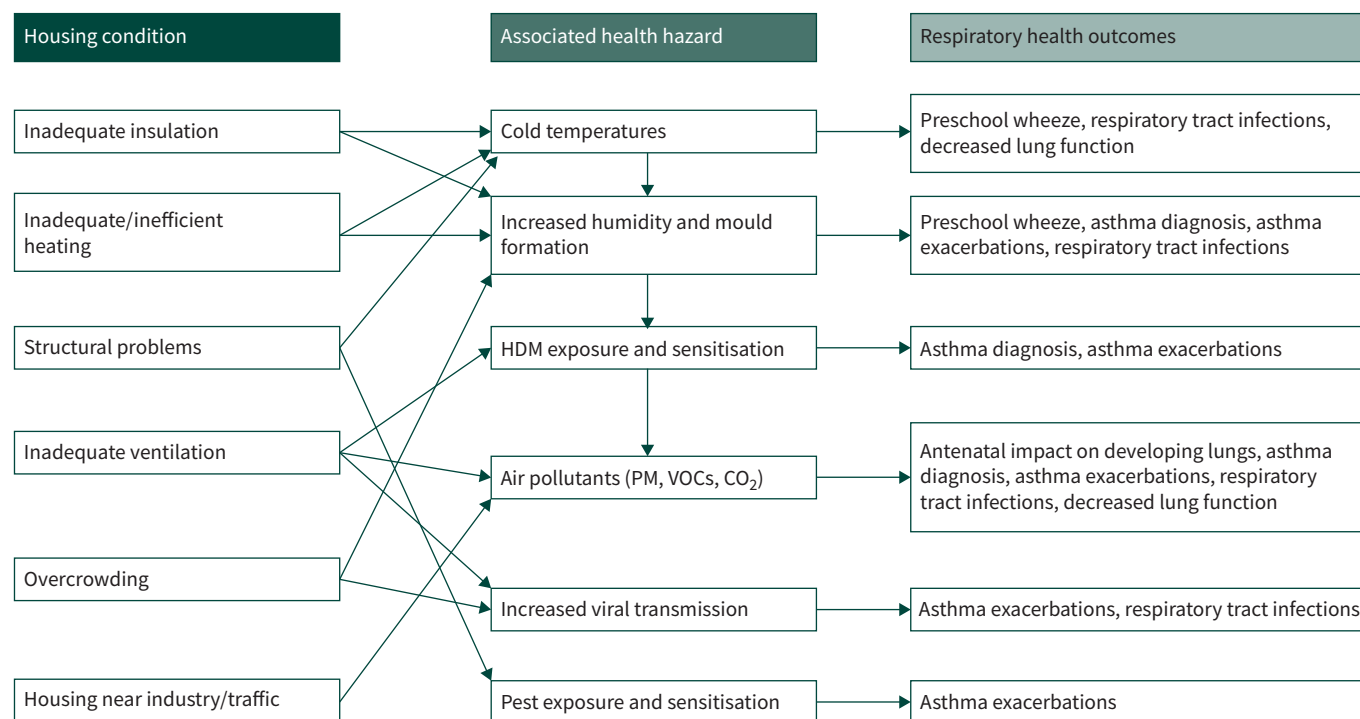


FIGURE 1 How poor housing impacts paediatric respiratory health. HDM: house dust mite; PM: particulate matter; VOCs: volatile organic compounds; CO₂: carbon dioxide.

which are felt to be related to the environment in which they live have been developed in the UK, the first of which is based at Alder Hey Children's Hospital (Liverpool, UK). Here, a specialist assessment of how poor-quality housing and IAQ contributes to their respiratory morbidity means that families can take away detailed reports to support them with seeking improvements or better-quality housing with either their private landlords or council-managed accommodation. As clinicians we are not legal experts; however, what we can do is link, in an evidence-based way, the exposure (poor-quality housing) to the detrimental health outcomes that these CYP face.

Further research into how interventions for families that live in poor-quality housing can remediate problems to improve respiratory health needs to be undertaken. Significant changes need to be undertaken at governmental and council level to ensure that accommodation provided by housing associations/councils and by landlords is of a quality that will not contribute to poorer respiratory health. This is in keeping with the UNCRC and UNICEF's guidance on the child's right to have adequate housing for their physical development [1, 3]. Stakeholders should also work with families to empower them if they report difficulties with their home, supporting them to address these issues.

Key points

- Poor-quality housing results in poor indoor air quality, which significantly negatively affects respiratory health in children and young people.
- Children and young people from lower-income backgrounds are most at risk of living in poor-quality housing.
- Addressing the threat of living in poor-quality housing, through either rehousing or modifications within the home, results in improved respiratory outcomes for children.
- Urgent action is needed from all stakeholders to understand the effect of poor-quality housing on respiratory health in children and take action to redress these issues.

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